Statlig program for forurensningsovervåking

COMPREHENSIVE PROCEDURE FOR FOUR PROBLEM AREAS ON THE NORWEGIAN WEST COAST

2352

2007

SPFO-Report: 1009/2007
TA-number: 2352/2007
ISBN-number:978-82-577-5250-7

Employer: The Norwegian Pollution Control Authority (SFT)
Executing research institution: Norwegian Institute for Water Research (NIVA)

Comprehensive Procedure for Four Problem Areas on the Norwegian West Coast

Report
1009/2007

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

REPORT

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Akvaplan-NIVA A/S
Gaustadalléen 21 N-0349 Oslo, Norway Phone (47) 22 18 51 00 Telefax (47) 22 18 52 00 Internet: www.niva.no	Televeien 3 N-4879 Grimstad, Norway Phone (47) 37 29 50 55 Telefax (47) 37 04 45 13	Sandvikaveien 41 N-2312 Ottestad, Norway Phone (47) 62 57 64 00 Telefax (47) 62 57 66 53	P.O.Box 2026 N-5817 Bergen, Norway Phone (47) 55 30 22 50 Telefax (47) 55 30 22 51	 N-9005 Tromsø, Norway Phone (47) 77 68 52 80 Telefax (47) 77 68 05 09

Title	Serial No.	Date
Comprehensive Procedure for four Problem Areas on the Norwegian West Coast	5515-2007	14.12.2007
	Report No. Sub-No. O-27447	Pages Price 30
Author(s) Jarle Molvær and Torulv Tjomsland	Topic groups Oceanography, Marine Eutrophication	Distribution Open
	Geographical area Western Norway	Printed NIVA

Client(s)	Client ref.
Norwegian Pollution Control Authority	6006150

Abstract

The Norwegian west coast from Lindesnes to Stad has previously been classified according to the OSPAR Common Procedure, involving 21 main areas each consisting of several subareas. Four Problem Areas were identified. The present classification has focused on the subareas to the problem areas and four out of 16 subareas changed classification to Possible Problem and Non Problem Area. Compared to the Comprehensive Procedure for the main Areas, this study shows a more detailed and probably a more correct classification.

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

Jarle Molvær
Project manager

D. Durand
Research manager

Jarle Nygard
Strategy Director

ISBN 978-82-577-5250-7

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. In 2007 a classification of the Norwegian west coast using the Comprehensive Procedure, was carried out by Norwegian Institute for Water Research (NIVA) according to contract from Norwegian Pollution Control Authority (SFT).

In a meeting between SFT and NIVA on 26.10.07, NIVA was asked for a memo which in more detail describes the classification of four previously identified problem areas. After receiving a draft, SFT decided to upgrade the memo to a report. The present report is based on the same data and method as the previous Comprehensive Procedure for the west coast, and the reader is assumed to be familiar with that report.

At NIVA, Torulv Tjomsland has calculated the nutrient load to the coastal areas while Jarle Molvær is responsible for the rest of the report.

Oslo, 14.12.2007

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 (in 2002-2003 and in 2006-2007), screening of the Norwegian west coast in 2002-2003, screening of the coastline from Stad to the Norwegian/Russian border in 2003 and Comprehensive Procedure for the Norwegian west coast in 2007.

Method and data
The previous Comprehensive Procedure for the Norwegian west coast was applied for 21 main areas and four Problem Areas were identified, each containing several subareas. This study has aimed for a more detailed classification of the subareas to these four Problem Areas, to see whether this would provide useful information. The classification has been based on the same data and method as in the previous Comprehensive Procedure.

However, a more detailed classification the risk of classification based on old or insufficient data is also greater.

Results
The classification is summarised in the Table below where four out of 16 subareas have changed classification:

Main Area	Number of Subareas	Classification		
		Problem Area	Possible Problem Area	Non Problem Area
A1	7	5	1	1
A2	2	2		
A4	4	2	1	1
A7	3	3		

Compared to the Comprehensive Procedure for the main areas, this study shows a more detailed and probably more correct classification. It therefore illustrates the trade-off between a broad overall area classification which may not fit some subareas, and a classification of every subarea where lack of proper classification problem may be a problem.

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).
- Comprehensive Procedure for the Norwegian west coast (Molvær et al., 2007)

During the previous Screening the west coast was divided into 106 areas, as both SFT and NIVA considered too detailed for a Comprehensive Procedure (CP). In the CP a total of 21 areas were classified, each containing several of the original 106 areas.

In a meeting between SFT and NIVA on 26.10.07, NIVA was asked for a memo which

1. *describes how the 21 areas were selected – advantages and disadvantages compared to a higher number of areas.*
2. *illustrates whether an increased number of (sub)areas would change the classification of the 4 Problem Areas*

The classification should use the same data and methods as previously used in the CP (Molvær et al., 2007), but with less discussion.

After reading a draft memo, the SFT decided to have the results as the present report.

2. Selection of Areas

Norwegian coastal waters may be divided into three categories, namely fjords including estuaries, archipelagos and the coastal water proper. The Norwegian west coast consists of a very large number of fjords – small and very large (the Sognefjord: length 204 km and depth 1308 m) and islands forming archipelagos (Figure 1). Nutrients from urban wastewater are discharged from point sources and nutrients from runoff are often concentrated to a few large rivers. Within a coastal area, this may create significant gradients in nutrient load and in environmental quality.

