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The National Monitoring Programme in the Kattegat and Skagerrak

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1 Summary

To facilitate the development of the OSPAR eutrophication monitoring programme, this report presents the statistical strength of trends reported in the 2002 Common Procedure Report[1]. After correcting nutrient records to a reference salinity of 30 psu (to compensate for the effects of dilution), ortho-phosphate concentration exhibits a significant negative trend in the inshore Kattegat and Skagerrak. Significant decreases in silicate were observed in all areas. These changes caused changes in Redfield and other nutrient ratios. Indirect indicators of eutrophication (autumn, bottom oxygen concentration; growing-season chlorophyll-a concentration) exhibited significant trends. Chlorophyll-a concentration increased in the Skagerrak, while oxygen concentration decreased in all areas, apart from the inshore Kattegat.

Spatial characteristics of the study area were tested using probability mapping. The Kattegat was found to be well represented by 8 divisions, while 4 areas were suitable Skagerrak.

Changes in the current monitoring programme were not recommended. Increasing sampling frequency could interfere with the statistical independence of measurements – an assumption for the validity of trend calculations. Filling gaps in the existing time series improves the statistical significance of observed trends. This requires effective data exchange between monitoring institutions, and possibly data archaeology.

[1] 'Swedish National Report on the Eutrophication Status in the Kattegat and the Skagerrak OSPAR Assessment 2002', SMHI Reports Oceanography No. 31, 2003.

2 Background

The OSPAR 'Convention on the Protection of the Marine Environment of the North East Atlantic' covers the area from 36°N, and between 42°W and 51°E, excluding the Mediterranean & Black Sea, and the Baltic Sea south of lines from Hasenore to Gniben; Korshage to Spodsbjerg; and Gilbjerg Head to Kullen. The Kattegat and Skagerrak are part of the Convention area. The Convention started as an agreement to deal with oil pollution in the North Sea. By 1992, a convention had been drafted for the protection of the marine environment of the North East Atlantic. This came into force in 1998, and Sweden is a Contracting Party.

In 1998, the Commission adopted a number of strategies to direct its future work. The Eutrophication Strategy[2] calls for the identification of the eutrophication status of the Commission area by the Contracting Parties using a common methodology (the `Common Procedure'). The Common Procedure was devised to:

> '…characterise the maritime area in terms of problem areas, potential problem areas and non-problem areas with regard to eutrophication and to enable regional comparisons of eutrophication status on a Convention-wide basis.'[3]

The Common Procedure consists of the '*Screening Procedure'* and the *'Comprehensive Procedure'.* The Screening Procedure is an overview to identify those areas likely to be '*non-problem*' areas with regard to eutrophication. All areas identified as '*problem*'or '*potential problem*' areas by the Screening Procedure are then subject to the Comprehensive Procedure. The Comprehensive Procedure attempts to form an holistic assessment of the eutrophication status based on five information categories:

a. the causative - nutrient enrichment related – factors (Category I)
b. the supporting environmental factors;
c. the direct effects of nutrient enrichment; (Category II)
d. the indirect effects of nutrient enrichment; (Category III)
e. other possible effects of nutrient enrichment. (Category IV)

The causative factors describe the degree of nutrient enrichment, in terms of organic and inorganic nitrogen and phosphorus as well as silicon. Both anthropogenic and natural nutrient sources are considered. Trends in nutrient concentrations, the ratios between the different nutrients, fluxes (between sediment and water phases, as well as across regional boundaries) and nutrient cycles are all causative factors. Supporting environmental factors are light penetration, hydrodynamics, climate/weather conditions and zooplankton grazing.

Indicators of the direct effects of nutrient enrichment are primarily based on phytoplankton. Particular attention is paid to phytoplankton biomass, measured in terms of chlorophyll a concentration, organic carbon and cell numbers, as well as bloom characteristics (frequency; duration), changes in annual primary productivity and shifts in species composition. Changes in macrophytes and microphytobenthos are also considered.

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[2] '*2003 Strategies of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic',* OSPAR Ref. No: 2003-21 http://www.ospar.org/eng/html/sap/welcome.html

[3] '*Draft Starting Point for the further development of the Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area',* EUC 03/11/1-E, Annex 4: http://www.ospar.org/zip/SZ20040527-111700-9735/document.zip

Indirect effects of nutrient enrichment may be changes in organic material, such as changes dissolved and particulate organic carbon, occurrences of surface foam or slime, or increased sedimentation. Changes in oxygen concentration or consumption, increasing frequency of anoxic events, the occurrence of anoxic patches of surface sediment, and mortality in fish and benthic organisms resulting from low oxygen levels may also indicate nutrient enrichment and are considered to be indirect indicators. Changes in ecosystem structure, and particularly in benthic community abundance, structure and biomass can also be considered.

In 2002, the OSPAR Contracting Parties carried out an evaluation of the eutrophication status within the convention area. The '*Swedish National Report on Eutrophication Status in the Kattegat and Skagerrak*' (Håkansson et al, 2003) describes eutrophication status in terms of the four categories, with contributions from the SMHI, the Geological Survey of Sweden, the National Board of Fisheries, the Swedish Environmental Protection Agency, Kristineberg Marine Research Station and the Tjärnö Marine Biological Laboratory.

Nutrient loading, through run-off from both point (rivers) and diffuse (streams and ground water) sources, through atmospheric deposition and through trans-boundary fluxes (in particular from the Baltic outflow) were presented. Nutrient enrichment was described based on observed winter nutrient levels, corrected to a reference salinity value of 30 psu. This allows intercomparison with data from other environments within the Convention area. Time series of salinity-corrected nutrient concentrations, and ratios between different nutrients were presented. Concentrations and ratios were based on averages of surface (0 – 10 metres depth), winter (December, January and February) data. Winter values were used to give an idea of nutrient levels unaffected by biological activity. Surface data were used on the assumption that these nutrients are the most available for primary productivity.

These annual (winter) values were derived from averaging all observations within the Skagerrak and Kattegat respectively, and also dividing each area into an inshore and offshore component, resulting in four regions in total. The boundary between inshore and offshore was set as one (first-order, baroclinic) Rossby radius from the nearest coast (including islands). This length scale was chosen to allow the separation of local, nearshore effects – perhaps caused by water treatment works discharge – from the larger scale offshore conditions. The difference in Rossby radius between the Kattegat and Skagerrak was mainly due to the difference in mixed layer depth between the two regions. Shoreline position was taken from Wessel and Smith's (1996) shoreline database.

Evidence for the direct effects of nutrient enrichment (Category II) came from changes in chlorophyll-a concentration – as an indicator of biomass - as well as changes in primary productivity, phytoplankton indicator species, harmful algae and macrophytes. Chlorophyll-a data were surface values (0 – 10 metres), averaged over each area, and also over the growing season. Because blooms can start in February in the Kattegat, and occur even into November, the growing season was defined as February – November. No correction for salinity was applied, as there was no linear trend with salinity for either of the two main sea areas presented.

Indicators for indirect effects of eutrophication (Category III) were bottom oxygen concentration, as well as changes in zoobenthos and demersal fish, nutrient levels in sediment, and occurrences of mussel infection from algal toxins. Oxygen concentrations were averaged to give autumn values (August, September and October), from the deepest point of each sample profile. Autumn oxygen concentrations in bottom water are usually representative of the 'worst case' and are the values that most severely affect bottom fauna.

Comparison of the 30 psu-corrected indicator concentrations with those background values published by OSPAR were presented in Table 11 in the previous report, and are repeated here in Table 1 for reference. Elevated levels of DIN and DIP (above the Common Procedure's 'Critical' levels) were found in the Kattegat, though not the Skagerrak. Chlorophyll-a levels were above the 'critical' threshold in the inshore regions of both the Kattegat and Skagerrak. Offshore, chlorophyll-a concentrations were higher than the OSPAR 'background' levels, though not critical. No trends in nutrient concentrations, ratios, or chlorophyll-a concentration were claimed in the earlier report. Trends in oxygen concentration were calculated on the basis of linear regression of the regionally and autumn-averaged data.

The OSPAR Eutrophication Committee propose improvements to the eutrophication monitoring within the OSPAR area, in particular with improved, regional guidelines recommending the frequency and spatial resolution of sampling, while taking into account the tools and guidance developed for implementing EC Directives and other international agreements. As a first step in this process the Eutrophication Committee require

> 'an indication of the level of trend that can be detected, and the power to detect trends, in an assessment of the currently available data sets for nutrients and eutrophication effect parameters'[4].

A trend is defined as a lasting (generally greater than 10 years) linear or non-linear change of a monitoring variable. The power to detect trends is any change, calculated as a percentage per year that can be detected with X% probability within a Y year period. Techniques to assist with this analysis were suggested. These include: assessing levels and normal variability of representative stations from areas unaffected by anthropogenic sources or impacts; building up long time series and describing changes in these in quantitative terms; following up effects of remedial measures to improve environmental quality; and the detection of short term incidents.

This present report describes our ability to determine trends in the data presented in the OSPAR 2002 Assessment, the statistical strength of those trends, and recommendations for changes in the Common Procedure, on the basis of this data analysis.

