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The Comprehensive Procedure for the Norwegian West Coast – Eutrophication Status

Report 992/2007

Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

The Norwegian west coast from Lindesnes to Stad has been classified according to the OSPAR Common Procedure. Compared to the previous assessment in 2002, this classification is based on new data on nutrient load and more data on oxygen conditions, hard bottom fauna and flora (especially sugar kelp) as well as other data from a number of recipient studies. 21 areas have been classified. The two striking features are overall increased nutrient loads and lack of monitoring data. The existing data has been of very varying quality, but 4 Problem Areas, 14 Potential Problem Areas and 3 Non Problem Areas have been identified. The high number of Potential Problem Areas is caused by the combination of increased nutrient load and insufficient data for assessment of effects.
There is a definite need for systematic monitoring with a long perspective, especially of Category II-III effects, and with focus on selected Potential Problem Areas.

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

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Preface

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

We also thank Gunn Helen Henne at Sogn & Fjordane county for being especially helpful in providing reports for use in this assessment.

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

Oslo, 27.8.2007

Jarle Molvær

Contents

Summary

As a contracting party to OSPAR, Norway has agreed to apply the Common Procedure for the Identification of Eutrophication Status of the Maritime Area of the Oslo and Paris Commissions on its coastal waters. The procedure has been applied to the coastal water off the Norwegian Skagerrak coast (1999), as Comprehensive Procedure to the fjords and archipelago along the Skagerrak coast (2002-2003 and 2006-2007), screening of the Norwegian west coast in 2002-2003 and screening of the coastline from Stad to the Norwegian/Russian border in 2003.

The present study reports the results from the Comprehensive Procedure for the Norwegian west coast from Lindesnes to Stad.

Method and data
In the previous screening a total of 106 fjord areas were given an initial classification. In the present study the number of areas is reduced to 21, each containing several fjords and coastal areas from the previous screening.

The OSPAR classification system has been used wherever possible. In some instances the classification uses the Norwegian Classification System (NCS) for nutrients, chlorophyll *a*, oxygen and soft bottom fauna. The classification has mainly been based on data from the period 2001-2006, and especially:

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

In addition the assessment has incorporated data from a number of local recipient studies. A striking observation from this classification exercise is that there are perhaps hundreds of small, local studies with very limited relevance for classification purposes, but is an almost total lack of long-time monitoring series. Bergen, and to some extent Stavanger and Haugesund are exceptions.

Results
In this assessment four features stand out:

1. A high increase in the nutrient load over the last 15-20 years. As this to a large extent is caused by increased discharges from the aquaculture industry, it also implies changes in two other features:
   - A shift in the distribution, from point sources associated with cities or rivers: often combined – to far more diffuse loads from aquaculture farms.
   - A shift in distribution over the year, towards a significant increased nutrient load in the months May-September. In Eutrophication assessments that is important.
2. Highly varying topography, from the open coastline in Area 3 to the Sogn & Fjordane County with its archipelagos and where the Sognefjord and the Nordfjord reaches respectively 200 km and 100 km into the country.
3. An increase in water exchange from south to north, due to increased tidal and meteorological forcing
4. Lack of monitoring data. Only the fjords around Bergen, partly around Stavanger, the Karmsund and the Sørfjord in Hardanger have been monitored on a reasonably regular basis. Most of the other recipient studies that this classification uses have focused on obvious local problems, like oxygen conditions in basins behind fjord sills, soft bottom fauna in fjord basins with oxygen problems or near outfalls of municipal waste water, or hard bottom flora and fauna near such outfalls. And many local studies at fish farms sites. Where the results were

found to describe only a small part of the area, this is taken into account in the "Integrated Classification".

The classification has been carried out for each of the 21 areas. Due to limited data, the classification has often been made with many reservations. These are given as comments and focuses on limitations like;

- there are no data
- the data are from studies more than 5-7 year ago and may not be representative for the present situation
- data covers only a minor part of the area.

This has been evaluated for each area, also considering the status in neighbouring areas. However, for a large number of areas with an increased nutrient load there are too few data for an assessment of consequences. In this case the classification is Potential Problem Area according to the Common Procedure. The classification is summarized as:

- *4 were classified as Problem Areas (1,2, 4 and 7)*
- *14 areas were classified as Potential Problem Areas (5, 6, 8, 10, 11, 12,13,14,15,17, 18, 19, 20, 21)*
- *3 areas were classified as Non Problem Areas (3, 9, 16)*

Outlook and trends

Over the last 15-20 years the anthropogenic nutrient load to the marine waters of the Norwegian west coast has increased significantly in spite of regulation and treatment plants for municipal and industrial discharges. For the future state of environment along the sheltered parts of the West Coast it is important to change this trend.

Models of climatic changes predict changes in the freshwater runoff to the Norwegian west coast, due to rising temperatures and increasing precipitation. The linked models predict no major changes in nitrate fluxes up to a 40-50% increase in this century, depending on chosen scenario. The accompanying effect in the estuary on primary production was indicated to be from almost no effect to a 15-20 % increase. Thus a worst-case situation can have a clearly negative effect on areas which already are eutrophicated.

Climate changes can change other variables such as currents and transport of heat. The combination of increased surface temperatures and eutrophication may be a threat to the sugar kelp populations even at the west coast.

Improvement of the classification

<u>Data</u>

There is a definite need for increased systematic, long-time-perspective monitoring of the west coast environment, and especially regarding <u>Category II-III effects</u>. There is also a need to improve/update the assessments background concentrations of nutrient during winter (area –specific) for the west coast coastal waters and fjords. One may need 10 years of monitoring to state a reasonable certain status and identify trends. The classification assumes that the decline of sugar kelp on the Norwegian west coast to some extent is caused by eutrophication. If future studies of the kelp disappearance prove otherwise, the classification should be revised.

The lack of data applies to most areas, but follow-up studies should focus on Potential Problem Areas which have experienced a strong increased load. Secondly one may consider monitoring in one or two of the Non Problem Areas, as the classification partly is due to lack of data.

The classification systems

There is a general weak definition in the OSPAR assessment of Chl-a, among them the definition of the growing season, the minimum number of observations and the definition of the maximum Chl-a. Assessment of oxygen deficiency (Category III) could incorporate oxygen consumption in basins with stagnant waters during at least a part of the year.

The Norwegian Classification System (NCS) was developed in the early 90-ies, based on data from the previous 10-15 years. There is an update in preparation, using the vast amount of higher quality data and better insight in eutrophication processes and effects from the last 10 years. This update will include classification according to the Water Framework Directive, and closer harmonization of the OSPAR Classification and NCS should also be a goal.

1. Introduction

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

- Comprehensive Procedure for fjords and archipelagos of the Norwegian Skagerrak coast (Molvær et al., 2003a, 2007)
- Screening of fjords and archipelagos of the Norwegian west coast (Molvær et al., 2003b)
- Screening of fjords and archipelagos from Stad to the Norwegian/Russian border (Aure and Skjoldal, 2003).

In the previous screening the Norwegian coast from Lindesnes to Stad was divided into 106 areas, of which 60 areas were classified as “Potential Problem Areas”. Many of the comments to the classification concerned uncertainties due to lack of relevant observations, either because

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

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

2. Description of the assessed area

2.1 Overall description of the Norwegian west coast

In the present report the Norwegian west coast is defined as the coast from Lindesnes in the south to Stad (62ºN) to the north (***Figure 1***). The average population density along the coast is low and only Stavanger (117000) and Bergen (244000) have more than 50000 inhabitants. In general the communities have wastewater discharges to the sea with primary or secondary treatment – depending on the size of the outfall and the recipient - submerged outfalls, high primary dilution and trapping of the plume below the surface layer.

According to the Urban Waste Water Directive the coast between Lindesnes and Stad has been designated as a sensitive area, with exception for the Grimstadfjord near Bergen.

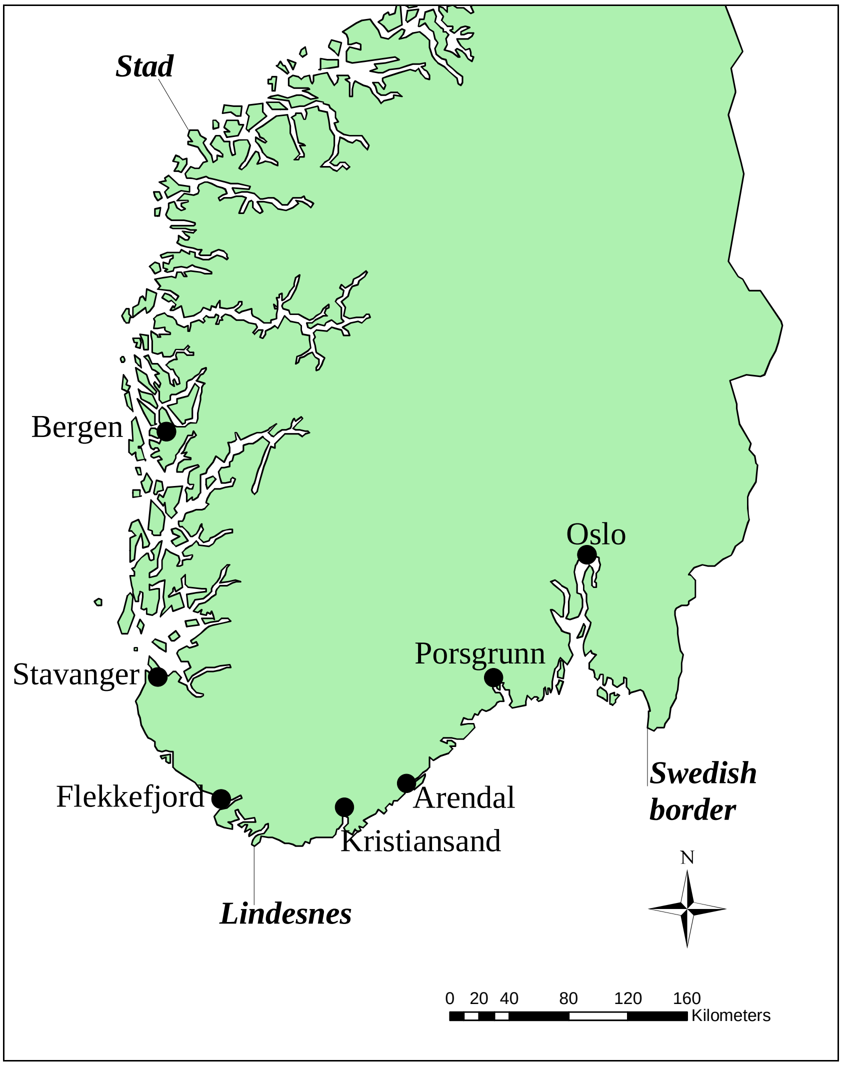


Figure 1. *Overall view of the coastline of southern Norway, showing the Norwegian west coast from Lindesnes to Stad, subjected to the Comprehensive Procedure in this report.*

The coastal waters along the Norwegian west coast are basically a mixture of three water masses:

- Freshwater runoff from the west coast
- The Norwegian Coastal Current (NCC, see **Figure 2**), combining local runoff to the coast, outflow from the Baltic Sea and the large rivers draining to the southern part of the North Sea.
- North Sea water.

The water volume transport of the NCC increases from typically 0.2-0.3 million m^3/s at the Skagerrak coast (**Figure 3**) to 1 million m^3/s or more off the west coast of Norway.

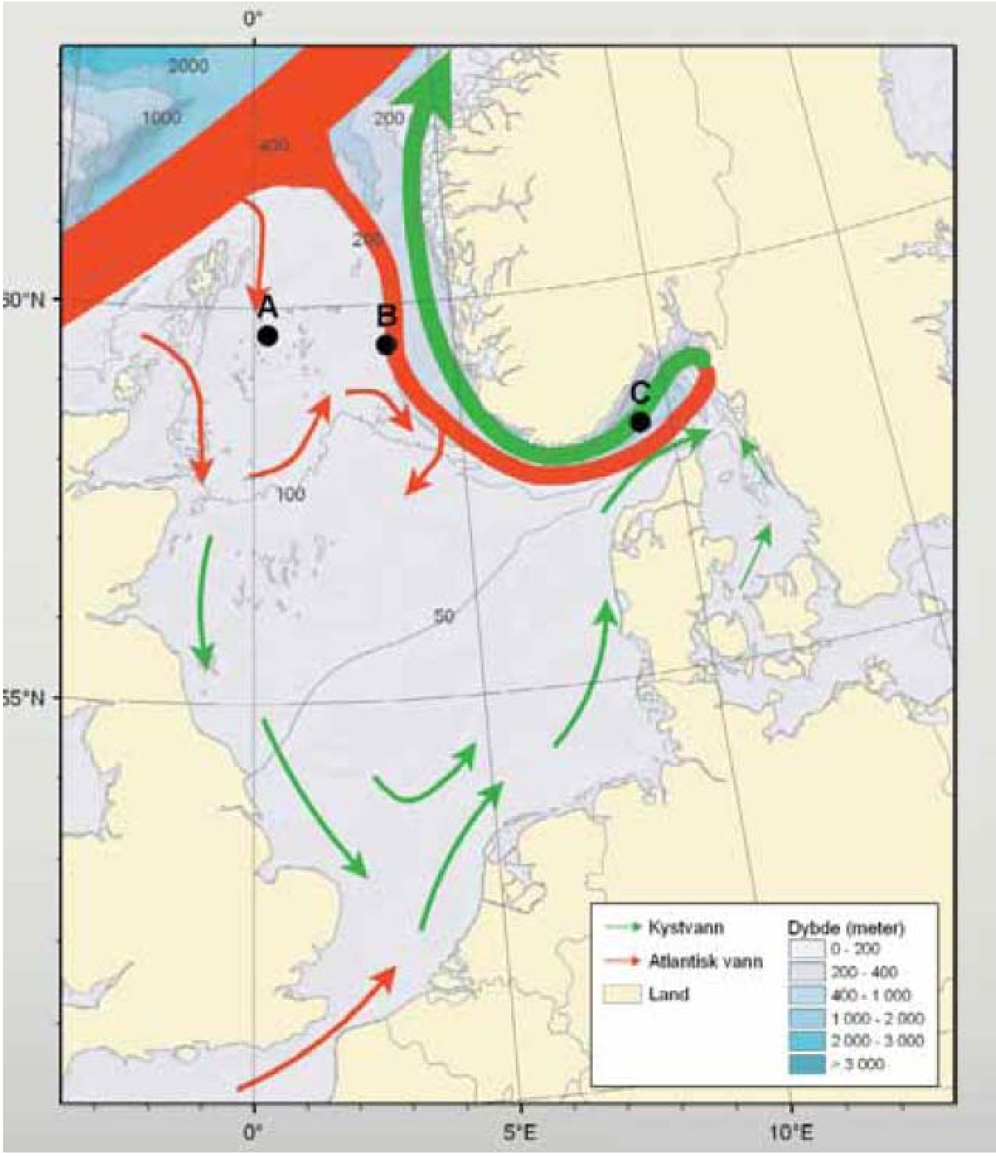


Figure 2. *Main circulation features and bathymetry of the North Sea and Skagerrak. Red arrows: Atlantic water. Green arrows: Coastal water. Source: IMR, Bergen.*

The water exchange in the coastal zone is driven by input of fresh water, tidal currents and meteorological forces (wind stress and air pressure variations). In most areas, the exchange of surface and intermediate water masses is rapid and extensive, often the matter of a couple of days or weeks. The tidal amplitude on the increases from typically 0,15 m at Stavanger, to 0,45 m at Bergen and 0,6 m in the northernmost areas. Compared to the Skagerrak coast the water exchange is significantly higher.

Most of the population lives in cities or towns situated in inner parts of fjords, or in other topographically sheltered areas along the coast. Generally, the topography and thus the water exchange of the local recipients vary considerably, both according to the local topography and as the tidally forced water exchange increases significantly from Lindesnes to Stad. 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.

2.2 Catchment information

Norway is a country with vast natural resources, and large parts of the country are covered by forests and mountainous areas. The land cover of the mainland may be divided into areas covered by forest, agriculture and artificial surfaces, mountains and mountain plateaus, as well as lakes and wetlands, **Figure 3**. The land use is shown in **Figure 4** and the two main RID-rivers are described in **Table 1**.

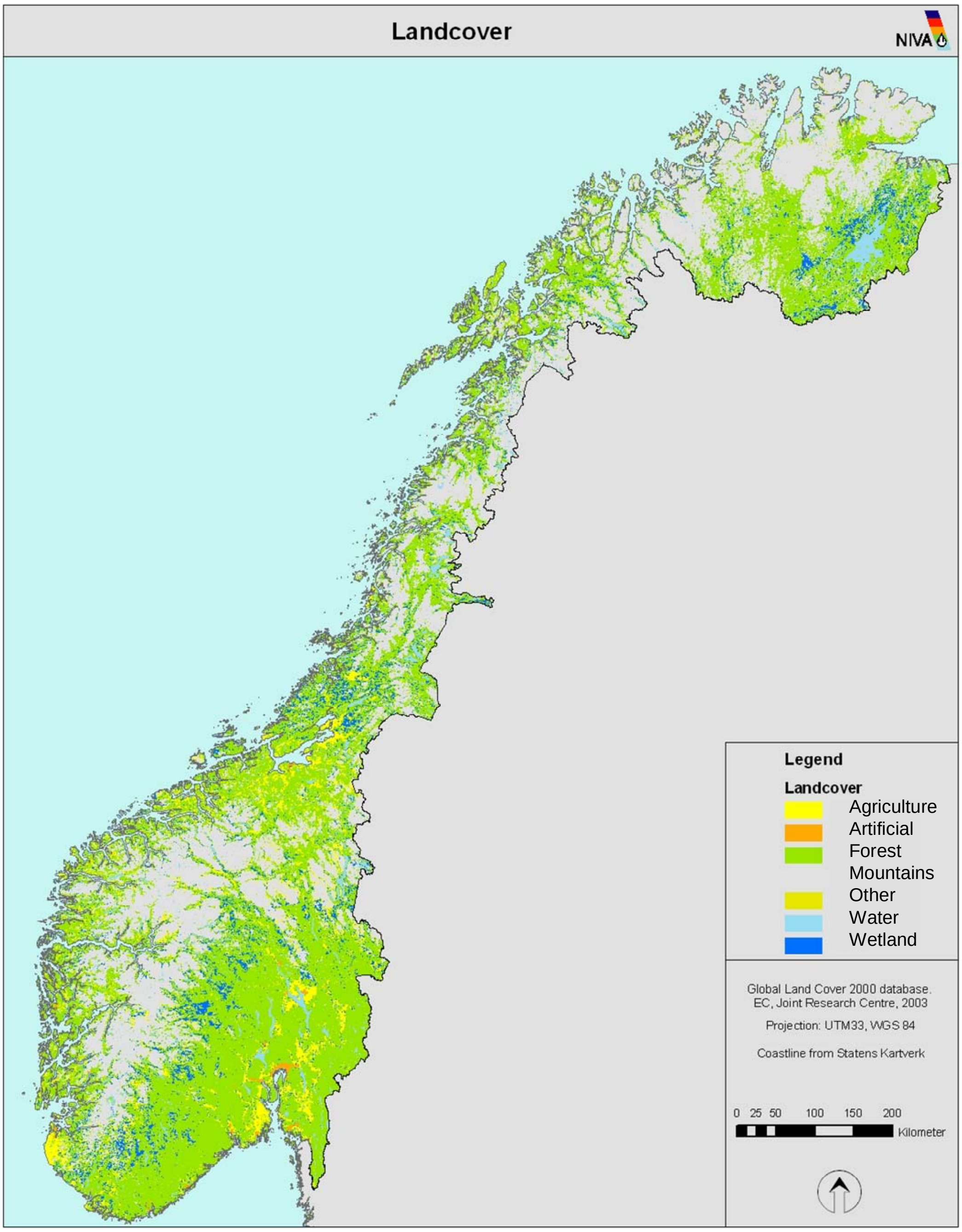


Figure 3. *Land cover map of Norway. See also* **Figure 4** *where the land use is shown.*