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 (SP) divided into 106 areas, each including one or several “statistical areas” (Molvær et al., 2003). The fjord areas varied from approximately 5 km^2 to 800 km^2, with a median of 27 km^2. Within many areas were highly varying environmental conditions, from very sensitive fjord basins to open areas with high water exchange.

For the Comprehensive Procedure in 2007 both SFT and NIVA found that the number of areas should be reduced because:

1. a classification of 106 areas would have a detailing level that would not be necessary in the CP
2. for a large number of these areas one expected to find insufficient environmental data for a classification, leaving many with a Possible Problem status.

In the CP-report (Molvær et al., 2007) a 2-step assessment was therefore used:

1. starting with an update of nutrient load and other relevant environmental information for all previous 106 areas
2. then establish a more regional assessment for 21 aggregated areas, which were used in the further classification.

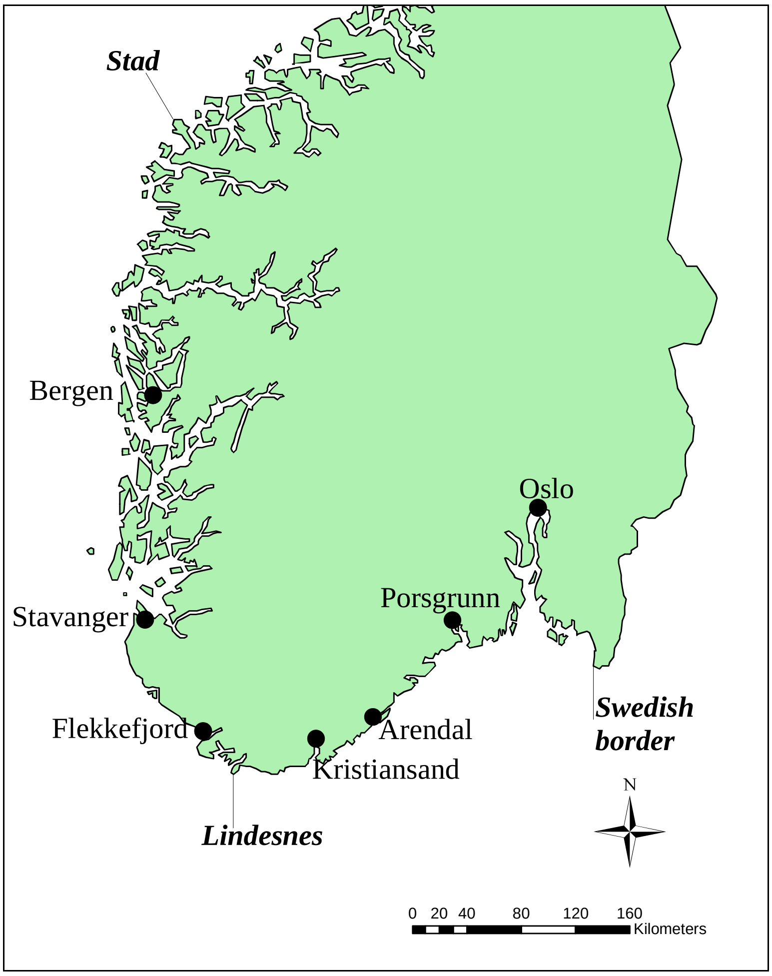

Figure 1. *Overall view of the coastline of southern Norway, showing the Norwegian west coast from Lindesnes to Stad, subjected to the previous Comprehensive Procedure.*

3. Method and data

3.1 The OSPAR classification scheme

The assessment is based on the OSPAR common assessment criteria (**Table 1.**).

Table 1. *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%.

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 it is 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 shown in **Table 2**.

Table 2. *Examples of the integration of categorised assessment parameters.*

	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"
	-	-	+	"Problem Area"
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.

In the CP of 2007 (Molvær et. al., 2007) several of the fjords and coastal areas were classified according to the Norwegian classification system (NCS), and like the previous classification 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. For more details about the NCS, see Appendix A.

3.3 Data and method

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.

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.

Landbased anthropogenic load
The landbased anthropogenic nutrient load has been calculated as in the previous Comprehensive Procedure (see Molvaer et al., 2007), with the difference that for the four Problem Areas (A1, A2, A4 and A7) the load for the subareas were not aggregated.

Over the last 15-20 years the anthropogenic nutrient load from landbased sources to the west coast has increased significantly by approximately 120% for nitrogen and 130% for phosphorus. 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. .

3.3.2 Water quality and biological data

The data on water quality and biological conditions are 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 2**). 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. For a discussion of phytoplankton as indicators of Eutrophication, see Molvaer et al. (2007).

In this study the observations are used and classified according to the OSPAR criteria. Data describing water quality and biological conditions (hard bottom flora and fauna, soft bottom 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.