[4] 'Review of the OSPAR Nutrient Monitoring Programme Terms of Reference for intersessional work, EUC 2003 Summary Record, EUC 03/11/1-E, Annex 7'

3 Aim

To facilitate the development of the eutrophication monitoring programme, contracting parties were asked to report the statistical strength of trends derived from the time series reported in the 2002 Common Procedure. To meet this request, the Swedish Environmental Protection Agency implemented a special project within Environmental Monitoring, called ‘Statistical evaluation of the national offshore programme in the Kattegat and Skagerrak’. The project has the following aims:

1. To describe the pelagic programme’s potential to detect spatial and temporal trends

2. To state the statistical strength of the observed trends.

3. To recommend eventual changes as a result of the OSPAR Comprehensive Procedure.

This report describes the statistical strength of the trends based on Swedish data, and presents:

- A description of the national monitoring programme within the Kattegat and Skagerrak

- The ability of the national offshore monitoring programme to confirm trends in eutrophication variables, and the statistical significance of these trends.

- The spatial resolution – that is to say – the geographical coverage which each measurement station represents

- Recommendations for future changes in the pelagic monitoring programme.

4 Methodology

4.1 Trends in eutrophication variables

The significance level of a statistical test for some particular trend-free stochastic process is the probability that the test would indicate a trend (or fail to accept the hypothesis of no trend) at some pre-selected nominal significance level α. The power of the test is the probability that the test indicates a trend when the stochastic process does in fact have a trend. The power of a trend is a function of the stochastic process, as well as the trend magnitude, and record length.

A range of methods exist for the detection of trends. Hirsch et al (1982) presented an evaluation of three common trend analysis tools. They generated 3000 random, trend-free signals, using six different distributions (500 series per distribution) simulating a dataset of monthly measurements lasting 5, 10 and 20 years. The distributions were:

1. normal and independent (simply a random, normally distributed series);
2. log-normal and independent (a skewed distribution);
3. normal and independent with a seasonal cycle;
4. normal and autoregressive (earlier values influence the current value);
5. normal autoregressive with a moving average;
6. and log-normal autoregressive with a seasonal cycle overlaid.

The authors applied increasing linear trends to the random data, and tested the ability of linear regression, seasonal linear regression (where data are 'de-seasonalized' before applying linear regression) and the seasonal Kendall test to identify the trends at an $\alpha = 0.05$ significance level.

The proportion of trends identified by each of the three methods were analysed. The regression based methods appeared to be robust in rejecting trends in the non-seasonal where there were none – even when the data deviated from normality. Where data had some dependence on earlier values in the series (the autoregressive series), but had no trend and no seasonality, the Seasonal Kendall test was not clearly inferior to the regression techniques. In the moving average case, it was superior, accepting the no-trend hypothesis in cases where both the regression cases had rejected it. Where the data was seasonal, the two seasonal methods were superior, with the linear regression method unable to identify trends at a 95% confidence band.

In general terms, it was found that if the data were normally distributed and non-seasonal, linear regression was the most powerful tool for identifying trends. Where data are normally distributed but seasonal, then the seasonal linear regression might be the most powerful method (depending on the magnitude of the seasonality). Where it is not certain that the above criteria are met, then the Seasonal Kendall test was the most powerful.

In the Swedish 2002 OSPAR Assessment, no trend analyses were carried out on the nutrient or chlorophyll-a data beyond visually inspecting the (salinity-corrected) time series. Because of the problems of presenting trends based on data with a strong seasonal cycle, the previous report presented time-averaged data. Each year's nutrient concentrations were based on measurements of the 'surface winter pool' - that is the observed concentrations measured from the upper 10 metres of the water column, between December and February. The upper 10 metres can be considered to represent the *photic* zone, where light penetrates making photosynthesis possible. During winter biological activity is at a minimum and nutrient concentrations are highest, indicating nutrient availability to fuel the spring bloom. Nutrient concentrations presented in the 2002 Assessment are presented in Figure 2 and Figure 3.

Chlorophyll-a concentrations were averaged over the growing season. As the onset (and also end) of bloom activity in the Kattegat and Skagerrak is difficult to predict., the growing season was considered to extend from February to November. These time series are presented as Figure 4.

Oxygen data were analysed using conventional linear regression, and the amount of variance explained method presented in terms of Pearson's r^2 value. *Figure 1* shows the oxygen time series used in the 2002 Assessment.

On the basis of the results reported by Hirsch et al (1982; 1991), Mann-Kendall and Seasonal Kendall tests (Mann, 1945; Kendall, 1975) were used to test for the existence of trends in the data. These methods have been widely used for trend analysis of water quality data and method descriptions are presented in Hirsch et al (1982; 1991).The magnitude of any trend, and confidence intervals, were assessed using Sen's Method (Sen, 1968; Thiel, 1950), These methods are non-parametric, so make no assumptions on the shape of the data distribution. They are robust when handling outliers or gaps in the time series, and even values below the detection limit.

To apply the Seasonal Kendall test, all data are divided according to season often monthly. The difference between the same months in all the other years is calculated, and a test quantity S, generated, where S is the number of data pairs where $x_k > x_j$ less the number of pairs where $x_j > x_k$.

This can be described in terms of a sign function:

$$sign(x_k - x_j) = \begin{cases} 1, x_k - x_j > 0; \\ 0, x_k - x_j = 0; \\ -1, x_k - x_j < 0; \end{cases}$$

The test quantity *S* is then defined as:

$$S = \sum_{j=1}^{n-1} \sum_{k=j+1}^{n} sign(x_k - x_j)$$

For no trend, the expected value of S would be 0. The '*no trend*' hypothesis is tested using:

$$Z = \frac{S}{\sqrt{Var(S)}}$$

where:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)}{18}$$

t is the number of 'tied' values, where $sign(x_k-x_j)$ is equal to zero. The probability of obtaining a certain Z value can be checked from the normal distribution. For a 90% probability that we have a trend (or alternatively, that we abandon our no-trend hypothesis), we require a Z value ≥ 1.645.

In the analyses presented here, the same input data were used as in the 2002 OSPAR Assessment. Trends in nutrient concentrations and ratios, as well as chlorophyll a and oxygen concentrations were assessed. Analyses were repeated for the same temporally-averaged data as were previously reported, but also, using the Seasonal Kendall test, for the entire data sets (averaged to provide monthly means). Data were aggregated spatially in the same way as before. Trends were investigated for the 'raw' (uncorrected for salinity) and the 'corrected' data.

4.2 Spatial coverage

Data reported in the 2002 OSPAR Assessment were aggregated according to distance from the nearest shoreline. The governing distance was the Rossby radius, calculated for the Kattegat and Skagerrak respectively. This was a relatively crude method that took no account of discharges into different areas, or of the dominant hydrographic or bathymetric features.

For this study, probability mapping was chosen to assess the 'typicality' of a measurement over a certain spatial scale. The method had been used previously, in the STAMP study (STatistical Analysis and Modelling of Phytoplankton dynamics) funded by the Nordic Council of Ministers, and reported in Carstensen et al (2002) and also Danielsson et al (2004).

Probability mapping is a quantitative method that tests the hypothesis of spatial homogeneity within large areas. Because it uses data from all stations in an area, the effect of individual stations is reduced. The method works by estimating the relative frequency of observations in an area having a concentration higher than the overall (all areas, all times) mean. Because calculating the frequency based on the individual observations may bias the results due to the different frequency of sampling in each sub-region, the STAMP group followed Choynowski's (1959) method to calculate frequencies based on a probability distribution, rather than on the actual data. Further details of the method are presented in Carstensen et al (op. cit.); Danielsson et al (op. cit), while the detailed description of the method was described be Cressie and Read (1985; 1989).

Probability mapping is used to estimate the probability that the mean concentration within a region is not significant different from the overall mean, taking into account the varying number of observations in each subarea. The method uses probabilities based on a probability distribution instead of the observed data. The number of observations in each subarea, *i*, is calculated as:

$$S_i = \begin{cases} 1 & \text{if } \mathrm{x_{ij}} > \overline{\mathrm{x}} \\ 0 & \text{otherwise} \end{cases} \qquad i = 1, 2, 3, ..., m.$$

S_i is Binominal distributed, Bin[$n_i p$], where n is the number of observations and p is the probability of $S_i = 1$ estimated by:

$$p_i = \frac{\sum_i^m S_i}{n_i}.$$

The null hypothesis, h_o, assumes that there is homogeneity within the area, i.e. $p_1=p_2= \ldots =p_m=p$. A rejection of h_0 means that the frequency of "high" concentrations is either higher or lower than expected. The expectance number, under h_0 is:

$$E_i\left[S_i\right] = n_i \overline{p} = \overline{\lambda}_i,$$

Where $\overline{p}$ is given by

$$\overline{p} = \frac{\sum_i^m S_i}{\sum_i^m n_i}.$$

As p_i is low (<0.1) and the number of observations n_i is high (>10), S_i is approximately Poisson distributed, Poi[λ_i], and the final statistics becomes:

$$E_i = \begin{cases} \sum_{t \geq S_i} e^{(-\overline{\lambda}_i)} (\overline{\lambda}_i)^t / t! & S_i \geq \overline{\lambda} \\ \sum_{t < S_i} e^{(-\overline{\lambda}_i)} (\overline{\lambda}_i)^t / t! & S_i \leq \overline{\lambda} \end{cases}$$

Values of $E_i < 0.05$ indicated that the region, *i*, has significant higher or lower concentrations than the overall mean. More information about the method can be found in: Cressie and Read, 1989; Carstensen et al., 2002; and Danielsson et al.,2004.

This present study used a simliar, depth-based, division of the Kattegat as the STAMP group. The Kattegat was divided by the 10 and 20 metre depth contours, and and the offshore section was further sub-divided into areas nominally covering the outflow plumes from the Sound and Great Belts respectively, the central part, an the east and west sections of the Kattegat-Skagerrak front. A lack of data along the coast of Jutland (Jylland) and Zealand (Sjælland) led to these areas being amalgamated with the adjacent offshore areas. On the Swedish side, the coastal section was divided into a northern and a southern component. The division is shown in Figure 6.