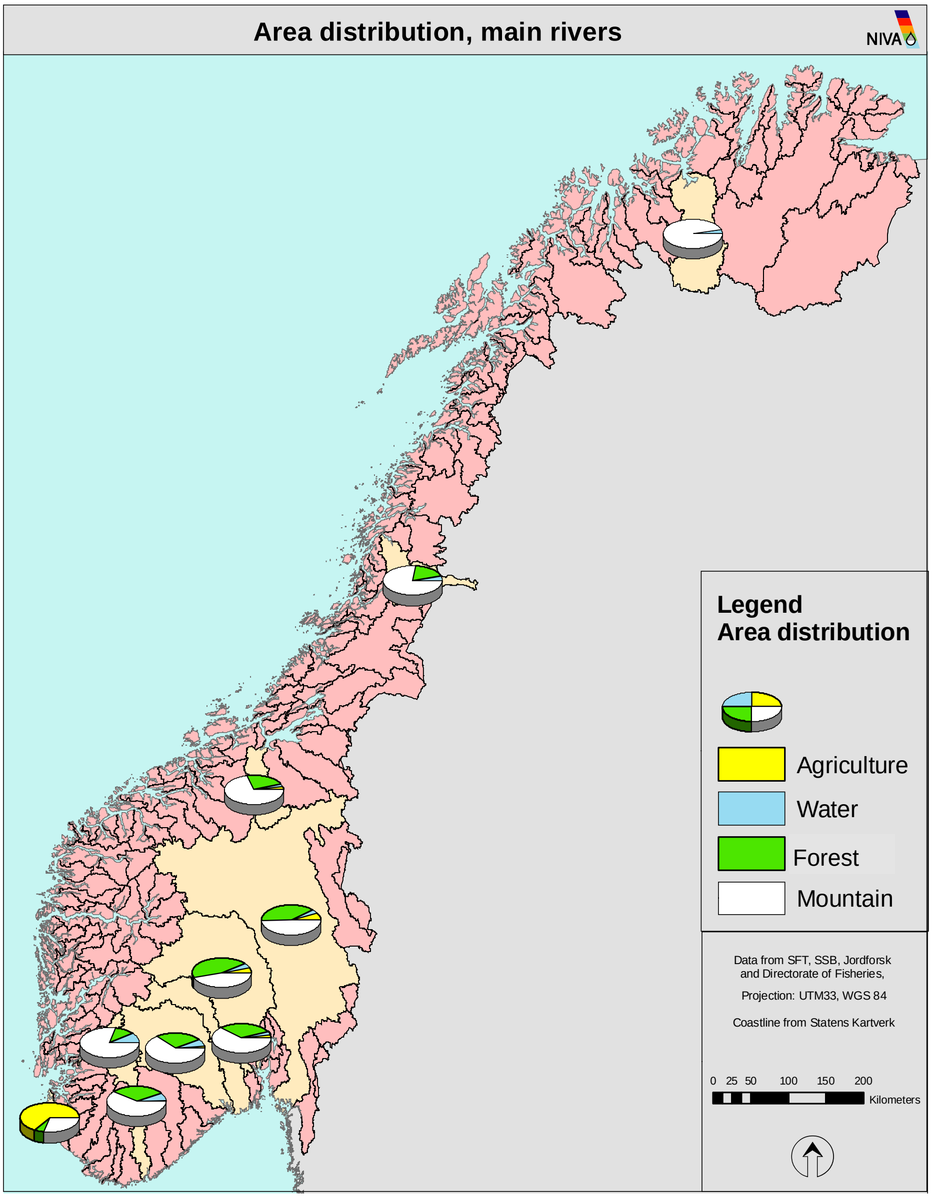


Figure 4. *Land use in the catchment areas of the 10 mainRID rivers. "Water" signifies proportion of lakes in the catchment; "Mountains" include moors and mountain plateaus not covered by forest. Based on data from SFT, Statistics Norway, Bioforsk, Directorate of Fisheries, and Statens Kartverk.*

Orreelva and Suldalslågen are draining into the coastal area of the North Sea. *Orreelva* is a relatively small river with a catchment area of only 105 km^2, and an average flow of 335 000 m^3/day or 3.9 m^3/s, but it is included in the RID Programme since it is draining one of the most intensive agricultural areas in Norway. River *Suldalslågen*, with a drainage area of 1457 km^2 and population density of only 2.4 persons/ km^2 has been included in the study to represent a relatively non-polluted watercourse. The river is, however, heavily impacted by hydropower development. These rivers are sampled 12-16 times/year.

Table 1. *The main RID-rivers draining to the west coast, their catchment size and long term average flow.*

Name of river	Catchment area (km^2)	Long term average flow (1000 m^3/day)	County with river outlet
Orreelva	105	335	Rogaland
Suldalslågen	1457	7420	Rogaland

Due to the topography the west coast is separated into very many – often small – catchments and is practically impossible to monitor all of them. However, in addition to Orreelv and Suldalslågen a total of 16 other rivers are sampled 4 times/year and the data used in calculations of nutrient transport. For more info, see Borgvang et al. (2007).

2.3 Areas for assessment

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

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

Statististics Norway assembles statistics for so-called “Statistical Areas”. From topographic and demographic parameters and taking into considerations that relatively homogenic areas are preferable, the west coast was in the 2003-Screening divided into 106 areas, each including one or several “statistical areas”. Forty-six areas were declared as Non Problem Areas, either based on specific data or because

- The anthropogenic nutrient load was low, and
- The areas have mainly high and unrestricted water exchange.

In this report a 3-step assessment is used:

1. start with an update of nutrient load and other relevant environmental information for all previous areas
2. as some of these (sub)areas are rather small the second step is to give a more regional assessment for 21 aggregated areas, which is used in the further classification.
3. the third step to present an overall classification of the whole coastline between Lindesnes and Stad

Nutrients from urban wastewater are usually discharged from point sources and nutrients from runoff are often concentrated to a few large rivers. Within a coastal area, this may create gradients in nutrient load and in environmental quality. The fjord areas in this report vary from approximately 5 km^2 to 800 km^2, with a median of 27 km^2. Within most areas are highly varying environmental conditions, from very sensitive fjord basins to open areas with high water exchange.

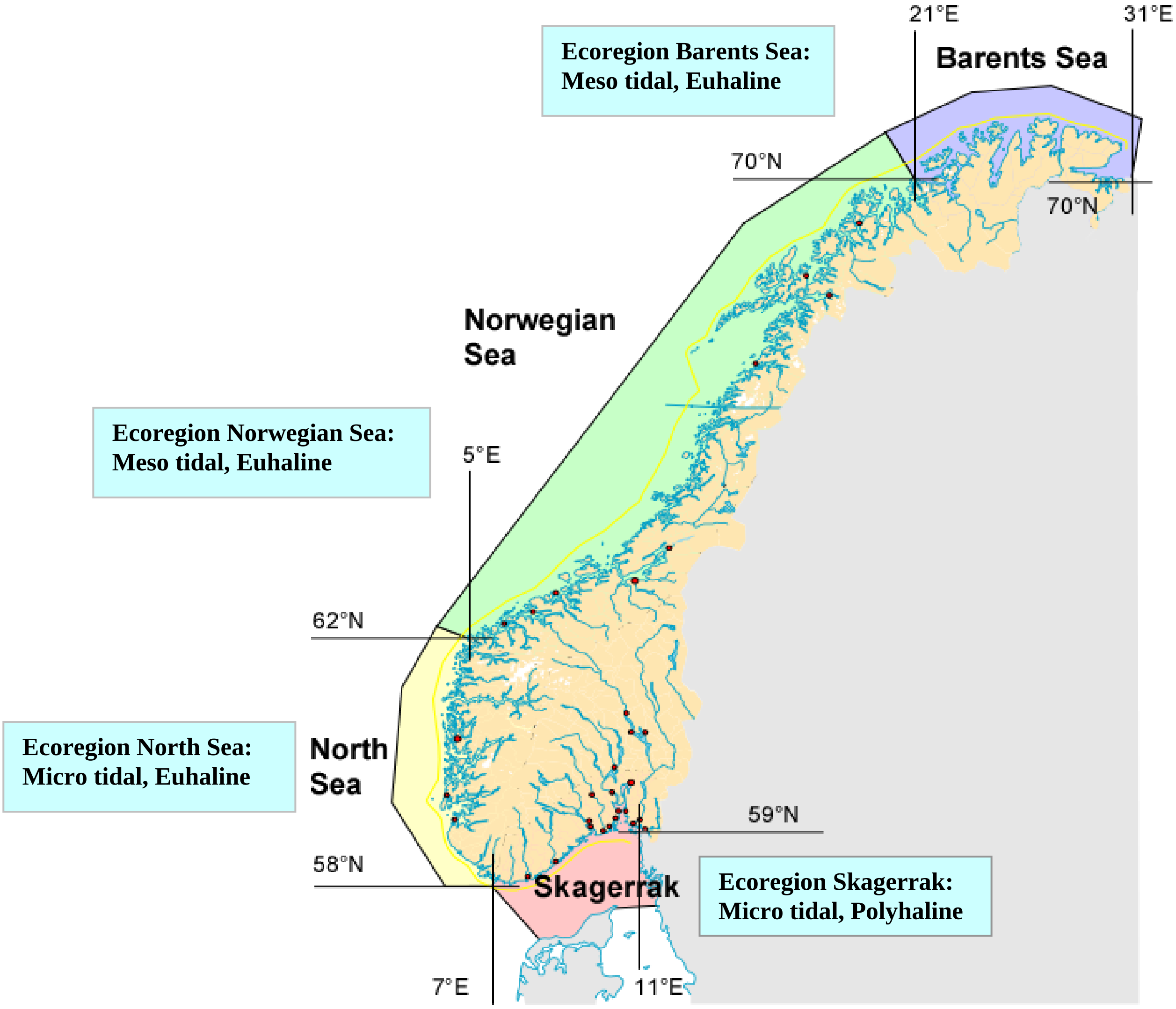


Figure 5. *The present suggestion of Norwegian typology with 4 ecoregions (based on Moy et al., 2003).*

3. Method and data

3.1 The OSPAR classification scheme

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2 The Norwegian classification system (NCS)

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

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

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

In Norway, most nutrient observations are made in April-October. The discharge from agriculture and precipitation dependent nutrient sources will vary during the year and with climatic variations. Cold winters results in lower discharges and warm winters the opposite. The discharge from the major west coast rivers shows the largest transport in May-July due to snow melting in the mountains. Thus summer observations of nutrients are of interest, especially in areas dominated by agriculture, and because they will be more associated with biological effects than winter observations. As the OSPAR assessment criteria for nutrients are limited to winter observations, the NCS will be used when the data allows it.

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

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

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

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

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

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

3.3 Data and quality of time series

3.3.1 Calculation of nutrient loads

Transboundary load

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

As nutrient concentrations in the surface water generally decrease between Arendal and Lista (Moy, et al., 2006), and concentrations at Utsira are about the same as at Lista, the impact of transboundary transport from the Skagerrak decreases west of Lindesnes. However, bursts of Skagerrak waters can influence the situation along the Southern West Coast when wind conditions are favourable (Aure and Sætre, 1981), but the effect is limited in time and space. Natural favourable conditions for upwelling (Lista) and transport from the Atlantic are also significant factors.

The overall impression is that the transboundary load from the Skagerrak has little influence on the surface water quality along the west coast. The OSPAR winter nutrient criteria classify the outer coastal waters as non problem areas. This corresponds with the conclusion of ANON (1997). Furthermore this indicates that a change in eutrophication status of the fjords and the coastal archipelagos should be associated with an increased anthropogenic nutrient load.

Table 7. *Winter observations at station Lista and station Utsira, with corresponding classifications according to the Norwegian Classification System (NCS).*

Station	N	Tot-P µM	PO_4-P µM	Tot-N µM	NO3+NO2-N µM
Lista (2001-2006)	15	0.7 (NCS=II)	0.47 (NCS=I)	15.6 (NCS=I)	5.98 (NCS=I)
Utsira (2006)	3	0.65 (NCS=I)	0.42 NCS=I)	15.5 (NCS=I)	4.76 (NCS=I)

Table 8.*Summer observations at station Lista and station Utsira, with corresponding classifications according to the Norwegian Classification System (NCS).*

Station	N	Tot-P µM	PO_4-P µM	Tot-N µM	NO3+NO2-N µM	Chl-a µM
Lista (2001-2006)	15	0.40 (NCS=I/II)	0.07 (NCS=I)	13.8 (NCS=I)	0.46 (NCS=I)	1.31 (NCS=I)
Utsira (2006)	2	0.38 (NCS=I)	0.06 (NCS=I)	14.7 (NCS=I)	0.14 (NCS=I)	0.55 (NCS=I)

Landbased anthropogenic load
The landbased anthropogenic nutrient load has been calculated in a two-step processes.

1. The annual nutrient input from anthropogenic sources (industrial, municipal wastewater, scattered dwellings, agriculture and aquaculture) for the years 1985, 1990 and 1995-2005 was calculated for 98 areas from Lindesnes to Stad. For rivers included in the RIDprogram, these data were used for the calculations. For the other areas the nutrient load has been calculated by running the input model "TEOTIL" (Bratli and Tjomsland 1996, Selvik et al. 2007). The nutrient load has also been calculated pr. month.

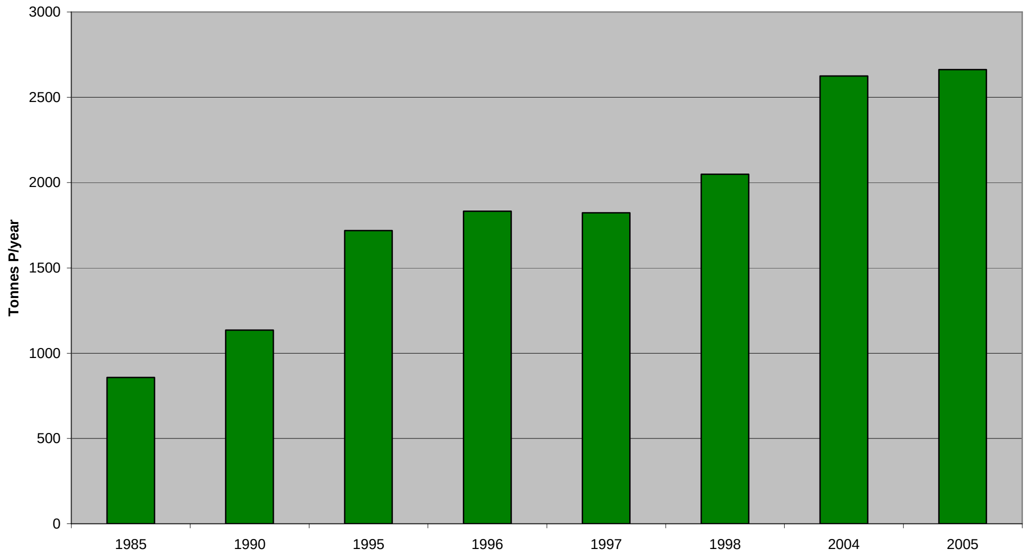
   Run-off coefficients from various types of agricultural fields have been developed and adjusted according to measures implemented. Concerning background losses of nutrients, fixed run-off coefficients have been developed for non-cultivated areas, as well as for deposition on water bodies. The inputs are theoretical and the annual meteorological variations are averaged out over the years.

2. These detailed nutrient loads were then aggregated into 21 main areas (A1-A21).

Over the last 15-20 years the anthropogenic nutrient load from landbased sources to the west coast has increased significantly, and by approximately 120% (nitrogen) and 130% (phosphorus) since 1990 (**Figure 6**). In this assessment the annual anthropogenic nutrient load for the period 1997-2005 is used, with exception for the phosphorus load where data for 1999-2003 have been discarded due to analytical problems with the river samples. Over this period the input of phosphorus and nitrogen to the Norwegian west coast from landbased sources and the aquaculture industry have increased by 40-45% (Selvik et al. 2007).

This also implies changes in two other features:
1. A shift in the distribution, from point sources associated with cities or rivers: often combined – to a far more diffuse load from aquaculture farms.
2. A shift in distribution over the year, towards significant increased nutrient load in the months May-September. In Eutrophication assessments that is important.

This increase in nutrient load indicates an overall classification as Potential Problem Area for the whole west coast (see **Table 3).**



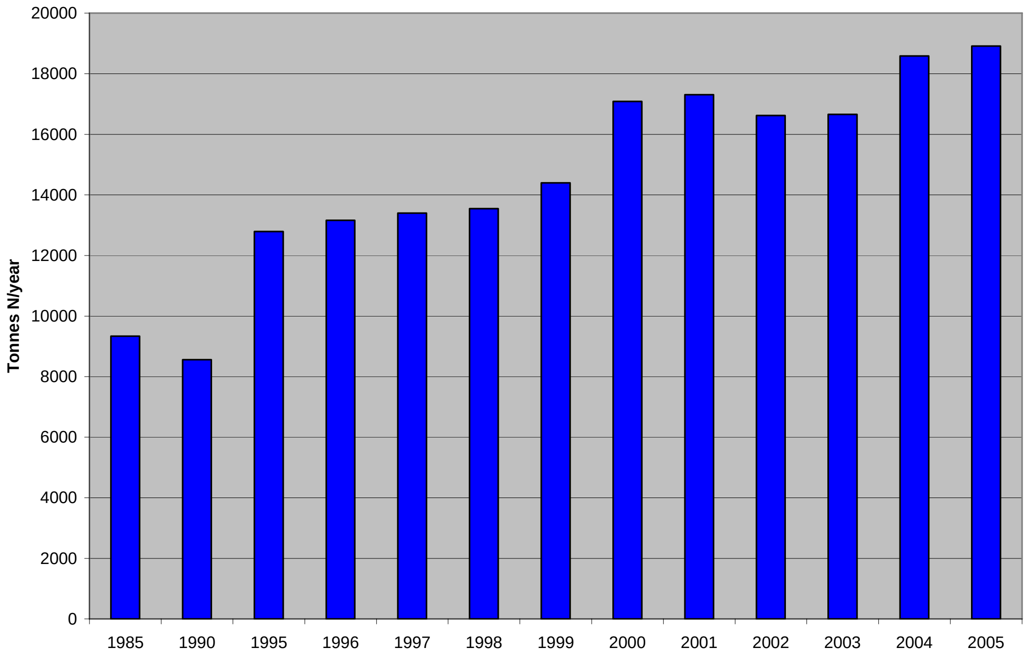


Figure 6. *Annual anthropogenic load of total phosphorus to the Lindesnes- Stad coast (upper Figure) and total nitrogen (lower Figure). Note that phosphorus data from 1999-2003 have been discarded.*

3.3.2 Water quality and biological data

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

The evaluation of toxic algae and mussel infection (blue mussel) are mainly based on data from weekly sampling on 8 stations on the west coast (**Figure 9**). Stations 8-10 are located in Rogaland county, stations 11-13 in Hordaland county and stations 14-15 in Sogn and Fjordane county. In general these stations are considered representative for the situation on the coast.

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

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

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

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

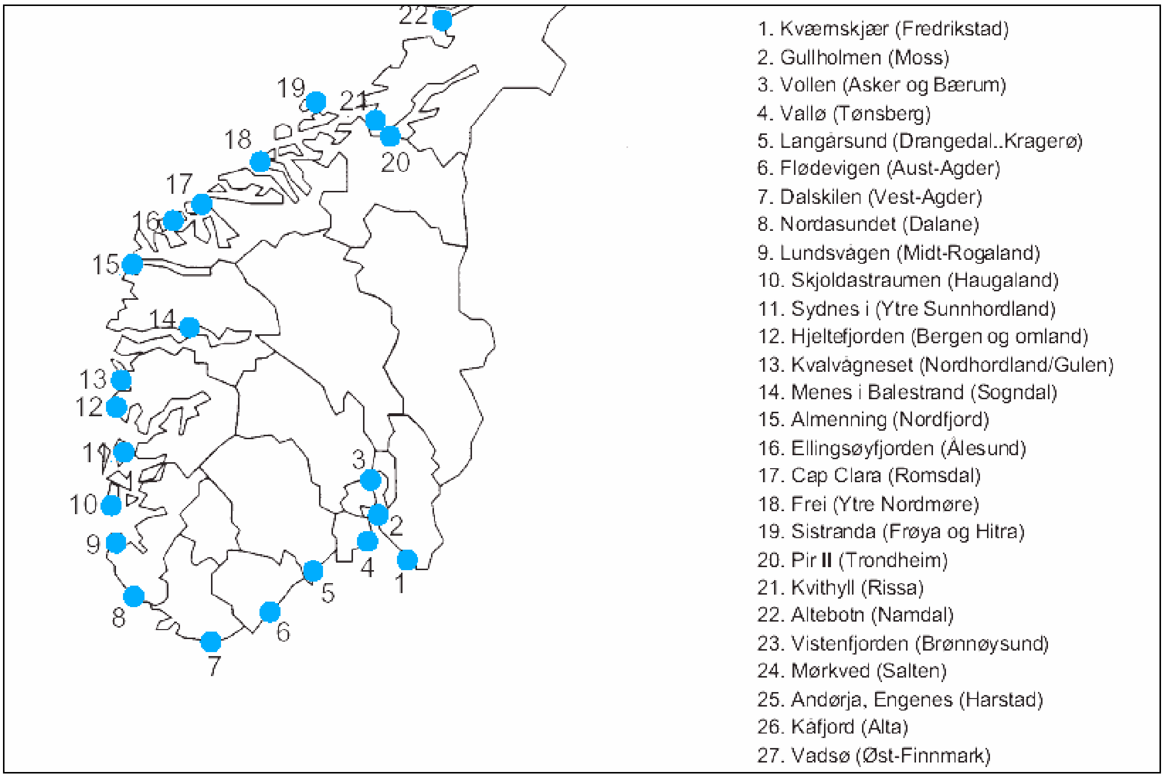


Figure 7. *Stations for monitoring of toxic algae and mussel toxins in southern Norway (from Hestdal et al., 2001).*

The observations used in this assessment are mainly from monitoring programmes like “the Norwegian Coastal Monitoring Programme”, numerous local studies by the University of Bergen, Institute for Marine Research Bergen, NIVA, IRIS, Rådgivende Biologer AS and others. Observations from local recipient studies in West-Agder, Rogaland, Hordaland and Sogn & Fjordane counties are to a large extent focussing on very local areas, like the close surroundings to an aquaculture farm or a specific municipal or industrial outfall. This type of data is not suited for overall classification of an area.