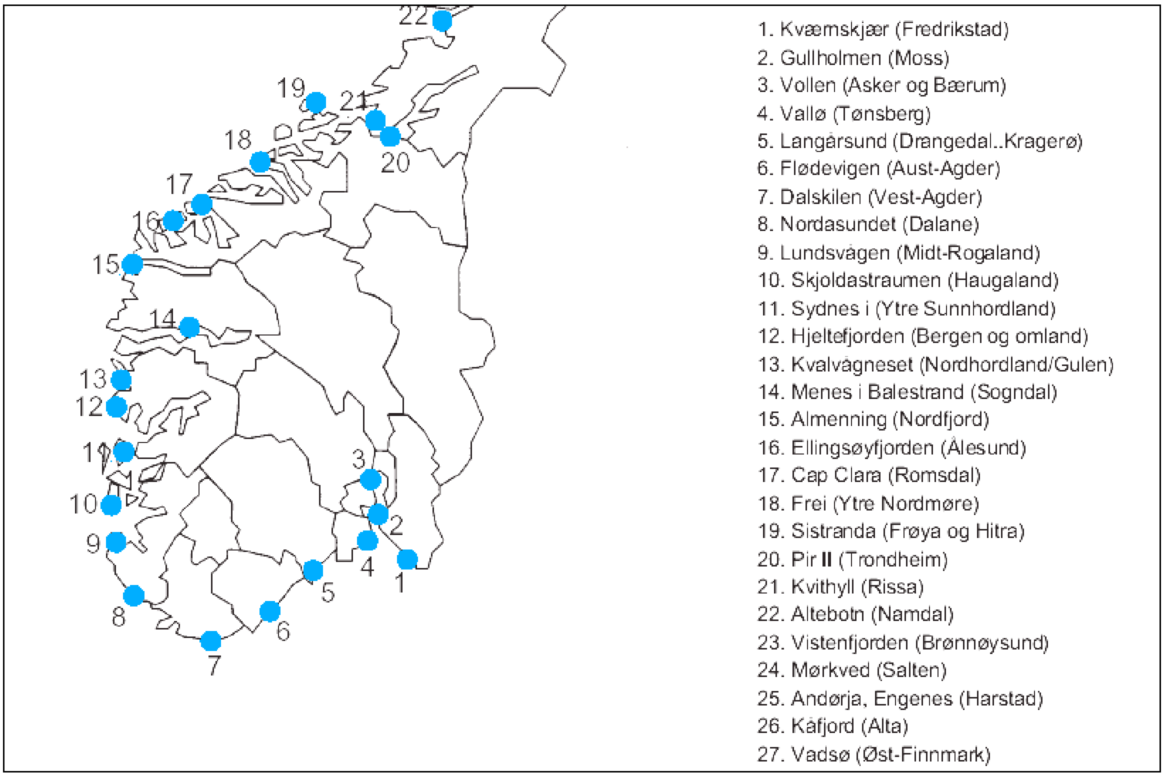

Figure 2. *Stations for monitoring of toxic algae and mussel toxins in southern Norway (from Hestdal et al., 2001).*

4. Classification of the four Problem Areas, with focus on subareas

4.1 Introduction

The assessment focuses on subareas of the four main areas which the CP-2007 classified as Problem Area (areas A1, A2, A4 and A7). The reporting format for the subareas areas 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 1**
4. An initial classification according to **Table 2** or the Norwegian classification system (NCS).

In the Classification Tables the abbreviations PA (Problem Area), PPA (Possible Problem Area) and NPA (Non Problem Area) are used.

4.2 A1 - Lindesnes to Fedafjord

This area consists of 7 subareas (Figure 3).

Nutrient load
The average anthropogenic nutrient load for the 7 sub areas has decreased during the last 10 years (**Table 3**).

Table 3. *Anthropogenic nutrient load for 7 subareas in area A1. Averages for 1997-2000 and 2001- 2005, with exception for phosphorus where data from 2004-2005 are used.*

Subarea	Nitrogen (tonnes)		Phosphorus (tonnes)	
	1997-2000	2001-2005	1997-2000	2004-2005
Lenefjord	1,9	1,3	0,2	0,15
Grønsfjord	1,9	1,3	0,2	0,15
Rosfjord	15,3	10,6	1,6	1,21
Spindsfjord	15,3	10,6	1,6	1,21
I. Lyngdalsfj.	77,3	67,4	6,6	4,3
Y. Lyngdalsfj.	24,4	19,6	2,8	1,9
Framvaren	3,4	2,7	0,4	0,4

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 (**Table 4**). The Spindsfjord is mainly an archipelago.

