



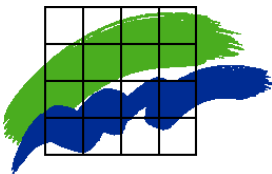
r/v Gunnar Thorson

# Monitoring Cruise Report

**Cruise no.: 218**

**Time: 15 - 19 September 2003**

**Area: The Sound, the Kattegat,  
the Belt Sea and  
the Arkona Sea**



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## Data Sheet

Title: Monitoring Cruise with r/v Gunnar Thorson in the Sound, the Kattegat, the Belt Sea and the Arkona Sea

Subtitle: Cruise no. 218, 15-19 September 2003

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Serial title: Monitoring Cruise Report

Publisher: National Environmental Research Institute<sup>©</sup>  
Ministry of the Environment

Week/year of publication: 45/2003

Please quote: Ærtebjerg, G. 2003: Monitoring Cruise with r/v Gunnar Thorson in the Sound, the Kattegat, the Belt Sea and the Arkona Sea. Cruise no. 218, 15-19 September 2003. National Environmental Research Institute, Denmark. Monitoring Cruise Report.

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Keywords: Marine, monitoring, hydrography, eutrophication

ISSN (electronic): 1600-1656  
(Only published electronically) [http://www.dmu.dk/1\\_om\\_dmu/2\\_afdelinger/3\\_hav/CruiseReports/index.htm](http://www.dmu.dk/1_om_dmu/2_afdelinger/3_hav/CruiseReports/index.htm)

Number of pages: 8

***The numbers of the Monitoring Cruises may not be successive, as the numbers also include other types of cruises.***

Published by: National Environmental Research Institute  
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# Monitoring cruise with r/v Gunnar Thorson in the Sound, the Kattegat, the Belt Sea and the Arkona Sea, 15-19 September 2003

## Cruise no. 218

**Report:** Gunni Ærtebjerg

**Cruise leader:** Kjeld Sauerberg

**Participants:** Dorete Jensen, Hanne Ferdinand, Peter Kofoed, Troels Rasmussen (NERI).  
Halfdan Hasler, Anders Hansen (Trainees)

*This report is based on preliminary data, which might later be corrected. Citation permitted only when quoting is evident.*

### Summary

Since August the minimum oxygen concentrations had decreased, except in the northern Kattegat, but the concentrations this year are still significantly higher than at the same time last year. However, widespread oxygen deficiency (<2.8 ml/l) was observed in the southern Kattegat, the Sound, the Great Belt, the Mecklenburg Bight and the Arkona Sea, while severe oxygen deficiency (<1.4 ml/l) at the cruise was only observed in the Fehmarn Belt (1.1 ml/l). However, measurements made by Danish counties and German authorities showed widespread severe oxygen deficiency in the sea north of Funen, the southern Little Belt with associated coastal waters, western Kiel Bight, Lübeck Bight and Mecklenburg Bight (*figure 7*). A report on oxygen deficiency in September 2003 is available at: <http://iltrapport.dmu.dk> (in Danish with an English summary).

At the cruise the temperature generally was higher than normal in the whole water column due to the warm summer. The salinity generally was lower than normal in the surface waters due to outflow from the Baltic Sea, but higher than normal in the bottom waters.

In the surface layer generally no inorganic nitrogen nutrients were present, while at least traces of phosphate were present in most areas. Silicate concentrations of 1-10 µmol/l were present in the surface water in all areas, except in the northern and central Kattegat.

In the bottom water nitrate concentrations above 6 µmol/l were observed only in the south-eastern Kattegat. In the Belt Sea the nitrate concentration in the bottom water was relatively low. Very high ammonium concentrations (4.0-9.5 µmol/l) were observed in the bottom water in the central Sound, the southern Great Belt and especially in the Mecklenburg Bight. High silicate and phosphate concentrations were observed in the bottom water east of Anholt, in the southern Great Belt and the Arkona Sea. High phosphate concentrations were also observed at the bottom in the Fehmarn Belt and Mecklenburg Bight.

