r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 232

Time: 17 - 20 October 2005

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, 17-20 October 2005 Cruise no. 232

Report: Gunni Ærtebjerg

Cruise leader: Kjeld Sauerberg
Participants: Dorete Jensen, Hanne Ferdinand, Madalena Andersen

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

Summary

Since September oxygen depletion had spread to an exceptionally large area. For the season very unusual severe oxygen deficiency (<1.4 ml/l) was widespread in the southern Belt Sea with minimum oxygen concentrations in the bottom water of 0.0-0.9 ml/l in the Fehmarn Belt and Mecklenburg Bight. Obviously, some oxygen depleted water flow over the Darss Sill and towards north along the east side of Falster. Also in the deep part of the Arkona Sea severe oxygen depletion was present with 0.8 ml/l at the bottom. In the deep parts of the Sound and the Great Belt oxygen depletion (<2.8 ml/l) was observed with 1.6-2.7 ml/l at the bottom.

Normally the coverage of oxygen depletion declines in October due to increasing frequency of strong winds and decreasing temperature. However, this year the calm and warm late summer weather had caused both the coverage and the intensity of oxygen depletion to increase. The stratification of the water column was unusually strong for the season with low saline water from the Baltic Sea in the surface and unusual high salinity in the bottom water, witnessing on low mixing and exchange of the water masses.

Very high concentrations of phosphate (2.1-4.5 µmol/l), ammonium (5.2-7.6 µmol/l) and silicate (56-78 µmol/l) were observed in the oxygen depleted bottom water of the Fehmarn Belt and Mecklenburg Bight.

In the surface layer the nitrate concentration was still low (≤0.1 µmol/l) in most areas. However, in the northern Great Belt and western Kattegat 0.6-1.1 µmol/l was found. The lowest phosphate concentrations of 0.1-0.2 µmol/l were observed in the surface of the south-eastern Kattegat, while in the southern Belt Sea 0.7 µmol/l was found. The silicate concentration in the surface was at least 4.5 µmol/l and up to 17 µmol/l. Thus only potential nitrogen limitation seemed to prevail.

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*.

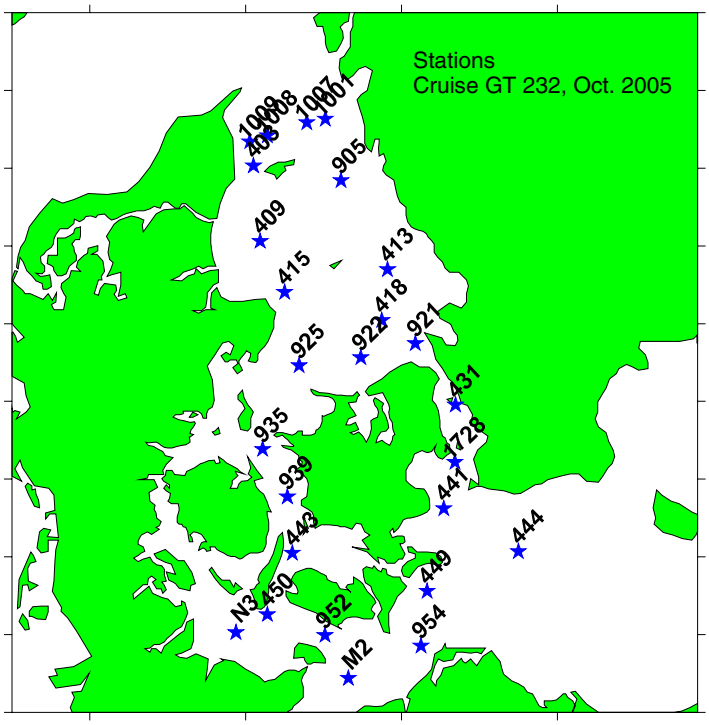

Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 17-20 October 2005 in the Sound, the Arkona Sea, the Belt Sea and the Kattegat. Gunnar Thorson cruise no. 232.