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

Table 4. *Topographic characteristics for 6 fjord basins.*

Fjord	Basin depth (m)	Sill depth (m)
Lenefjord	240	3
Grønsfjord	ca.200	ca. 30
Inner Lyngdalsfjord	116	6
Outer Lyngdalsfjord	255	18
Framvaren	180	2
Rosfjord[4]	175/130	85/80

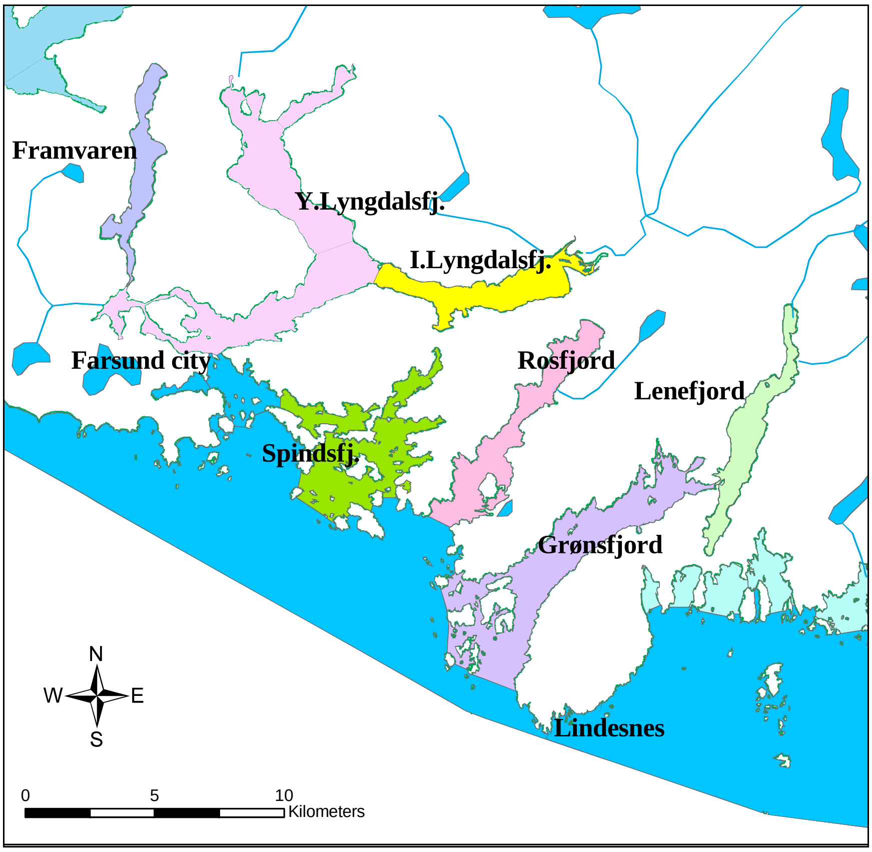

Figure 3. *The Lindesnes – Farsund coast with 7 subareas.*

[4] There are two sills and two basins and the pair of numbers refers to the outer basin and inner basin respectively

Water quality, biological conditions and degree of nutrient enrichment.

There have 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 above-mentioned 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. Fjord basins behind several sill/basins are especially sensitive (Lenefjord, Inner Lyngdalsfjord and Framvaren).

Except for some areas close to sewage outfalls the hard bottom flora and fauna were in general good condition. The Rosfjord is an open fjord basin without any sills, and a study in 1992 (Jacobsen et al., 1994) concluded with:

- good environmental quality
- no effects from nutrients in the water body or benthic communities, except from stations very close to the discharge of municipal sewage.
- High oxygen concentrations

With a decreasing nutrient load, there is no reason to expect serious problems since 1992.

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).

Classification

Using the classification system described in Appendix, the subareas have been classified (**Table 5**). Questionmarks illustrate lack of data. Five out of seven subareas are classified as problem areas.

Table 5. *Area A1. Integrated classification table for the subareas.*

Category	Assessment Parameters	Le	Gr	Ro	Sp	I-Ly	Y-Ly	Fr
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	**?**	**?**	**?**	**?**	**?**	**?**	**?**
	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)	**?**	**?**	**?**	**?**	**?**	**?**	**?**
Classification		**PA**	**PA**	**NPA**	**PPA**[1]	**PA**	**PA**	**PA**

1): not enough data for a proper classification, but taking into consideration a topography where island, narrow and shallow sounds probably creates restricted water exchange, a classification as Possible Problem Area should be preferred to Non Problem Area.

4.3 A2 - Fedafjord and Flekkefjord

This area consists of two subareas (Figure 4).

Nutrient load
There is one town on the coastline: Flekkefjord (city population approx. 5700). In the Fedafjord the average anthropogenic nutrient load has increased during the last 10 years, while the load into the Flekkefjord area has decreased (**Table 6**).

Table 6. *Anthropogenic nutrient load for area A2. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 are used.*

Subarea	Nitrogen (tonnes)		Phosphorus (tonnes)	
	1997-2000	2001-2005	1997-2000	2004-2005
Fedafjord	91,7	186	3,9	19,0
Flekkefjord	296	266	54,5	43,4

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 periods of low renewals of the basin water. 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. A sill at 50 m depth separates the fjord into a main part and an inner part, and a study from 1984-85 showed a brief period with oxygen concentrations below 2 mlO_2/l in the inner basin water (Knutzen et al., 1986).

The Flekkefjords have been studied on several occasions during the 1980-90ies, and a study of nutrients and oxygen in 2003 contains 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 Tjørsvågbukta and Grisefjord with hydrogen sulphide below 18-20 m depth.

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).