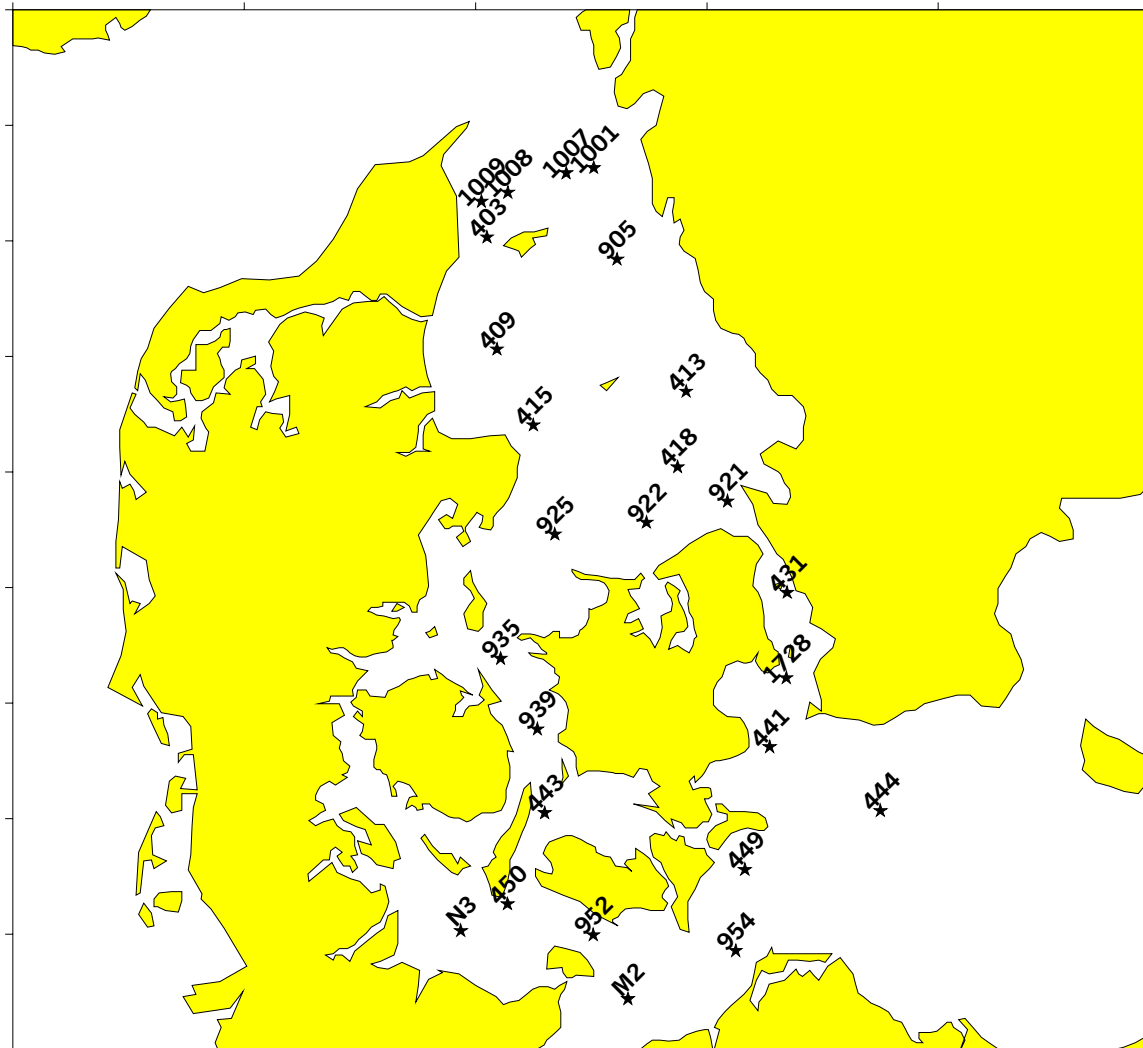
The chlorophyll-a concentration in the surface water was relatively low (0.9-2.0 µg/l) in all areas, except in the Fehmarn Belt. However, in the western Kattegat and Great Belt a pronounced subsurface maximum of 3.9-8.4 µg/l was present in 10-15 m depth. In the eastern and southern Kattegat the highest concentrations (1.5-2.2 µg/l) were found in 15-20 m depth. In the Fehmarn Belt the highest concentrations (3.0-3.6 µg/l) were observed in the surface layer.

## General

The objectives of the cruise were:

- To determine the actual situation in the open Danish waters;
- To trace the influence of land based discharges of nutrients;
- To establish reference data for the local monitoring in coastal areas;
- To continue time series for trend monitoring.