Meteorology

Characteristics of the weather conditions in October 2005 are given in *table 1*. October was generally warm, dry and relatively calm with dominating wind from south-east. Only at the end of the month (week no. 43) stronger winds occurred (*figure 2*).

Table 1 Deviations in monthly mean temperature and precipitation in October 2005 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
October	+1.9	-24	4.2	E-SE-S

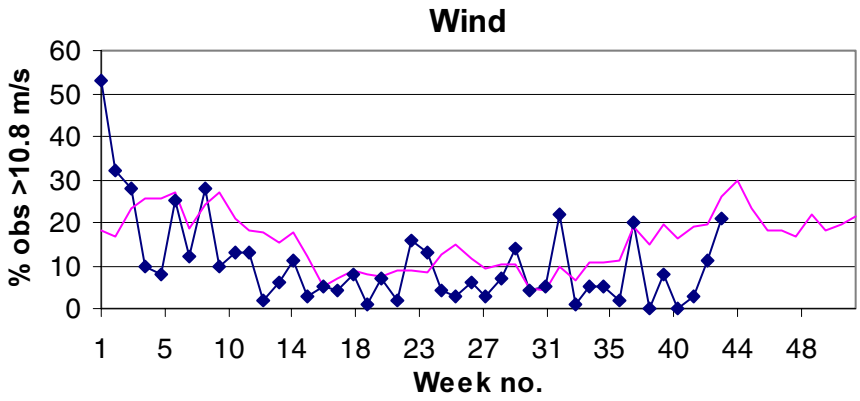

Figure 2 Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2005 (connected points) compared to mean for the period 1994-2004 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m depth) ranged from 11.7-11.9° C in the north-western Kattegat (St. 403, 1009) and Fehmarn Belt (St. 952) to 14.1° C in the central Arkona Sea (St. 444). The bottom near temperature ranged from 8.9° C in the north-eastern Kattegat (St. 1001) to 14.2° C in the north-western Kattegat (St. 403, 1008, 1009). In the Arkona Sea a cold intermediate layer with 6.1-10.0° C was observed in 26.4-33.7 m depth (*figure 3*).

The surface salinity ranged from 7.7-8.0 in the Arkona Sea (St. 441, 444, 449) to 20.6 in the north-eastern Kattegat (St. 1001, 1007) and 21.6 in Ålborg Bight (St. 409). The bottom water salinity ranged from 16.9-18.1 in the Arkona Sea (St. 444, 449) to 34.0-35.15 in the north-eastern Kattegat (St. 905, 1001, 1007) (*figure 3*).

Compared to long-term monthly means (Lightship observations 1931-1960) for October the surface temperature was 0.9-2.4° C higher than average, except in the southern Belt Sea. Also the bottom water temperature was 0.8-1.8° C higher than normal, except in the north-eastern Kattegat. The surface salinity was much lower (2.7-6.4) than average for the season, except in Ålborg Bight. Contrary, the bottom water salinity was much higher (0.4-5.2) than normal in all areas. The salinity stratification was thus unusually strong for the season in all areas, and witness on strong outflow from the Baltic Sea and unusual low mixing of the water masses.

Nutrients

The nitrate concentration in the surface layer was still low (0.0-0.1 µmol/l) in the eastern Kattegat, southern Belt Sea and the Arkona Sea, but somewhat higher (0.6-1.1 µmol/l) in the northern Great Belt (St. 925, 935, 939) and western Kattegat (St. 409, 415). In the bottom water the highest nitrate concentration of 10.5 µmol/l was observed in the central Sound (St.431). Otherwise, the highest concentrations (7.0-8.7 µmol/l) were found in the eastern and southern Kattegat and the Great Belt (*figure 4a*). The highest nitrite concentration of 0.6-1.6 µmol/l was observed in intermediate layers in the northern Kattegat (St. 403, 905, 1001, 1008, 1009) (*figure 4b*). Extremely high ammonium concentrations of 5.2-7.6 µmol/l were observed at the bottom in the southern Belt Sea (St. M2, 450, 952, 954) (*figure 4c*).