Observations from “Ships of Opportunity” (FerryBox) at two stations between Haugesund and Bergen are incorporated (**Figure 8**).

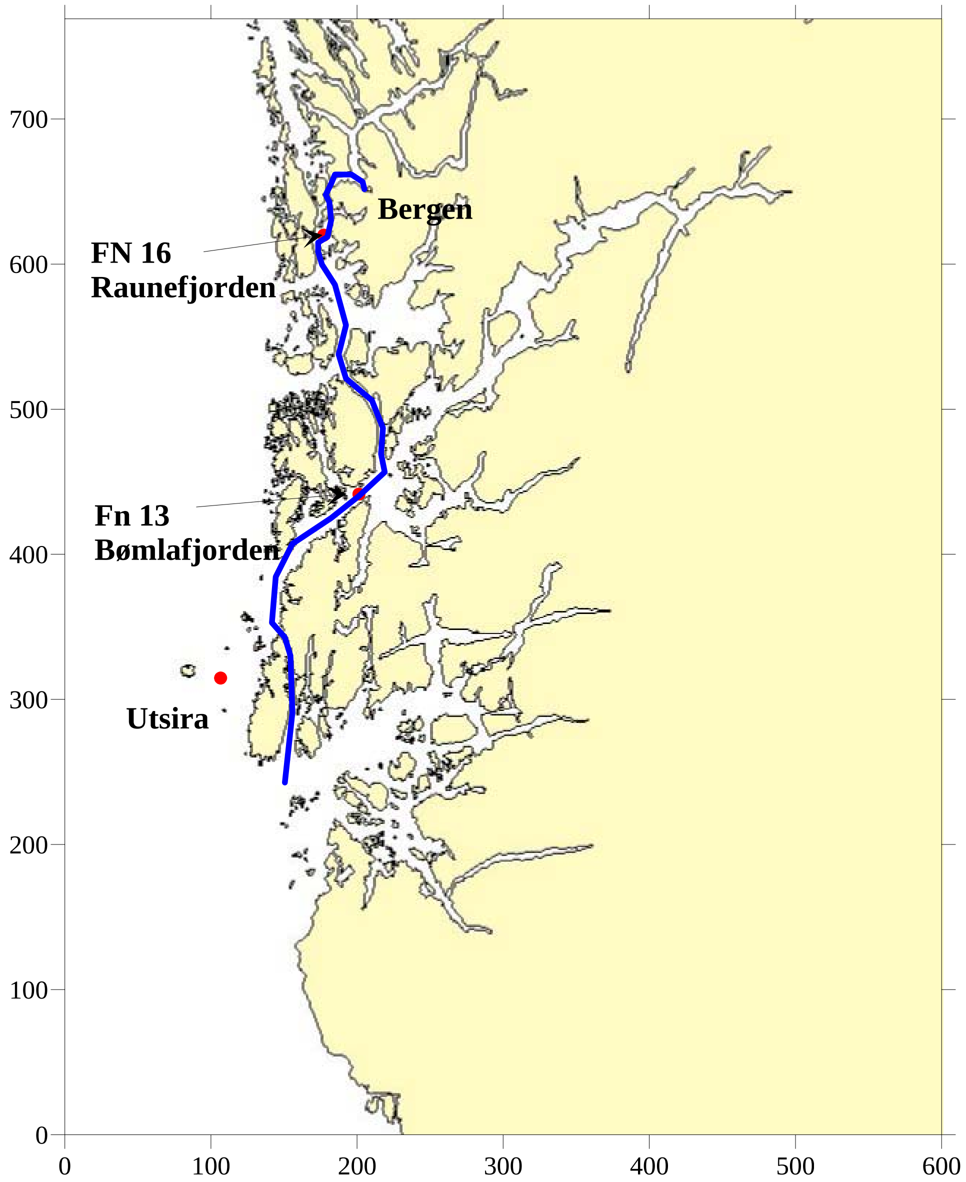


Figure 8. *The track of "Fjord Norway" and stations Fn 13 and Fn 16 with sampling of nutrients and chlorophyll at 4 m depth.*

4. Eutrophication assessment

4.1 Introduction

The reporting format for the 22 areas covering the Norwegian west coast will in general follow the outline described in OSPAR's "Comprehensive Procedure" (OSPAR 2005), with four main items:

1. Area (names and map showing geographical location).
2. Description of the area, including environmental information
3. Assessment according to***Table 2*.**
4. An initial classification according to ***Table 3,*** or the Norwegian classification system (NCS). Note that this is an overall classification for the area. In most areas there are small parts that could have a different classification.

At the end a final classification is made, taking into consideration other available information.

The assessment focuses on areas which the 2003-screening classified as Potential Problem Area (PPA) or/and areas where there are new and substantial information for some of the assessment parameters in ***Table 2***.

Especially two classification factors are updated since the previous screening in 2003:
- The anthropogenic nutrient loads: (Category I)
- Macroalgae, and especially sugar kelp: (Category II)

In addition information and results from a large number of local studies have been checked out. However, very many of these are site-specific studies of localities for fish farms, and of very limited use in a broad assessment like the present.

4.2 Lindesnes to Stavanger

For classification purposes this coastline is divided into 3 areas which are classified according to the procedure outlined in Chapter 3 (***Figure 9***).

A1 The coast from Lindesnes to Fedafjord

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

Nutrient load
There are two towns on the coastline: Farsund (city population approx. 3100) and Lyngdal (city population approx. 3700). The average anthropogenic nutrient load is reduced during the last 10 years (***Table 9***).

Table 9. *Anthropogenic nutrient load for area A1. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1996-2000	2001-2005	1996-2000	2004-2005
127	114	13	4,8

Topographic and hydrophysical characteristics.

The coastline consists of a number of fjords with varying loads and varying degree of water exchange. Several of the fjords like the Lenefjord, Grønsfjord, Inner and outer Lyngdalsfjord and in particular Framvaren – are deep fjord basins with narrow and shallow sills – and very restricted water exchange.

The freshwater inflow is varying, but the Lygna river creates a marked brackish surface layer and strong vertical stratification in the Lyngdal fjords

Water quality, biological conditions and degree of nutrient enrichment.

There has not been any studies of the water quality of the fjords during the last 5 years, but the general situation is well known. All of the abovementioned fjords experience periods of anoxic conditions in the basin water, and to a large extent from natural restricted water exchange over the fjord sill. Correspondingly the soft bottom fauna in several of the fjord basins is very poor.

Except for some areas close to sewage outfalls the hard bottom flora and fauna were in general good condition.

There has note been any update during the last five years. The area is included in the follow-up studies for the sugar kelp decline on the coast of southern Norway (Åsen 2006, Moy et al., 2006).

In 2002 this area was classified as Problem Area. The integrated overall classification is shown in ***Table 10***.

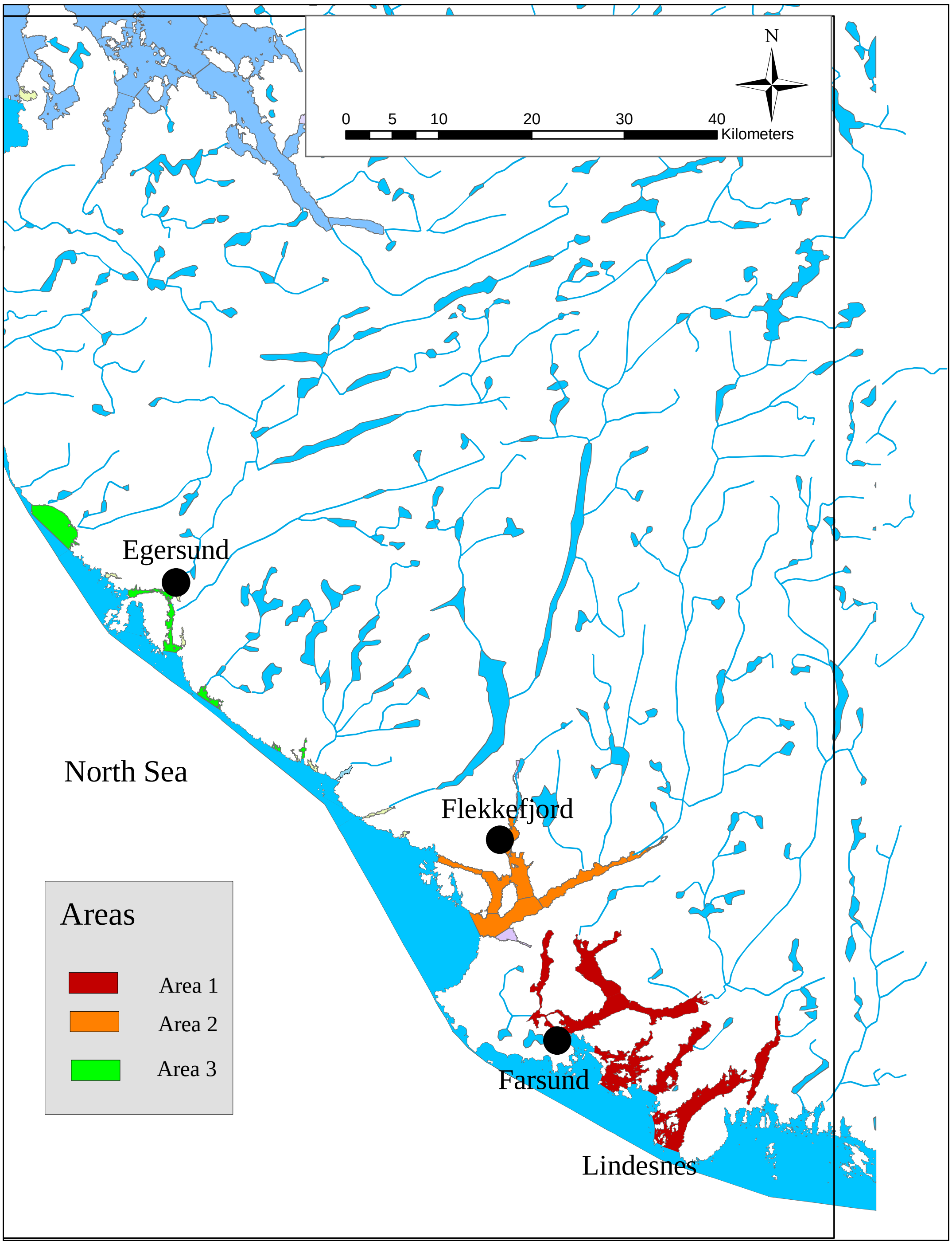


Figure 9. *The Lindesnes – Egersund coast, showing the three classification areas (A1-A3).*

__Table 10.__ Area A1. Integrated initial classification table.

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Reduced load	**-**
	Winter DIN- and/or DIP concentrations	No data	
	Increased winter N/P ratio (Redfield N/P = 16)	No data	
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	No observed decline in sugar kelp (Åsen 2006). Very good condition (Moy et al 2006).	**-**
Indirect Effects (III)	Degree of oxygen deficiency	Several fjord basins	+
	Changes/kills in Zoobenthos and fish mortality	Several fjord basins	+
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem Area

Final classification: The problems are connected to fjords and other areas with limited water exchange. However, these are major parts of the area. The final classification is **Problem Area**

A2 The Fedafjord and Flekkefjord region

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a). The area is shown in ***Figure 9***.

Nutrient load

There is one town on the coastline: Flekkefjord (city population approx. 5700). The average anthropogenic nutrient load has increased during the last 10 years (***Table 11***).

Table 11. *Anthropogenic nutrient load for area A2. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
376	453	57	85

Topographic and hydrophysical characteristics.

The coastline consists of two fjord systems. The long and straight Fedafjord with a fjord sill and a small basin in the innermost part. The freshwater inflow from Kvina river creates a marked brackish surface layer and strong vertical stratification in the Fedafjord.

The fjords around Flekkefjord (Grisefjord, Tjørsvågbukta, Lafjord) – with very shallow sills and deep basins – experience low renewals of the basin water behind the fjord sills. In this region the freshwater inflow is less and the brackish layer usually of higher salinity and smaller depth than in the Fedafjord.

Water quality, biological conditions and degree of nutrient enrichment.

There has not been carried out any studies of water quality or biological conditions in the Fedafjord during the last 10-15 years.

The Flekkefjords has been studied on several occasions during the 1980-90ies, and a study of nutrients and oxygen in 2003 has the most recent information (Moy and Oug, 2004). In the surface layer the winter concentrations of total phosphorus and phosphate were classified as *Good-Very Good* according to the NCS, while the concentration of total nitrogen and nitrate were classified as *Poor*. There were no significant changes since the previous study in 1994-1995 (Jacobsen et al., 1996).

As expected the basin water behind the fjord sills in the Flekkefjord region experience oxygen problems to varying degree, and worst in the Grisefjord. The typical rate of oxygen decrease in the basin water was 0,31 ml/month, and considered to be within the normal interval for fjords on the Norwegian Skagerrak coast.

The area is included in the follow-up studies for the sugar kelp decline on the coast of southern Norway (Åsen 2006, Moy et al., 2006).

Evaluation

In 2002 this area was classified as Problem Area. The integrated classification is shown in ***Table 12***.

__Table 12.__ A2. Integrated initial classification table.

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increasing	+
	Winter DIN- and/or DIP concentrations	Low DIP, moderately high DIN	-
	Increased winter N/P ratio (Redfield N/P = 16)	No increase	-
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 observed decline in sugar kelp (Åsen 2006). Very good condition (Moy et al 2006)	-
Indirect Effects (III)	Degree of oxygen deficiency	Local fjord basins	+
	Changes/kills in Zoobenthos and fish mortality	Due to periodic oxygen problems	+
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem Area

Final classification: The problems are connected to fjords and other areas with limited water exchange. However, these are major parts of the area. The final classification is **Problem Area**

A3 Coastal area Flekkefjord - Egersund

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a). The area is shown in ***Figure 9***.

Nutrient load
There is one small town on the coastline: Egersund (city population approx. 9500).The average anthropogenic nutrient load has increased during the last 10 years (**Table 13**).

Table 13. *Anthropogenic nutrient load for area A3. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
998	1148	93	131

Topographic and hydrophysical characteristics
Except from Hidra and the local archipelago south of Egersund, the coastline is relatively straight and without island. The most recent study (Moy et al., 1997) concluded that the water exchange between fjord and coastal water was high.

Water quality, biological conditions and degree of nutrient enrichment.

The 1996-study covered the southern part of the Egersund fjord system and the city main outfall of municipal sewage is afterwards relocated to this area. The results from the previous study may not be representative for the present situation. However, the main findings should be mentioned:

- In the inner part of the area the summer concentration of total phosphorus and total nitrogen corresponded to NCS-classes III (Fair) and II (Good) respectively. In the southern part the nutrient concentration was low, corresponding to class I (Very Good) for both N and P.
- The concentration of Chlorophyll a corresponded to class I-II
- Measurements of oxygen concentrations showed classes I-II.
- The samples from hard bottom flora and fauna and soft bottom fauna did not show any eutrophication effects, but were representative for a fjord system with high water exchange and a substantial nutrient load.

Evaluation
The integrated classification is shown in ***Table 14***.

Table 14. *A3. Integrated initial classification table.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase	+
	Winter DIN- and/or DIP concentrations	No recent data	**?**
	Increased winter N/P ratio (Redfield N/P = 16)	No recent data	**?**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No recent data	**?**
	Nuisance specie/harmful species; *Dinophysis* spp., *Alexandrium* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	No recent data	**?**
	Macrophytes including macroalgae (region specific)	No decline in sugar kelp (Åsen 2006) Very good condition (Moy et al 2006)	**-**
Indirect Effects (III)	Degree of oxygen deficiency		**-**
	Changes/kills in Zoobenthos and fish mortality		**-**
	Organic Carbon/Organic Matter		
Other Possible Effects (IV)	Algal toxins; DSP (Castberg et al. 2005, Dahl et al 2006, Hestdal 2001-2003)		**?**

Initial classification: Potential Problem Area.

Final classification: Problems could be expected in the Egersund archipelago, with limited water exchange, but have not been observed. The final classification is **No Problem Area**

4.3 Rogaland county

There are ten towns on the coastline from Stavanger and to Hordaland county: the three largest are Stavanger (city population approx. 113000), Sandnes (city population approx. 46000) and Haugesund (city population approx. 32000). For classification purposes the coast of Rogaland county is divided into 4 areas (**Figure 10**). The Norwegian sugar kelp study includes a number of stations in Rogaland and on a number of stations the negative effects are serious (**Figure 11**).

The areas will be classified according to the procedure outlined in Chapter 3.

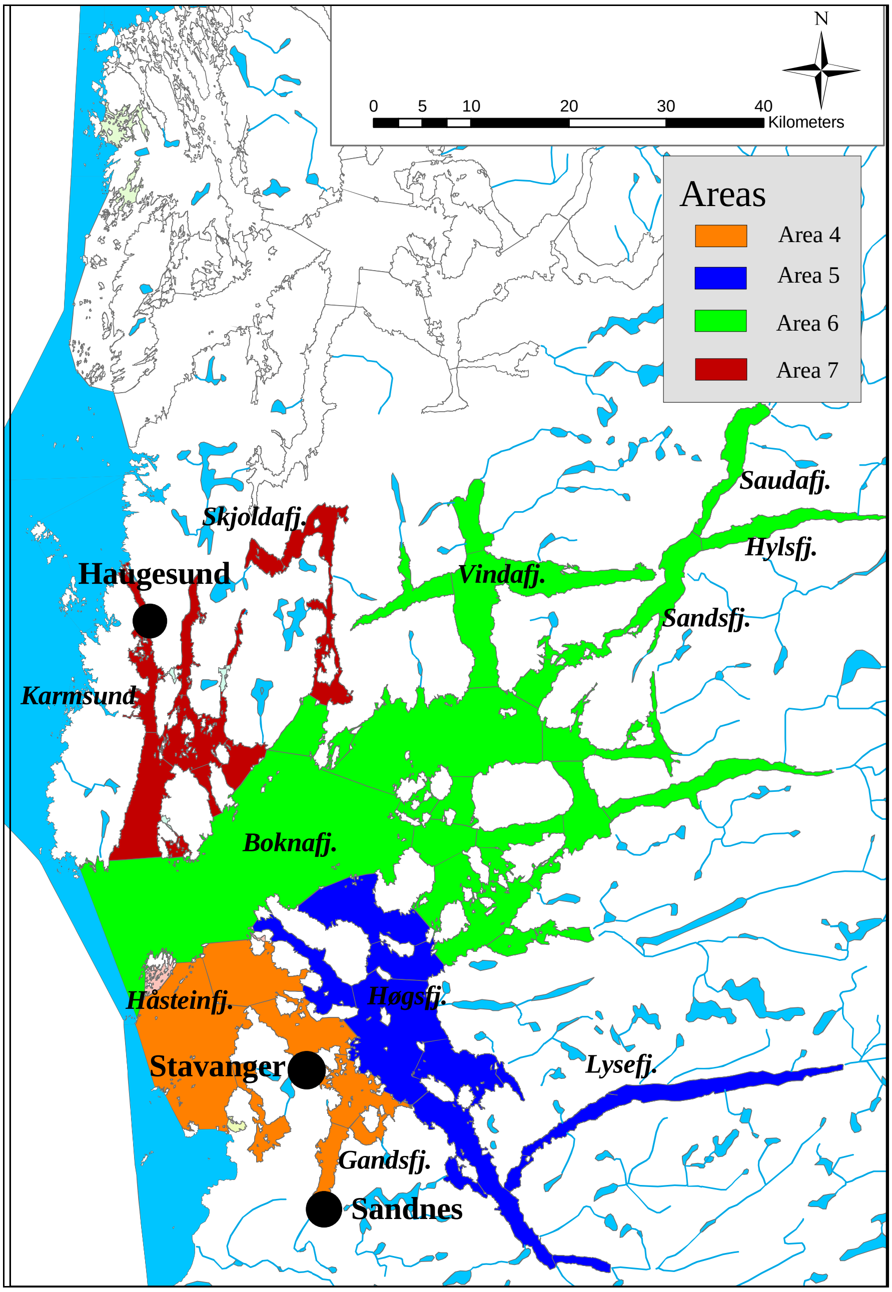


Figure 10. Rogaland County showing the four classification areas (A4-A7).

