



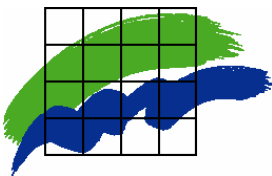
r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: GT 238

Time: 18 - 22 September 2006

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



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Data sheet

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Monitoring cruise with r/v Gunnar Thorson in the Sound, the Arkona Sea, the Belt Sea and the Kattegat, 18-22 September 2006

Cruise no. GT 238

Report: Gunni Ærtebjerg

Cruise leader: Kjeld Sauerberg

Participants: Dorete Jensen, Hanne Ferdinand, Peter Kofoed

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

Summary

The surface temperature was unusually high for the season, except at the Darss and Drogden sills, probably due to mixing of cold bottom water to the surface. The bottom water temperature was low in the Kattegat and the Sound, but higher than average in the Belt Sea, and the bottom water salinity was generally high in all areas. This mirrors the exceptionally warm September, and generally very low wind activity. However, stronger winds in the beginning of September seemed to have created some mixing in the Belt Sea, but not in the Kattegat and the Sound. Thus the chlorophyll concentration in the uppermost 10 m was low (0.7-1.8 µg/l) in the eastern and southern Kattegat, while the concentration in the Belt Sea and Arkona Sea was somewhat higher and up to 4.0 µg/l in Kiel Bight.

The lowest oxygen concentrations of 1.4-2.7 ml/l (21-43% saturation) were observed in the southern Belt Sea and Arkona Sea with the lowest concentration in the Mecklenburg Bight. Also in the central eastern Kattegat the minimum oxygen concentration was relatively low with 2.6 ml/l (39%) east of Anholt. Compared to mean for September last year, the minimum oxygen concentrations this year were generally higher.

Nitrogen nutrients were exhausted in the surface layer in all areas, while phosphate and silicate were present, except in the Kattegat. The highest concentrations of ammonium, phosphate and silicate were generally observed at the bottom in the areas with the lowest oxygen concentrations, e.g. in the Arkona Sea, southern Belt Sea and south-eastern Kattegat. Extremely high ammonium concentrations of up to 5.7-8.8 µmol/l were observed at the bottom in the Fehmarn Belt and at Gedser Rev, and high ammonium concentrations of 3.2-3.6 µmol/l were also found in the Arkona Sea, the Sound, Mecklenburg Bight, southern Great Belt and south-western Kattegat. These high ammonium concentrations might stem from decay of large amounts of cyanobacteria observed in August, combined with stagnating bottom water with relatively low oxygen concentration.

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 NOVANA, the HELCOM monitoring programme (COMBINE) for the Baltic Sea area (the Arkona Sea, the Sound, the Belt Sea, the Kattegat), and the OSPARCOM monitoring programme (JAMP) for the Greater North Sea (the 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 monitoring stations of the cruise are shown in *figure 1*. Besides the monitoring measurements, special investigations were performed on DOM.