The cruise is part of the Danish nation wide monitoring programme NOVA 2003, the HELCOM monitoring programme for the Baltic Sea area (Arkona Sea, Sound, Belt Sea, Kattegat), and the OSPARCOM monitoring programme for the Greater North Sea (Kattegat). The main scope of the cruise was to monitor the oxygen situation, but also the hydrography and the concentrations of nutrients and chlorophyll-*a*. The stations of the cruise are shown in *figure 1*.



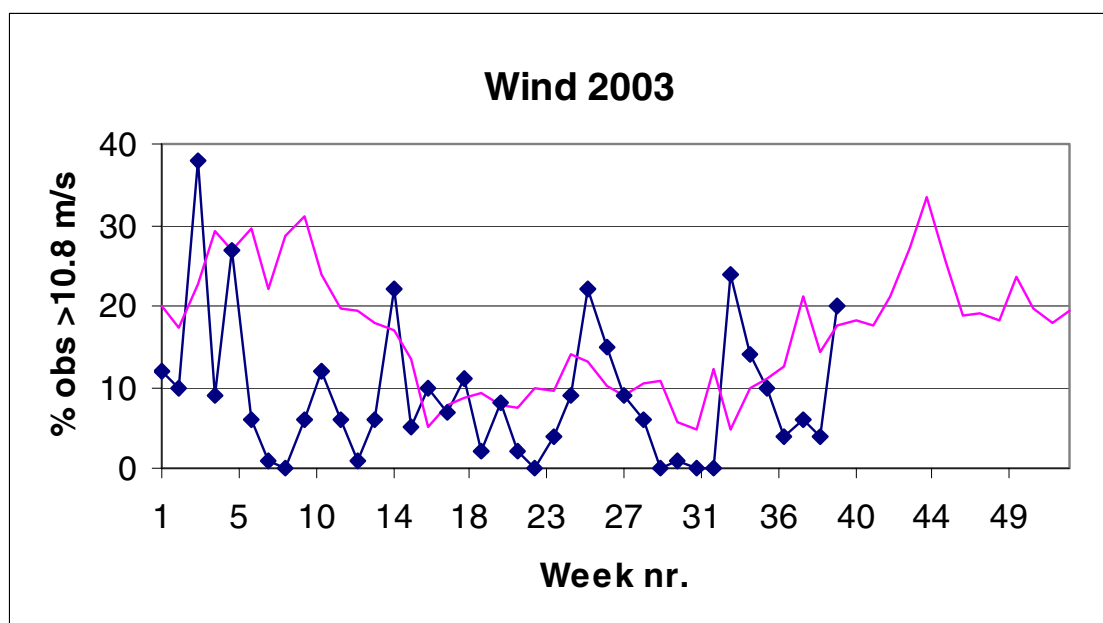
**Figure 1.** Stations of the monitoring cruise with r/v Gunnar Thorson 15-19 September 2003 in the Sound, Arkona Sea, Belt Sea and Kattegat. Gunnar Thorson cruise no. 218.

## Meteorology

Characteristics of the weather conditions during September 2003 are given in *table 1*. As in August the temperature was higher and the precipitation lower than average. The mean wind force was relatively low and the dominating wind direction from south-west and west. The frequency of wind exceeding gale force (*figure 2*) was low in the first three weeks of September (weeks 36-38), but was about average in the last week of the month (week 39).

**Table 1.** Deviations in monthly mean temperature and precipitation in September 2003 in Denmark compared to long-term monthly means 1961-90, monthly mean wind force and dominating wind directions (based on data from the Danish Meteorological Institute).

Month	Temperature deviation °C	Precipitation % deviation	Mean wind force m/s	Dominating wind direction
September	+1.3	-45	4.3	SW-W



**Figure 2.** Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2003 (connected points) compared to mean for the period 1994-2002 (thin line). Based on data from the Danish Meteorological Institute.

## Hydrography

The surface temperature (1 m depth) varied between 15.0 and 17.0 °C in the whole area, lowest in the Arkona Sea and highest in the eastern Kattegat and southern Belt Sea. The bottom water temperature ranged from 8.6-9.9 °C in the eastern Kattegat (St. 921, 413, 905, 1001) to 15.3-15.8 °C in the Mecklenburg Bight and the Kiel Bight (St. M2, N3) (*figure 3*).

The surface salinity ranged from 7.4 in the Arkona Sea (St. 441, 444) to only 24.4-24.8 in the western and northern Kattegat (St. 409, 1008, 1009, 1001). The bottom water salinity ranged from 16.8-18.5 in the Arkona Sea (St. 444, 449) to 34.0-34.85 in the northern Kattegat (St. 403, 905, 1001, 1007, 1008, 1009) (*figure 3*). The salinity stratification was relatively strong for the season.