All available surface (<10m) data (DIN, DIP, SiO_3 and Chl-a) from 1960-2002 were used in the analysis. Nutrient data were taken from the winter months, December, January and February while Chl-a was taken from the growing season, March to November. Because of the strong salinity gradients between several of the regions, the analysis was repeated with salinity corrected (30 psu) concentrations.

Initial tests using a depth-based division of the Skagerrak showed that 4 regions would probably suffice. In the open Skagerrak, west of 11°E, a division along 58°N created two regions: Region 1 represented the open Skagerrak and the beginning of the Norwegian Coastal Current and region 2 the Jutland Coastal Current. East of 11°E, Region 3 represented the northward going Baltic Current and the outflow plume from Göta älv. Region 4 represents the inshore stations including the fjords of the Swedish West Coast. This is shown in Figure 5.

5 Results

5.1 Trend analysis

In the OSPAR Assessment (Håkansson et al, 2003), winter nutrient values were salinity-corrected to 30 psu. These eutrophication indicator time series were around 35 years long – from 1965 to 2002 – with more data gaps towards the beginning, rather than at the end of the series. These time series are presented in *Figure 1 - Figure* 4. Results of the trend analysis are presented in Table 5 to Table 8, for the regions 'Inshore Kattegat', 'Offshore Kattegat', 'Inshore Skagerrak' and 'Offshore Skagerrak' respectively. These results are then summarised in Table 9

When the Mann-Kendall test was applied to these series, it was not possible to detect significant trends in nutrient concentrations, except for an increase in DIN in the inshore Kattegat and offshore Skagerrak, and increasing DIP in the inshore Skagerrak. Applying the seasonal Kendall test allows the use of the entire dataset – rather than the quarter that is used when data are seasonally averaged. This increases the statistical strength of the test, allowing detection of significant trends data that were previously unclear. The results may be summarised as follows:

- Uncorrected DIN levels had a significant, decreasing trend in the offshore Kattegat, though not elsewhere.
- Uncorrected DIP values showed a significant, decreasing in the inshore Kattegat and Skagerrak. These remained significant after salinity correction, although their significance had reduced.
- Silicate levels decreased in both the offshore Kattegat and Skagerrak. This trend is apparent in both the corrected and uncorrected data.
- The inshore Skagerrak had a significant positive silicate trend in the uncorrected data, which became a significant, negative trend with correction.
- All areas showed significant negative trends in silicate after salinity correction
- The trend in the DIN:DIP ratio was significantly positive in the offshore areas.
- DIP:SiO_3 and DIN:SiO_3 ratios in both offshore areas had significant, increasing trends. DIP:SiO_3 has also increased in the inshore Kattegat.
- The trend in surface chlorophyll-a concentration was significant and positive across the Skagerrak
- A significant negative trend in near-bottom oxygen concentrations exists in all areas except the inshore Kattegat.

A Masters research project underway at SMHI at the time of writing (Berntsson, *in prep*), using data from one station in the offshore Kattegat (Anholt East), from 1993 – 2002, shows significant, decreasing trends in both phosphorus and nitrogen concentrations of 0.015 and 0.142 µmol/litre/year respectively. The analysis is based on Total Phosphorus and Total Nitrogen values.

5.2 Spatial Analysis

Regions significantly different from the mean field were identified probability mapping. The amount of data available in each Kattegat region is presented in Table 10, while results for the Kattegat are presented in Table 11. Maps showing the position of sampling stations, and the grouping of data are presented in the Appendix. Results are presented both for non-salinity corrected and salinity corrected data and shows which regions that have significant higher or lower mean concentrations than the overall mean over the period analysed.

Skagerrak

The non-salinity-corrected data indicate that region 4 has significant higher mean concentrations of DIN. The higher concentration can be attributed to region 4 being an archipelago with high DIN concentrations originating from terrigenous sources. Region 2 and 4 has been identified to have mean DIP concentrations deviating from the overall mean. Region 4 is near land and has a strong salinity gradient towards open seas - low salinity usually means low concentrations of DIP while oceanic, high salinity water usually have a high concentration of DIP. The Jutland Current, region 2, is one of the main supplier of DIP to Skagerrak and Kattegat, explaining the high concentrations (Fonselius, 1995).

For SiO_3 there is only one region that has significantly lower mean concentrations, region 1. High concentrations of SiO_3 are found in river runoff but not in open sea areas as the Skagerrak.

The method does not appear to work for Chlorophyll-a. This is possibly due to Chlorophyll-a behaving in a different way to nutrients. Chlorophyll-a concentrations show large spatial variations and various peaks during the growing season. It would maybe be more appropriate to only study the Chl-a concentration during the spring bloom.

Region 1, 2 and 4 are identified to have lower/higher concentrations than the overall mean. The highest concentrations of Chl-a can probably be found in the frontal area between Skagerrak and Kattegat, region 3, with salinity varying between 20-25 psu. Areas with lower and higher salinity might be less favourable for plankton production.

After correcting for salinity, areas 1,2 and 4 and significantly different both the mean DIN and DIP. Silicate differs significantly from the mean in areas 2 and 4. The highlighting of area 2 indicates the effect of the Baltic Stream, which dominates in areas 1 and 3. Area 2, with high salinity – has its silicate values amplified by the correction process.

Kattegat

The non-salinity-corrected data set indicates regions 1 and 3 as having significantly higher mean concentrations of DIN than the overall mean. The same result was obtained by Danielsson et al, 2004. Region 3 and 4 were identified to have significant lower mean concentrations of DIP, probably due to the high influence of low saline Baltic surface water on the region. The outflow plume of the Baltic surface water can also explain the result for SiO_3, which indicates that region 2 and 3 have significant higher concentrations.

Strong, and often complex salinity gradients are a feature of the Kattegat and Skagerrak. Correcting the data set to a reference salinity of 30 psu attempts to remove this signal. The results of probability mapping of salinity-corrected data are difficult to explain. The DIN signal in the Kattegat remains unchanged. DIP concentrations, were significantly low in regions 3 & 4 prior to salinity correction. After correction, areas 4,5 and 7 are considered to be significantly different from the overall average. Region 4 may be strongly affected by local land run-off. Area 5 and 7 are more difficult to explain. It is possible that they have higher than average DIP levels, because of inflowing Skagerrak water – but this current lies under the Baltic outflow, so must be mixed to the surface layer to affect this analysis. After correction of the silicate data, it appears that the entire southern Kattegat is significantly different from the overall Kattegat-mean value. This is likely to be due to the effect of the Baltic outflow. but it is likely that the regions would not have the same if hydrographic features like salinity not had been included in the grouping of the regions. Results from both the Skagerrak and the Kattegat indicate that the area is strongly influenced by water masses with large variations in salinity. To completely exclude these variations in this test was not useful.

6 Discussion

6.1 Monitoring eutrophication

Development of the monitoring programme

The first national attempt to cover the physical status of marine waters was done in 1877, primarily to better understand fluctuations in fish resources. The expedition was initiated by F.L. Ekman but the main results were published many years later by Pettersson in 1893. Under the Hydrographic-Biological Commission established in 1901 (Fonselius, 2001), expeditions were organised in co-operation with other countries. Before the Great War only temperature, salinity and oxygen were measured, with pH and alkalinity added after 1921. No data were collected during the First and Second World Wars (Fonselius, 2001).

The Hydrographic Department of the National Fishery Board was established in 1948. In 1960 the Hydrographic Department started monitoring phosphate and some years later added nitrite and nitrate, followed by silicate and ammonium, to the list of observed parameters. In the beginning, hydrographic cruises were carried out annually at most. After the 1950s, this increased to between 4 - 6 cruises per year.

Increasing awareness of environmental problems related to eutrophication and toxins in marine waters called for more detailed information. During the 1990s, efforts were made to understand seasonal time scales in the Skagerrak and Kattegat, with several major environmental research projects related to environmental problems. ’The Skagerrak Experiment’ (Dybern et al., 1994 and Danielssen et al., 1997), the Swedish multidisciplinary research project ”Large-scale environmental effects and ecological processes in the Skagerrak-Kattegat” (Reported in Journal of Sea Research, vol 35, parts 1-3, 1996) and the Danish Marine Research Programme (Jørgensen & Richardson, 1996) all contributed to the understanding of processes, environmental impacts and system analysis.

Sweden’s National Marine Environmental Monitoring Programme

The Swedish Government, in ’Miljöproposition’ (Environmental Proposal) 1997/98:145, gives guidance on the time frames within which improvement measures should be observable by the marine environmental monitoring programmes. The national environmental goals include an improved marine environment (no eutrophication; balanced marine environment), and ecosystem recovery, that should be observable (measurable) by 2010. Within a generation (20 years) the improvement in marine environmental quality should be complete – assuming that the marine ecosystem can respond sufficiently quickly. Recovery of the Baltic marine environment is expected to take longer, though signs of recovery should be apparent (measurable) by 2020.

The Swedish National Environmental Monitoring Programme is managed by Naturvårdsverket – The Swedish Environmental Protection Agency. The Agency has the responsibility to ensure that environmental monitoring programmes (atmospheric, terrestrial and marine) meet the requirements set by Sweden’s government. These requirements are that the environmental monitoring programmes shall:

- describe the environmental status;
- assess environmental threats;
- suggest remedial actions for environmental improvement;
- follow up the effects of remedial actions;
- provide a basis for the analysis of various discharge sources' national and international environmental impact.

In addition to these requirements, the programme should be adapted to suit changes in the legal requirements for assessing environmental quality, and provide data to assess whether Sweden is working towards its national environmental targets, as well as providing data to meet Sweden's obligations for international reporting of environmental data.