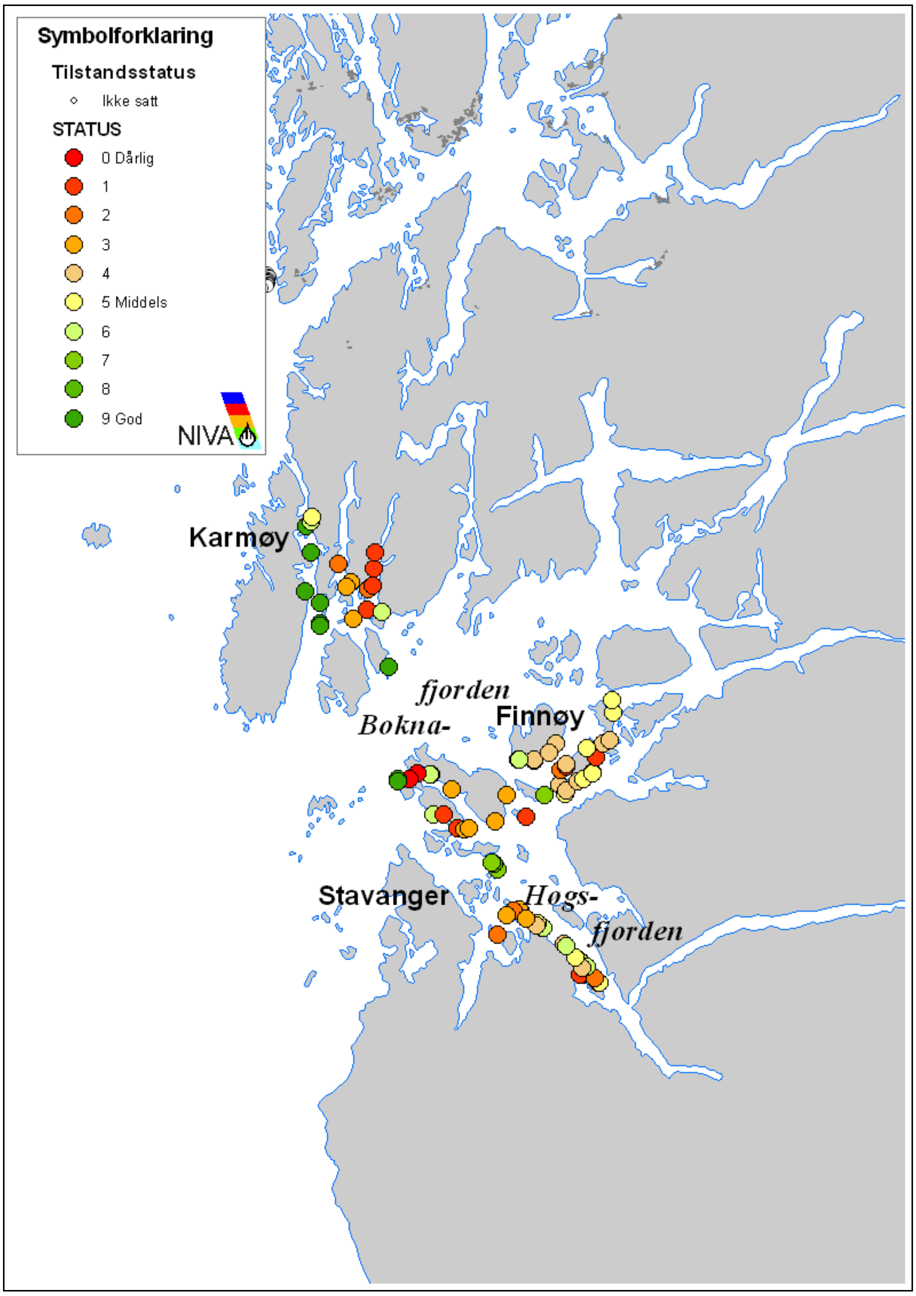


Figure 11. *Sugar kelp stations in Rogaland county (2005-2006). The situation is classified according to a scale where Green= good, Yellow= middle, Red= bad. After Moy et al. (2007).*

A4 The Stavanger fjords

The area is shown in **Figure 10**.

Nutrient load
The municipal sewage from the city of Stavanger and nearby areas is processed through a secondary treatment plant before discharge at 80 m depth in northern part of the Haasteinfjord. The average anthropogenic nutrient load shows a minor decrease during the last 10 years (***Table 15***).

Table 15. *Anthropogenic nutrient load for area A5. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1017	850	57	53

Topographic and hydrophysical characteristics
Topographically the area is very variably, at one end including Hafrsfjord with its shallow sill and stagnant basin water and the other end the Haasteinfjord without sills, strongly influenced by the coastal current and with high water renewal rate.

In general the freshwater inflow is low, the surface salinity is measured in the 25-30 range and the vertical stratification moderate.

Water quality, biological conditions and degree of nutrient enrichment.

The most updated information is found in at study from 2001-2002 (Tvedten et. al., 2003) and monitoring of Aamøyfjord northwest of Stavanger during 1999-2005 (Tvedten, 2005). The first study included hydrography, water chemistry (N, P, O_2, chlorophyll a,), hard bottom flora and fauna and soft bottom fauna, secchi depth measurements and sediment analysis, while the Aamøyfjord study included water chemistry.

In the Hafrsfjord high nutrient concentrations, low oxygen concentration in the basin water (periods with H_2S), reduced hard bottom flora, and fauna and few species of soft bottom fauna in the basin is observed. In the basin water of Gandsfjord and Riskafjord the oxygen conditions was classified as Bad/Very (classes IV-V) according to the NCS.

However, for the major part of Area 4, the water quality and biological conditions did not show any significant effects from nutrient or organic loads.

Evaluation
The integrated classification is shown in **Table 16**.

Table 16. A4. *Integrated initial classification table.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Constant or slightly decrease	-
	Winter DIN- and/or DIP concentrations	Hafrsfj NCS=III. Otherwise NCS class I-II (Tvedten et.al., 2003a)	+
	Increased winter N/P ratio (Redfield N/P = 16)	Harfsfj. Near 24 (Tvedten et.al., 2003a). Otherwise normal.	+
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Vistavika and Hafsrfj. increased. Otherwise NCS class I-II (Tvedten et.al., 2003a)	-
	Nuisance species/harmful species; *Dinophysis* spp., *Alexandrium* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)	Littoral assemblages in good condition in Håsteinsfj. (Tvedten et al 2003a)	-
Indirect Effects (III)	Degree of oxygen deficiency	Periodically no O_2 in Hafrsfj. and very low concentrations in Gandsfjord and Riskafjord. Good in remaining areas (Tvedten 2005, Tvedten et al 2003a)	+/-
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna absent due to periodically low O_2 in Hafrsfj. Otherwise bottom fauna diverse and in good condition (Tvedten et al 2003a)	+/-
	Organic Carbon/Organic Matter	High TOC content in sediments in Hafsfj. (Tvedten et al 2003a)	+/-
Other Possible Effects (IV)	Nuisance species/harmful species; *Dinophysis* spp., *Alexandrium* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Toxic mussels	**?**

Initial classification: The effects vary highly due to varying load, topography and water exchange: Problem area.

Final classification: The problems are connected to fjords and other areas with limited water exchange. However, these are major parts of the area. The final classification is **Problem Area**

A5 Høgsfjord and Lysefjord east of Stavanger

The area is shown in **Figure 10**.

Nutrient load

The average anthropogenic nutrient load has increased during the last 10 years (***Table 17***).

Table 17. *Anthropogenic nutrient load for area A5 Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
562	637	64	83

Topographic and hydrophysical characteristics

These are long and deep fjords (Høgsfjord maximum depth 268 m) without shallow sills and with a moderate supply of freshwater. The vertical stratification is moderate with a typical surface salinity of 25-30.

Water quality, biological conditions and degree of nutrient enrichment.

Information on water quality and biological conditions in the Høgsfjord is found in Tvedten et al., (2003b). Except from the small Høle basin the nutrient and chlorophyll concentrations were low (NCS class I-II) and oxygen concentration relatively high (NCS-classes I-II).

The soft bottom fauna in the Høgsfjord basin was considered normal, but with relatively few species.

Evaluation

The integrated classification is shown in **Table 18**.

Table 18. *A5. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increased load	**+**
	Winter DIN- and/or DIP concentrations	NCS class I (Tvedten et.al., 2003b)	**-**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	NCS class I-II (Tvedten et.al., 2003b)	**-**
	Region/area specific phytoplankton indicator species		**?**
	Macrophytes including macroalgae (region specific)	Littoral locally in bad condition (Tvedten et al 2003a) some decline in sugar kelp (Moy et al. 2007), but littoral zone in Høgsfj was of good status (Tvedten et al 2003b)	**(+)**
Indirect Effects (III)	Degree of oxygen deficiency	Low O_2-values at Kalvøy, can be naturally. Moderate to high O_2-values (Tvedten et al 2003b)	**-**
	Changes/kills in Zoobenthos and fish mortality	Soft bottom fauna in bad to moderate condition with sign of heavy organic load and low O_2 content (Tvedten et al 2003a,b)	**(+)**
	Organic Carbon/Organic Matter	High organic content (Tvedten et al 2003a,b)	**+**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)		**?**

Initial classification: Potential Problem area.

Final classification: The area include some fjord basins and bays which are sensitive to nutrient and organic load/show effects from nutrients and organic load. These constitute small part of the area, but the observations of increased load and declining sugar kelp is a warning. **Potential Problem Area.**

A6 Boknafjord, Saudafjord, Hylsfjord, Vindafjord and the Sandsfjord

The basis for classification is briefly discussed. For a broader description, see Molvær et al. (2003a). The area is shown in **Figure 10**.

Nutrient load
The average anthropogenic nutrient load has increased during the last 10 years (***Table 19***).

Table 19. *Anthropogenic nutrient load for area A6. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1374	1506	208	252

Topographic and hydrophysical characteristics
This is a large fjord system with varying topographic and hydrographic features. The eastern parts receive high freshwater discharges which create a brackish surface layer and strong vertical salinity gradients. In the Boknafjord the impact from freshwater diminishes.

Water quality, biological conditions and degree of nutrient enrichment.

There have been carried out a number of site-specific studies at localities for fish farms, but none comprehensive studies of the fjord areas since 2000. The basis for an overall classification is therefore lacking.

Evaluation
The integrated classification is shown in **Table 20**.

Table 20. *A6. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	**Score**
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increasing	+
	Winter DIN- and/or DIP concentrations	No recent data	?
	Increased winter N/P ratio (Redfield N/P = 16)	No recent data	?
Direct Effects (II)	Maximum and mean chlorophyll a concentration	No recent data	?
	Region/area specific phytoplankton indicator species	Nuisance species, *Prymnesium parvum.* Elevated levels (Dahl, 2002).	?
	Macrophytes including macroalgae (region specific)	Some decline in sugar kelp (Moy et al. 2007)	(-)/+
Indirect Effects (III)	Degree of oxygen deficiency		?
	Changes/kills in Zoobenthos and fish mortality		?
	Organic Carbon/Organic Matter	No data	?
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	?

Initial classification: The increased load and indications of Indirect Effects: Potential Problem Area.

Final classification: There is very little data as basis for a classification. However, the observations of increased nutrient load and declining sugar kelp is a warning: **Potential Problem Area.**

A7 The Karmøy-Haugesund region

The area is shown in **Figure 10** and includes the Skjoldafjord, Førdesfjord, Førlandsfjord and the Karmsund. No recent data from the Skjoldafjord and Førlandsfjord have been found. However, with an extremely narrow and shallow sill and a wide and deep basin with permanent hydrogen sulphide in the basin water, the Skjoldafjord is in itself an obvious problem area.

Nutrient load

The average anthropogenic nutrient load has increased significantly during the last 10 years (***Table 21***).

Table 21. *Anthropogenic nutrient load for area A7. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
470	698	50	89

Topographic and hydrophysical characteristics

The topography and hydrography characteristics in this area is very varying, from the enclosed Skjoldafjord basin at one end to the Karmsund with its high tidally and meteorologically driven water exchange at the other end. The Førdesfjord and Førlandsfjord may be placed somewhere between these two extremes.

Water quality, biological conditions and degree of nutrient enrichment.

A study of water quality (nutrients, oxygen, and chlorophyll) and soft bottom fauna in Førdesfjord was carried out in 2001-2002 (Tvedten and Molversmyr, 2002). They found *Fair-Very Bad* (NCS-classification) oxygen conditions in the middle and inner part of the fjord. The concentrations of nutrients (winter) and chlorophyll (summer) in the surface layer were classified as *Good-Very Good*. In the inner half of the fjord the soft bottom fauna was significantly reduced due to low oxygen concentrations and with very high concentration of organic carbon in the sediments over most of the fjord.

The Karmsund has been monitored since 1990 both in connection with municipal outfalls and discharges of seaweed residues (see Tvedten 2005 and Molvaer et al. 2006). According to the NCS the overall water quality classification for nitrogen was *Good-Very Good* both summer and winter, while the phosphorus classification was *Good – Fair.* Chlorophyll was classified as *Good-Very Good*, with an average concentration about 2 µg/l. Except from two small enclosed basins the oxygen concentration were classified as *Very Good.*

The sediments had high concentration of TOC, and mainly of marine origin. Near the discharge of seaweed residues the fauna community structure and diversity are affected, but the discharge is also expected to enhance the production of invertebrates and fish. Outside 2-3 km from the discharge the benthic habitat conditions are normal.

Evaluation
The integrated classification is shown in ***Table 22***.

Table 22. *A7. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increased	**+**
	Winter DIN- and/or DIP concentrations	NCS I-III	**+/-**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Low concentrations	**--**
	Nuisance species/harmful species; *Alexandrium* spp., *Dinophysis* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)	Very good condition (Walday et al 2004), but some decrease in sugar kelp (Moy et al. 2007)	**(-)/+**
Indirect Effects (III)	Degree of oxygen deficiency	Generally no problem, but decreasing O_2 content in deep waters from outer to inner basins in Førdesfjord	**-/+**
	Changes/kills in Zoobenthos and fish mortality	Inner part of Førdesfjord is affected by low O_2 conditions. Changes in middle Karmsund	**+**
	Organic Carbon/Organic Matter	High TOC in inner Førdesfjord and in Karmsund	**+**
Other Possible Effects (IV)	Algal toxins; Azaspiracid, DSP (Castberg et al. 2005, Dahl et al 2006, Hestdal 2001-2003)	Toxic mussels	**?**

Initial classification: Problem area.

Final classification: **Problem area**

4.4 Hordaland county

The city of Bergen with city population of approx. 245000 is the dominating city on the coastline. Others are Leirvik (11100) and Odda (5300). For classification purposes the coast of Hordaland county is divided into 7 Areas (A8-A14) as indicated in **Figure 12**. In the following the areas will be classified according to the procedure outlined in Chapter 3. In general there is very few new data since the previous assessment and the description of each area will be brief.

The Norwegian sugar kelp study includes a number of stations in Hordaland and on some stations the negative effects are serious (***Figure 13***).

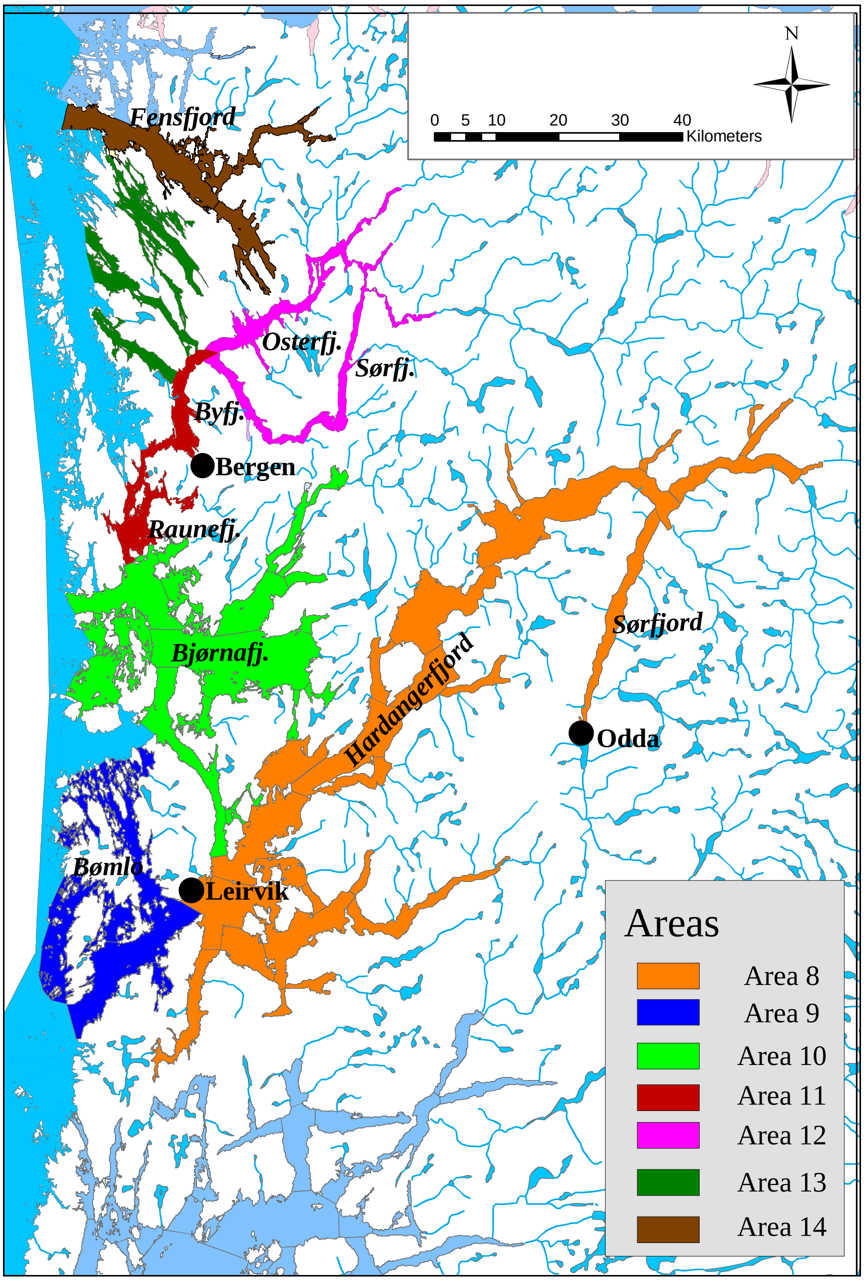


Figure 12. *Hordaland county showing the 7 classification areas A8-A14*

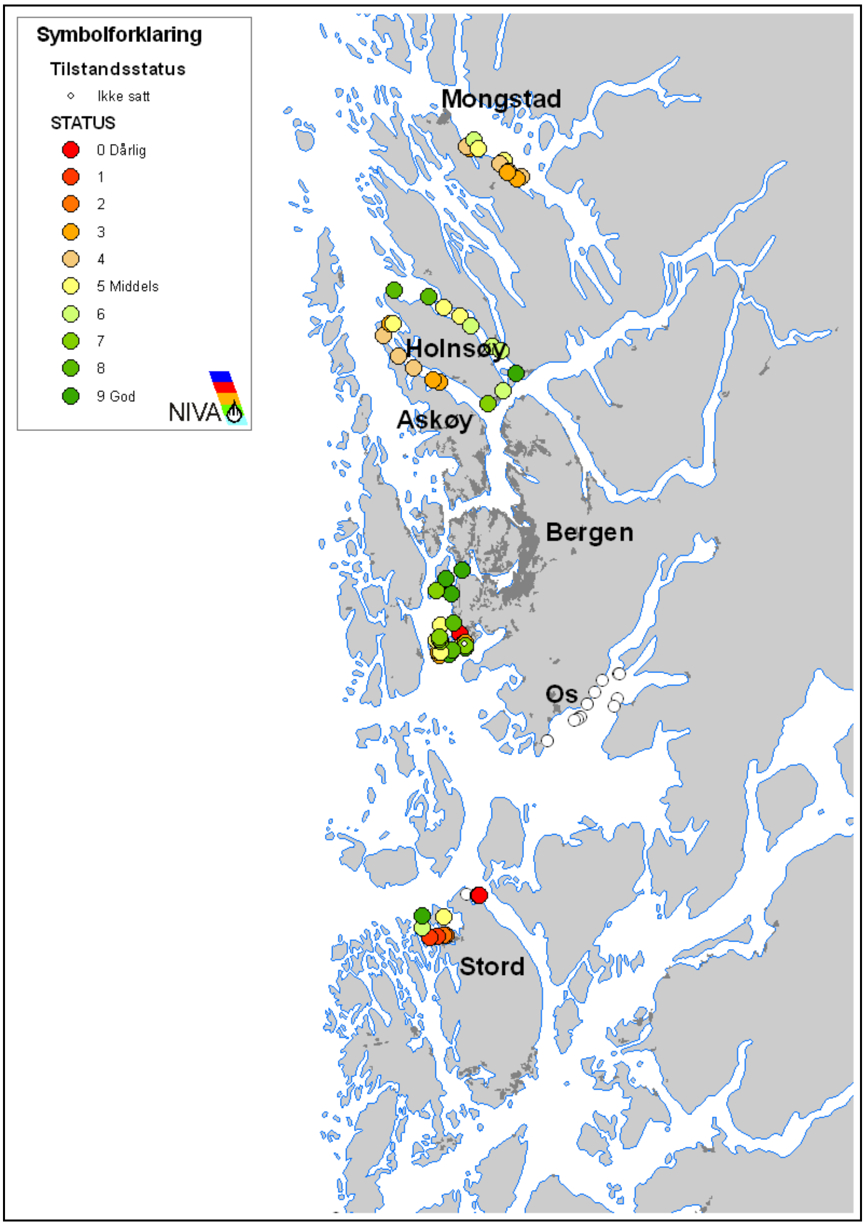


Figure 13. *Sugar kelp stations in Hordaland county (2005-2006). The situation is classified according to a scale where Green= good, Yellow= middle, Red= bad. After Moy et al. (2007).*

