r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 233

Time: 14 - 18 November 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, 14-18 November 2005 Cruise no. 233

Report: Gunni Ærtebjerg

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

Summary

The minimum oxygen concentrations had increased significantly in all areas since the cruise in October, and oxygen depletion was no longer present at the stations visited. The lowest oxygen concentration of 4.0 ml/l (65% saturation) was observed in the Sound, and 4.3-5.0 ml/l (70-80%) was found in the eastern and southern Kattegat, northern Great Belt and Mecklenburg Bight. In all other areas the minimum oxygen concentration was higher than 5.1 ml/l.

Periods with strong winds from the end of October through November had exchanged and mixed the water masses. Thus, the water was generally warmer and more saline, and the stratification was weaker than usual for the season. In the southern Belt Sea and the Darss Sill area the water column was even rather homogenous. The mixing and exchange of water masses had eliminated the oxygen depletion and the high ammonium, phosphate and silicate concentrations observed in October in the bottom water in the southern Belt Sea and Arkona Sea.

The mixing of nutrient rich bottom water to the surface had significantly increased the chlorophyll concentration, except in the central and northern Kattegat. In the southern Belt Sea and most of the Great Belt a mean concentration in the uppermost 15 m of 6.1-7.2 µg/l was observed. In the southern Kattegat, the Sound, central Arkona Sea and northern Great Belt the mean concentration was 4.2-4.7 µg/l.

The nitrate concentration in the surface layer was still low (<1 µmol/l) in the southern Kattegat, the Sound, Arkona Sea and southern Belt Sea. Also the phosphate concentration was low (≤0.2 µmol/l) in the surface of the southern Kattegat, the Sound and northern Great Belt, and even silicate was low (0.5-1.0 µmol/l) in the south-eastern Kattegat. Thus, potential nutrient limitation of the primary production could still occur in these areas. Surface concentrations of nutrients were generally highest in the Drogden and Darss Sill areas due to mixing of bottom water into the surface.

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*. Sediment samples for analysis of dioxins and heavy metals were taken at 9 stations.

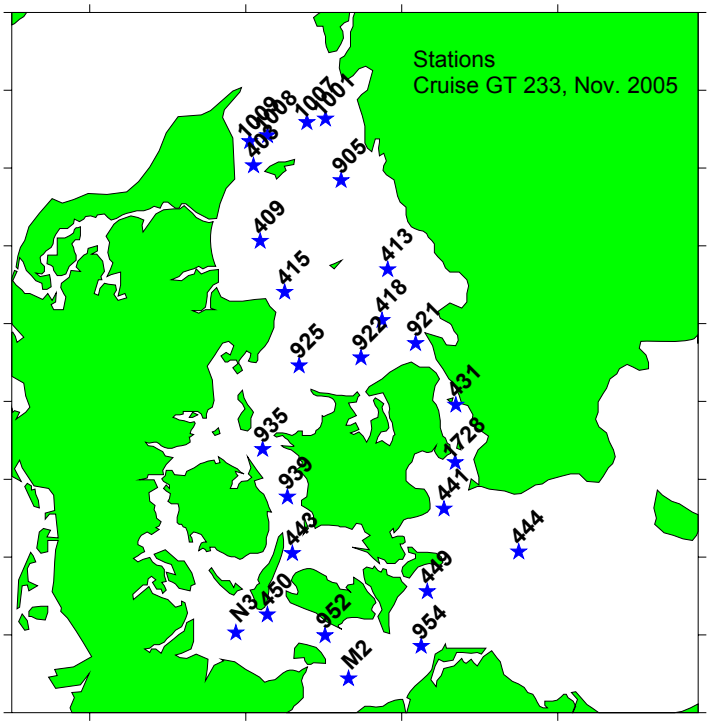

Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 14-17 November 2005 in the Sound, the Arkona Sea, the Belt Sea and the Kattegat. Gunnar Thorson cruise no. 233.

Meteorology

Characteristics of the weather conditions in November 2005 are given in *table 1*. November was as the previous months generally warm and dry but relatively windy with dominating wind from south and southwest (*figure 2*).

Table 1 Deviations in monthly mean temperature and precipitation in November 2005 in Denmark compared to long-term monthly mean 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
November	+1.4	-11	4.9	S-SW

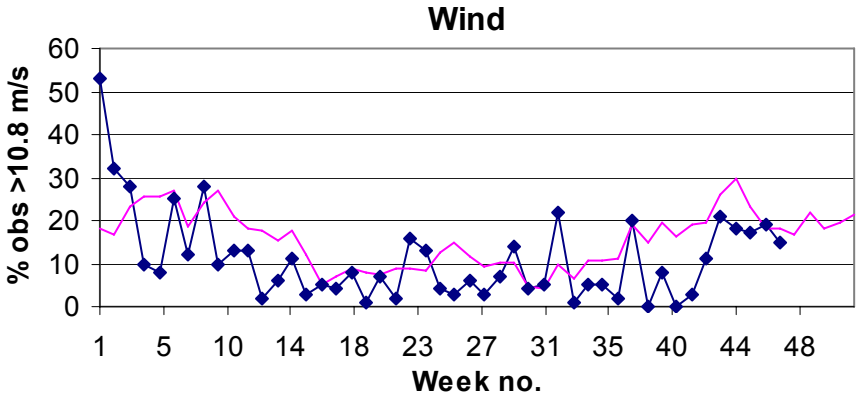

Figure 2 Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2005 (connected points) compared to mean for the period 1994-2004 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m depth) varied from 9-10° C in the central and southern Kattegat and the Sound to 11.0-11.4° C in the north-western Kattegat (St. 403, 1008, 1009) and southern Belt Sea (St. 450, 952, 954). The bottom near temperature ranged between 11.0° C and 12.6° C with the highest temperatures in the eastern Kattegat (St. 413, 418, 904, 1007). In the Arkona Sea a cold intermediate layer with 8.3-10° C was present in 28.7-30.7 m depth (*figure 3*).