The lowest phosphate concentration of 0.1-0.2 µmol/l was observed in the surface in the south-eastern Kattegat (St. 413, 418, 921, 922). The highest concentrations both in the surface (0.7 µmol/l) and at the bottom (2.1-4.5 µmol/l) were observed in the southern Belt Sea (St. M2, 450, 952,954) (*figure*

5a). The silicate concentration in the surface was in all areas at least 4.5 µmol/l and up to 17 µmol/l. Also the highest silicate concentrations of 56-78 µmol/l were found at the bottom in the southern Belt Sea (St. M2, 450, 952, 954). In the Arkona Sea 49-57 µmol/l was observed, and in the Great Belt ca. 36 µmol/l (*figure 5b*).

Chlorophyll-*a*

In the western Kattegat a distinctive subsurface chlorophyll maximum (4.5-5.7 µg/l) was observed in about 10 m depth (St. 403, 409, 415, 1009). In the other areas the chlorophyll was relatively evenly distributed in the uppermost 10-15 m. The highest mean concentration in the uppermost 15 m (3.5-4.0 µg/l) was found in the western Kattegat (St. 409, 415) and Kiel Bight (St. N3). In the Arkona Sea the mean concentration was 3.2 µg/l (St. 441, 444), and in the Belt Sea 2.0-2.7 µg/l, but in the eastern Kattegat 1.3-1.7 µg/l (*figure 6*).

Oxygen

The lowest oxygen concentrations of 0.0-0.9 ml/l (0-14% saturation) were observed in the southern Belt Sea (St. M2, 450, 952, 954) and the central Arkona Sea (St. 444). East of Falster (St. 449) and in the central Sound (St. 431) the minimum oxygen concentration was 1.6 ml/l (25-26%). In the Great Belt the minimum concentration in the deep channel varied from 2.1 ml/l (35%) in the south (St. 443) to 2.7 ml/l (46%) at the border to Kattegat in the north (St. 925). In the south-eastern Kattegat (St. 413, 418, 921, 922) 2.9-3.2 ml/l (46-54%) was observed. At the rest of the deeper stations of the cruise the oxygen minimum saturation was above 63% (*figure 7*).

Compared to mean for October last year and in the 1980s, the minimum oxygen concentrations this year were generally lower.

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 observed in the southern Belt Sea and the Arkona Sea. Oxygen depletion was observed in the central Sound, east of Falster and in the deep parts of the Great Belt. *Figure 8* shows the stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of October 2005, and where oxygen depletion or severe oxygen depletion was observed.