Compared to long term monthly means (Lightship observations 1931-1960) for September the temperature was 0.2-1.9 °C higher than normal in the whole water column, except for 0.6 °C lower than normal temperature in the bottom water east of Anholt. The surface salinity during the present cruise was generally 0.6-4.2 lower than normal, except for 0.4 higher than normal in the western Kattegat (St. 409). The bottom water salinity was higher than normal, except in the Fehmarn Belt (St. 952).

## Nutrients

In the surface layer generally no inorganic nitrogen nutrients were present (*figure 4*). In the bottom water nitrate concentrations above 6 µmol/l were observed only in the south-eastern Kattegat (St. 413, 418, 921, 922). In the Belt Sea the nitrate concentration in the bottom water was relatively low (*figure 4a*).

Relatively high nitrite concentrations (0.8-1.5  $\mu\text{mol/l}$ ) were observed in the bottom water in the southern and north-western Kattegat (St. 418, 922, 403, 1008) (*figure 4b*). Very high ammonium concentrations (4.0-9.5  $\mu\text{mol/l}$ ) were observed in the bottom water in the central Sound, the southern Great Belt and especially in the Mecklenburg Bight (St. 431, 443, 450, M2) (*figure 4c*).

Phosphate concentrations  $>0.1 \mu\text{mol/l}$  were present in the surface water in all Great Belt, the Mecklenburg Bight (St. M2), the western Arkona Sea (St. 1728, 449, 954) and the northern Kattegat (St. 1007, 1008, 1009), and traces were present in most other areas. The highest concentrations were observed in the Great Belt (0.17-0.27  $\mu\text{mol/l}$ ). In the bottom water phosphate above 1.0  $\mu\text{mol/l}$  was observed east of Anholt, in the southern Great Belt, Fehmarn Belt, Mecklenburg Bight and the Arkona Sea (*figure 5a*). Silicate concentrations above 1  $\mu\text{mol/l}$  and up to 10  $\mu\text{mol/l}$  were present in the surface water in all areas, except the northern and central Kattegat. High concentrations ( $>25 \mu\text{mol/l}$ ) were observed in the bottom water in the eastern Kattegat (St. 413, 921), southern Great Belt (St. 443, 450) and Arkona Sea (St. 444, 954) (*figure 5b*).