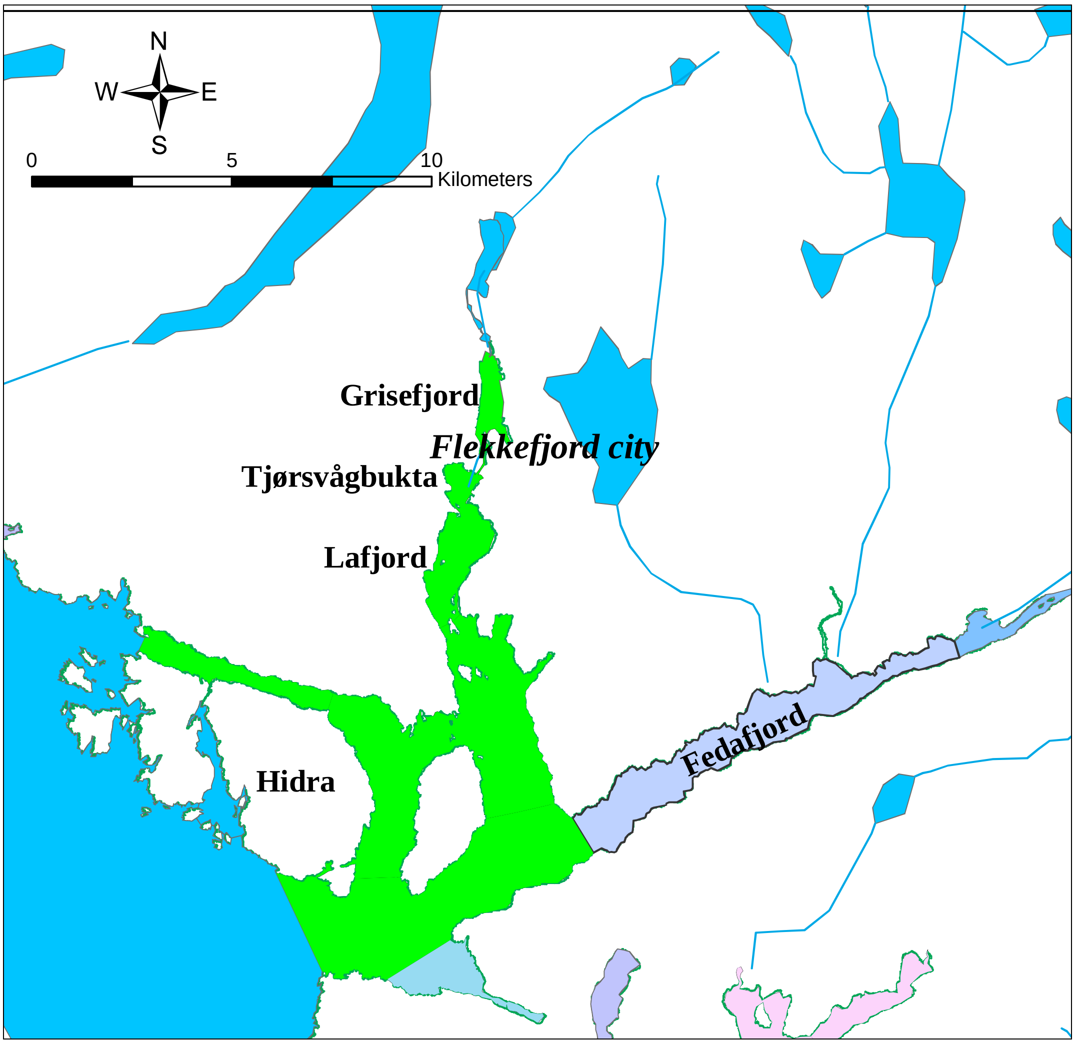

Figure 4. *The Fedafjord and the Flekkefjords. Note that the Flekkefjord subarea also contains the area inside Hidra.*

Classification
Using the tables in Appendix the subareas are classified in **Table 7**. Questionmarks illustrate lack of relevant/recent data. Both areas are classified as problem areas.

Table 7. *Area A2. Integrated classification table for the subareas.*

Category	Assessment Parameters	Fe	Fl
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	**?**	**?**
	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)	**?**	**?**
Classification		**PA**[1]	**PA**

1): not enough recent data for a proper classification, but taking into consideration the increasing load, a topography where a narrow and shallow sill creates low water exchange in the basin water and the open connection to the Flekkefjord (PA), a classification as Problem Area should be preferred to Possible Problem Area.

4.4 A4 -The Stavanger fjords

This area consists of 4 subareas (Figure 5).

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 8**). Fo**r** the Åmøyfjord+Riskafjord+Byfjord, the calculations show a significant increased load since 1997.

Table 8. *Anthropogenic nutrient load for area A4 with four subareas. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 are used.*

Subarea	Nitrogen (tonnes)		Phosphorus (tonnes)	
	1997-2000	2001-2005	1997-2000	2004-2005
Hafrsfjord	169	119	10,8	5,3
Håsteinfjord +Kvitsøyfjord	697	610	29,8	19,3
Åmøyfjord+ Riskafjord+ Byfjord	97	118	12,0	17,9
Gandsfjord	3,1	2,3	0,42	0,33

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 of the environment around the Stavanger peninsula is found in at study from 2001-2002 (Tvedten et. al., 2003a) 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 – including Håsteinfjord and Kvitsøyfjord - the water quality and biological conditions did not show any significant effects from nutrient or organic loads.