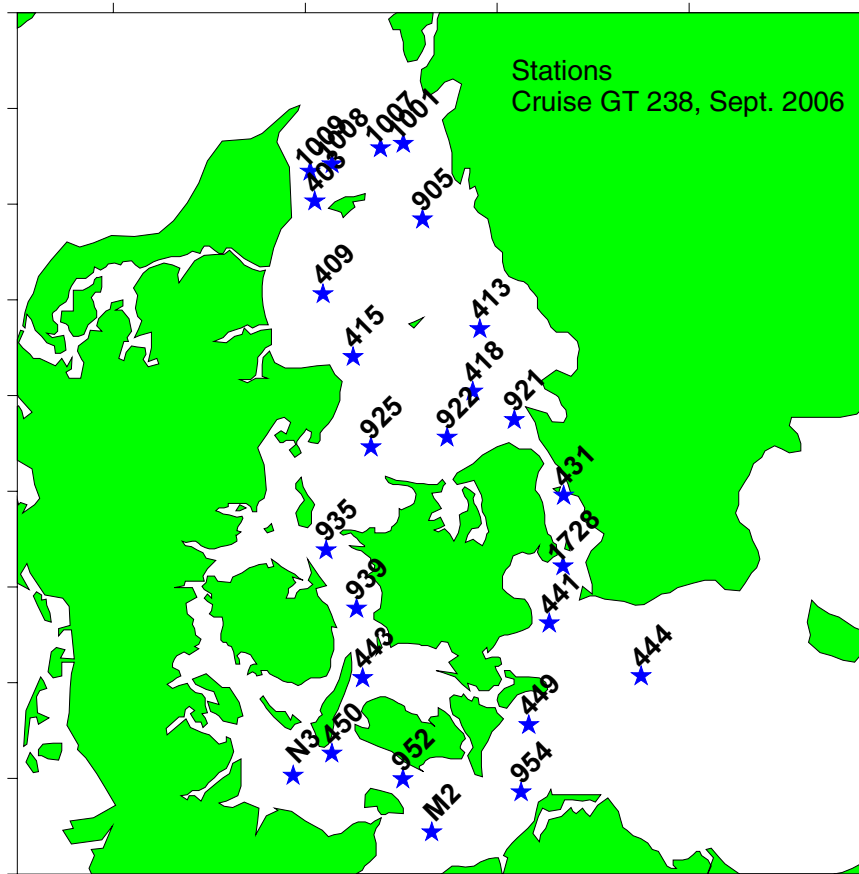


Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 18-21 September 2006 in the Sound, the Arkona Sea, the Belt Sea and the Kattegat. Gunnar Thorson cruise no. GT 238.

Meteorology

Characteristics of the weather conditions in September 2006 are given in *table 1*. As July, September was record warm, the precipitation was relatively low, and the calm weather continued, except for strong winds in the beginning of September (week 36, *figure 2*). The dominating wind direction was east and southeast, except for the windy period in the beginning of the month, when the directions were southwest and west.

Table 1 Deviations in monthly mean temperature and precipitation in September 2006 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	+3,5	-55	4.8	E-SE/SW-W

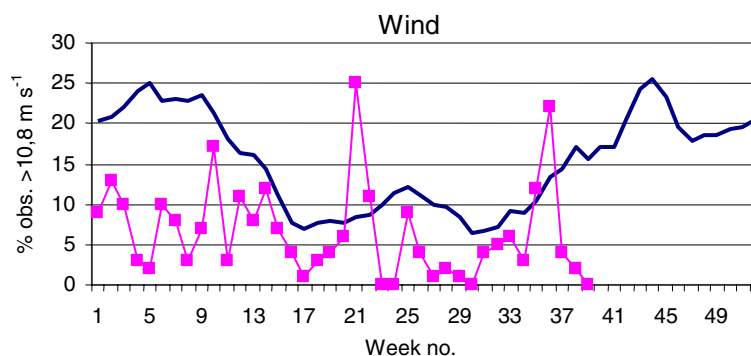


Figure 2 Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2006 (connected points) compared to 3-weeks running mean for the period 1994-2004 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m depth) varied from 13.6-14.8° C at the Darss Sill, Drogden Sill and east of Falster (St. 954, 1728, 449), and 15.3-15.9° C in the central and northern Sound (St. 431, 921) to 16.0-16.9° C in all other areas. The bottom near temperature ranged from 7.3-8.8° C in the eastern Kattegat (St. 413, 418, 905, 1001), and 9.7-9.9° C in the central and northern Sound (St. 431, 921) to 13.6° C in the central Great Belt (St. 939), 14.5-15.0° C in Fehmarn Belt (St. 952, 954), and 17.9° C in the deep Arkona Sea (St.444) (*figure 3*).

The surface salinity ranged from 7.7-8.6 in the Arkona Sea (St. 441, 444, 449, 1728) to 25.1-26.1 in the northern Kattegat (St. 403, 1001, 1007, 1008, 1009). The bottom water salinity ranged from 18.1-18.4 in the Arkona Sea (St. 444, 449) to 34.9-35.1 in the eastern Kattegat (St. 418, 905, 1001) (*figure 3*). The salinity stratification was generally a little below average for the season in Kattegat, but above average in the Belt Sea.

Compared to long-term monthly means (Lightship observations 1931-1960) for September the surface temperature was 0.9-1.7° C above average, except for 1.5° C below average at the Darss Sill (St. 954). In the eastern Kattegat (St. 413) and Læsø Rende the bottom water temperature was 0.5-1.1° C lower than normal. In the other areas the bottom water temperature was 1.1-2.4° C higher than average. The surface salinity was higher than average in the Kattegat, but lower than normal in the Belt Sea. The bottom water salinity was above normal, except in the north-eastern (St. 1001) and south-western Kattegat (St. 925).