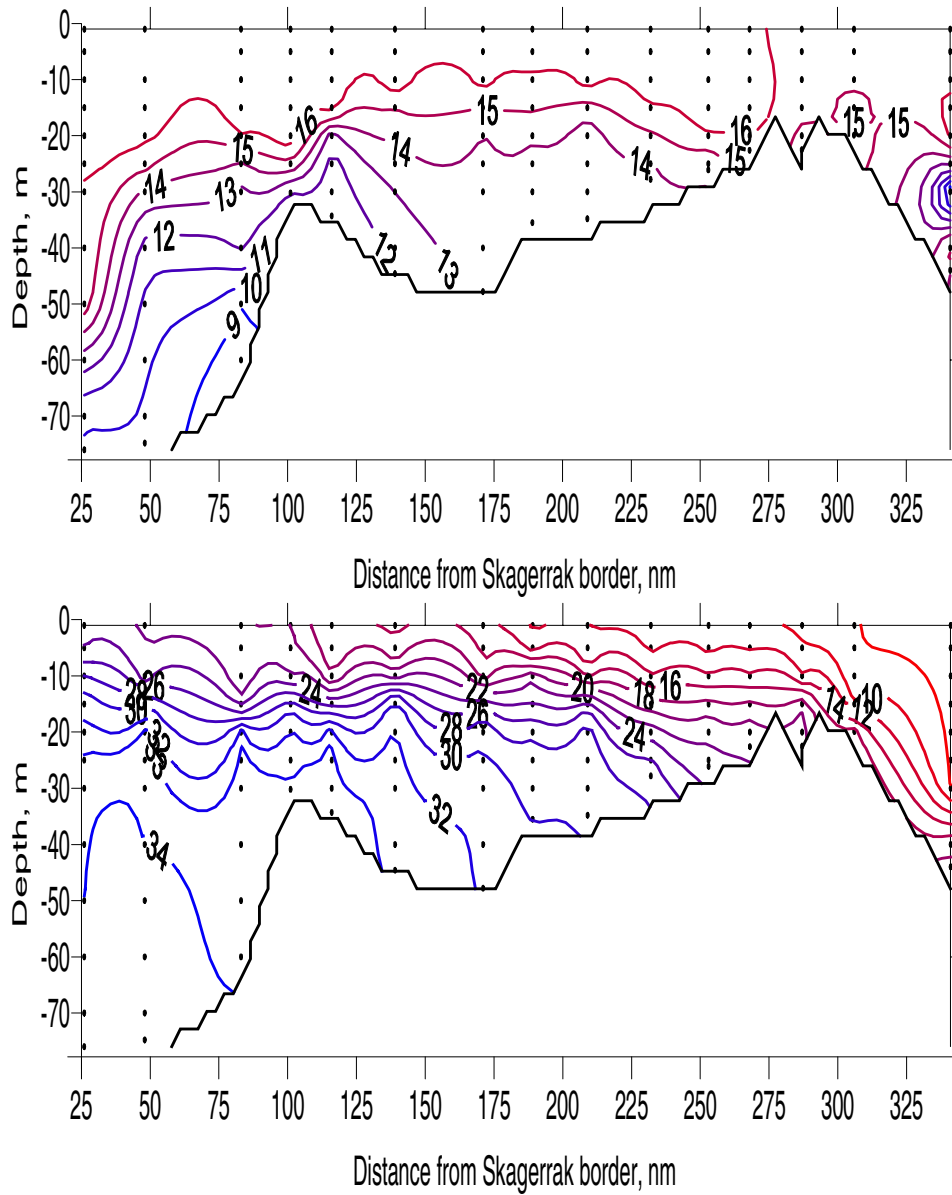
### **Chlorophyll-a**

The chlorophyll-a concentration in the surface water was relatively low (0.9-2.0  $\mu\text{g/l}$ ) in all areas, except in the Fehmarn Belt (St. 952, M2) where the concentration in the upper 5 m was 3.1-3.7  $\mu\text{g/l}$  (*figure 6*). However, in the western Kattegat (St. 409, 403, 1009, 1008) and Great Belt (St. 935, 939 and 443) a pronounced subsurface maximum of 3.9-8.4  $\mu\text{g/l}$  was present in 10-15 m depth. In the eastern and southern Kattegat the highest concentrations (1.5-2.2  $\mu\text{g/l}$ ) were found in 15-20 m depth. In the Fehmarn Belt the highest concentrations (3.0-3.6  $\mu\text{g/l}$ ) were observed in the surface layer, while in the Arkona Sea the vertical distribution within the upper 20 m was rather homogenous (*figure 6*).