(source: Naturvårdsverket web site http://www.naturvardsverket.se)

The environmental monitoring programmes cover many parameters though only the most important ones related to eutrophication issues are mentioned here. Nutrients in the water column are of strategic importance to monitor during the winter months, whereas oxygen conditions, especially in deep waters, are measured during early autumn in order to observe the nutrient status and eutrophication effects. Plankton and chlorophyll a are monitored at monthly intervals, but with higher frequency during spring bloom periods.

In 1996 regular, monthly, monitoring cruises were initiated, covering physical, chemical and biological parameters in the water column. Data are also collected during the annual cruises of the National Fisheries Authority, when they take part in the International Bottom Trawl Survey, and during additional winter 'nutrient mapping' cruises. All these cruises make use of the Fisheries Research Vessel Argos. Table 2 lists the parameters measured, and depths sampled in the Kattegat and Skagerrak. Different depths are sampled in the Baltic. Inshore sampling in the region is carried out on behalf of local councils and 'water management authorities[5]'. In the Kattegat and Skagerrak, cruises take place using the SMHI vessel 'Sensor' during the first week of each month.

The Swedish Meteorological and Hydrological Institute keeps hydrographical and hydrochemical data. The data hosts are responsible for quality control, banking, and delivery of monitoring data to international conventions and other organisations. The Swedish national monitoring data are delivered to the International Council for the Exploration of the Sea (ICES), which serves as data centre for both HELCOM and OSPAR.

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[5] The Swedish 'Vattenvårdsförbund' are regional associations of stakeholders – typically town and county councils, as well as industry and fisheries groups - responsible for managing water quality from streams and lakes, through to the coastal zone.

Data quality is ensured through participation in a range of quality assurance programmes. SMHI participates in QUASIMEME, and the Oceanographic Laboratory has been ISO-accredited through SWEDAC since 1994. SMHI as a whole has been ISO accredited since 2003. The quality of the monitoring work also benefits from the laboratory staff participation in national and EU-funded research projects, and from their contribution to HELCOM and GOOS expert groups.

The positions of the current hydrographic stations (post 1996 in the Kattegat and Skagerrak) sampled at annual or higher frequencies, are shown in Figure 7a. The approximate frequency of observations is presented in Figure 7b. Table 3 lists the stations included in the National Monitoring Programme in the Kattegat and Skagerrak. Table 4 describes the other parameters (hydrochemistry, biology) taken at each station.

The marine monitoring programme was revised in 2000. This revision was based in part on a study that described the minimum sampling requirements, in space and time, for sea areas from the Kattegat to the Bothnian Bay (Andersson et al, 2000). Using spatial correlation techniques it was found that, for surface waters (0 - 10 m), to obtain a correlation of less than 90% between adjacent stations in the Kattegat, stations should be more than 8 nm apart (for salinity), 13 nm apart (total phosphorus) and more than 10 nm apart (total nitrogen). This requirement for station separation is met by the current winter nutrient mapping expedition plan, though not by the regular (~monthly) monitoring cruises.

The same study also recommended that, because summer inorganic nutrient concentrations are close to the detection limit and so do no contribute to improved trend estimates, nutrient monitoring needs to describe winter concentrations, as well as the onset and end of the summer period. The difficulty in predicting the start and end of the summer nutrient conditions, combined with the requirements for biological monitoring (such as those related to phytoplankton activity) led to the current monitoring programme.

This present study highlights potential problems with salinity correction of whole year datasets. The influence of the salinity correction on the time series is apparent from the differences in results between raw and salinity-corrected datasets (and in particular, in the *Z* values presented in Table 5 - Table 8). In the Kattegat, decreasing trends in DIN (offshore) and DIP (inshore) became insignificant with salinity correction. Where the trend was previously insignificant, such as with inshore DIN, a significant positive trend was discovered after salinity correction. The effect of salinity correction on summer data requires particular attention. In the uncorrected data set, there were 72 tied DIP values – i.e. pairs of datapoints which contributed nothing to the trend. After salinity correction, there were none. This is because under bloom conditions, both DIN and DIP are used up. Salinity correction of these ’zero’ values creates values, which can lead to the detection of spurious trends.

An alternative approach, in areas such as the Kattegatt may be to use data from within defined salinity limits.

7 Conclusions

The current Swedish National Pelagic Monitoring Programme is able to detect significant trends in eutrophication indicators. Trend analyses were carried out using long data records – from 1955 onwards in the case of oxygen, 1965 for nutrients, and 1980 for chlorophyll-a (1986 in the Skagerrak).

- Using the Seasonal Mann-Kendall analysis increased the statistical strength of trend analysis, compared with the reporting of averaged winter nutrient concentrations
- To be able to extract trends from these data, it is better to have monitoring data from the entire year, rather than just winter pool values.
- Salinity correction of summer data should be avoided, as it creates a signal based entirely on the salinity, which then contributes to a false trend assessment.
- Silicate levels are decreasing significantly in the offshore areas. This result comes through with and without salinity correction. Inshore silicate also appears to be decreasing, though the signal is not significant before salinity correction, nor in the winter data.
- The increasing offshore Redfield (DIN:DIP) ratio, and the changes in the ratios involving silicate, suggest that changes in the plankton community structure will occur, or are occurring.
- Surface chlorophyll-a concentrations are increasing in the Skagerrak
- Using autumn-mean data from 1955 – 2002 (as presented in the 2002 OSPAR Assessment) it was not possible to determine the existence of a trend in oxygen concentration in the inshore Kattegat. In all other regions however, the trend in oxygen concentration is significant, and negative.
- Improvements in the sampling programme may not be obtained by further increasing the frequency of sampling. It is assumed in the statistical analysis that the data points are statistically independent, and increasing the sampling frequency may invalidate this assumption.
- Missing data in the series reduces the statistical strength of the analyses. Therefore it is important to put try to fill these gaps. This can be acheived through data archaeology. More effective is to improve data exchange between institutes, and promote the work of the of the international data centres.
- Probability Mapping provides insight into the typical number of sub-regions within the Kattegat and Skagerrak. The monitoring programme needs to resolve the differences across these basins.
- Earlier work (Andersson et al, 2000) indicates 10 nm to be a suitable minimum distance between stations in the Kattegat. This leads to the recommendation that there be 2 stations per sub-region in the Kattegat.
- Inorganic nutrients do not require year round measurement, though the onset and end of summer conditions should be observed, and the needs of other parameters considered when designing a monitoring programme.

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9 Figures and tables

Parameters	Background	Critical	Observed	Evaluation
DIN	4.5 / 10	>6 / >15	7 / 7 / 8 / 8	+ / + / - / -
DIP	0.4 / 0.6	>0.6 / >0.9	0.65 / 0.65 / 0.6 / 0.6	+ / + / - / -
DIN/DIP	16	> 25	< 16 / 16 / >16 / 16	- / - / - / -
DIN/SiO_3	1	> 2	1 / 1 / 1.3 / 1.7	- / - / - / -
DIP/SiO_3	0.083	> 0.125	0.1 / 0.1 / 0.1 / 0.125	- / - / - / -
Chlorophyll-a	1.5	> 2.25	2.5 / 2 / 3 / 2	+ / - / + / -

Table 1 Summary of nutrient status and assessment during the 1990s. The different water bodies are shown as Coastal Kattegat / Offshore Kattegat / Coastal Skagerrak / Offshore Skagerrak. Background and critical reference levels only exist for offshore waters.

Kattegat		Skagerrak	
Sampling Depths (metres)	Parameters	Sampling Depths (metres)	
0 – 10 m (integrated sample)	Chlorophyll-a; Primary Productivity; Secchi depth	0 – 10 m (integrated sample)	Chlorophyll-a; Primary Productivity; Secchi depth
0	Temperature; Salinity; pH; Oxygen (and H_2S when appropriate); DIP; Total Phosphorus; NO_2; NO_3; NH_4; Total Nitrogen; Silicate	0	Temperature; Salinity; pH; Oxygen (and H_2S when appropriate); DIP; Total Phosphorus; NO_2; NO_3; NH_4; Total Nitrogen; Silicate
5		5	
10		10	
15		15	
20		20	
25		30	
30		40	
40		50	
50		75	
Bottom	Temperature; salinity; Oxygen (and H_2S when required)	100	
		125	
		150	
		200	
		300	

Table 2 Base variables in the Swedish National Monitoring Programme in the Kattegat and Skagerrak

Station	Lat	Lon	Bottom Depth	No. Depths
P2	**5752**	**1118**	**96**	**10**
SLÄGGÖ	**5815,5**	**1126**	**62**	**9**
Å13	**5820,2**	**1102**	**85**	**10**
Å14	**5819**	**1056,5**	**110**	**10**
Å15	**5817,7**	**1051**	**130**	**11**
Å16	**5816**	**1043,5**	**202**	**13**
Å17	**5816,5**	**1030,8**	**340**	**15**
M6	5810	930	640	17
HS5	5744,2	1000,4	89	10
GF4	5733	1131,5	79	12
GF6	5732	1119,5	42	8
GF8	5727,9	1054	40	8
GF9	5726	1042,5	26	6
LÄSÖ RÄNNA	5717,6	1044,5	43	8
409 ÅLBORG BUGT	5651,4	1047,5	15	4
925 KATTEGATT SW	5607,9	1109,6	45	9
FLADEN	**5711,5**	**1140**	**75**	**12**
L:A MIDDELGRUND	5657,5	1145,5	100	14
ANHOLT E	**5640**	**1207**	**55**	**10**
ST MIDDELGRUND	5634	1213	44	9
KULLEN	5614	1222,2	23	6
LAHOLM-3 (YG)	5633,3	1234	21	5

Table 3 List of CTD stations in the Kattegat and Skagerrak. Stations in bold are part of the monthly monitoring programme. Anholt E and Släggö are taken 24 times per year.