A8 The Hardangerfjord

The area is shown in **Figure 12**.

Nutrient load
The average anthropogenic nutrient load has increased by 70-80% during the last 10 years due to an increased production in aquaculture farms (***Table 23***).

Table 23. *Anthropogenic nutrient load for area A8. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1251	2111	221	401

Topographic and hydrophysical characteristics
The Hardangerfjord is the second largest fjord in Norway with a length of approx. 180 km and a depth of more than 800 m.

From the surrounding mountains – including the glacier Folgefonni - the fjord receives a large amount (typically annual mean of 250-300 m^3/s) of fresh water which creates a significant vertical stratification which is especially well established in the inner part.

Water quality, biological conditions and degree of nutrient enrichment.

Except from the Sørfjord there are very few data series that may be used for an overall description of water quality and biological conditions in the Hardangerfjord, and to evaluate trends over the last 6-8 years.

In the Sørfjord water quality in the southern part has been monitored since 1995 and very serious oxygen problems and high nitrogen concentrations were observed due to very high industrial discharges of oxygen-consuming nitrogen compounds. However, after the discharge stopped in 2002 the situation has improved significantly, even though some problems remain (see Molvaer, 2006).

There have not been any comparably studies of hard bottom or soft bottom communities since 1996 and therefore no information for use in this assessment.

There is a large number of aquaculture farms in this area (***Figure 14***) and also many studies at these locations (within a few hundreds of meters), but the information is not suited for this type of broad assessment. However, in its annual report "Kyst og havbruk 2007", the Institute of Marine Research, Bergen, describes results from a project where the 3D-model NORWECOM was used to simulate effects on the phytoplankton community with increasing nutrient discharges from the aquaculture industry (Eknes, 2007). The experiment showed that the increase in concentration of phytoplankton due to nutrient discharge from the fish farms in 2003 was small, when averaged over larger areas. Even by allowing ten times the 2003 discharge, the concentration of phytoplankton in the area increased by 13% at the most. However, the results were sensitive for the location of the farms, disfavouring locations in the more sheltered inner areas.

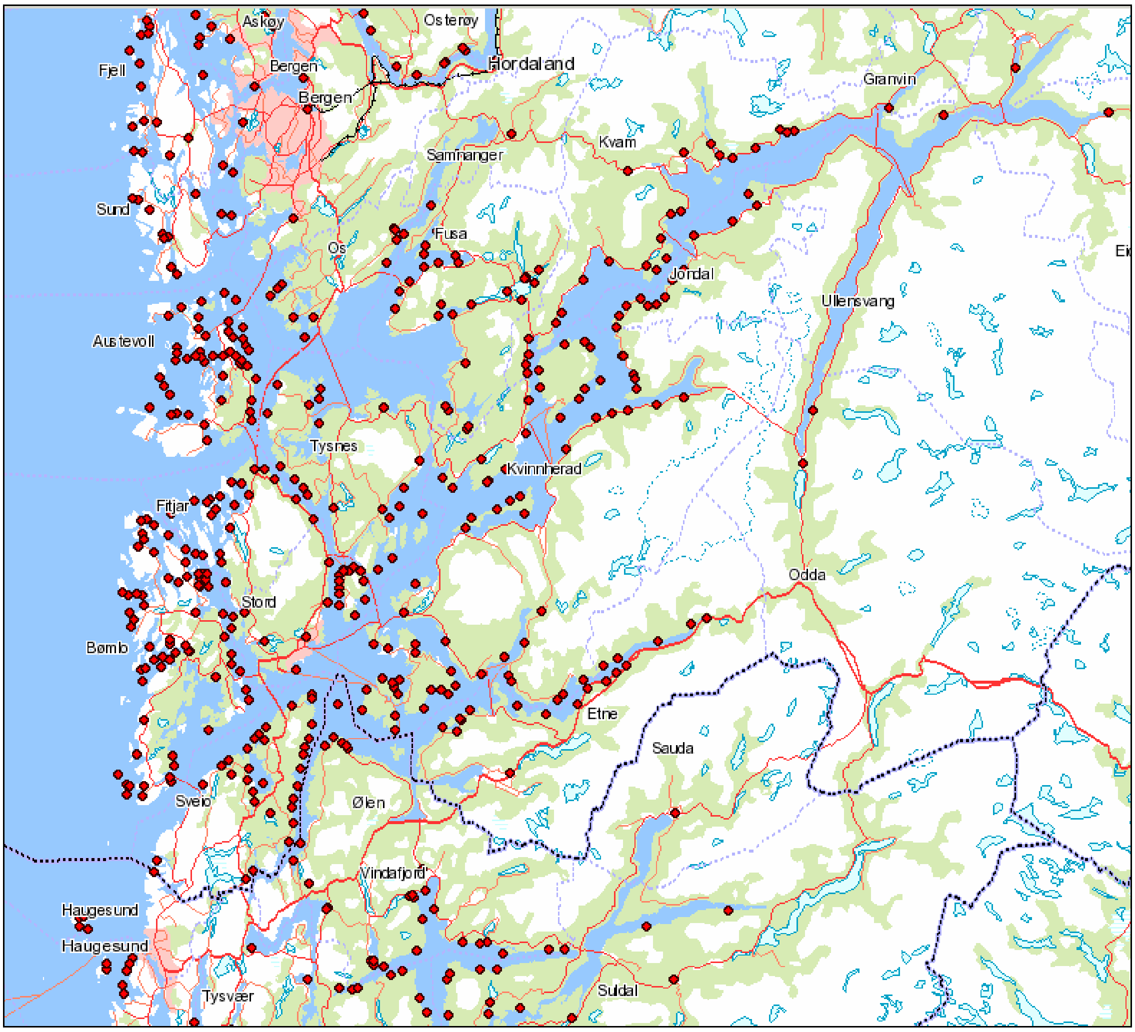


Figure 14. *Approved localities for aquaculture in Hordaland between Haugesund and Bergen in 2007. Source: fiskeridir.no*

The report does not describe the corresponding nutrient load or other model details. As mentioned above the anthropogenic P-load for 2003 were not been calculated in this report, but for 2004 – and a 10-fold increase - the N- and P-load may been calculated as shown in ***Table* 24**. The "Sum" includes all main sources except the contribution through the water exchange with coastal waters.

Table 24.*Nutrient load from aquaculture, anthropogenic sources and as Sum (including background runoff) in the Hardangerfjord in 2004, and with a tenfold increase.*

	Year	**Aquaculture**	**Anthropogenic**	**Sum**
Nitrogen	2004	1353	2063	3935
	2004loadx10	13530	14200	16070
Phosphorus	2004	287	337	373
	2004loadx10	2870	2920	2955

Looking at the 2004-load multiplied by ten, there are no Norwegian fjords with comparable nutrient loads. The anthropogenic P-load would even be significantly higher than the combined anthropogenic P-load over the coastline Lindesnes-Stad in 2004-2005, while the N-load would be about 4000 tons less.

There is one more relevant source of information. Results from the ongoing sugar kelp-project indicate that the hard bottom flora may be quite sensitive to a changing environment (temperature changes, combined with nutrient loads). Observations from areas south and north of the Hardangerfjord suggest that in areas with limited water exchange the sugar kelp is disturbed. Photos of hard bottom flora from the Hardangerfjord provided by the Hordaland county authorities (FMVA) have been shown to participants in the sugar kelp-study who find the effects similar to those in affected areas of the Skagerrak coast and of Rogaland (Moy, pers.comm.). As regards effects on the sugar kelp, both observations and the IMR experiment suggest ***location*** of fish farms in areas with restricted water exchange can be a problem.

Evaluation
The integrated classification is shown in ***Table 25***.

Table 25. *A8. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase	+
	Winter DIN- and/or DIP concentrations	No basis for a general assessment	-
	Increased winter N/P ratio (Redfield N/P = 16)	No basis for a general assessment	-
Direct Effects (II)	Maximum and mean chlorophyll a concentration		-/?
	Nuisance species/harmful species; Alexandrium spp., *Dinophysis* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	?
	Macrophytes including macroalgae (region specific)	Indications and warnings	?/+
Indirect Effects (III)	Degree of oxygen deficiency	Only local problems (Sørfjorden)	-/+
	Changes/kills in Zoobenthos and fish mortality		-
	Organic Carbon/Organic Matter		?
Other Possible Effects (IV)	Algal toxins; Azaspiracid, DSP (Castberg et al. 2005, Dahl et al 2006, Hestdal 2001-2003)	Toxic mussels	?

Initial classification: **Potential problem area**.

Final classification: There has been a strong increase in nutrient and organic load, without any organized monitoring of Direct or Indirect Effects. Even though the NORWECOM model runs indicate that the fjord can tolerate far higher loads than the present, the Hardangerfjord should be classified as **Potential Problem Area** until studies of Direct or Indirect Effects have been carried out.

A9 The Bømlo area

The area is shown in **Figure 12**.

Nutrient load

The overall nitrogen load for this area has decreased during the last 10 years, while the phosphorus load shows some increase. The outfalls of municipal sewage are directed to recipients with relatively high water exchange.

Table 26. *Anthropogenic nutrient load for area A9. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
652	376	11	18

Topographic and hydrophysical characteristics

The Bømlo area is an archipelago close to the sea. Water exchange is good except in some smaller polls and sheltered bays.

Water quality, biological conditions and degree of nutrient enrichment.

There are generally few observations from the area, but a number of studies on fish farms localities like Tveranger and Johnsen (2004), Tveranger et. al. (2006a,b). These studies are in general not suited for an overall classification.

From 2005 and 2006, hydrochemical observations from the FerryBox system aboard Fjord Norway was sampled at 4 meters depth from Bømlofjorden (FN 16) (***Figure 8***). The concentrations are in Class I (NCS) are shown in ***Table 27*** and ***Table 28***. Investigations of sugar kelp (Moy et.al. 2007), showed reduction in some of the few visited localities (***Figure 13***).

Table 27. *Average winter concentrations (December – February) of nutrients (µM) and salinity observations at 4 meters depth from the FerryBox system on Fjord Norway.*

Station	N-obs	Sal	PO_4-P (DIP)	DIN	DIN/DIP
FN 13	8	30.0	0.35	5.21	19.1
FN 16	8	30.24	0.33	5.19	19.7

Table 28. *Average summer concentrations (June-August) of nutrients (µM), chlorophyll-a and salinity observations at 4 meters depth from the FerryBox system on Fjord Norway.*

Station	N-obs	Sal	Tot-P µg/l	PO_4-P µg/l	Tot-N µg/l	NO3+NO2-N µg/l	NH4-N µg/l	Chl-a µg/l
FN 13	5	30.45	11.9	3.8	137	6.4	6.8	1.22
FN 16	5	31.42	11.3	3.8	124	8.6	7.4	1.16

Evaluation
The integrated classification is shown in Table 29.

Table 29. A9. *Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)		**-**
	Winter DIN- and/or DIP concentrations	Bømlafjorden	**-**
	Increased winter N/P ratio (Redfield N/P = 16)	Bømlafjorden	**-**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Bømlafjorden	**-**
	Region/area specific phytoplankton indicator species	No data	**?**
	Macrophytes including macroalgae (region specific)	Locally reduced sugar kelp (Moy, et.al., 2007)	**?**
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)	No data	**?**

Initial classification: The overall classification of the area will be a Non Problem Area, but locally problem areas exists.

Final classification: **Non Problem Area**

A10 Hardangerfjord to Bergen

The area is shown in **Figure 12**.

Nutrient load

The average anthropogenic nutrient load has increased during the last 10 years (***Table 30***).

Table 30. *Anthropogenic nutrient load for area A10. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
2171	2382	412	463

Topographic and hydrophysical characteristics

The area is a mixture between archipelagos and fjords, with larger open areas in between. Locally, there are smaller areas with very restricted water exchange, as Lygrepollen (a poll with depths up to about 200 meter and sill depth at the narrow entrance about 20 m).

Water quality, biological conditions and degree of nutrient enrichment.

Generally few observations from the area. Local studies have been carried out at Langmuen (increased load and indication of reduction in sugar kelp (Moy, et.al, 2007) and Skeiosen (increased nutrient load, moderate to bad soft bottom fauna and elevated TOC concentrations in sediments (Heggøy et.al., 2005c). However, a larger sill fjord as the Samnanger fjord, has normal conditions in the littoral zone and soft bottom fauna (Heggøy et. al., 2006). This is also the situation in the Fanafjord, except for some smaller areas (Heggøy et.al., 2005).

Evaluation
The integrated classification is shown in ***Table 31***.

Table 31. *A10. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)		+
	Winter DIN- and/or DIP concentrations		**?**
	Increased winter N/P ratio (Redfield N/P = 16)		**?**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**?**
	Region/area specific phytoplankton indicator species	No data	**?**
	Macrophytes including macroalgae (region specific)	Locally reduction in sugar kelp (Moy et.al., 2007)	**+/-**
Indirect Effects (III)	Degree of oxygen deficiency	Locally low oxygen (Heggøy et al 2005c)	**-/+**
	Changes/kills in Zoobenthos and fish mortality		**?**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	**?**

Initial classification: The overall classification of the area will be a Potential Problem Area

Final classification: The environmental conditions in this area are varying, and an overall classification is difficult to find, but **Potential Problem Area** seems reasonable.

A11 Fjords around Bergen

The area is shown in **Figure 12**.

Nutrient load
This area is recipient for the city of Bergen and surrounding communities. The average anthropogenic nutrient load has increased somewhat during the last 10 years (***Table 32***).

Table 32. *Anthropogenic nutrient load for area A11. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
134	197	23	25

Topographic and hydrophysical characteristics
The topography and hydrophysics of this area is very varying, from relatively open and deep fjords like the Korsfjord to the south Raunefjord and the Byfjord outside Bergen city, with high water exchange, to the very enclosed Nordåsvatn with a narrow and shallow sill and a deep basin inside.

The freshwater runoff is moderate to small, and the surface salinity at Raunefjord is typically around 30 decreasing to 15-25 in the Byfjord. Field studies and models show a dominating northwards current through the Raunefjord – Byfjord.

Water quality, biological conditions and degree of nutrient enrichment.

Most of this area has been covered by a periodic monitoring programme sponsored by city of Bergen since 1973, and carried out by the University of Bergen. The monitoring has included water quality, soft bottom fauna and hard bottom flora and fauna. The latest report is Heggøy et al. (2005a).

Observations from 4 m depth summer and winter with the FerryBox system aboard Fjord Norway from FN 13 (Raunefjorden), do not indicate any eutrophication problems in the free water masses (***Table 27*** and ***Table 28***) and the fjord system shows no other signs of eutrophication effects. In the Byfjord the surface nutrient concentration correspond to classes I-II in the NCS. However, the authors point out that the oxygen in the bottom water and the soft bottom fauna show a (weak) decreasing trend. In the Nordåsvatn the trend is positive (water quality, soft bottom fauna), while the situation in smaller and more local recipients are varying.

In the archipelago west of Bergen there have been a number of local studies of the recipients, usually with focus on identifying obvious weak recipients (like Johnsen 2000, Brekke et al. 2001, 2003). More general studies of the fjords in Fusa and Os communities to the south-east of Bergen were carried out in 2005 (Heggøy et al. 2005b, Heggøy and Johannessen 2006a, Johansen e. al. 2002). The overall finding from these studies were that there is a large number of rather small recipients (small fjords/polls/sheltered bays) with low water exchange, and these are sensitive to nutrients and organic loads.

Evaluation
As noted above this area contains a large number of recipients, where many are sensitive due to low water exchange. The overall classification is shown in ***Table 33***

Table 33. *A11. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in N and constant P	**+/-**
	Winter DIN- and/or DIP concentrations	According to NCS	**-**
	Increased winter N/P ratio (Redfield N/P = 16)		**-**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	According to NCS	**-**
	Nuisance species/harmful species; *Dinophysis* spp. *Prorocentrum* cf minimum/balticum, *Pseudo-nitzschia* spp. (Dale&Egge pers com to WE)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)		**-**
Indirect Effects (III)	Degree of oxygen deficiency	Byfjord: negative trend	**+**
	Changes/kills in Zoobenthos and fish mortality	Byfjord: negative trend	**+**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	**?**

Initial classification: Problem area.

Final classification: The problems seem to be associated with long-term developmend in the Byfjord, near Bergen, and a number of small recipients. An overall classification as **Potential Problem Area** is suggested**.**

A12 Fjords northeast of Bergen: Osterfjord - Sørfjord

The area is shown in **Figure 12**.

Nutrient load
The average anthropogenic nutrient load has increased significantly during the last 10 years (***Table 34***).

Table 34. *Anthropogenic nutrient load for area A12. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
971	1305	178	256

Topographic and hydrophysical characteristics

The Osterfjord/Sørfjordsystem is a landlocked fjord system with several deep side fjords with narrow and shallow sills. Local freshwater discharges characterise the surface water in the area (Salinity from 13-28 in the upper 2 meters) and are crucial for deep water exchanges and oxygen conditions in the side fjords with shallow sills. Regulation of fresh water discharges to some of the side fjords (as the Bolstadfjord). In spite of naturally anaerobic deep water in the Bolstadfjord, the regulation of the runoff (increased winter discharges) can reduce the deep water renewals in frequency and volume (Molvær og Magnusson, 1984).

Water quality, biological conditions and degree of nutrient enrichment.

Some parts of the area have been monitored regularly since 1991 (Johnsen et.al. 2005). Winter surface concentrations of nitrate (2003-2004) in the Sørfjord are more or less over 8-11 µM, but with salinities in the surface layer sometimes below 20 µM.