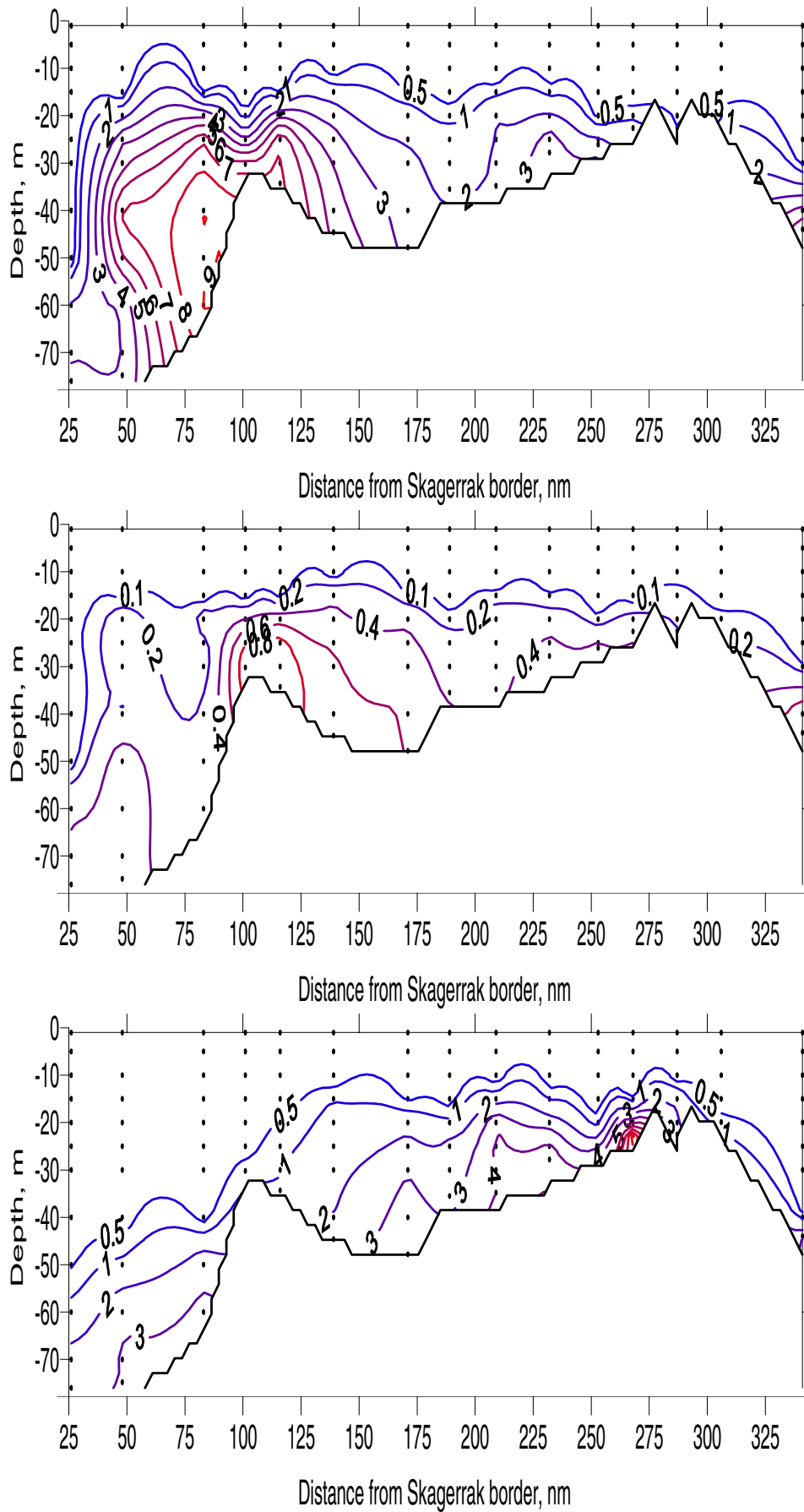
### **Oxygen**

Since August the minimum oxygen concentrations have decreased, except in the northern Kattegat. However, the concentrations this year are significantly higher than at the same time last year. The lowest oxygen concentration observed was 1.1 ml/l (17% saturation) in the Fehmarn Belt (St. 952) (*figure 5c*). In the south-eastern Kattegat and the Sound (St. 413, 418, 921, 922, 431) the minimum concentrations were 1.5-2.7 ml/l (22-44%). In the Great Belt (St. 925, 935, 939, 443, 450) the minimum concentrations were 2.0-2.3 ml/l (33-38%), and in the Mecklenburg Bight (St. M2, 954) 1.6-1.7 ml/l (26-27%). Also in the Arkona Sea and the western Kattegat (St. 444, 409) relatively low oxygen concentrations were observed (3.2-3.4 ml/l, 35-43%). Compared to mean for September in the 1980s, the minimum oxygen concentrations this year were generally lower, except in the northern Kattegat.

In Denmark oxygen depletion is defined as minimum oxygen concentrations below 2.8 ml/l (4 mg/l), and severe oxygen depletion as below 1.4 ml/l (2 mg/l). From these definitions oxygen depletion was generally observed in all areas, except the northern Kattegat, and severe oxygen depletion was found in the Fehmarn Belt (St. 952). In *figure 7* is shown the stations visited by the Danish counties, NERI, SMHI and Swedish and German coastal authorities within the first three weeks of September 2003, and where oxygen depletion or severe oxygen depletion was observed.