Station	Temp	Salt	pH	Alkali nity	O_2	PO_4	Tot P	NO_2	NO_3	NH_4	Tot N	SiO_2	Hum /Lig	Prim-prod	Chloro -phyll	Phyto-plankto
P2	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**	
SLÄGGÖ	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**	**S/E**
Å13	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**	
Å14																
Å15	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**				
Å16																
Å17	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**	**S/E**
M6	X	X			X	X	X	X	X	X	X	X				
HS5	X	X			X	X	X	X	X	X	X	X				
GF4	X	X			X	X	X	X	X	X	X	X				
GF6	X	X			X	X	X	X	X	X	X	X				
GF8	X	X			X	X	X	X	X	X	X	X				
GF9	X	X			X	X	X	X	X	X	X	X				
LÄSÖ RÄNNA	X	X			X	X	X	X	X	X	X	X				
409 ÅLBORG BUGT	X	X			X	X	X	X	X	X	X	X				
925 KATTEGATT SW	X	X			X	X	X	X	X	X	X	X				
FLADEN	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**	
L:A MIDDELGRUND	X	X			X	X	X	X	X	X	X	X				
ANHOLT E	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**S/E**
ST MIDDELGRUND	X	X			X	X	X	X	X	X	X	X				
KULLEN	X	X			X	X	X	X	X	X	X	X				
LAHOLM-3 (YG)	X	X			X	X	X	X	X	X	X	X				

Table 4 Additional parameters measured at Kattegat & Skagerrak stations in the National Monitoring Programme. Stations in bold are ’high frequency’ stations.

		Mann-Kendall test			Sen's test (change/year)		
	Parameter	Z	P	Significant Trend?	Lower 90% slope	Median slope	Upper 90% slope
Seasonal (monthly) test results	DIN	1.56	0.9406	No	-0.000	0.009	0.018
	DIP	-5.27	>0.999	Yes	-0.003	-0.002	-0.002
	SiO_3	-0.61	0.7291	No	-0.033	-0.008	0.013
	DIN@30psu	-1.24	0.8925	No	-0.025	-0.010	0.004
	DIP@30psu	-3.09	0.9990	Yes	-0.002	-0.002	-0.001
	SiO_3@30psu	-2.15	0.9842	Yes	-0.068	-0.036	-0.008
	DIN:DIP@30psu	-1.16	0.8770	No	-0.106	-0.039	0.015
	DIP:SiO_3@30psu	-2.39	0.9916	Yes	-0.003	-0.001	-0.000
	DIN:SiO_3@30psu	0.77	0.7794	No	-0.003	0.004	0.011
	Chlorophyll-a	0.52	0.6985	No	-0.022	0.006	0.029
Winter values	DIN@30psu	1.78	0.9625	Yes	0.005	0.080	0.170
	DIP@30psu	-1.34	0.9099	No	-0.008	-0.004	0.001
	SiO_3@30psu	-0.24	0.5948	No	-0.169	-0.024	0.161
Autumn values	Oxygen	0.34	0.6331	No	-0.020	0.006	0.038

Table 5 Results of Inshore Kattegat Trend Analysis. P is the probability (for a two-sided distribution) that there is no trend.

		Mann-Kendall test			Sen's test (change/year)		
	Parameter	Z	P	Significant Trend?	Lower 90% slope	Median slope	Upper 90% slope
Seasonal (monthly) test results	DIN	-2.50	0.9938	Yes	-0.013	-0.008	-0.003
	DIP	-0.62	0.7324	No	-0.001	-0.000	0.000
	SiO_3	-2.53	0.9943	Yes	-0.044	-0.027	-0.009
	DIN@30psu	1.31	0.8708	No	-0.004	0.006	0.016
	DIP@30psu	1.32	0.9082	No	-0.000	0.000	0.001
	SiO_3@30psu	-3.79	>0.999	Yes	-0.055	-0.039	-0.022
	DIN:DIP@30psu	3.63	>0.999	Yes	0.042	0.075	0.105
	DIP:SiO_3@30psu	2.08	0.9812	Yes	0.000	0.001	0.002
	DIN:SiO_3@30psu	2.95	0.9984	Yes	0.007	0.015	0.023
	Chlorophyll-a	0.36	0.6406	No	-0.020	0.004	0.019
Winter values	DIN@30psu	1.30	0.9032	No	-0.012	0.053	0.102
	DIP@30psu	-0.68	0.7517	No	-0.005	-0.002	0.002
	SiO_3@30psu	-1.10	0.8643	No	-0.169	-0.070	0.028
Autumn values	Oxygen	-3.30	>0.999	Yes	-0.068	-0.050	-0.027

Table 6 Result of Offshore Kattegat Trend Analysis

		Mann-Kendall test			Sen's test		
	Parameter	Z	P	Significant Trend?	Lower 90% slope	Median slope	Upper 90% slope
Seasonal (monthly) test results	DIN	1.63	0.9484	No	-0.001	0.015	0.035
	DIP	-3.01	0.9987	Yes	-0.002	-0.001	-0.000
	SiO_3	1.82	0.9656	Yes	0.005	0.031	0.063
	DIN@30psu	-1.45	0.9265	No	-0.056	-0.023	0.003
	DIP@30psu	-2.81	0.9975	Yes	-0.001	-0.001	-0.000
	SiO_3@30psu	-3.72	>0.999	Yes	-0.218	-0.151	-0.092
	DIN:DIP@30psu	-1.33	0.9082	No	-0.255	-0.115	0.038
	DIP:SiO_3@30psu	0.97	0.8340	No	-0.000	0.000	0.001
	DIN:SiO_3@30psu	0.10	0.5398	No	-0.005	0.000	0.008
	Chlorophyll-a	1.77	0.9616	Yes	0.002	0.029	0.058
Winter values	DIN@30psu	1.20	0.8849	No	-0.027	0.062	0.140
	DIP@30psu	1.85	0.9678	Yes	0.000	0.003	0.005
	SiO_3@30psu	-0.55	0.7088	No	-0.167	-0.056	0.131
Autumn values	Oxygen	-2.42	0.9922	Yes	-0.052	-0.028	-0.011

Table 7 Results of inshore Skagerrak trend analysis

		Mann-Kendall test			Sen's test		
	Parameter	Z	P	Significant Trend?	Lower 90% slope	Median slope	Upper 90% slope
Seasonal (monthly) test results	DIN	-0.96	0.8315	No	-0.012	-0.004	0.003
	DIP	-1.04	0.8508	No	-0.001	-0.000	0.000
	SiO_3	-6.14	>0.999	Yes	-0.056	-0.045	-0.033
	DIN@30psu	-0.55	0.7088	No	-0.011	-0.003	0.005
	DIP@30psu	-1.18	0.8810	No	-0.001	-0.000	0.000
	SiO_3@30psu	-4.00	>0.999	Yes	-0.060	-0.040	-0.024
	DIN:DIP@30psu	2.12	0.983	Yes	0.014	0.073	0.137
	DIP:SiO_3@30psu	2.22	0.9868	Yes	0.000	0.001	0.001
	DIN:SiO_3@30psu	2.86	0.9979	Yes	0.005	0.011	0.019
	Chlorophyll-a	2.38	0.9913	Yes	0.020	0.043	0.073
Winter values	DIN@30psu	2.12	0.9830	Yes	0.020	0.081	0.135
	DIP@30psu	1.29	0.9015	No	-0.001	0.002	0.005
	SiO_3@30psu	-1.15	0.8749	No	-0.128	-0.052	0.010
Autumn values	Oxygen	-3.50	>0.999	Yes	-0.029	-0.019	-0.010

Table 8 Offshore Skagerrak trend analysis

	Parameter	Inshore Kattegat	Offshore Kattegat	Inshore Skagerrak	Offshore Skagerrak
Seasonal (monthly) test results	DIN		↓		
	DIP	↓		↓	
	SiO_3		↓	↑	↓
	DIN@30psu				
	DIP@30psu	↓		↓	
	SiO_3@30psu	↓	↓	↓	↓
	DIN:DIP@30psu		↑		↑
	DIP:SiO_3@30psu	↓	↑		↑
	DIN:SiO_3@30psu		↑		↑
	Chlorophyll-a			↑	↑
Winter values	DIN@30psu	↑			↑
	DIP@30psu			↑	
	SiO_3@30psu				
Autumn values	Oxygen		↓	↓	↓

Table 9 Summary of trend significance from the Mann-Kendall and Seasonal Kendall tests. Arrow direction indicates whether the significant trends are positive or negative. A blank cell indicates that trends were insignificant. '@30psu' indicates that the concentrations were corrected to a reference salinity of 30 psu.

Region	DIN	DIP	SiO_3	Chl-a
1	240	269	193	536
2	106	108	92	239
3	790	844	690	1289
4	503	500	467	1432
5	509	592	467	1012
6	388	439	362	1230
7	445	598	239	474
8	261	350	133	300

Table 10 Number of observations in each region in the Kattegat during the period 1960-2002.

	DIN	DIP	SiO_3	Chl-a
Regions, no salinity correction	1,3	3*,4*	2,3	2,4
Regions, salinity corrected to 30 psu.	1,3 (y=0.012x+7.2)	4,5,7 (y=0.0081x+0.41)	1,2,3,4,5 (y=-0.27x+15)	-

Table 11 Regions in the Kattegat having significantly higher/lower average concentrations than the overall average. The significance level is set to 0.05, and significantly lower values are indicated by *.