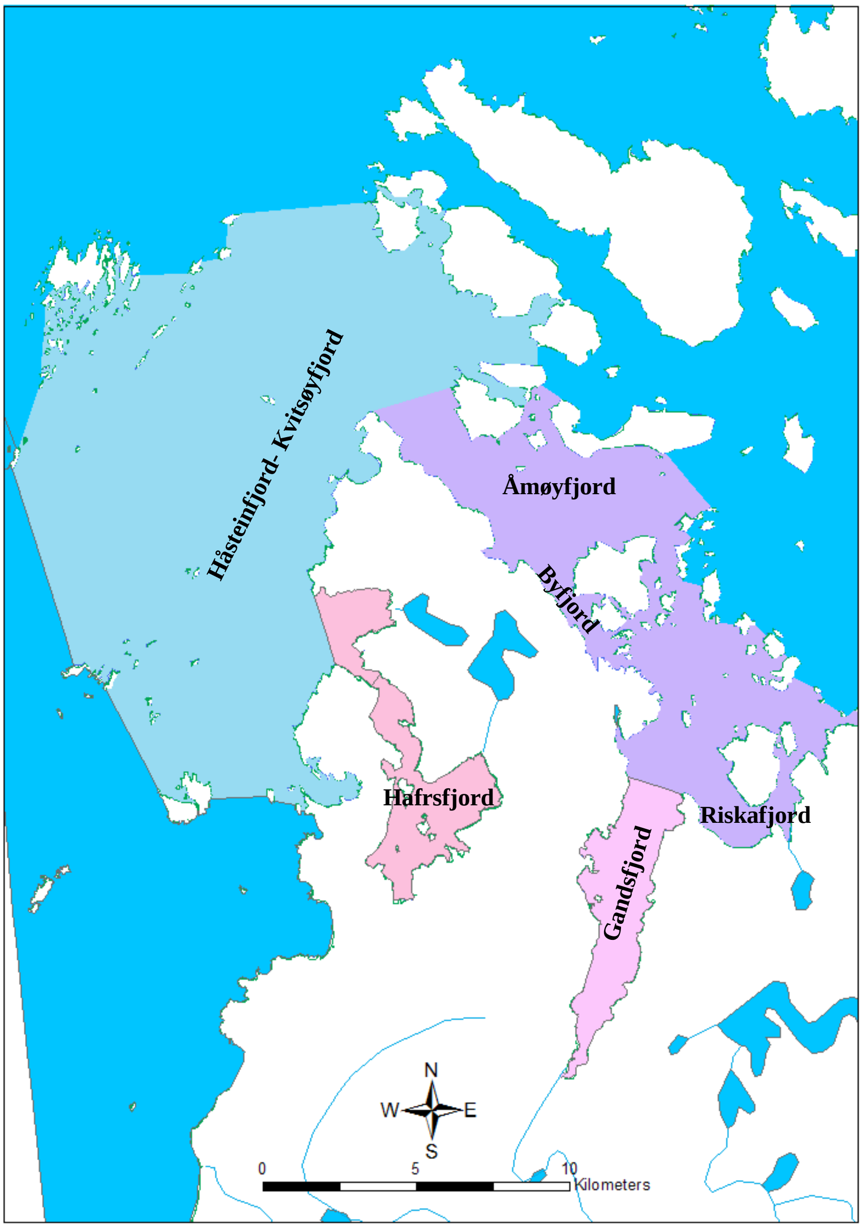

Figure 5. *The Stavanger fjords with four subareas.*

Classification

Using the tables in Appendix the subareas are classified in **Table 9**. Questionmarks illustrate lack of relevant/recent data. Two areas are classified as problem areas,

Table 9. *Area A4. Integrated classification table for the subareas.*

Category	Assessment Parameters	Ha	Hå	Åm	Ga
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	**?**	**?**	**?**	**?**
	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)	**?**	**?**	**?**	**?**
Classification		**PA**	**NPA**	**PPA**[1)]	**PA**

1) The preliminary classification was Problem Area. However, taking into account the monitoring data a classification as Possible Problem Area seems more proper.

4.5 A7 - Karmøy-Haugesund

This area consists of 3 subareas (Figure 6) and includes the Skjoldafjord, Førdesfjord, Førlandsfjord and the Karmsund.

Nutrient load

The anthropogenic nutrient load has increased during the last 10 years for all subareas (**Table 10**).

Table 10. *Anthropogenic nutrient load for subarea in area A4. Averages for 1997-2000 and 2001-2005, with exception for phosphorus where data from 2004-2005 are used.*

Subarea	Nitrogen (tonnes)		Phosphorus (tonnes)	
	1997-2000	2001-2005	1997-2000	2004-2005
Skjoldafjord	45,3	110	1,8	9,5
Førlandsfjord + Førdesfjord	50,8	19	2,1	10,7
Karmsund	357	468	45	55

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.

No recent data from the Skjoldafjord and Førlandsfjord have been found. However, with an extremely narrow and shallow sill (1,5-2 m deep) and a wide and deep basin (maximum depth 109 m) with permanent hydrogen sulphide in the basin water (Ravdal, 1973a) – and increasing nutrient load - the Skjoldafjord is in itself an obvious problem area .