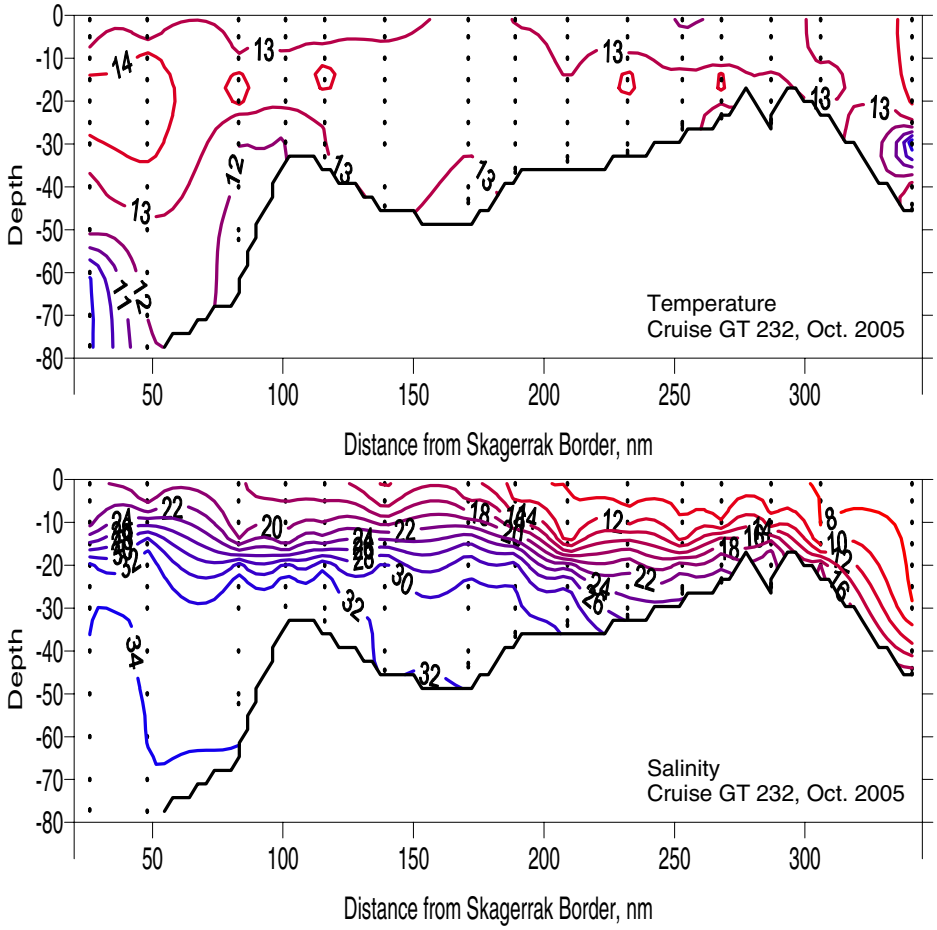

Figure 3 Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