	DIN	DIP	SiO_3	Chl-a
Region, no salinity correction	4	2,4*	1*	1,2,4
Regions, salinity corrected to 30 psu.	1,2,4 (y=0.22x+14)	1,2,4 (y=0.0035x+0.49)	2,4 (y=0.94x+35)	-

Table 12 Skagerrak regions having significantly higher/lower average concentrations than the overall average. Significant lower values are denoted by *. The significance level is set to 0.05.

Region	DIN	DIP	SiO_3	Chl-a
1	625	960	520	843
2	403	458	346	297
3	446	723	380	492
4	1980	2775	1528	1616

Table 13 Number of observations in each region in Skagerrak during the period 1960-2002.

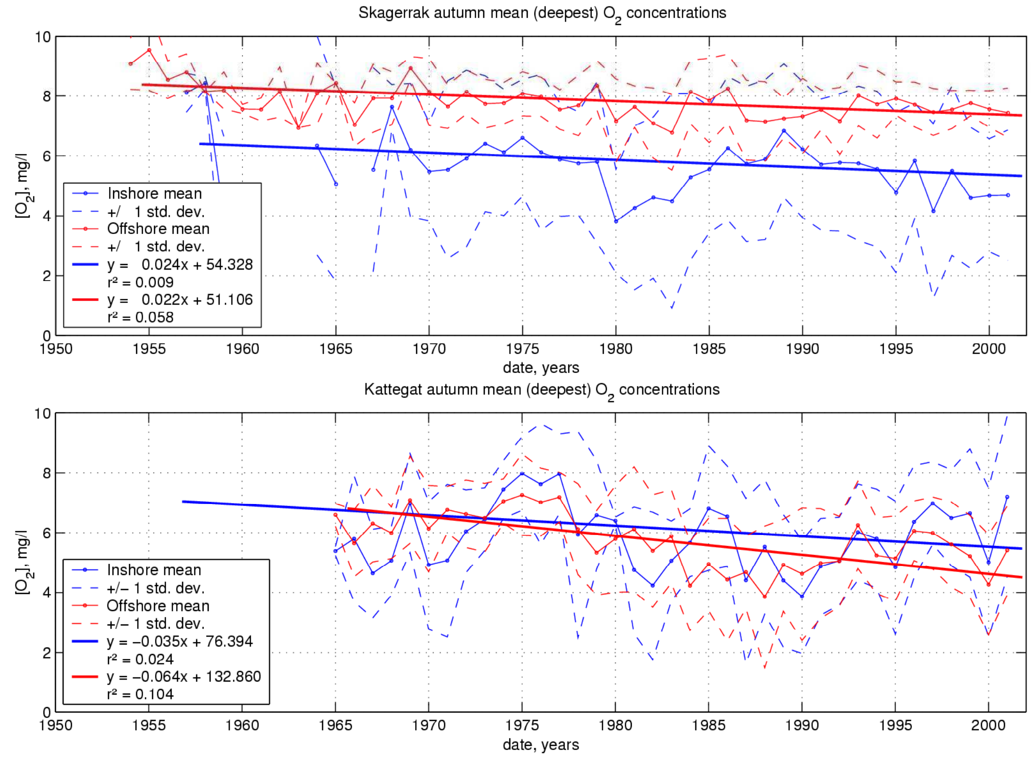


Figure 1 Autumn inshore (blue) and offshore (red) bottom oxygen concentrations in the Skagerrak (upper) and Kattegat (lower), together with their respective linear regression parameters