Nutrients

In the surface layer nitrate was exhausted in all areas, and DIN concentrations above 0.5 µmol/l were not found within the uppermost 10 m of the water column, except in the central Sound (St. 431). In the bottom water the highest nitrate concentrations of 6.3-8.4 µmol/l were observed in the eastern central Kattegat (St. 413, 418), while the concentrations in the Belt Sea were low (<2.5

$\mu\text{mol/l}$), except in Mecklenburg Bight (*figure 4a*). The highest nitrite concentrations of 0.5-1.1 $\mu\text{mol/l}$ were observed in the bottom water of the northern and eastern Kattegat (St. 403, 413, 418, 922, 1001, 1007, 1008, 1009). Extremely high ammonium concentrations of up to 5.7-8.8 $\mu\text{mol/l}$ were observed at the bottom in the Fehmarn Belt and at Gedser Rev (St. 952, 954). But high ammonium concentrations in the bottom water of 3.2-3.6 $\mu\text{mol/l}$ were also observed in the Arkona Sea (St. 444), the Sound (St. 431), Mecklenburg Bight (St. M2), southern Great Belt (St. 443), south-western Kattegat (St. 925) and north-eastern Kattegat (St. 1001) (*figure 4b and 4c*).

In the surface water phosphate concentrations of 0.25-0.35 were observed from Mecklenburg Bight over Gedser Rev to east of Falster (St. M2, 954, 449). Also in the surface water of all other areas, except the eastern and southern Kattegat, phosphate concentrations above 0.05 $\mu\text{mol/l}$ were found. At the bottom the highest phosphate concentrations of 1.0-1.5 $\mu\text{mol/l}$ were found in the Arkona Sea (St. 444), southern Belt Sea (St. 954, M2, 952, 450) and east of Anholt (St. 413) (*figure 5a*). Silicate above 1 $\mu\text{mol/l}$ and up to 8-10 $\mu\text{mol/l}$ was present in the surface water, except in most of the Kattegat, highest in the Arkona Sea. At the bottom the highest silicate concentrations of 38-41 $\mu\text{mol/l}$ were found in the Fehmarn Belt (St. 450, 952), and 20-33 $\mu\text{mol/l}$ were observed in the Arkona Sea (St. 444, 449), the southern Belt Sea (St. 954, M2, N3, 443), south-eastern Kattegat (St. 413, 418, 921) and central Sound (St. 431) (*figure 5b*).

Chlorophyll a

The chlorophyll concentration was quite homogeneously distributed in the surface layer. In the Kattegat the mean concentration in the uppermost 10 m was low, 0.7-1.8 $\mu\text{g/l}$, except for 2.4-2.8 $\mu\text{g/l}$ in Ålborg Bight (St. 409, 415), which was also observed in the Sound (St. 431, 921). In the Belt Sea and Arkona Sea the concentration was somewhat higher and the mean for the uppermost 10 m varied from 2.9 $\mu\text{g/l}$ east of Falster to 4.0 $\mu\text{g/l}$ in the Kiel Bight (*figure 6*).

Oxygen

The lowest oxygen concentrations of 1.4-2.7 ml/l (21-43% saturation) were observed in the southern Belt Sea and Arkona Sea (St. 450, N3, 952, M2, 954, 444) with the lowest concentration in the Mecklenburg Bight (St. M2). Also in the central eastern Kattegat the minimum oxygen concentration was relatively low with 2.6 ml/l (39 %) east of Anholt (St. 413) (*figure 7*).

Compared to mean for September last year, the minimum oxygen concentrations this year are generally higher, except in the southern Great Belt (St. 450). Compared to mean for September in the 1980s the minimum oxygen concentrations this year are generally higher, except in the southern Belt Sea and central Arkona Sea.

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 severe oxygen depletion was not observed at the cruise, while oxygen depletion was found in the central Arkona Sea, the southern Belt Sea and east of Anholt. *Figure 8* shows the stations visited by the Danish counties, NERI, SMHI and Swedish and German coastal authorities within the first 3 weeks of September 2006, and where oxygen depletion or severe oxygen depletion was observed.