Heggøy et al. (2005a) show indications for a negative trend, as:

- Decreasing oxygen concentration in the fjord bottom water
- Negative trend in the soft bottom fauna

These are the same signals as observed in the Byfjord near Bergen. None of these signals are very strong, but the authors advice continued monitoring.

Evaluation
The integrated classification is shown in ***Table 35***.

Table 35. *A12. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Significant increase	**+**
	Winter DIN- and/or DIP concentrations	Nitrate ClassII-III (NCS) Phosphate Class I (NCS)	**-**
	Increased winter N/P ratio (Redfield N/P = 16)		**-**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**-**
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)		**?**
Indirect Effects (III)	Degree of oxygen deficiency	Weak negative trend	**+**
	Changes/kills in Zoobenthos and fish mortality	Weak negative trend	**+**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	**?**

Initial classification: Problem area.

Final classification: *As the oxygen levels and the changes in zoobenthos are small – though negative* **-** *a*n overall classification as **Potential Problem Area** is suggested**.**

A13 Fjords north of Bergen: Herdlafjord - Lurefjord

The area is shown in **Figure 12**.

Nutrient load

The overall anthropogenic nutrient load for this area has been relatively constant during the last 10 years, and relatively low (***Table 36***). The outfalls of municipal sewage are in general directed to recipients with relatively high water exchange.

Table 36. *Anthropogenic nutrient load for area A13. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
1035	1103	119	117

Topographic and hydrophysical characteristics

The area consists of a mixture between deeper fjords, straits and a great amount of smaller polls and bays. Water exchange can be restricted in fjords like the Lurefjord with sill depth of about 20 m and the deepest part inside the sill reaching about 440 meters depth.

Water quality, biological conditions and degree of nutrient enrichment.

Observations from Herdlafjord is from Vassenden and Johannessen (2006) and Moy et.al. (2007), showing decline in sugar kelp (Moy, et.al., 2007) and locally low oksygen due to shallow sills and high TOC content in sediments as well as improvement in soft bottom communities (Vassenden and Johannessen, 2006). As for the Lurefjord the sugar kelp populations was vigorous (Moy, et.al, 2007) and soft bottom fauna in good condition (Heggøy et.al, 2005b).

There are not enough observations of nutrients for classification, but most of the few nitrate observations in the winter period were in class III (NCS), while phosphate was in class III only at a few stations.

Evaluation
The integrated classification is shown in ***Table 37***.

Table 37. *A13. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Constant	**-**
	Winter DIN- and/or DIP concentrations	To few observations	**?**
	Increased winter N/P ratio (Redfield N/P = 16)	To few observations	**?**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	No data	
	Nuisance species/harmful species; *Alexandrium* spp., *Dinophysis* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)	Varying from areas with declining sugar kelp populations to vigorous populations (Moy, et.al. 2007).	+
Indirect Effects (III)	Degree of oxygen deficiency	Periodically low oksygen (Heggøy et al, 2005b).	
	Changes/kills in Zoobenthos and fish mortality	Soft bottom communities in good to less good condition, varying in the area (Heggøy et al., 2005b).	+
	Organic Carbon/Organic Matter	High TOC in deep areas with restricted water exchange (Vassenden and Johannessen 2006 and Heggøy et.al. 2005b).	**?**
Other Possible Effects (IV)	Algal toxins; DSP (Castberg et al. 2005, Dahl et al 2006, Hestdal 2001-2003)	Toxic mussels	**?**

Initial classification: Problem area

Final classification: **Potential Problem Area.** This classification is due to the great variability in the area with fjords with limited water exchange, thus extra sensitive to external loads.

A14 Fensfjord - Masfjord

The area is shown in **Figure 12**.

Nutrient load

The overall anthropogenic nitrogen load for this area has increased significantly during the last 10 years while the phosphorus load has been relatively constant (small decrease) (***Table 38***).

Table 38. *Anthropogenic nutrient load for area A14. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
149	382	17	14

Topographic and hydrophysical characteristics

The area dominates by to fjords surrounded by smaller polls and bays, often with topographical restricted water exchange. The Fensfjord is a ca. 500 m deep, a relatively open fjord with a deep sill (over 200 m deep) separating it from the open sea. The Masfjord connects to the Fensfjord and has maximal depth of about 490 meter, with a restricted sill area with sill depth about 80-90 meters depth. Fresh water discharge to the fjord is about 20 m^3/s (30 years average). The surface salinity is high, except in areas close to rivers.

Water quality, biological conditions and degree of nutrient enrichment.

Fensfjord was classified as a NPA in the screening procedure 2003. However, decline in sugar kelp is observed (Moy, et.al. 2007) along a part of the coast at Mongstad (Figure 13) indicating eutrophication problems as well as good to moderate soft bottom communities in the sheltered inner parts of Hindenesfjord, situated inside the Fensfjord (Heggøy et al., 2005b). Other smaller fjords and small polls are observed with less good soft bottom conditions and low oxygen content (Heggøy et al., 2005b). These areas are very sensitive for changes in nutrient loads and water exchange.

There are no relevant observations from the Masfjord.

Evaluation
The integrated classification is shown in ***Table 39***.

Table 39. *A14. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in N and decrease in P	**+/-**
	Winter DIN- and/or DIP concentrations		**?**
	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)	Observed decline of sugar kelp in one part of the area (Moy, et.al. 2007).	**?**
Indirect Effects (III)	Degree of oxygen deficiency	In smaller polls and fjords with restricted water exchange (Heggøy et.al., 2005b)	**-**
	Changes/kills in Zoobenthos and fish mortality	Good conditions in soft bottom communities, except in some polls with restricted water exchange (Heggøy et.al., 2005b)	**-**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	**?**

Initial classification: Non Problem area

Final classification: As there is a lack of information from the Masfjord as an important part of the area, the classification could be set to **Potential Problem Area**

4.5 Sogn & Fjordane county

For classification purposes the coast of Sogn & Fjordane county is divided into 7 Areas (A15-A21) as indicated in ***Figure 15***. In the following the areas will be classified according to the procedure outlined in Chapter 3.

There are three towns on the coastline: Førde (city population approx. 8800), Florø (city population approx. 8300) and Måløy (city population approx. 3000). The county authorities has provided the present project with a list of approximately 70 marine studies over the last 7-9 years, but more than 60 are studies of localities for fish farms (***Figure 16***). These studies cover very small areas and are in general not suited for broader assessments like the present one.

The Norwegian sugar kelp study includes a number of stations in Sogn & Fjordane county and in the Dalsfjord the negative effects are serious (**Figure 17**).

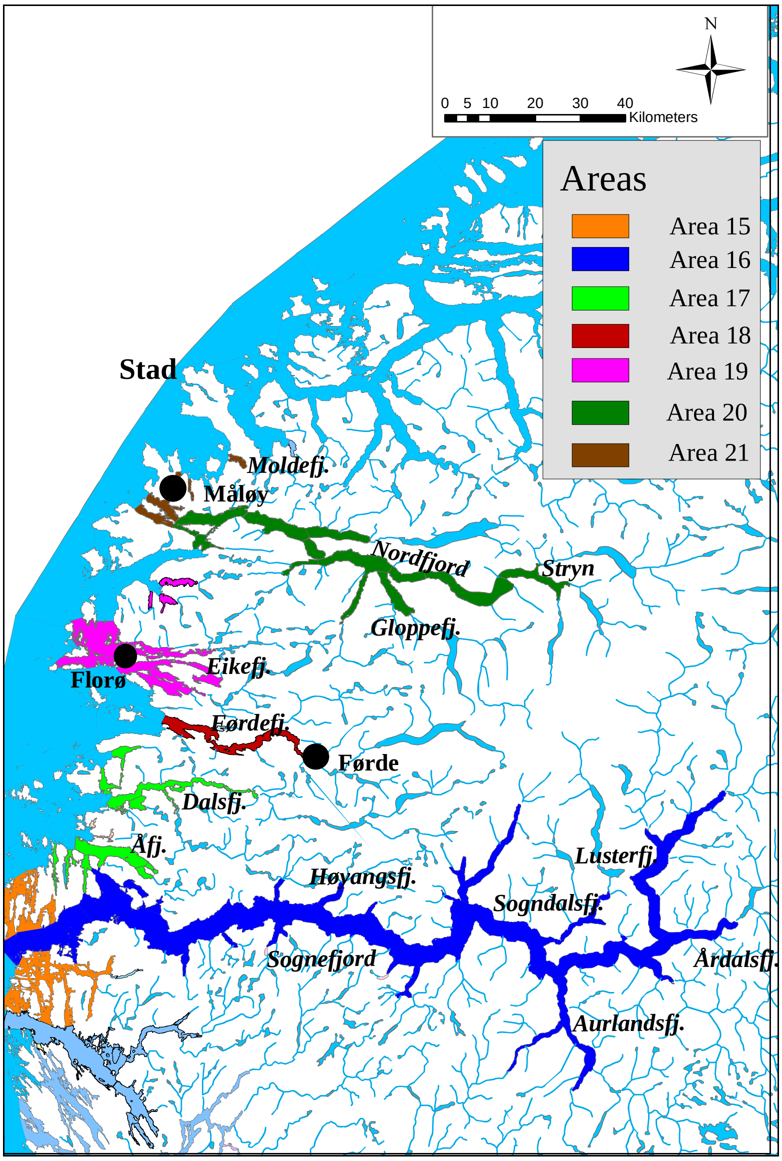


Figure 15. *Sogn & Fjordane county with areas A15-A21*

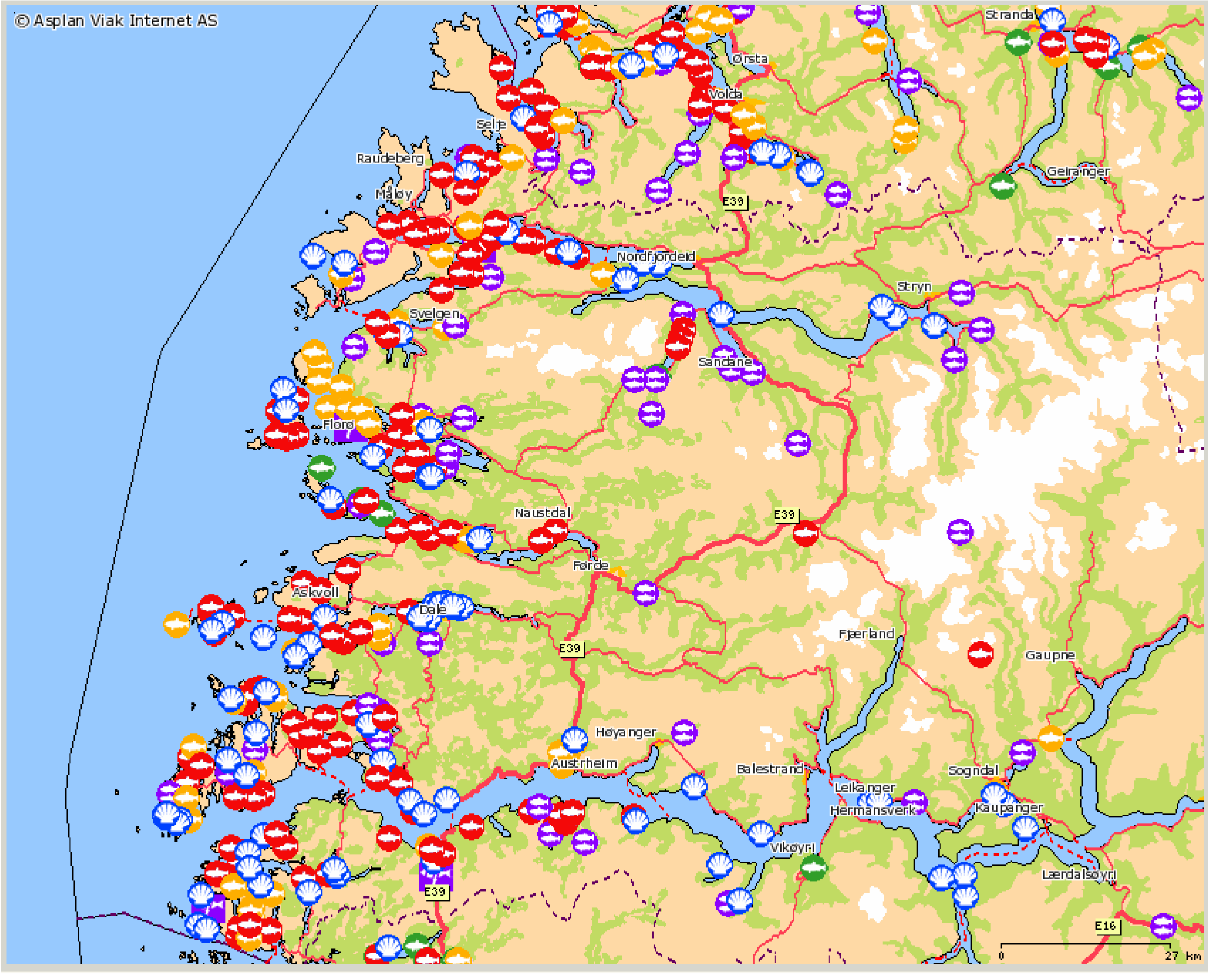


Figure 16. *Approved localities for aquaculture farms in Sogn & Fjordane county (source: Fylkesatlas Sogn og Fjordane).*

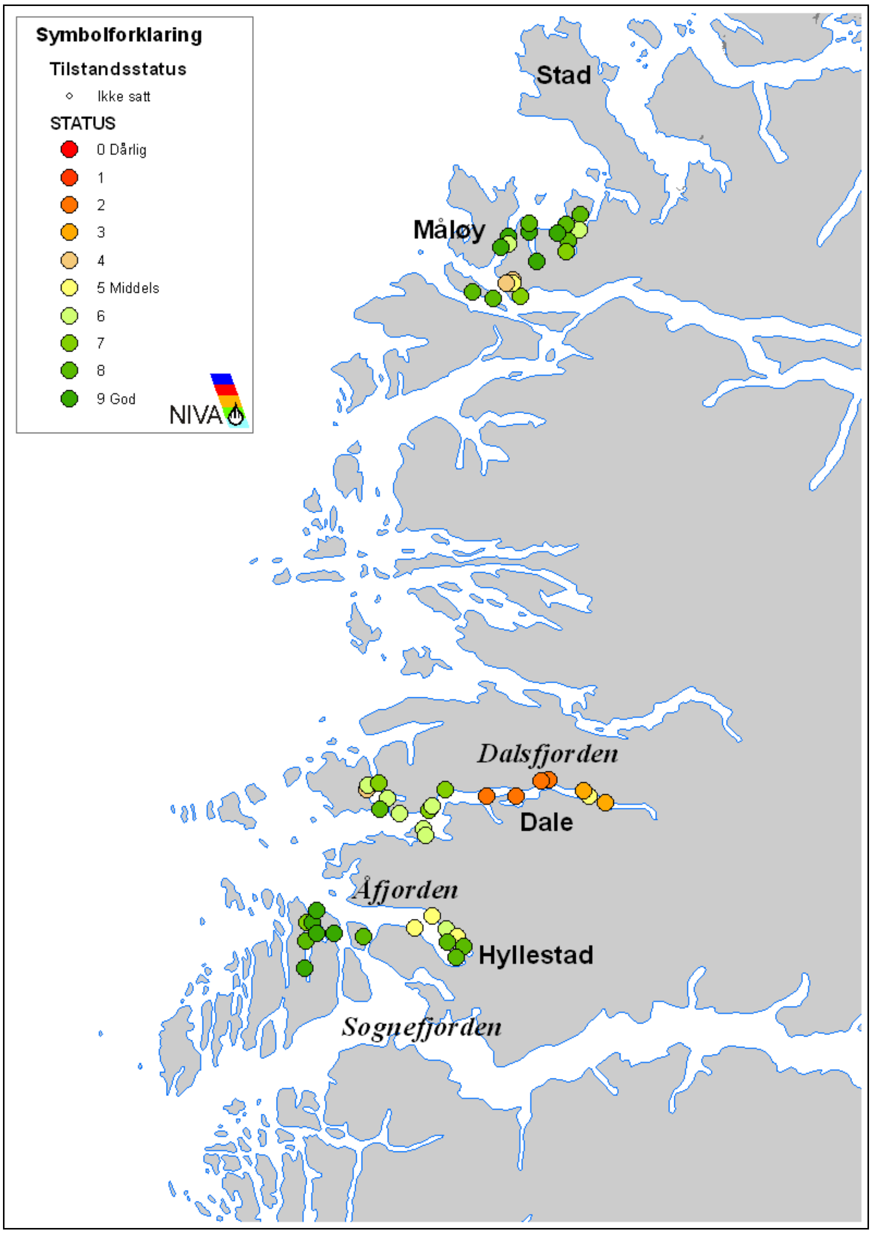


Figure 17.*Sugar kelp stations in Sogn & Fjordane county (2005-2006). The situation is classified according to a scale where Green= good, Yellow= middle, Red= bad. After Moy et al. (2007)*

A15 The Gulafjord and Sula

The area is shown in ***Figure 15*** and consists of two regions: the Gulafjord south and Sula to the north of Sognefjord.

Nutrient load

The overall anthropogenic nutrient load for this area has increased significantly during the last 10 years (***Table 44***). The outfalls of municipal sewage are in general directed to recipients with high water exchange.

Table 40. *Anthropogenic nutrient load for area A15. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
674	912	127	180

Topographic and hydrophysical characteristics

Both fjord regions consist of a large number of islands with narrow sounds. From general experience of the water exchange on these parts of the west coast (high meteorological and tidal influence) one shall expect high water exchange outside restricted polls or sheltered bays.

Water quality, biological conditions and degree of nutrient enrichment.

We have not found any comprehensive study of the recipients in either of the regions, only some local studies at fish farm localities.

The Norwegian sugar kelp study includes a number of stations in Sula to the north (the Dombefjord) and no effects were detected (***Figure 17***).

Evaluation
The integrated classification is shown in ***Table 43***.

Table 41. *A15. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in both N and P	+
	Winter DIN- and/or DIP concentrations		**?**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**?**
	Region/area specific phytoplankton indicator species	No data	**?**
	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)	No data	

Initial classification: The increased nutrient load and questionmarks about effects indicates a classification as Potential Problem Area

Final classification*:* There are no identified eutrophication problems in this area, but there are not data that justifies a classification as No Problem Area. Therefore: ***Potential Problem Area***

A16 The Sognefjord

The area is shown in ***Figure 15***.

Nutrient load
The population around the fjord is relatively low and mostly situated in the fjord branches (like the Høyangsfjord, Årdalsfjord and the Sogndalsfjord). The overall anthropogenic nutrient load for this area has been relatively constant during the last 10 years, and relatively low (***Table 44***). The outfalls of municipal sewage are in general directed to recipients with relatively high water exchange.

Table 42. *Anthropogenic nutrient load for area A16. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
997	1059	189	161

Topographic and hydrophysical characteristics
Sognefjord is the largest fjord in Norway with a total length of 204 km, maximum depth of 1308 m and a sill depth of 160 m. The main fjord branches into many smaller fjords like the Høyangsfjord, Fjærlandsfjord, Sogndalsfjord, Aurlandsfjord, Årdalsfjord and the Lusterfjord.

A high freshwater runoff to the fjord from surrounding mountains and glaciers creates a significant brackish surface layer, but varying in salinity and thickness over the year.

Water quality, biological conditions and degree of nutrient enrichment.

We have not found any recent studies of water quality or biological conditions in the main body of the Sognefjord, but a few from adjoining fjord branches but often dealing with toxic substances (Årdalsfjord, Høyangsfjord).

The **Sogndalsfjord - Barsnesfjord** environment was studied in 1999 (Myrseth et al., 2000). Both are fjords with relatively shallow sills (26 m and 8 m respectively) and deep basins inside (260 m and 80 m respectively). In the Barsnesfjord H_2S was observed in the basin water, and there were no living animals in the samples of bottom fauna. Additional oxygen samples down to 56 m depth in May 2003 (Golmen et al., 2003) showed oxygen throughout the water column.

In the Sogndalsfjord the water body was well oxygenated down to 50 m, and with poor oxygen content below (ca. 2 mlO_2/l).

The same study also included a station in **Amblabukta** to the east of Sogndalsfjord. The station had very rich bottom fauna.

In all regions the littoral zone showed signs of local pollution near outlets.