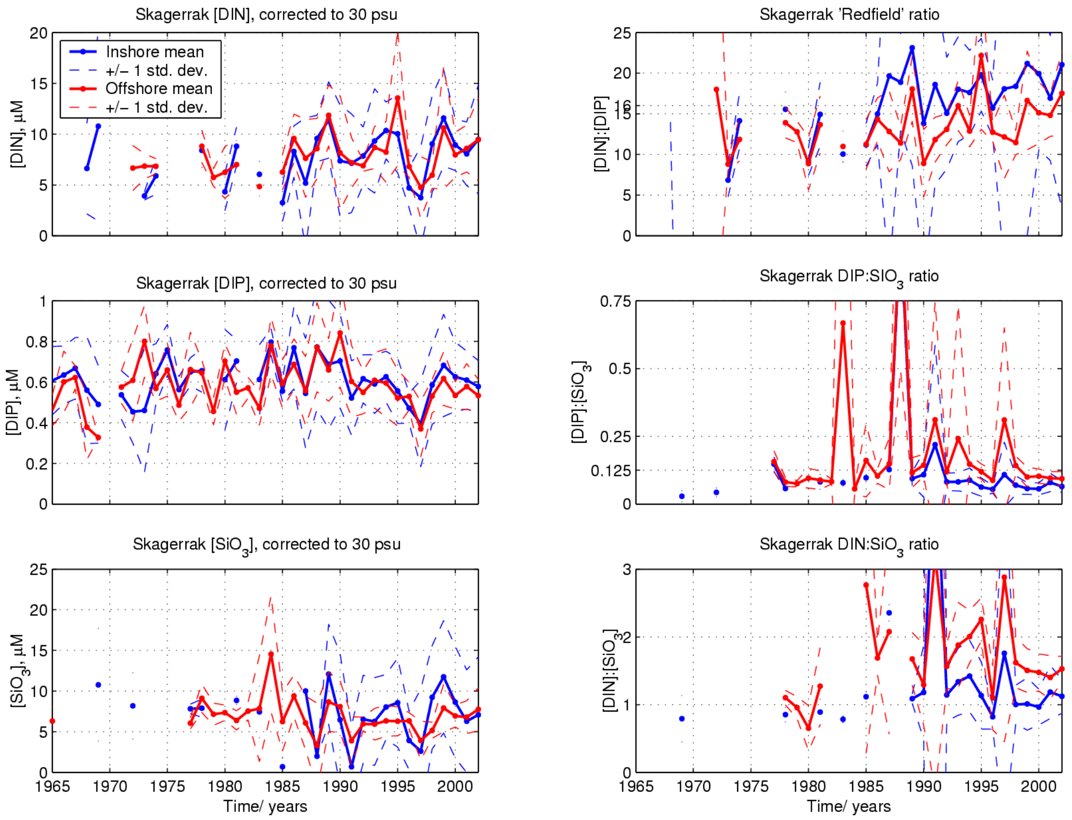


Figure 2 Skagerrak nutrient time series presented in the 2002 OSPAR Assessment

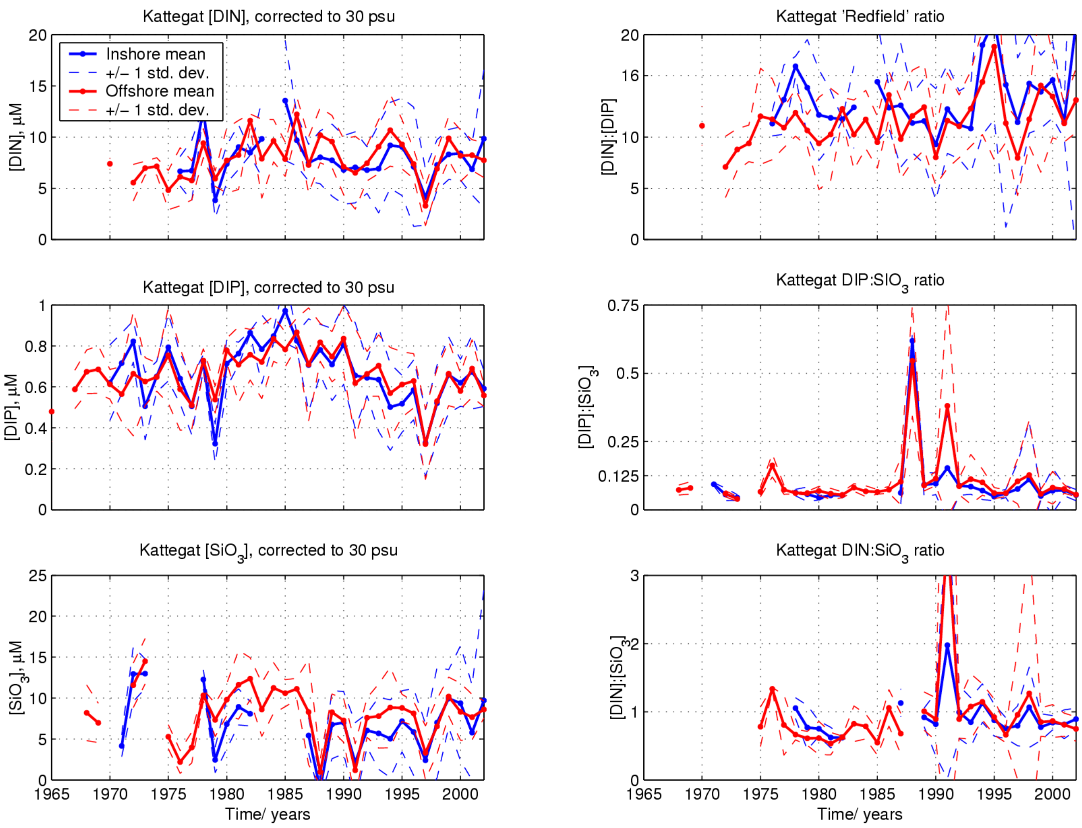


Figure 3 Kattegat nutrient time series presented in the 2002 Assessment

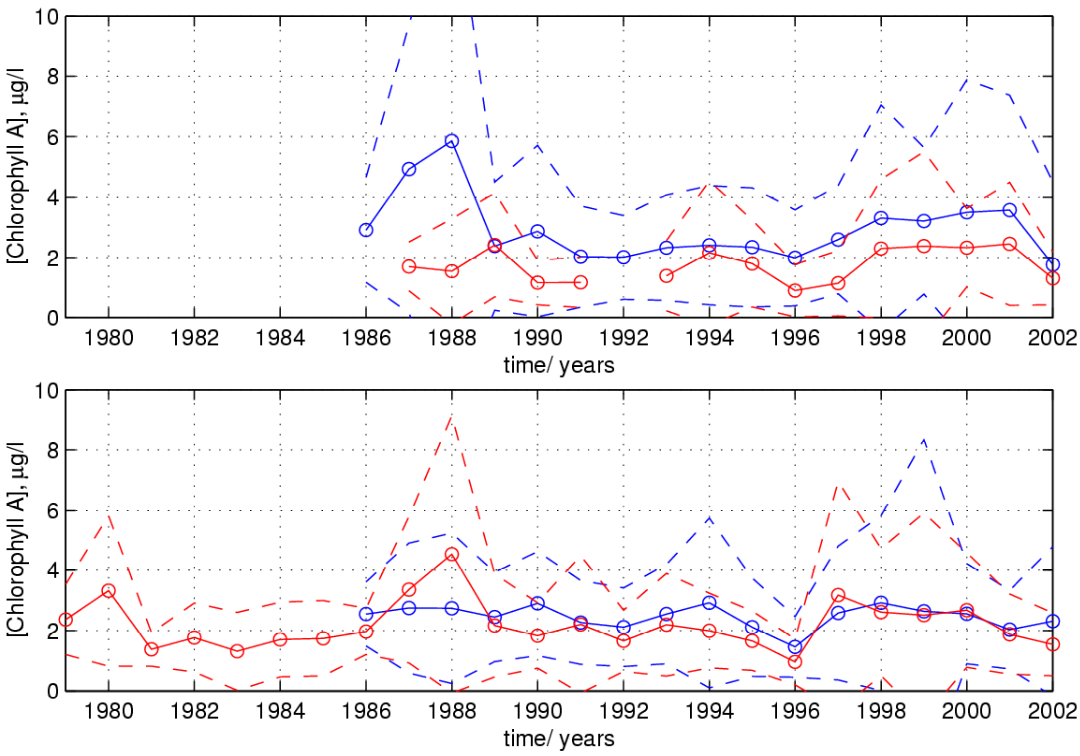


Figure 4 Mean growing-season Chlorophyll-a concentrations inshore (blue) & offshore (red) in the Skagerrak (upper) and Kattegat (lower)

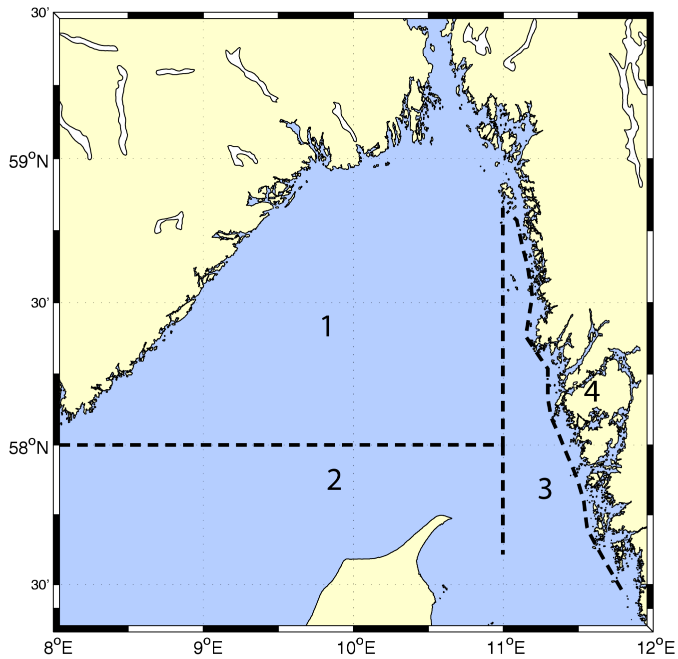


Figure 5 Division of the Skagerrak

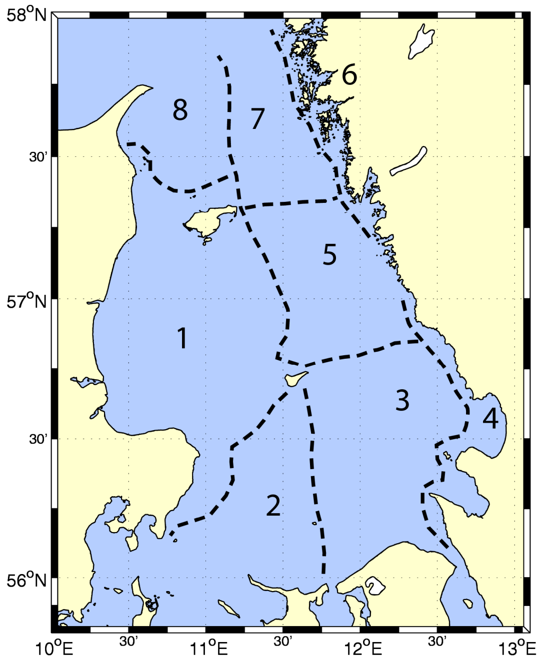


Figure 6 *Division of the Kattegat for spatial mapping*

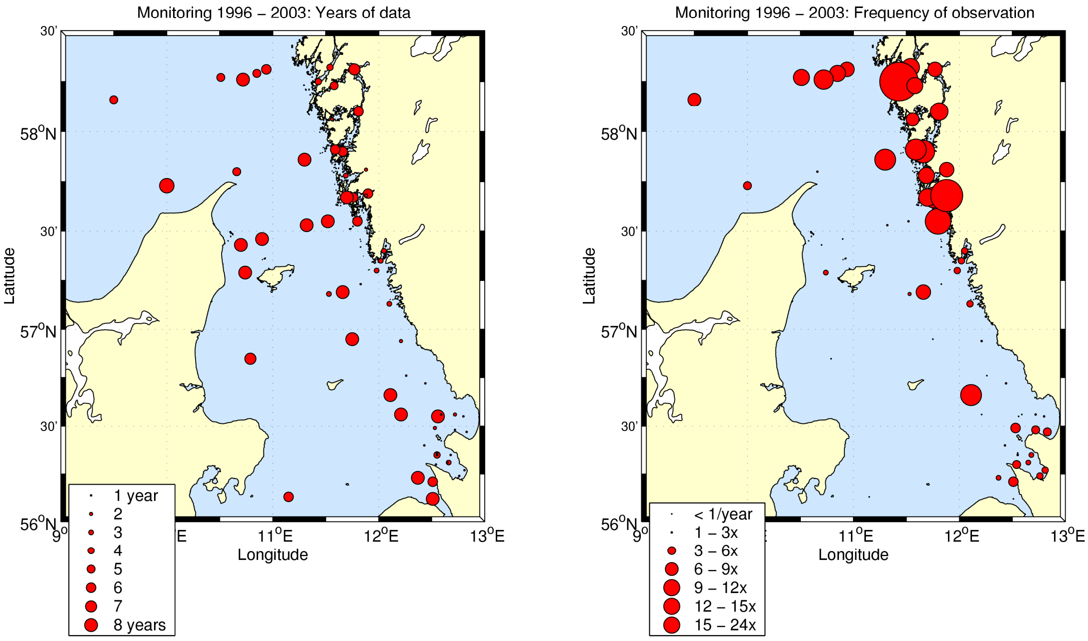
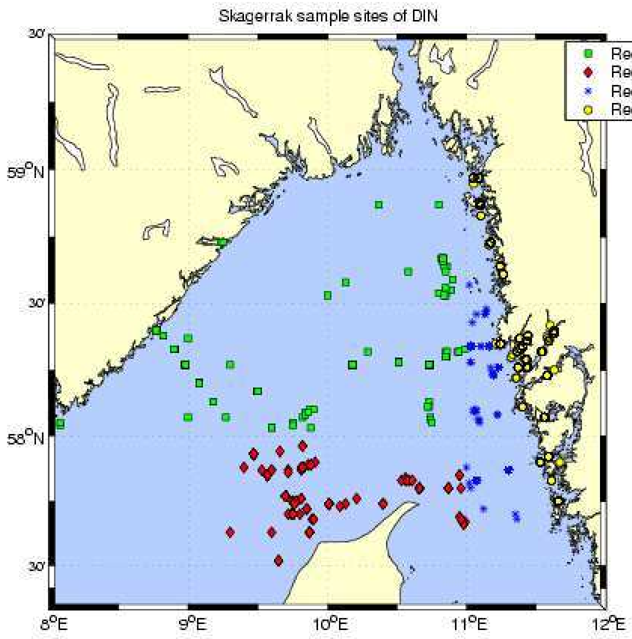
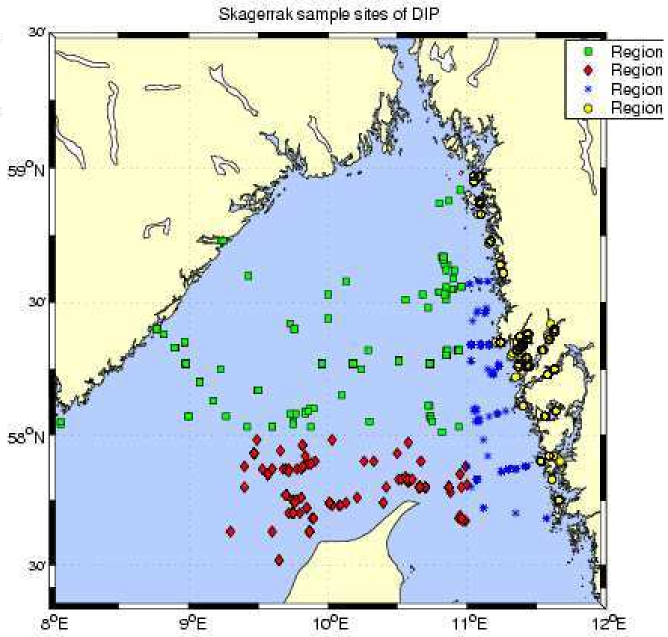