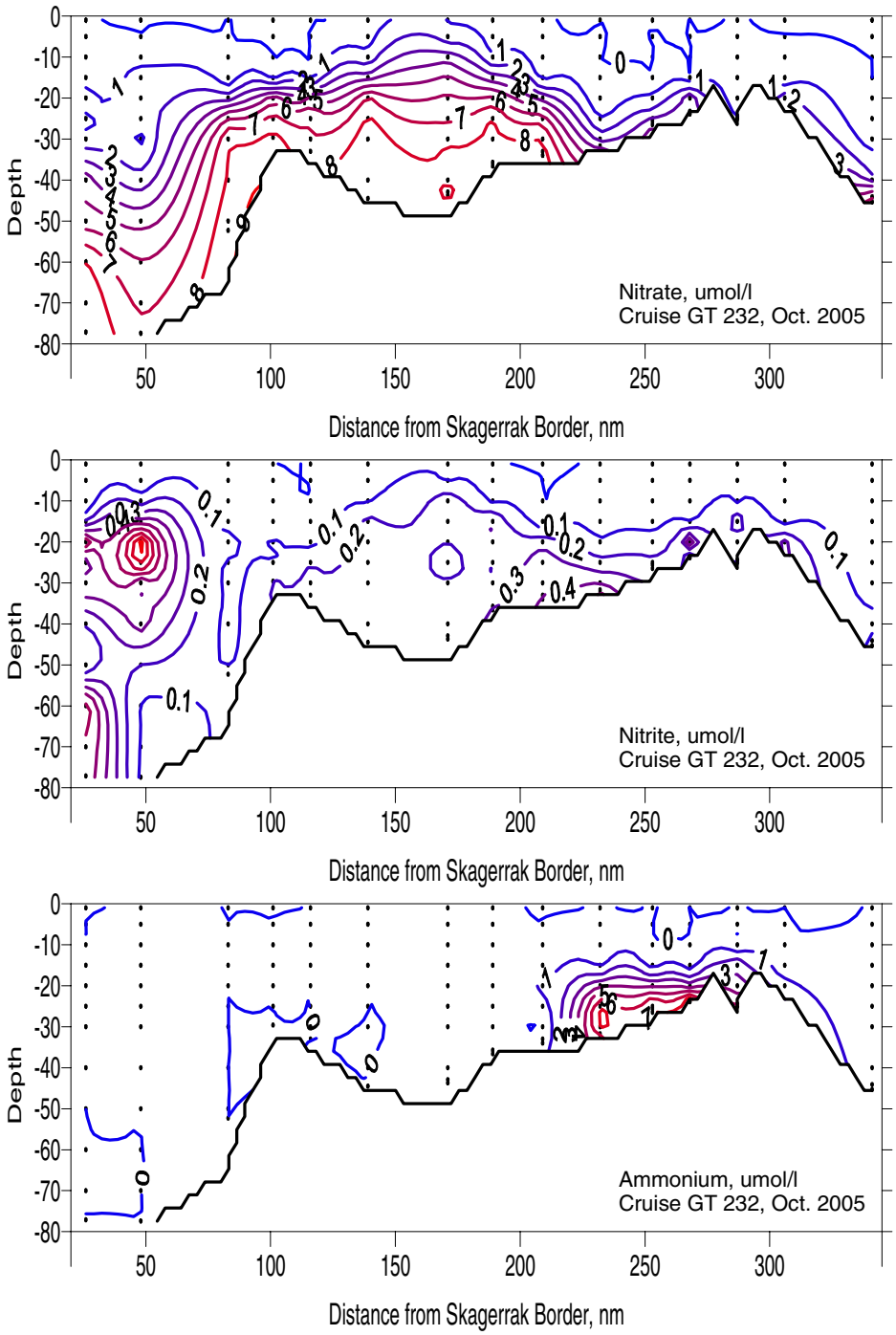

Figure 4 Nitrate (top), nitrite (middle) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