A study of the environment around a fish farm locality at Oppedal in the western part of Sognefjord may shed some light on the environment in the deep basin (Heggøy and Johannessen, 2006b). The samples were taken in November 2005. The oxygen was sampled down to 200 m depth where the concentration was 5,3 mlO_2/l (80% saturation). Samples of soft bottom fauna showed some local influence from the fish farm, but a single sample from the deep basin (1180 m depth) indicated class II (Good) according to the NCS.

Evaluation
It is difficult to give an overall classification based on datasets from two of the fjord branches. The lack of data from the middle and western part of the main fjord is especially unfortunate. The integrated classification is shown in ***Table 43***.

Table 43. *A16. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Constant	**-**
	Winter DIN- and/or DIP concentrations		**?**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**?**
	Nuisance species/harmful species; *Alexandrium* spp., *Dinophysis* spp., *Pseudo-nitzschia* spp. *Protoceratium reticulatum* (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)		**?**
Indirect Effects (III)	Degree of oxygen deficiency	Problems in some local fjord branches	**-/+**
	Changes/kills in Zoobenthos and fish mortality		**-?**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Nuisance species/harmful species; *Alexandrium* spp., *Dinophysis* spp., *Pseudo-nitzschia* spp. *Protoceratium reticulatum* (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**

Initial classification: Non Problem Area

Final classification*:* The elevated levels of nuisance/harmful species of harmful algae introduce an uncertainty, but according to **Table 2-Table 3** a classification as ***Non Problem Area*** is suggested.

A17 The Åfjord and Dalsfjord area

The area is shown in ***Figure 15***.

Nutrient load

The overall anthropogenic nutrient load for this area has increased significantly during the last 10 years (***Table 44***).

Table 44. *Anthropogenic nutrient load for area A17. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
175	334	32	48

Topographic and hydrophysical characteristics

The area is dominated by the Åfjord and the Dalsfjord, with deep basins (depth 350-400 m) behind relatively deep sills (130-170 m). Both receive marked freshwater runoff - especially Dalsfjord with the river Gaular (average 50 m^3/s) – creating a significant brackish surface layer in most of the fjords.

We have not found any studies of the water exchange in these fjords.

Water quality, biological conditions and degree of nutrient enrichment.

The Norwegian sugar kelp study includes a number of stations in this area and in the Dalsfjord serious effects were observed. To a smaller extent in the Åfjord (***Figure 17*)**.

There are site-specific studies of localities for fish farms and Heggøy et al. (2006) classified the soft bottom fauna (diversity index) in the deep outer basin as Good-Very Good.We have not found any other studies of water quality or biological conditions in this area.

Evaluation

The overall classification is shown in ***Table 45***.

Table 45. *A17. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase both N and P	+
	Winter DIN- and/or DIP concentrations		
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)		**+/-**
Indirect Effects (III)	Degree of oxygen deficiency	Not enough data	**-/?**
	Changes/kills in Zoobenthos and fish mortality		**-**
	Organic Carbon/Organic Matter	Not enough data	**-/?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Potential Problem Area

Final classification: **Potential Problem Area**

A18 The Førdefjord

The area is shown in ***Figure 15***.

Nutrient load
The overall anthropogenic nutrient load for this area has increased significantly during the last 10 years (***Table 46***).

Table 46. *Anthropogenic nutrient load for area A18. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
134	309	21	39

Topographic and hydrophysical characteristics
The Førdefjord is approximately 40 km long with a major sill approx. 30 km from the town Førde. The sill depth is 55-60 m with a basin depth of 416 m inside. Outside Førde is a small basin with a maximum depth of 53 m and sill depth 37 m.

The freshwater runoff the fjord is relatively large with the river Jølstra (average 53 m^3/s) as the main source. This creates vertical stratification with a significant brackish surface layer.

Water quality, biological conditions and degree of nutrient enrichment.

The studies of the Førdefjord has had their sponsors in Førde and concentrated on the innermost basin and the immediate areas outside it. The basin is recipient for the municipal wastewater from Førde and the studies have shown strong effects on soft bottom fauna (DNV 2001) and oxygen problems (Molvaer 2006a). There is very little information about the situation in the main basin, but a brief survey of oxygen conditions down to 260 m depth in March-May 2006 found concentrations about 3-3,3 mlO_2/l below 120 m depth (Molvaer, 2006b). That corresponds to class II (Fair) in the NCS.

These results indicate periods of low oxygen concentrations in the Førdefjord basin waters. There are no known observations of soft bottom fauna in the basin.

Evaluation
The integrated classification is shown in Table 47.

Table 47. A18. *Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase both N and P	+
	Winter DIN- and/or DIP concentrations		**?**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**?**
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)		**?**
Indirect Effects (III)	Degree of oxygen deficiency	Local problems. Indication of oxygen problem in main basin water.	+
	Changes/kills in Zoobenthos and fish mortality		**?**
	Organic Carbon/Organic Matter		**?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Problem Area

Final classification: Until the degree of oxygen problem in the main fjord basin is documented along with possible other Category III-effects, a classification as **Potential Problem Area** seems correct.

A19 The Florø area

The area is shown in ***Figure 15***.

Nutrient load
The overall anthropogenic nitrogen load has increased during the last 10 years while the phosphorus load has decreased some (***Table 48***).

Table 48. *Anthropogenic nutrient load for area A19. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
369	443	69	53

Topographic and hydrophysical characteristics
The topography of this coastline is highly varying, with several island combined with fjords or bays sheltered from the open coast partly by the islands and partly by sills.

The overall freshwater runoff is small and the vertical stratification is often weak and surface salinity high. However, fjords or bays in the eastern part of the area will have local freshwater runoff sufficient to create strong stratification.

Current measurements at localities for fish farms and the study of Bakke et al. (1998) show high tidally and meteorologically driven water exchange in the middle and western parts of the area. In the more enclosed eastern parts one may assume that the water exchange is markedly smaller.

Water quality, biological conditions and degree of nutrient enrichment.

The main source for assessing the marine environment of this area is a study from 1998, covering large parts of the area (Bakke et al., 1998). The study involved current measurements, water quality, hard bottom flora and fauna and soft bottom fauna. Supplementing these data are soft bottom sampling at localities for fish farms, like Aarseth (2005, 2006). As there has not been any large changes in the overall nutrient load, the data from 1998 should be reasonably representative for the present conditions.

The 1998-study showed serious oxygen problems (NCS-class IV-V) in the deep layers of several parts of the fjord system (Eikefjord, Stavangfjord, Florø), but no problems in the Solheimfjord or the Hellefjord. Corresponding to very low oxygen conditions, seriously reduced soft bottom fauna was observed in the Eikefjord and Florø basins.

The hard bottom flora and fauna did not show any effects from eutrophication. Compared to a similar study in 1985, the water quality and biological conditions show some improvement (except for Eikefjord).

Evaluation
The integrated classification is shown in ***Table 49***.

Table 49. *A19. Integrated initial classification table.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in N and decrease in P	**+/-**
	Winter DIN- and/or DIP concentrations	Not enough data	**?**
	Increased winter N/P ratio (Redfield N/P = 16)		**?**
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Not enough data	**?**
	Nuisance species/harmful species; *Alexandrium* spp., *Dinophysis* spp. (Castberg et al. 2005, Dahl 2001, 2002, 2005, Dahl et al. 2001, 2003, 2004, 2005, 2006)	Elevated levels	**?**
	Macrophytes including macroalgae (region specific)	No effects observed	**-**
Indirect Effects (III)	Degree of oxygen deficiency	Very low concentrations in some fjord basins	**+/-**
	Changes/kills in Zoobenthos and fish mortality	Effects in fjord basin with low O2	**+/-**
	Organic Carbon/Organic Matter	Local in some fjord basins	**+**
Other Possible Effects (IV)	Algal toxins not detected (Castberg et al. 2005, Dahl et al 2006, Hestdal 2001-2003)		**?**

Initial classification: Problem Area

Final classification: Studies in the inner part of the fjord areas show Category III-effects, while no such effects (except Florø harbour) have been observed in the western and more open parts. Classification: **Potential Problem Area**

A20 The Nordfjord

The area is shown in ***Figure 15***.

Nutrient load

The overall anthropogenic nitrogen load for this area has increased during the last 10 years while the phosphorus load has decreased some (**T*able 50***).

T*able 50.* *Anthropogenic nutrient load for area A20. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
596	643	90	59

Topographic and hydrophysical characteristics

Nordfjord is among the largest fjord in Norway with a total length of 106 km, several basins with maximum depths of 370-590 m and a sill depth of 120-130 m. The main fjord branches into many smaller fjords like the Hyenfjord, Gloppefjord, Ålfjord and the Eidsfjord.

A high freshwater runoff to the fjord from surrounding mountains and glaciers creates a significant brackish surface layer, but varying in salinity and thickness over the year.

Water quality, biological conditions and degree of nutrient enrichment.

We have not found any recent studies of water quality or biological conditions in the main body of the Nordfjord, but a few from adjoining fjord branches.

The fjord outside the Stryn, Loen and Olden communities in the innermost part of the Nordfjord was studied in 2000-2001 (Møskeland et al., 2001). The main findings were

- a soft bottom fauna that showed some signs of an increased organic load – like during a previous study in 1990
- sediment TOC corresponding to class I (Very Good) in the NCS
- hard bottom communities considered normal in brackish environments.
- Nutrient concentrations were classified as Good – Very Good according to the NCS
- Very low oxygen concentrations were observed in the deep basin water (class IV-V according to the NCS)

The Eidsfjord outside the Nordfjordeid community was studied in 2000-2001 (Johansen et al., 2001). The main findings were:

- a soft bottom fauna corresponding to class I (Very Good) in the NCS
- hard bottom communities considered normal in brackish environments.
- Oxygen and nutrients were sampled only once (February 2001) and the dataset is too small to be basis for a general classification

The Gloppenfjord was studied in 1995-96, and some of the findings may also represent the present situation (Lømsland et al., 1997). The main findings were:

- a soft bottom fauna corresponding to class I-II (Very Good - Good) in the NCS
- hard bottom communities showing significant effects from nutrients in the inner half of the fjord.

- Oxygen was sampled down to 290 m depth on 6 occasions and the concentrations corresponded to NCS-class I (Very Good).

Evaluation
It is difficult to give an overall classification based on datasets from the innermost part of the fjord and two of the fjord branches. The lack of data from the middle and western part of the main fjord body is especially unfortunate. The integrated classification is shown in ***Table 51***.

Table 51. *A20. Integrated initial classification table.*

Category	**Assessment Parameters**	**Description of Results**	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in N and decrease in P	**+/-**
	Winter DIN- and/or DIP concentrations	Data from inner part only	**-/?**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration	Data from inner part only	**-/?**
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)		**-/+**
Indirect Effects (III)	Degree of oxygen deficiency	In the inner part of the main fjord basin	**+**
	Changes/kills in Zoobenthos and fish mortality		**?**
	Organic Carbon/Organic Matter		**-**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: The observation of low oxygen concentration in the basin water indicate **Problem Area**

Final classification: Until the degree of oxygen problem in the main fjord basin is documented along with possible other III-effects, a classification as **Potential Problem Area** seems correct**.**

A21 Nordfjord-Stad

The area is shown in ***Figure 15***.

Nutrient load
The overall anthropogenic nitrogen load for this area has increased during the last 10 years while the phosphorus load has decreased some. The total load is relatively low (***Table 52***). The outfalls of municipal sewage are in general directed to recipients with relatively high water exchange.

Table 52. *Anthropogenic nutrient load for area A21. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 is used.*

Nitrogen load, tonnes		Phosphorus load, tonnes	
1997-2000	2001-2005	1997-2000	2004-2005
27	37	5	2

Topographic and hydrophysical characteristics
The topography of this coastline is highly varying, with several island combined with small fjords or bays sheltered from the open coast partly by the islands and partly by sills.

The overall freshwater runoff is small and except from local bays or minor fjords the vertical stratification is often weak and surface salinity high.

From studies of water exchange in the Måløy region (the Ulvesund, Golmen 1993) one may conclude that in general this is an area with high water exchange.

Water quality, biological conditions and degree of nutrient enrichment.

The water quality and biological conditions several regions of the **Vågsøy community** were studied in 1999 (Hjolman and Holm, 2000) and again in the Ulvesund in 2003 (Tveranger et al., 2003). The main recipient is the previous mentioned Ulvesund, but also small bays like Deknepollen and Skavøypollen were included in the 1999-study.

From these studies one may conclude that in the Ulvesund high water exchange creates an environment where oxygen conditions and bottom fauna were classified as Good- Very Good according to the NCS. However, at several stations the 1999-study the hard bottom flora showed eutrophication effects (green algae). There are no data that can verify whether this is still the situation.

In Deknepollen and Skavøypollen the soft bottom fauna was in bad conditions.

North of Vågsøy, at **Barmen**, the soft bottom fauna was sampled at two stations in 2004. The authors concluded that the fauna was typical for coastal areas with moderate organic load (NCS-class II).

The environmental conditions of **Moldefjord** to the north of Area 21 were studied in 2002 (Botnen and Johannessen, 2002), including oxygen, sediments and soft bottom fauna. The data were compared to data from a similar study in 1985. The oxygen conditions and soft bottom fauna in the fjord basin were classified as Bad – Very Bad according to the NCS, and worse than in 1985.

The Norwegian sugar kelp study includes a number of stations in this area and except from two adjoining localities, only minor or none effects have been detected (***Figure 17*****).**

Evaluation
The integrated classification is shown in ***Table 53***.

Table 53. *A21. Integrated initial classification table.*

Category	Assessment Parameters	Description of Results	Score
Degree of Nutrient Enrichment (I)	Riverine total N and total P inputs and direct discharges (RID)	Increase in N and decrease in P	**+/-**
	Winter DIN- and/or DIP concentrations		**?**
	Increased winter N/P ratio (Redfield N/P = 16)		
Direct Effects (II)	Maximum and mean chlorophyll *a* concentration		**?**
	Region/area specific phytoplankton indicator species	No data	
	Macrophytes including macroalgae (region specific)	Local assemblages of green algae observed in 1999. Local effects on sugar kelp	**+/?**
Indirect Effects (III)	Degree of oxygen deficiency	Local basins. Indication of negative trend (Moldefjord)	**+/-**
	Changes/kills in Zoobenthos and fish mortality	Local basins	**+/-**
	Organic Carbon/Organic Matter		**-/?**
Other Possible Effects (IV)	Algae toxins (DSP/PSP mussel infection events)	No data	

Initial classification: Possible Problem Area

Final classification: The classification – especially of the Ulvesund – is based on data from 1999. The main water body is probably in good condition due to high water exchange, but the uncertainty about the Ulvesund, Moldefjord, Deknepoll and Skavøypoll indicates a final classification as **Potential Problem Area.**

4.6 Summary of integrated classification

Compared to the screening in 2002-2003, this classification is based on new information about
- nutrient load
- oxygen conditions in a number of fjords and sheltered bays
- hard bottom fauna and flora (especially sugar kelp information). And in many fjords also soft bottom fauna.

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

In this assessment four features stand out:

2. A high increase in the nutrient load over the last 15-20 years. As this to a large extent is caused by increased discharges from the aquaculture industry, it also implies changes in two other features:
   - A shift in the distribution, from point sources associated with cities or rivers: often combined – to far more diffuse loads from aquaculture farms.
   - A shift in distribution over the year, towards a significant increased nutrient load in the months May-September. In Eutrophication assessments that is important.
5. Highly varying topography, from the open coastline in Area 3 to the Sogn & Fjordane county with its archipelagos and where the Sognefjord and the Nordfjord reaches respectively 200 km and 100 km into the country.
6. An increase in water exchange from south to north, due to increased tidal and meteorological forcing
7. Lack of monitoring data. Only the fjords around Bergen, partly around Stavanger, the Karmsund and the Sørfjord in Hardanger have been monitored on a reasonably regular basis. Most of the other recipient studies have focused on obvious local problems, like oxygen conditions in basins behind fjord sills, soft bottom fauna in fjord basins with oxygen problems or near outfalls of municipal waste water, or hard bottom flora and fauna near such outfalls. And many local studies at fish farms sites. Where the results are found to describe only a small part of the area, this is taken into account in the "Integrated Classification".

The classification has been carried out for each of 21 areas. Due to limited monitoring data, the classification have been made with some reservations. These are given as comments and focuses on limitations like;
- there are no data or only very site-specific data (like MOM-studies at fish farm localities)
- the data are from studies more than 5 year back and may not be representative for the present situation
- data covers only a minor part of the area.

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

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

The final classification area by area is shown in **Figure 18:**
- *4 out of 21 areas have been classified as Problem Areas (1,2, 4 and 7)*
- *14 areas were classified as Potential Problem Areas (5, 6, 8,10, 11, 12,13,14,15,17, 18, 19, 20, 21)*
- *3 areas were classified as Non Problem Areas (3, 9, 16)*

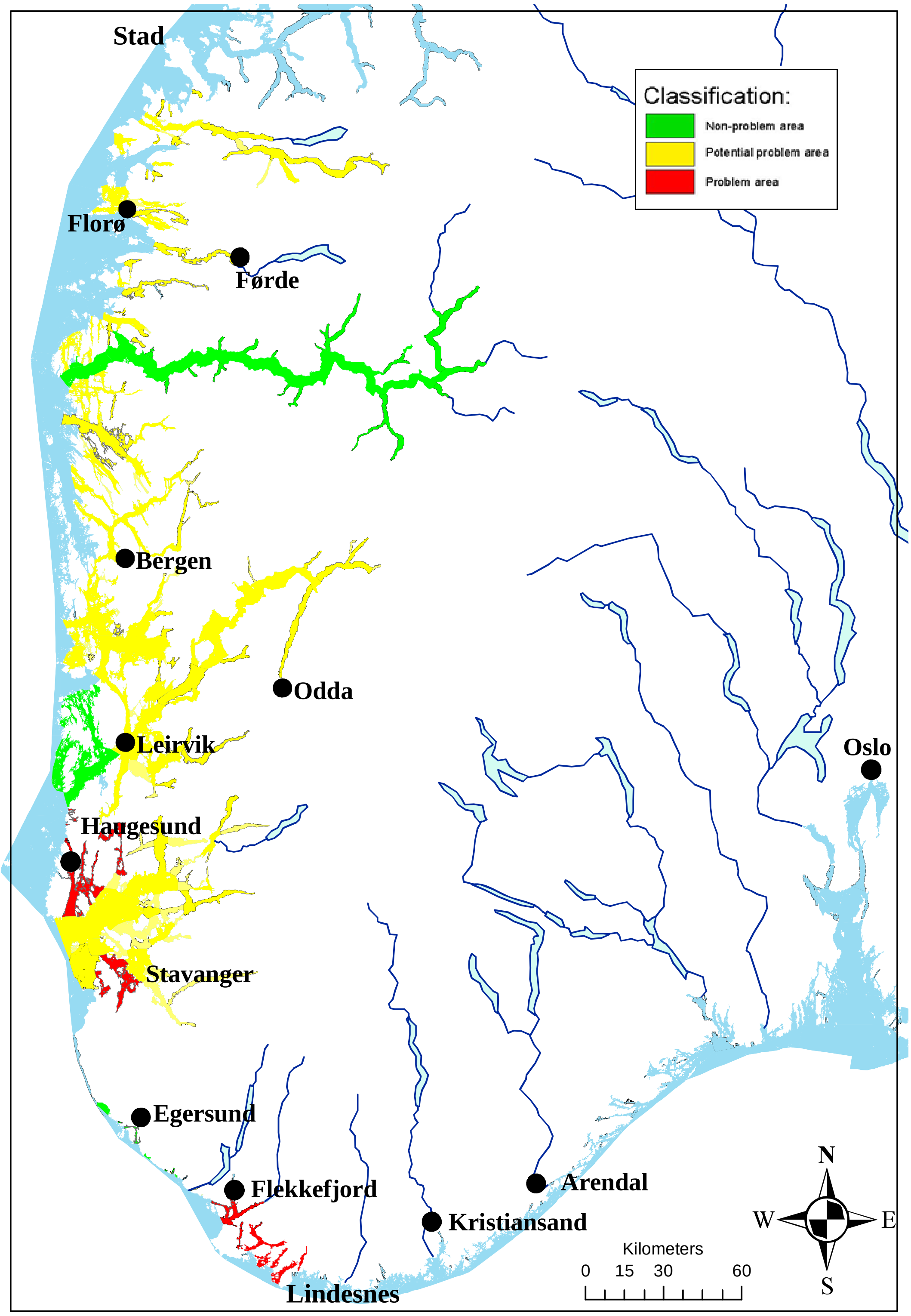


Figure 18. *Overall classification of the Norwegian West Coast from Lindesnes to Stad. Note that every area has* *<u>one</u>* *classification, even though it may contain minor parts that deviate.*

5. Perspectives

5.1 Implemented and further planned measures

Regarding inputs of nutrients from municipal sewage, new waste water treatment regulations came into force 1.1.2007. All discharges into sensitive areas have to undergo 90 % phosphorous removal from 31.12.2008.