The main water body of Førlandsfjord resides behind two sills, both at 12-13 m depth. The basin depths behind the sills are 31-37 m (Ravdal,1973b). The observations in 1972 (Ravdal, 1973b) concluded that during stagnation periods the oxygen conditions in the two basins probably should be classified as Bad or Very Bad (according to the present Norwegian classification system (Molvaer et al., 1997)). The hard bottom flora was considered normal.

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. Beyond 2-3 km from the discharge the benthic habitat conditions are normal.

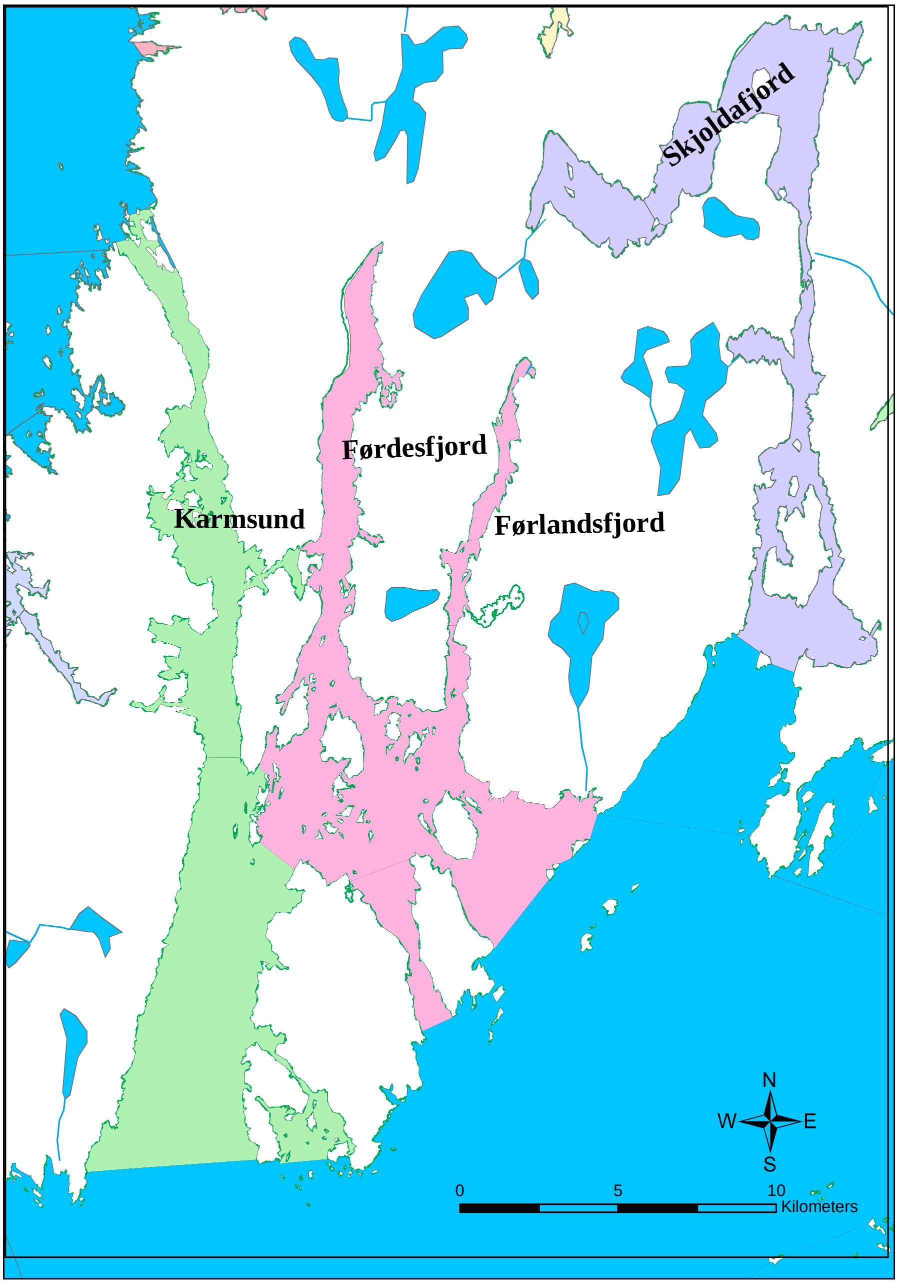

Figure 6. *The Karmøy-Haugesund area with 3 subareas.*

Classification

Using the tables in Appendix the subareas are classified in **Table 11**. Questionmarks illustrate lack of relevant/recent data. All areas are classified as problem areas. The problems in Skjoldafjord and Førde-/Førlandsfjord are related to the combination of increasing load and basin water with low renewal and high sensitivity for organic load.

Table 11. *Area A7. Integrated classification table for the subareas.*

Category	**Assessment Parameters**	Sk	Fø	Ka
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	**?**	**?**	**?**
	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)	**?**	**?**	**?**
Classification		**PA**	**PA**	**PA**

5. 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.

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].