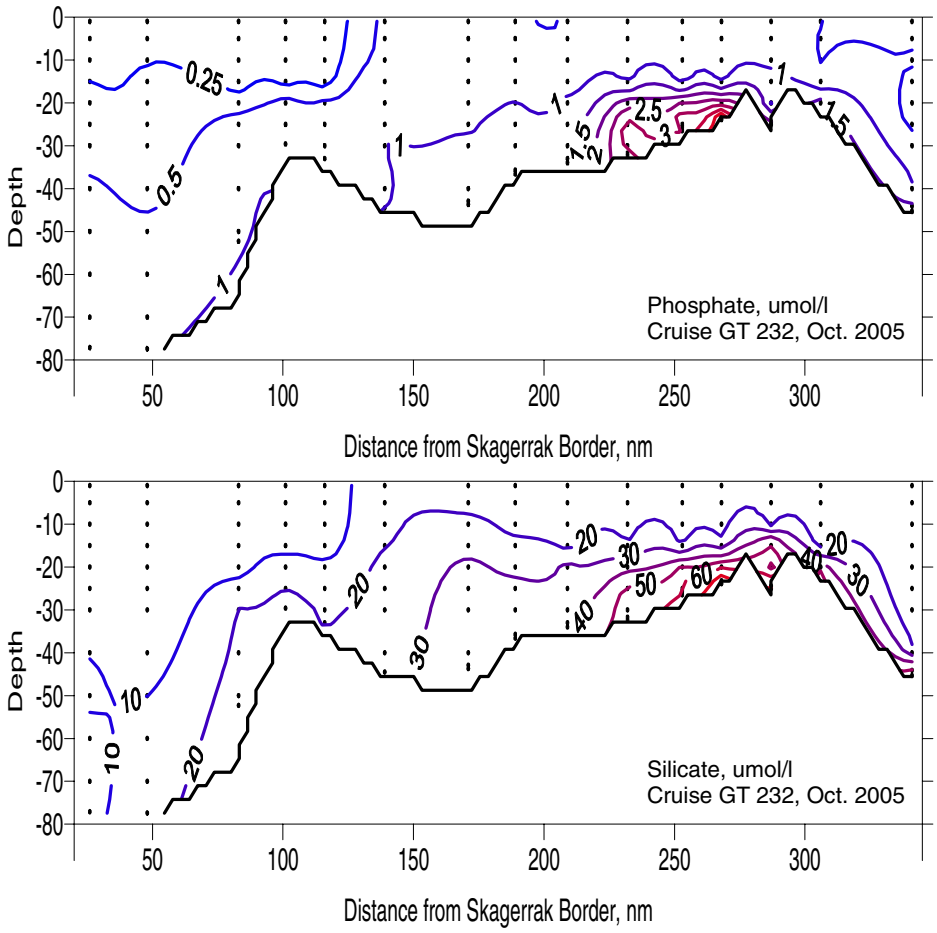

Figure 5 Phosphate (top) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

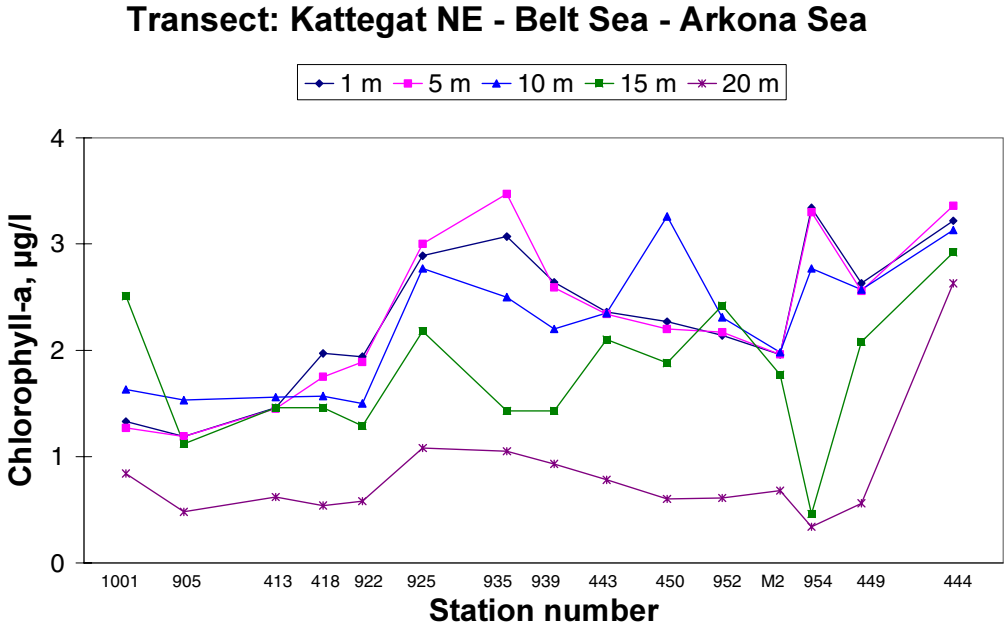

Figure 6 Chlorophyll-*a* at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

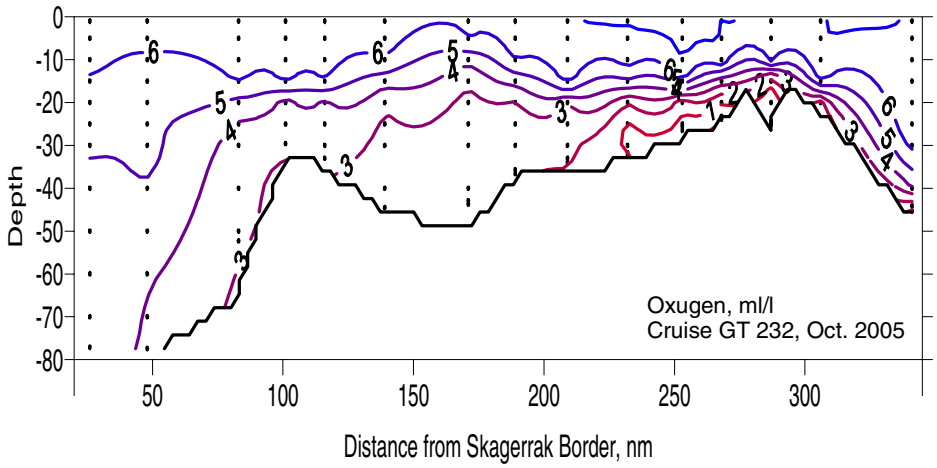