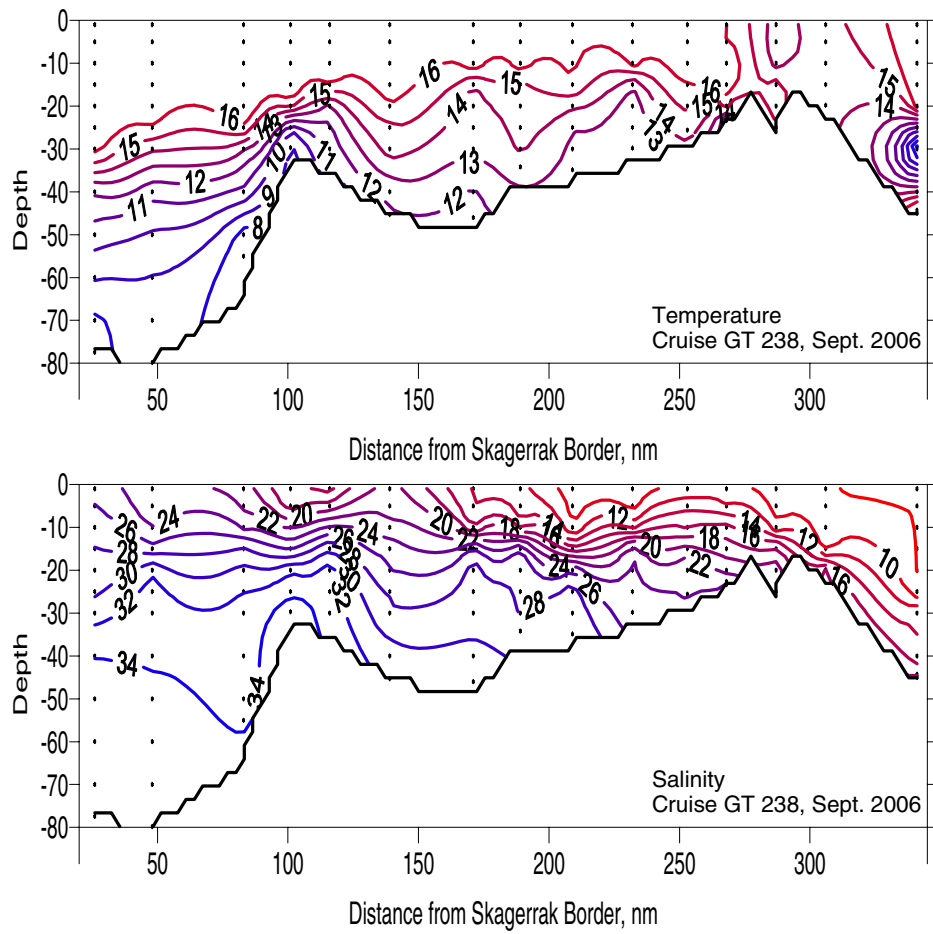


Figure 3 Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

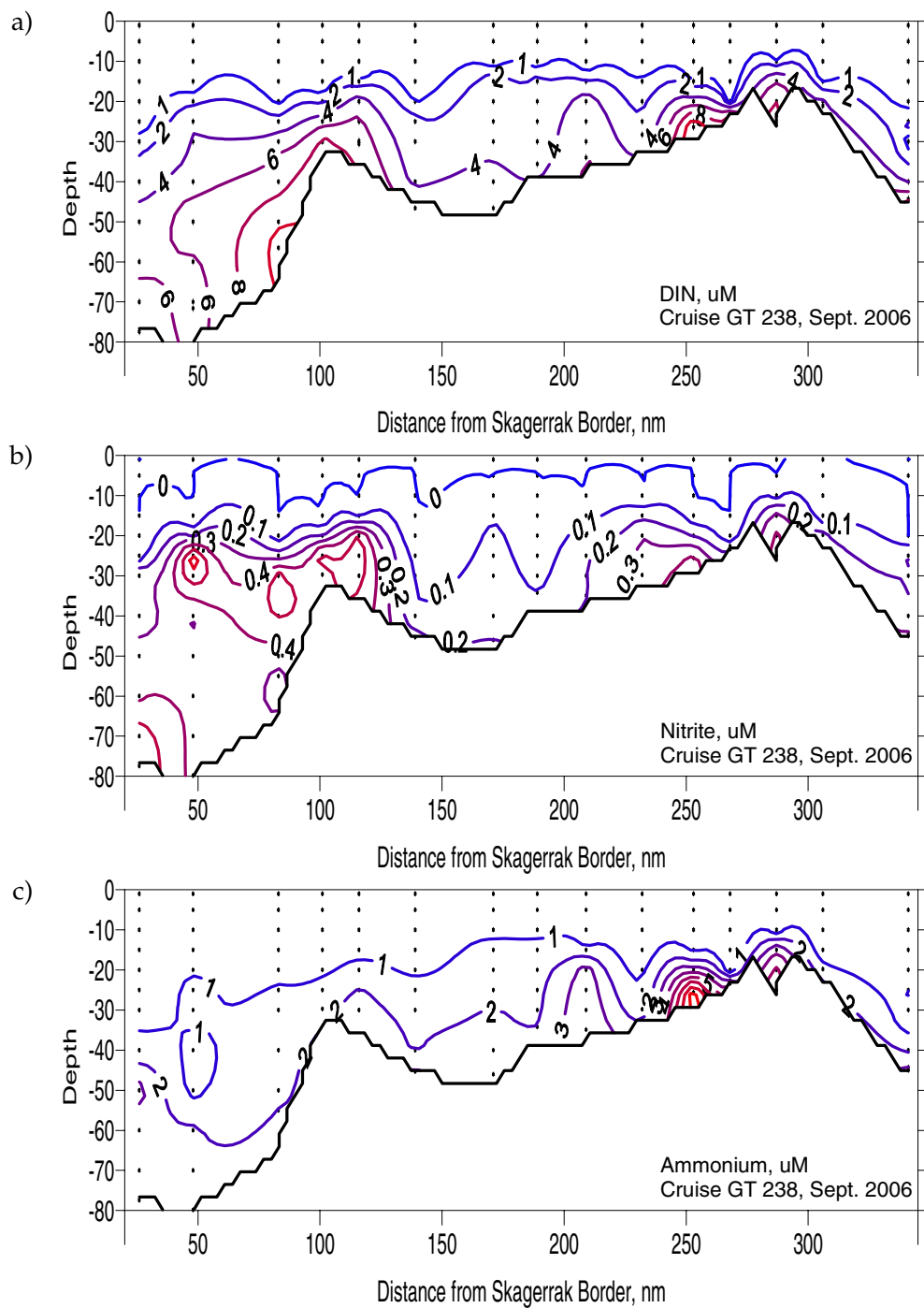


Figure 4 Dissolved inorganic nitrogen, DIN (top), nitrite (middle) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