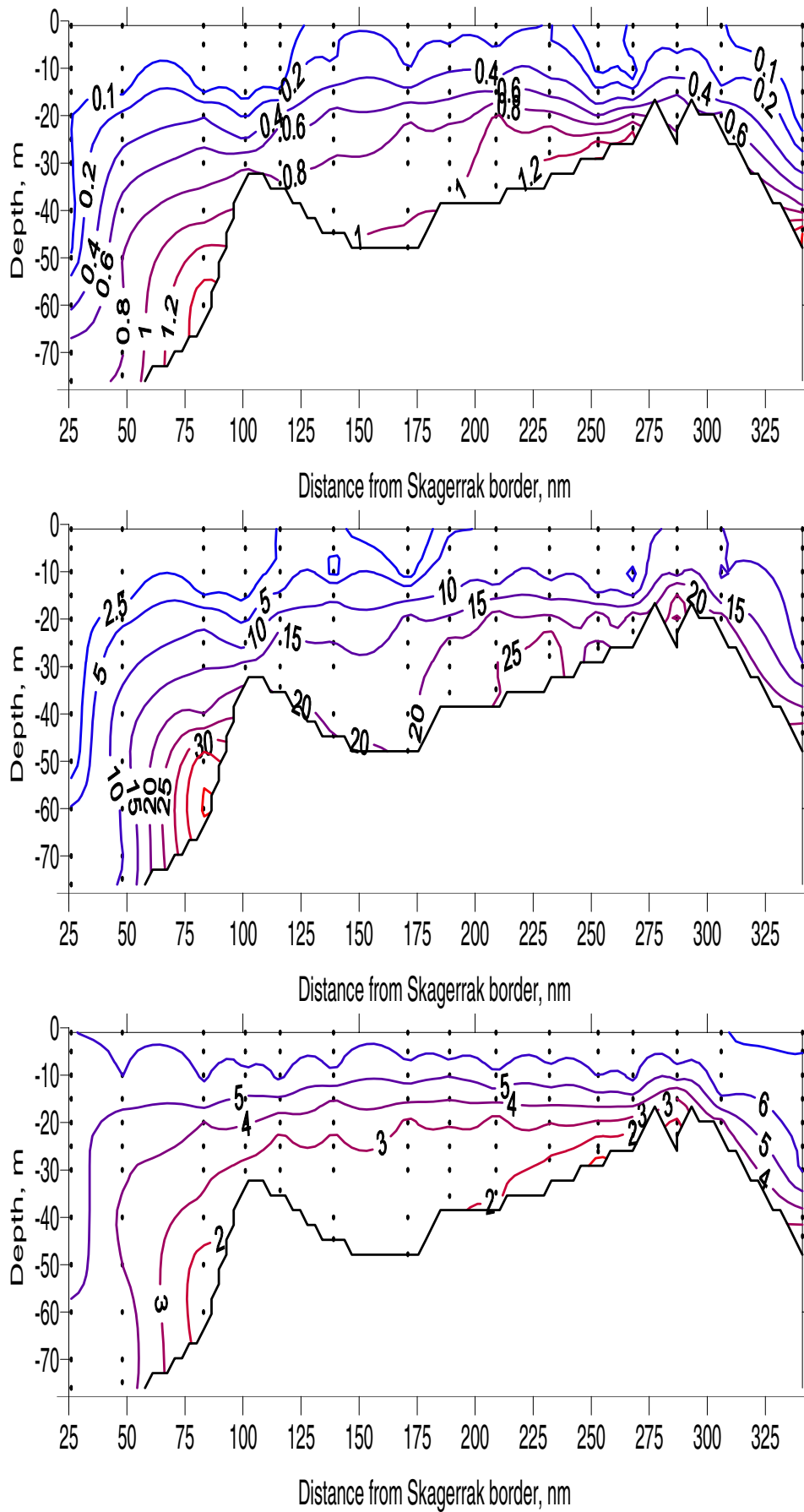


**Figure 3.** Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



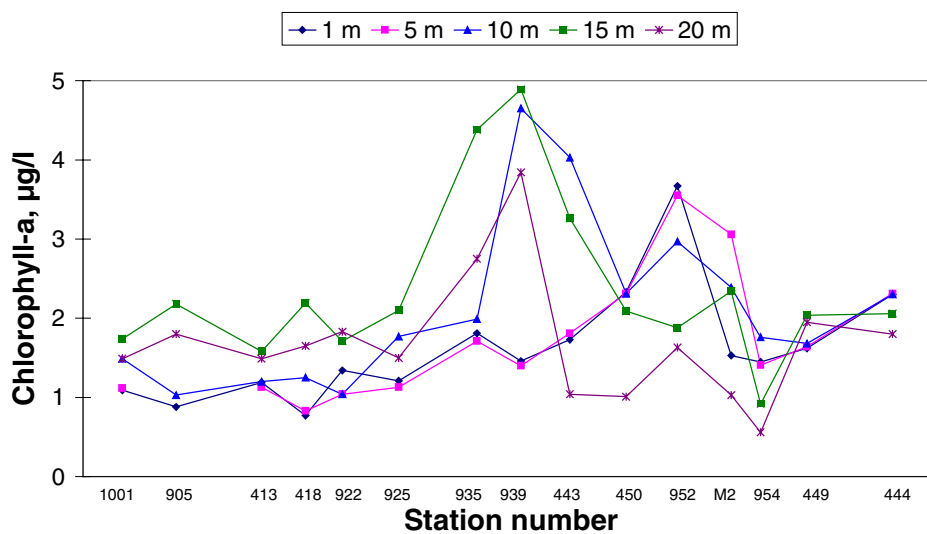
**Figure 4.** Nitrate (top), nitrite (mid) and ammonium (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