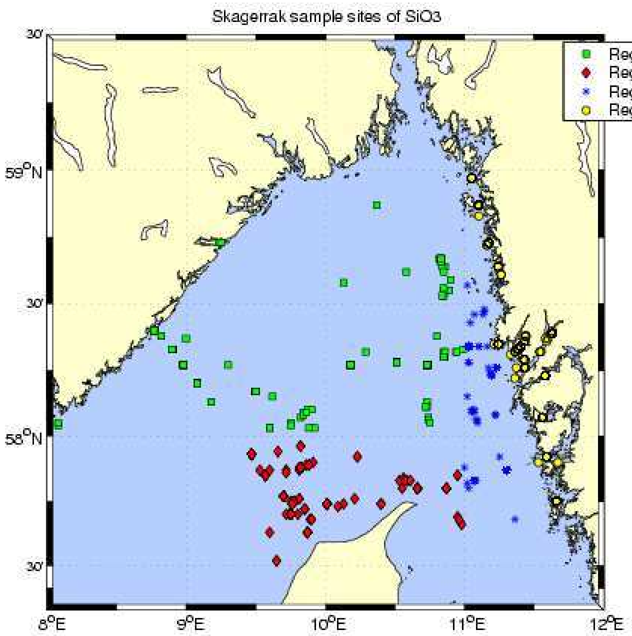
Figure 7 SMHI monitoring stations in the Kattegat and Skagerrak. Figure a, to the left, shows the number of years data (since 1996) available in the Swedish National Oceanographic Database (SHARK). Figure b, to the right, shows the approximate frequency of observation per year.

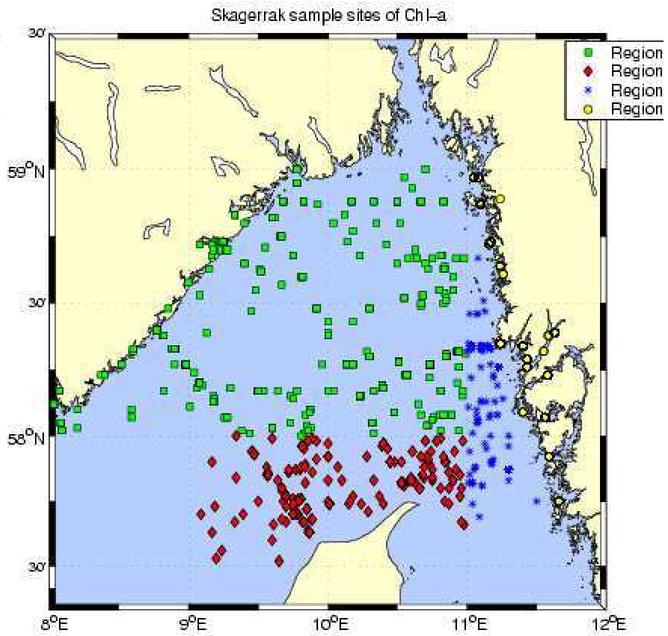
10 Appendices

10.1 Regions and sample sites for DIN, DIP, SiO_3 and Chl-a

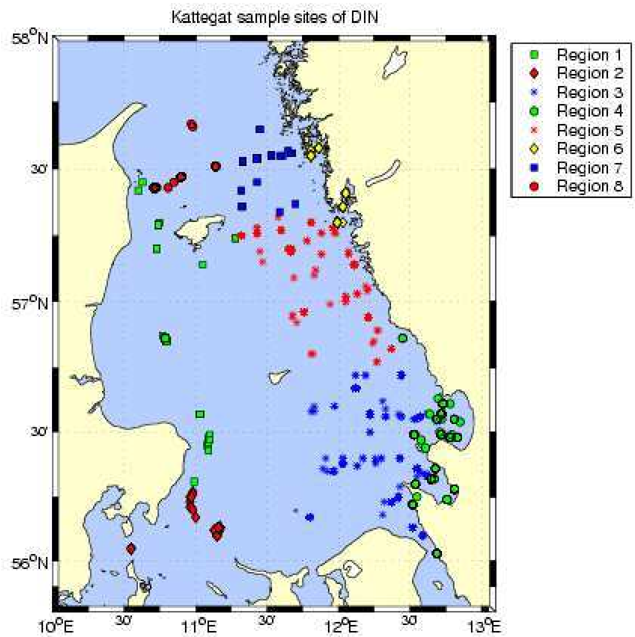


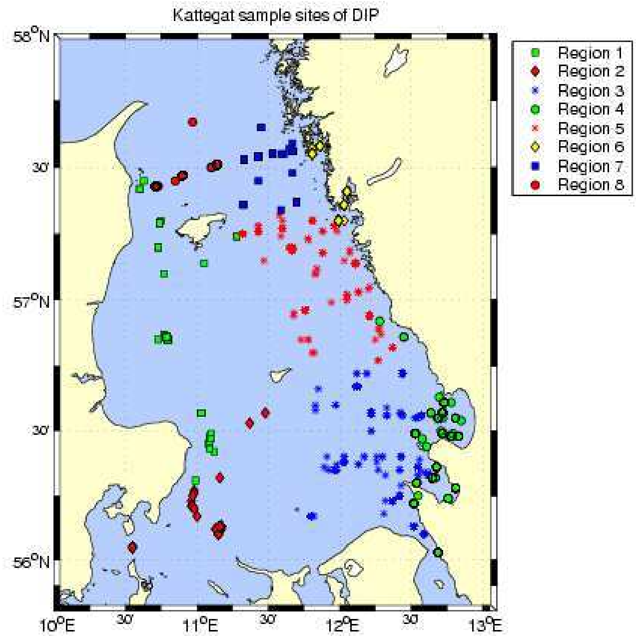


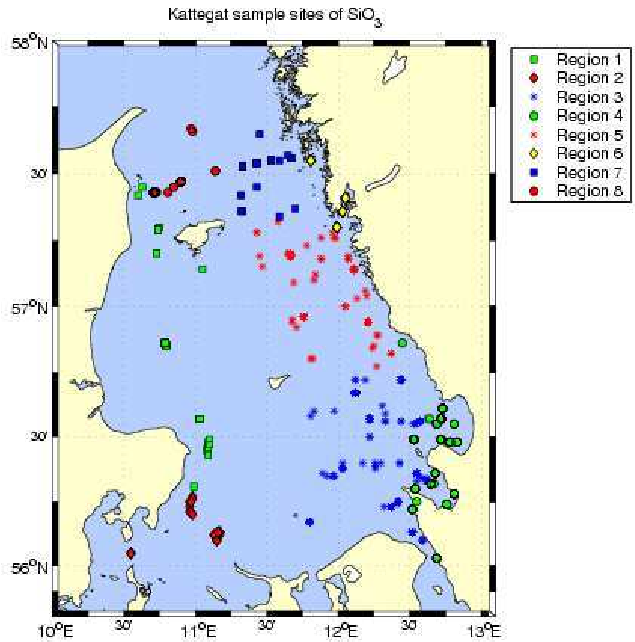


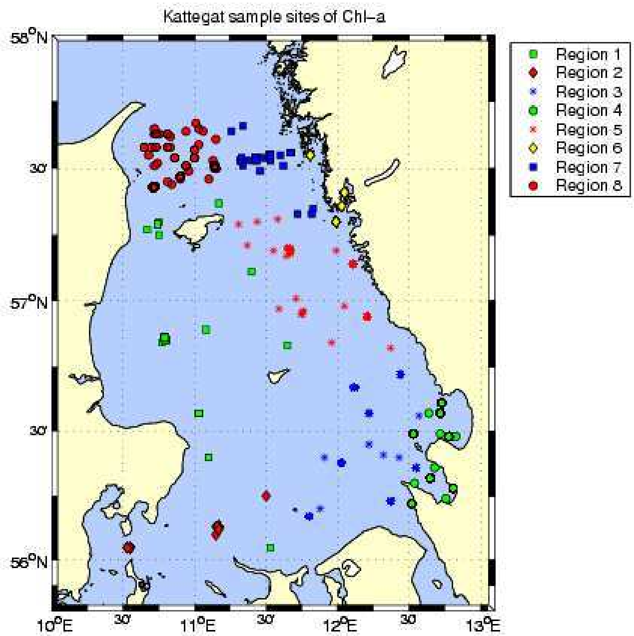


10.2 Regions & sample sites in Kattegat for DIN, DIP, SiO_3 and Chl-a









10.3 SMHI Publications

SMHI produces six report series. Three of these, the R-Series, are intended for an international audience so are often written in English. The other report series use Swedish.

Seriernas namn	Publiceras sedan
RMK (Rapport Meteorologi och Klimatologi)	1974
RH (Rapport Hydrologi)	1990
RO (Rapport Oceanografi)	1986
METEOROLOGI	1985
HYDROLOGI	1985
OCEANOGRAFI	1985

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