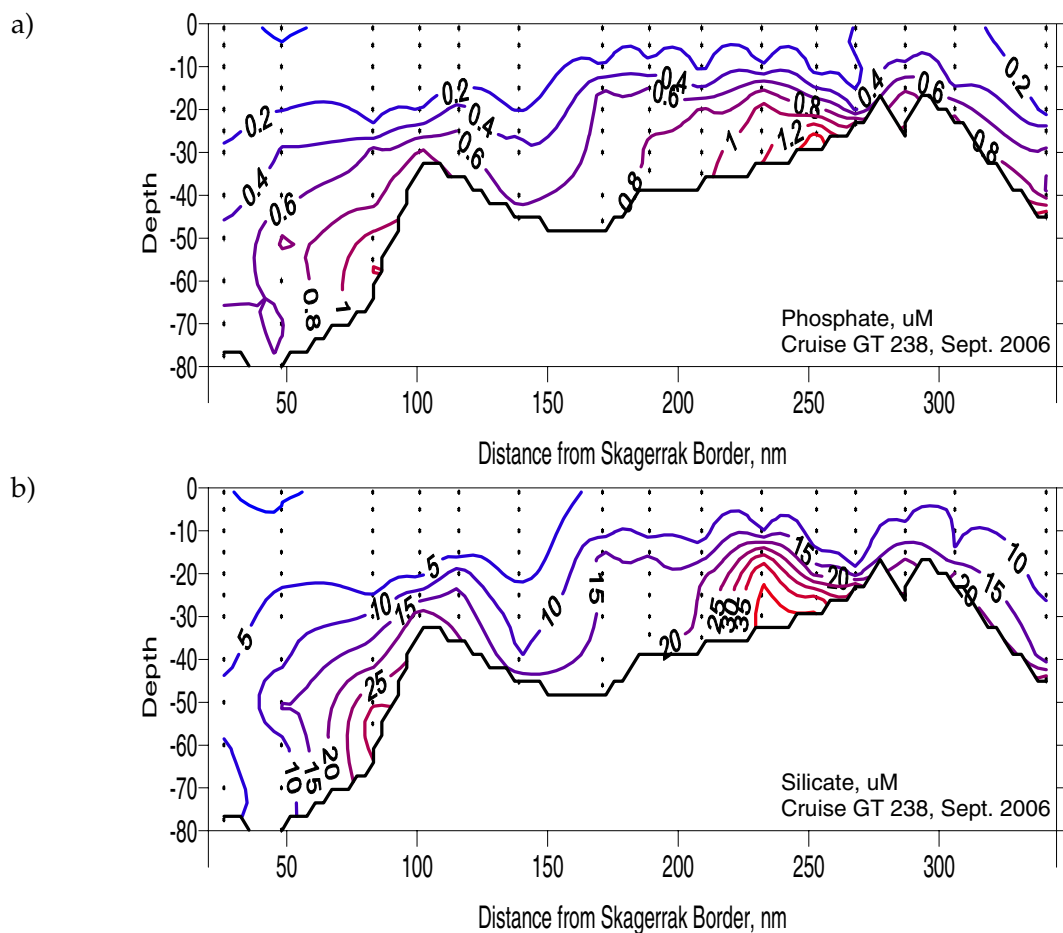


Figure 5 Phosphate (top) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

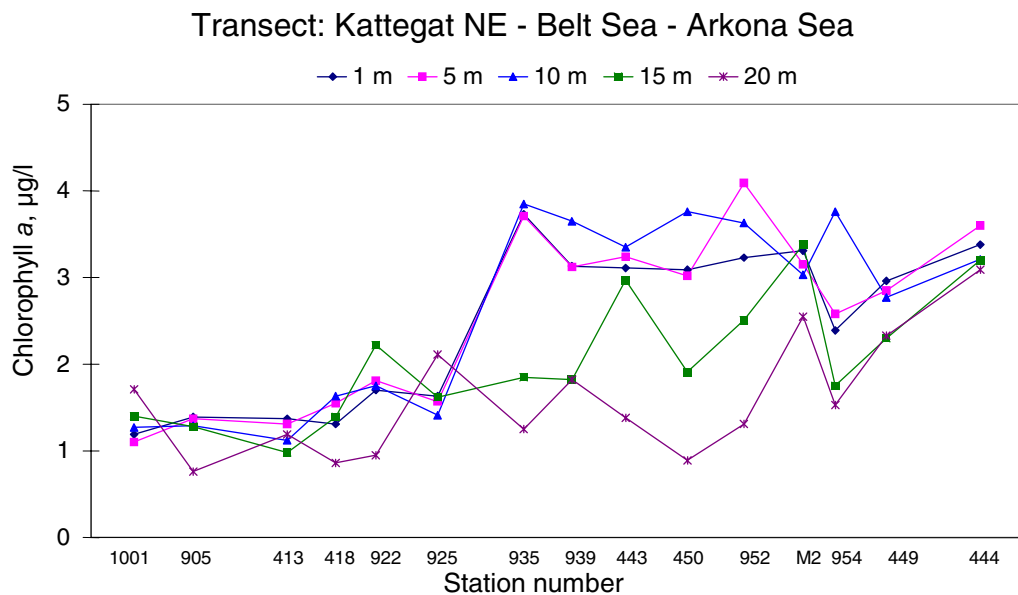


Figure 6 Chlorophyll a at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

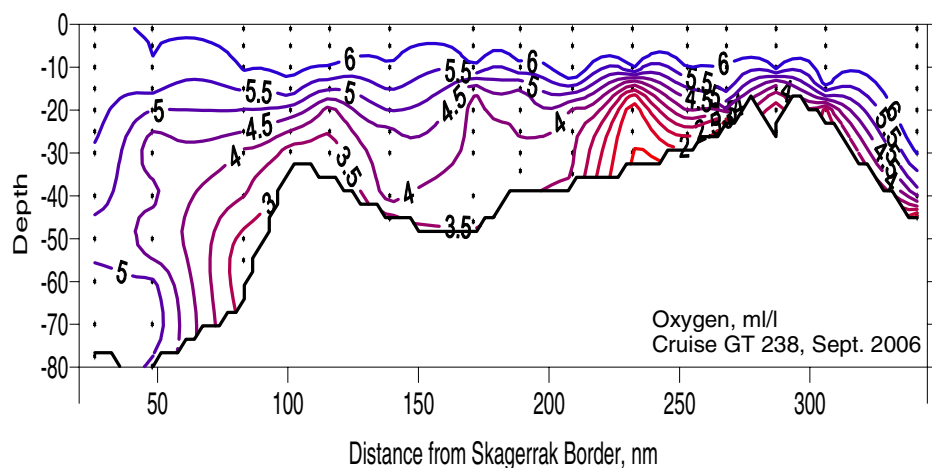