Figure 7 Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

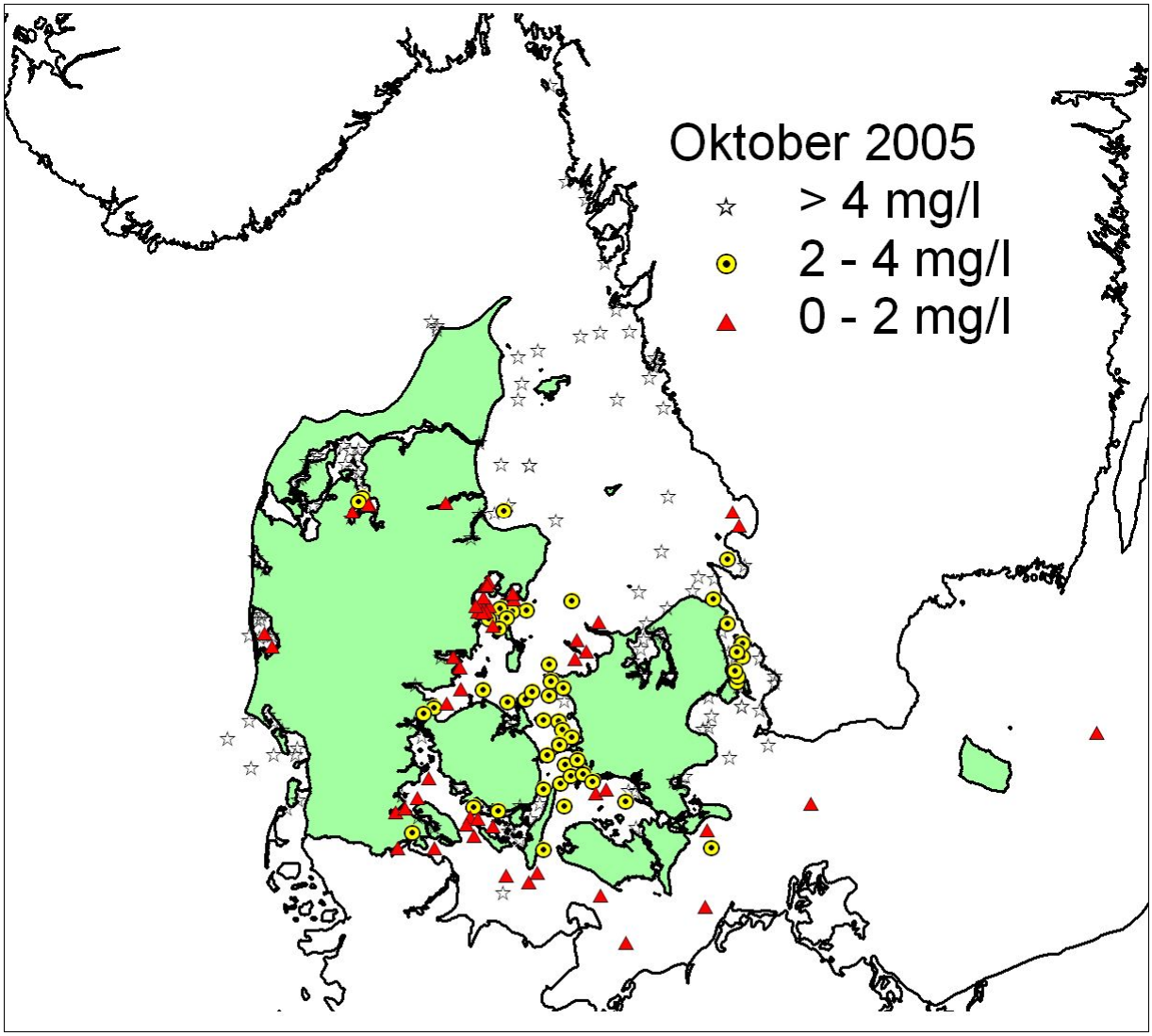

Figure 8 Stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of October 2005, and where oxygen depletion (<4.0 mg/l) and severe oxygen depletion (<2.0 mg/l) was observed.