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

Jacobsen, T., Magnusson, J., Oug, E. og Næs, K., 1994. Resipientundersøkelse i Rosfjorden Vest-Agder 1992. Vannutskiftning, vannkvalitet, strandsoneregistreringer, bløtbunnsfauna og miljøgifter i sedimenter. NIVA-rapport nr. 3017-1994. 50 sider. [In Norwegian]

Jacobsen, T., Golmen, L., Nygaard, K., Moy, F., 1996. Resipientundersøkelse i fjordene ved Flekkefjord 1994-1995. NIVA-rapport nr. 3456-1996. 53 sider+Vedlegg. [In Norwegian].

Knutzen, J., Molvær, J. og Ormerod, K., 1986. Undersøkelser i Fedafjorden 1984-85. Delrapport 2: Forurensningstilførsler, vannutskiftning og vannkvalitet. NIVA-rapport nr. 1850-1986. 37 sider. [In Norwegian]

Molvaer, 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].

Molvaer, 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 no. 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 nr. 5215-2006. 22 sider. [In Norwegian].

Molvaer, J., Eikrem, W., Magnusson, J., Pedersen, A. and Tjomsland, T., 2007. The OSPAR Comprehensive Procedure for the Norwegian West Coast – Eutrophication Status. SFT-report TA-2289/2007. NIVA-report no. 5474-2007. 86 pp.

Moy, F. and Oug, E. 2004. Vannkvalitet i fjordene ved Flekkefjord 2003. Næringssalter og oksygen. NIVA-rapport nr. 4916-2004. 31 sider. [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. [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.

Ravdal, E., 1973a. Undersøkelse av Nord-Rogalandfjordenes forurensningstilstand. Delrapport nr. 5 Grindefjorden/Skjoldafjorden. NIVA-rapport nr. 538-1972. 30 sider + Appendiks. [In Norwegian]

Ravdal, E., 1973b. Undersøkelse av Nord-Rogalandfjordenes forurensningstilstand. Delrapport nr. 4 Førlandsfjorden. NIVA-rapport nr. 537-1972. 13 sider + Appendiks. [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. and Molversmyr, Å., 2002. Miljøforholdene i Førresfjord 2001-2002. Rapport RF-2002/298. 39 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].

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. 35sider. [In Norwegian]

Appendix A

The Norwegian classification system (NCS)

The Norwegian criteria for marine water quality related to nutrients are shown in ***Table A1-Table A2.*** (Molvær et al., 1997)**.** In addition to these Tables, there are criteria for organic carbon in sediments and soft bottom fauna (***Table A3***). 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) for winter and summer. NCS-classes I-II for nutrients generally correspond to Non Problem Area. An elevated winter concentration (>50%) is generally a NCS-Class III-IV 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 nutrient discharge from aquaculture industry is at its highest in August-November. 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 aquaculture, 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 A1. *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^{o}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 A2. *Norwegian classification criteria for nutrients and secchi depth for salinity in the 0-20 range.*

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

Table A3. *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

Norwegian Pollution Control Authority (SFT)
PO Box 8100 Dep, 0032 Oslo, Norway. Office adress: Strømsveien 96
Telephone: +47 22 57 34 00 - Telefax: +47 22 67 67 06
E-mail: postmottak@sft.no - Internett: www.sft.no

Study undertaken by: Norwegian Institute for Water Research	ISBN-number 978-82-577-5250-7

Project responsible: Jarle Molvaer	SFT contact person: Torstein Finnesand	TA-number: 2352/2007

	Year 2007	Pages 30	SFT contract 6006150

Publisher: Norwegian Institute for Water Research Report no 5515-2007	Project financed by: Norwegian Pollution Control Authority (SFT)

Authors: Jarle Molvaer and Torulv Tjomsland
Title Comprehensive Procedure for four Problem Areas on the Norwegian West Coast
Summary The Norwegian west coast from Lindesnes to Stad has previously been classified according to the OSPAR Common Procedure, involving 21 main areas each consisting of several subareas. Four Problem Areas were identified. The present classification has focused on the subareas to the problem areas and four out of 16 subareas changed classification to Possible Problem og Non Problem Area. Compared to the Comprehensive Procedure for the main Areas, this study shows a more detailed and probably a more correct classification.

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

Statens forurensningstilsyn
Postboks 8100 Dep,
0032 Oslo
Besøksadresse: Strømsveien 96

Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@sft.no
www.sft.no

Statlig program for forurensningsovervåking omfatter overvåking av forurensningsforholdene i luft og nedbør, skog, vassdrag, fjorder og havområder. Overvåkingsprogrammet dekker langsiktige undersøkelser av:

- overgjødsling
- forsuring (sur nedbør)
- ozon (ved bakken og i stratosfæren)
- klimagasser
- miljøgifter

Overvåkingsprogrammmet skal gi informasjon om tilstanden og utviklingen av forurensningssituasjonen, og påvise eventuell uheldig utvikling på et tidlig tidspunkt. Programmet skal dekke myndighetenes informasjonsbehov om forurensningsforholdene, registrere virkningen av iverksatte tiltak for å redusere forurensningen, og danne grunnlag for vurdering av nye tiltak. SFT er ansvarlig for gjennomføringen av overvåkningsprogrammet.

TA-2352/2007
ISBN 978-82-577-5250-7