Figure 7 Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

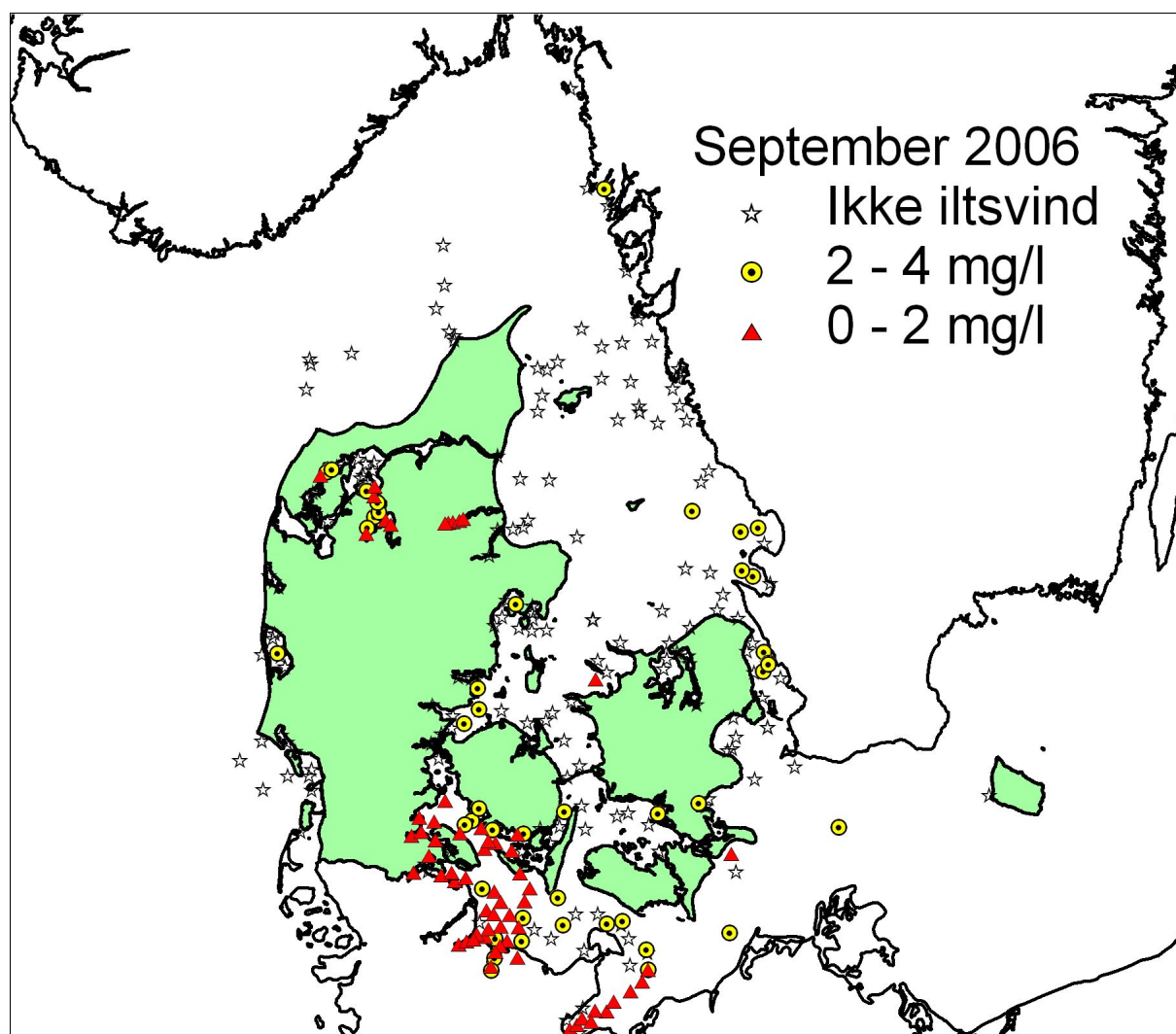


Figure 8 Stations visited by the Danish counties, NERI, SMHI, Swedish and German coastal authorities within the first 3 weeks of September 2006, and where oxygen depletion (< 4.0 mg/l) and severe oxygen depletion (< 2.0 mg/l) was observed.