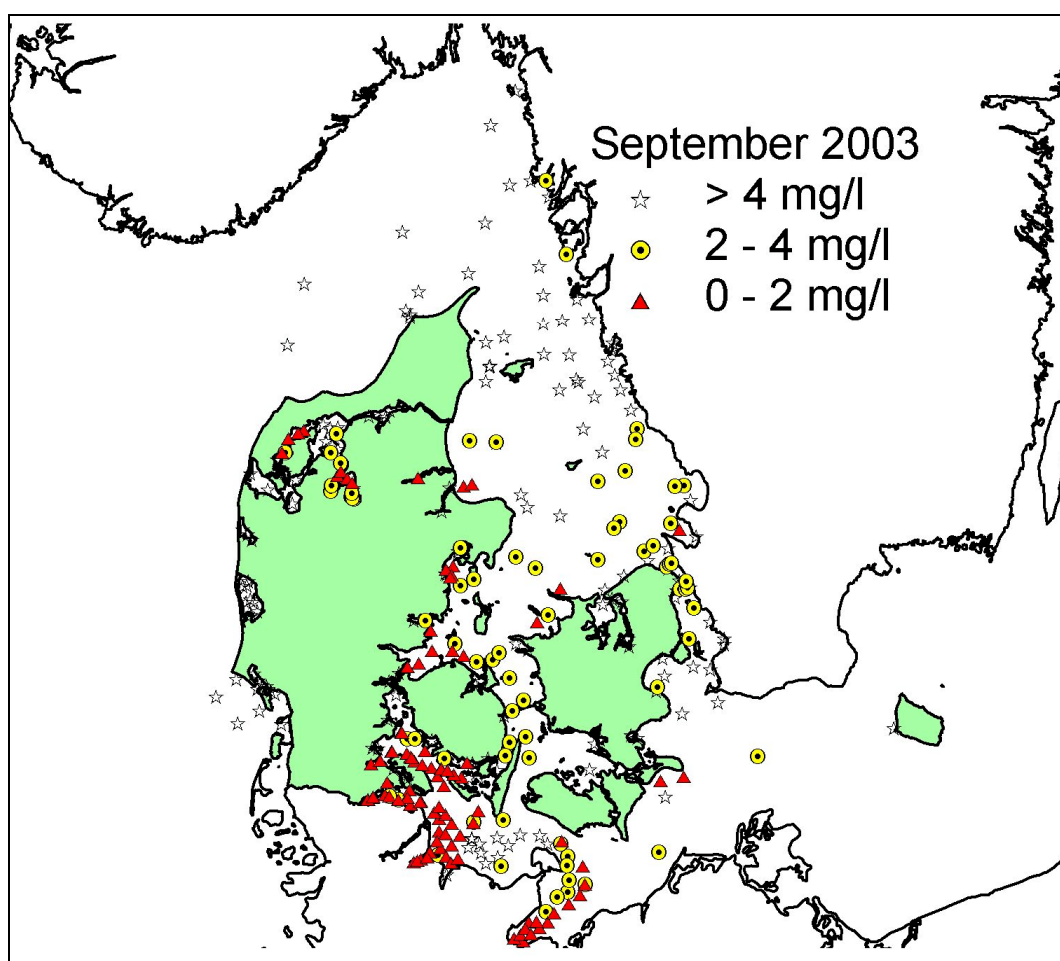


**Figure 5.** Phosphate (top), silicate (mid) and oxygen (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

**Transect: Kattegat NE - Belt Sea - Arkona Sea**



*Figure 6.* Chlorophyll-a at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



*Figure 7.* Stations visited by the Danish counties, NERI, SMHI and Swedish and German coastal authorities within the first three weeks of September 2003, and where oxygen depletion (<4 mg/l) and severe oxygen depletion (<2 mg/l) was observed.