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

5.2 Expected trends

Over the last 15-20 years the anthropogenic nutrient load to the marine waters of the Norwegian west coast has increased significantly in spite of regulation and treatment plants for municipal and industrial discharges. The future state of environment along the sheltered parts of the West Coast depend on changes in nutrient and organic load from the aquaculture industry, in the transboundary transport and development in connection with climatic changes.

Estimates of the impact of climatic change have been done for the Bjerkrheim river basin and its costal fjord in southwestern Norway (Kaste, et.al. 2006). From meteorological projections, linked models were used to assess the effects on hydrology, and nitrogen concentrations and fluxes in the area including the fjord.

Models of climatic changes predict changes in the freshwater runoff to the Norwegian west coast, due to rising temperatures and increasing precipitation. However, different meteorological prediction models differ in the effects. This relates especially to increased precipitation during summer and autumn, while these factors increase during winter are common. The freshwater runoff will increase during winter and lower runoff during snowmelt in the spring. The linked models (Kaste, 2006) project no major changes in nitrate fluxes up to a 40-50% increase in this century, depending on chosen scenario. The accompanying effect in the estuary on primary production was indicated to be from almost no effect to a 15-20 % increase. Thus a worst case situation can have a clearly negative effect on areas which already are eutrophicated. The perspective for these changes is 50-75 years, and is therefore difficult to use in this assessment.

Climate changes can change other variables such as currents and transport of heat. However, one direct effect as the decline of the sugar kelp (Moy, et al., 2007), is directly correlated with increasing air temperatures, especially in the end of July and the beginning of August (op. cit). The combination of high surface temperatures and eutrophication may be a threat to the sugar kelp populations even at the west coast.

5.3 Improvement of classification

There are two main aspects: Improvement of Data and improvement of the Classification Systems.

Data
There is an absolute need for increased systematic, long-time-perspective monitoring of the west coast environment, and especially regarding Category II-III effects. There is also a need to improve/update the assessments background concentrations of nutrient during winter (area –specific) for the west coast coastal waters and fjords. As for Category II - the same comment is relevant for the Chlorophyll-a mean and maximum concentration during growing season. One may need 10 years of monitoring to state a reasonable certain status and identify trends.

The lack of data applies to most areas, but follow-up studies should focus on Potential Problem Areas which have a high and increasing nutrient load (like Hardangerfjord, Osterfjord/Sørfjord, Førdefjord). Secondly one may consider monitoring in one or two of the Non Problem Areas, as the classification partly is due to lack of data.

The classification systems
There is a general weak definition in the OSPAR assessment of Chl-a, among them the definition of the growing season, the minimum number of observations and the definition of the maximum Chl-a.

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

The Norwegian Classification System (NCS) was developed in the early 90-ies, based on data from the previous 10-15 years. There is an update in preparation, using the vast amount of higher quality data and better insight in eutrophication processes and effects from the last 10 years. This update will include classification according to the Water Framework Directive, and closer harmonization of the OSPAR Classification and NCS should also be a goal.

The classification assumes that the decline of sugar kelp on the Norwegian west coast to some extent is caused by eutrophication. If future studies of the kelp disappearance prove otherwise, the classification should be revised.

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

6. Literature

ANON, 1997. The Norwegian North Sea Coastal Water. Eutrophication – status and trends. Report from expert group for evaluation of eutrophication in fjords and coastal waters. *State Pollution Control Authority* (SFT), Norway. 90 pp.

Aure, J. and Sætre, R. 1981. Wind effects on the Skagerrak outflow. In: *R.Sætre & M. Mork. The Norwegian Coastal Current. University Press, Bergen, Norway* : 263:293.

Aure, J. and Skjoldal, H.R., 2003. OSPAR Common Procedure for Identification of the Eutrophication Status. Application of the Screening Procedure for the Norwegian Coast north of 62ºN (Stad-Russian border). SFT report TA 1997/2003. 23 pp.

Bakke, S.M., Aspholm, O.Ø., Endresen, Ø., Nøland, S-A., Jensen, T.,1998: Resipientundersøkelse i Flora kommune. DNV-rapport 98-3557. 73 sider. [In Norwegian].

Borgvang, S.A., Stålnacke, P., Johansen, S.W., Skarbøvik, E., Beldring, S., Selvik, J.R., Tjomsland, T. and Harsten, S., 2007. Riverine inputs and direct discharges to Norwegian coastal waters – 2005. NPCA-report TA-2245/2007. NIVA-report 5380-2007. 152 pp.

Botnen, B. og Johannessen, P., 2002. Marinbiologisk undersøkelse av miljøforholdene i Moldefjorden, Selje kommune. Dept. of Fisheries and Marine Biology, University of Bergen. 24 sider. [In Norwegian].

Bratli, J.L. and Tjomsland, T., 1996. Brukerveiledning og dokumentasjon for TEOTIL. Modell for teoretisk beregning av fosfor- og nitrogentilførsler i Norge. O-94060. L.nr. 3426-96. NIVA-rapport. 84 s. [In Norwegian].

Brekke, E., Johnsen, G.H., Hellen, B.A., 2001. Undersøkelse av fem marine resipienter i Fjell kommune 2001. Rådgivende Biologer AS.[Rapport nr. 489. 24 sider. [In Norwegian].

Brekke, E., Johnsen, G.H., Tveranger, B., 2003. Undersøkelse av fem marine resipienter i Fjell kommune 2003. Rådgivende Biologer AS.[Rapport nr. 670. 21 sider. [In Norwegian].

Buhl-Mortensen, L., Aure, J., Alve, E., Husum, K., Oug, E., 2006. Effects of hypoxia on fjordfauna: The bottomfauna and environment of fjords on the Skagerrak Coast. Havforskningsinstituttet. Rapport no 3. 2006. [In Norwegian].

Castberg. T., Dahl E., Gustad E., Naustvoll L.J., 2005. Giftige alger - analyser før høsting av giftige alger. Fisken og havet, særnummer 2-2006:157-159. [In Norwegian].

Dahl E. 2001. Skadelige alger. Fisken og havet. Særnummer 2:58-60.

Dahl, E.2002. Skadelige alger. Fisken og havet, særnummer 2-2003: 58-60. [In Norwegian].

Dahl E. 2004. Skadelige alger. Fisken og havet, særnummer 2-2004:56-64. [In Norwegian].

Dahl E. 2005. Planteplankton langs kysten. Fisken og Havet, særnummer 2-2005:154-156. [In Norwegian].

Dahl. E., Danielsen D., Aure J. 2001. Plankton og næringssalter Fisken og havet. Særnummer 2:54-58.

Dahl E., Danielssen, D., Aure, J., Bøhle, B. 2003. Plankton og næringssalter. Fisken og havet, særnummer 2-2003: 52-57. [In Norwegian].

Dahl E., Danielssen, D., Aure, J., Rey, F., Bøhle, B. 2004.
Plankton og næringssalter. Fisken og havet, særnummer 2-2004:52-56. [In Norwegian].

Dahl E., Gustad E., Naustvoll L.J., 2006. Overvåkning av alger. Fisken og havet, særnummer 2-2006: 25-27. [In Norwegian].

DNV, 2001. Miljøovervåking av indre basseng i Førdefjorden 1999/2000. Sluttrapport. Rapport nr. 2001-0125. 33 sider +vedlegg. [In Norwegian].

Eknes, M., 2007: Effektar av auka utslepp av næringssalt frå fiskeoppdrett. In: Kyst og havbruk, særnr. 2-2007. Red: Dahl, E., Hansen, P.K., Haug, T., Karlsen, Ø. [In Norwegian].

Golmen, L., 1993: Gransking av vasskvalitet og strømforhold i Måløy hamn og ved Raudeberg. NIVA-rapport no. 2904-1993. 89 sider. [In Norwegian].

Golmen, L., Molvær, J. og Bjerknes, V., 2003. Forprosjekt ny Loftenesbru, Sogndal. Konsekvensvurdering for vasskvalitet i Barsnesfjorden ved endra utfylling i fjordmunningen. NIVA-report 4718-2003. 46 sider. [In Norwegian].

Heggøy, E., Johansen, P-O, Vassenden, G., Botnen, H.B., Johannessen, P.J., 2005. ”Byfjordundersøkelsen” – Overvåking av fjordene rund Bergen. Marinbiologisk miljøundersøkelse i 2004. Institutt for Biologi, Universitetet i Bergen. 194 sider. [In Norwegian].

Heggøy, E., Vassenden, G., Johannessen, P., 2005. Marinbiologisk miljøundersøkelse av resipienter i Os kommune i 2005. Institutt for Biologi, Universitetet i Bergen. 29 sider. [In Norwegian].

Heggøy, E. and Johannessen, P., 2006a. Marinbiologisk miljøundersøkelse av resipienter i Fusa kommune i 2005. Institutt for Biologi, Universitetet i Bergen. 43 sider. [In Norwegian].

Heggøy, E. og Johannessen, P., 2006b. Marinbiologisk miljøundersøkelse av oppdrettslokalitet ved Oppedal i Sognefjorden, Gulen kommune, i 2005. Institutt for Biologi, Universitetet i Bergen. 29 sider. [In Norwegian].

Heggøy, E., Johansen, P.-O., Johannessen, P., 2006c. MOM-C og lokalitetsklassifisering av to potensielle oppdrettslokaliteter ved Gjølanger i Fjaler kommune i 2006. VestBio. Institutt for Biologi, Universitetet i Bergen. Rapport nr. 8, 2006. 65 sider. [In Norwegian].

Hestdal, M., Aune, T., Tangen, K., Dahl, E. 2001. Overvåkingsprogrammet for algetoxiner 2000. ANT-rapport 9. [In Norwegian].

Hjolman, S. og Holm, J.A., 2000. Resipientundersøkelse i Vågsøy kommune, 1999. UNIFOB/Fjord-Lab. 79 sider. [In Norwegian].

Jacobsen, T., Golmen, L., Nygaard, K., Moy, F., 1996. Resipientundersøkelse i fjordene ved Flekkefjord 1994-1995. NIVA-rapport no. 3456-1996. 53 sider+Vedlegg. [In Norwegian].

Johansen, P-O, Heggøy, E., Vassenden, G., Botnen, H.B., Johannessen, P.J., 2002. Marinbiologisk miljøundersøkelse av resipienter i Os kommune i 2001. Institutt for Fiskeri- og Marinbiologi, Universitetet i Bergen. 68 sider. [In Norwegian].

Johansen, P-O, Heggøy, E., Botnen, H.B.,Vassenden, G., Johannessen, P.J., 2001. Undersøkelse av miljøforholdene i Eidsfjorden, Eid kommune i år 2001. UNIFOB, Bergen. [In Norwegian].
Johnsen, G.H., 2000. Undersøkelse av fem marine resipienter i Fjell kommune 2000. Rådgivende Biologer AS.[Rapport nr. 431. 23 sider. In Norwegian].

Johnsen, G.H., Hellen, B.A., Kålås, S., Sægrov, H., 2005. Hydrologiske undersøkelser i Bolstadfjorden våren 2005. Rådgivende Biologer AS.[Rapport nr. 857. 34 sider. [In Norwegian].

Kaste, Ø., Wright, R.F., Barkved, L.J., Bjerkeng, B., Engen-Skaugen, T., Magnusson, J., Sæhltun, N.R., 2006. Linked models to asses the impact of climatic change on nitrogen in a Norwegian river basin and fjord system. Science of the Total Environment 365, pp. 200-222.

Lømsland, E., Nygaard, E., Oug, E. og Pedersen, A.,1997: Resipientundersøkelse i Gloppenfjorden. NIVA-rapport no. 3623-1997. 98 sider. [In Norwegian].

Molvær, J., 2006. Utslipp av kommunalt avløpsvann til Førdefjorden. Undersøkelse av strømforhold, lagdeling og vannkvalitet på begge sider av fjordterskelen. NIVA-rapport 5159-2006. 43 sider. [In Norwegian].

Magnusson, J. og Molvær, J., 1984. Bolstadfjord og Glomfjord: Vurdering av effekter ved endret ferskvannstilførsel. I Andreassen, L. og Asvall, R.P. (eds.):Vassdragsreguleringers innvirkning på fjorder. Norsk Hydrologisk komite. Rapport nr. 19, 233-248. Oslo. [In Norwegian].

Molvær, J., Knutzen, J., Magnusson, J., Rygg, B., Skei, J. og Sørensen, J., 1997. Klassifisering av miljøkvalitet i fjorder og kystfarvann. Statens forurensningstilsyn. Veiledning 97:03. 36 sider. [In Norwegian].

Molvær, J., Magnusson, J., Selvik, J.R. and Tjomsland, T., 2003. Common Procedure for Identification of the Eutrophication Status of Marine Area of the Oslo and Paris Conventions. Report on the Screening Procedure for the Norwegian Coast from Lindesnes to Stad. SFT report TA 1928/2003. NIVA-report 4653-2003. 30 pp.

Molvaer, J, Norderhaug, K.M., Tvedten, Ø., 2006. FMC BioPolymer Haugesund. Undersøkelser av miljøeffekter fra utslipp av tarerester til Karmsundet – Sammendragsrapport. NIVA-rapport no. 5215-2006. 22 sider. [In Norwegian].

Moy, F., Nygaard, K., Rygg, B., 1997. Resipientundersøkelse i Søragapet, Eigersund. Førundersøkelse, 1996. NIVA-rapport no. 3689-1997. 101 sider. [In Norwegian].

Moy, F. and Oug, E. 2004. Vannkvalitet i fjordene ved Flekkefjord 2003. Næringssalter og oksygen. NIVA-rapport no. 4916-2004. 31 sider. [In Norwegian].

Moy, F., Bekkby, T., Cochrane, S. Rinde, E. and Voegele , B., 2003. Marin karakterisering. Typologi, system for å beskrive økologisk naturtilstand og forslag til referansenettverk. FoU-oppdrag tilknyttet EUs rammedirektiv for vann. NIVA-rapport nr. 4731-2003. 90 pp. [In Norwegian].

Moy, F., Aure, J. (HI), Dahl, E. (HI), Falkenhaug, T. (HI), Green, N., Johnsen, T., Lømsland, E., Magnusson, J., Pedersen, A., Rygg, B., Walday, M. 2006. Langtidsovervåking av miljøkvaliteten i kystområdene av Norge. Kystovervåkingsprogrammet. Årsrapport for 2005. Long-term monitoring of environmental quality in the coastal regions of Norway. Report for 2005 ; OR-5208: 94 s

Moy, F. (ed.), Alve, E., Christie, H., Helland, A., Magnusson, J., Steen, H., Tveiten, L. and Aasen, P.A., 2007. Status report no.2 from the Sugar Kelp Project. SFT report TA 2232/2007. NIVA-report 5344-2007. 60 pp. [In Norwegian].

Moy et al., 2007b. Long-term monitoring of environmental quality in the coastal regions of Norway. Report for 2006. In prep.

Myrseth, E., Hjolman, S., Johannessen, P-O., Botnen, H. og Johannessen, P., 2000. Marinbiologisk undersøkelse i Barsnesfjorden, Sogndalsfjorden og Amblabukta, Sogndal kommune. Rapport no. 4-2000. IFM, Universitetet i Bergen. 59 sider. [In Norwegian].

Møskeland, T., Bakke, S.M., Danielson, S., Dragsund, E., 2001. Resipientundersøkelse i indre Nordfjord. DNV rapport nr. 2001-1022. 43 sider. [In Norwegian].

OSPAR, 2005. Common Assessment Criteria, their Assessment levels and Area Classification within the Comprehensive Procedure of the Common Procedure. OSPAR Commission. Ref. No. 2002-20.

Selvik, J.R, Tjomsland, T., Borgvang, S.A. and Eggestad, H.O., 2007. Tilførsler av næringssalter til Norges kystområder i 2005, beregnet med tilførselsmodellen TEOTIL2. NIVA-rapport nr. 5330-2007. 57 pp. [In Norwegian].

Tvedten, Ø.F, 2005. Langtidsovervåking av to marine resipienter i Rogaland. Oppfølgende undersøkelser i perioden 2004-2005. Rapport RF-2005/204. 22 sider+Vedlegg. [In Norwegian].

Tvedten, Ø.F., Eriksen, V., Kongsrud, J., Brattenborg, N., 2003a. Miljøundersøkelse av marine resipienter rundt Stavangerhalvøya, 2001-2002. Rapport RF-2003/081. 126 sider. [In Norwegian].

Tvedten, Ø.F., Eriksen, V., Kongsrud, J., Brattenborg, N., 2003b. Miljøundersøkelse av marine resipienter i Sandnes kommune, 2001-2002. Rapport RF-2003/082. 122 sider. [In Norwegian].

Tvedten, Ø.F., Bergheim, A., Tandberg, A.H.S., 2006. Miljøundersøkelse ved FMC Biopolymer i Karmsundet 2005. Karmsund kommune. IRIS-rapport. Stavanger. [In Norwegian].

Tvedten, Ø.F, Molversmyr, A., 2002. Miljøforholdene i Førresfjord 2001-2002. Rapport RF-2002/298. 48 sider. [In Norwegian].

Tveranger, B., Brekke, E. og Johnsen, G.H., 2003. MOM-C resipientundersøkelse av Ulvesundet, vinteren 2003. Rådgivende Biologer, rapport nr. 644. 20 sider. [In Norwegian].

Tveranger, B. og Johnsen, G.H., 2004. MOM-C resipientundersøkelse av lokaliteten i Hillesøy i Bømlo kommune. Rådgivende Biologer, rapport nr. 739. 26 sider. [In Norwegian].

Tveranger, B., Brekken, E. og og Johnsen, G.H., 2006a. MOM-C resipientundersøkelse av lokaliteten i Breivik S i Bømlo kommune. Rådgivende Biologer, rapport nr. 927. 27 sider. [In Norwegian].

Tveranger, B., Brekken, E. og og Johnsen, G.H., 2006b. MOM-C resipientundersøkelse av lokaliteten i Kassosen, Bømlo kommune. Rådgivende Biologer, rapport nr. 925. 36 sider. [In Norwegian].

Aarseth, E., 2005: MOM-B undersøking utført i samsvar med NS 9410:2000 for Steinvik fiskefarm AS, 6940 Eikefjord. Lokalitet: Nord av Ålvåra i Flora kommune. 7 sider+vedlegg. [In Norwegian].

Aarseth, E., 2006: MOM-B undersøking utført i samsvar med NS 9410:2000 for Steinvik fiskefarm AS, 6940 Eikefjord. Lokalitet: Nord av Veidesund i Flora kommune. 6 sider+vedlegg. [In Norwegian].

Åsen, PA. 2006. Trekk fra den marine benthosalgevegetasjon fra Kristiansandsfjorden (VA) til Jøssingfjorden (Ro) - med spesiell referanse til sukkertare (Laminaria saccharina) og butare (Alaria esculenta). Agder Naturmuseums rapportserie 2006-4. 35s. [In Norwegian]

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Title
The OSPAR Comprehensive Procedure for the Norwegian West Coast – Eutrophication Status

Summary
The Norwegian west coast from Lindesnes to Stad has been classified according to the OSPAR Common Procedure. Compared to the previous assessment in 2002, this classification is based on new data on nutrient load and more data on oxygen conditions, hardbottom fauna and flora (especially sugar kelp) as well as other data from a number of recipient studies. 21 areas have been classified. The two striking features are overall increased nutrient loads and lack of monitoring data. The existing data has been of very varying quality, but 4 problem Areas, 14 Potential Problem Areas and 3 Non Problem Areas have been identified. The high number of Potential Problem Areas is caused by the combination of increased nutrient load and insufficient data for assessment of effects. There is a definite need for systematic monitoring with a long perspective, especially of Category II-III effects, and with focus on selected Potential Problem Areas.

4 emneord	4 subject words
OSPAR	OSPAR
Eutrofi	Eutrophication
Kystvann	Coastal water
Vestlandet	West coast