The surface salinity ranged from 7.9-9.7 in the Arkona Sea (St. 441, 444) to 30.0-31.8 in the western and northern Kattegat (St. 403, 409, 1007, 1008, 1009). The bottom water salinity ranged from 17.6-18.3 in the Arkona Sea (St. 444, 954) to 33.5-34.1 in the eastern Kattegat (St. 413, 418, 905, 921, 922, 1001) (*figure 3*).

Compared to long-term monthly means (Lightship observations 1931-1960) for November the temperature was 1.0-3.3° C higher than average in all areas and in the whole water column. Also the salinity was generally higher than average in all areas and in the whole water column, except for a little lower than normal salinity in the bottom water of the northern Kattegat. The salinity stratification was generally lower than average for the season, except in the south-western Kattegat. In the southern Belt Sea and the Darss Sill area the water column was rather homogenous. The hydrography witnessed that strong water exchange and mixing had taken place since the cruise in October.

Nutrients

The nitrate concentration in the surface layer was still low (<1 µmol/l) in the southern Kattegat (St. 413, 415, 418, 922, 921, 925), the Sound (St. 431), the Arkona Sea (St. 441, 444, 449) and the southern Belt Sea (St. M2, N3, 952), but higher (1.1-1.6 µmol/l) in the rest of Kattegat and in the southern Great Belt (St. 443, 939). In the bottom water the highest nitrate concentration of 5.1-6.1 µmol/l was observed in the southern Kattegat (St.921, 922, 925), northern Great Belt (St. 935) and the Sound (St. 431). In the northern Kattegat (St. 403, 1001, 1007, 1008, 1009) the nitrate concentration was 1.0-1.6 µmol/l in the whole water column (*figure 4a*). The highest nitrite concentration of 0.6-0.9 µmol/l was observed in the bottom water in the northern and eastern Kattegat (*figure 4b*). The highest ammonium concentrations of 1.6-2.5 µmol/l were observed at intermediate depths in the northern Kattegat (St. 403, 1001, 1007, 1008, 1009). In the Arkona Sea ammonium concentrations of 1.3-1.4 µmol/l were found at the bottom (*figure 4c*).

In the surface the lowest phosphate concentrations of 0-0.2 µmol/l were observed in the southern Kattegat (St. 413, 415, 921, 922, 925), the Sound (St. 431) and northern Great Belt (St. 935), and the highest (1.3 µmol/l) at the Darss sill (St.954) (*figure 5a*). In the bottom water the highest phosphate concentrations of 1.0-1.6 µmol/l were observed in the Arkona Sea (St. 444, 449, 954) and the Kiel Bight (St. N3). The lowest silicate concentrations of 0.5-1.0 µmol/l were found in the south-eastern Kattegat (St. 418, 922, 921, 925), and the highest (18-25 µmol/l) at Darss Sill (St. 449, 954). In the bottom water the highest silicate concentrations of 18-25 µmol/l were found in the Arkona Sea, Mecklenburg Bight and Kiel Bight (St. 444, 449, 954, M2, N3) (*figure 5b*).

The very high ammonium, phosphate and silicate concentrations observed in October in the oxygen depleted bottom water of the southern Belt Sea were eliminated, probably through mixing of the water column, which at the time of the cruise took place in the Darss Sill area.

Chlorophyll-*a*

Mixing of nutrient rich bottom water into the surface had significantly increased the chlorophyll concentration in the southern Belt Sea (St. M2, N3, 450, 952) and most of the Great Belt (St. 443, 939), where a mean concentration in the uppermost 15 m of 6.1-7.2 µg/l was observed. In the northern Great Belt (St. 925, 935), southern Kattegat (St. 415, 418, 921, 922), the Sound (St. 431) and the central Arkona Sea (St. 444) the mean concentration was 4.2-4.7 µg/l. The lowest mean concentrations of 0.9-2.1 µg/l were observed in the northern Kattegat (St. 403, 409, 905, 1001, 1007, 1008, 1009) and at the Drogden Sill (St. 1728) (*figure 6*).

Oxygen

The minimum oxygen concentration had increased significantly since the cruise in October. The lowest oxygen concentration of 4.0 ml/l (65% saturation) was observed in the Sound (St. 431). In the eastern and southern Kattegat (St. 413, 418, 905, 921, 922), northern Great Belt (St. 925, 935) and Mecklenburg Bight (St. M2) the minimum oxygen concentrations were 4.3-5.0 ml/l (70-80%) (*figure 7*).

Compared to mean for November last year and in the 1980s, the minimum oxygen concentrations this year were generally the same or higher, except in the southern Belt 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 neither severe oxygen depletion nor oxygen depletion was observed at the stations of the cruise. *Figure 8* shows the stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of November 2005, and where oxygen depletion or severe oxygen depletion was observed.

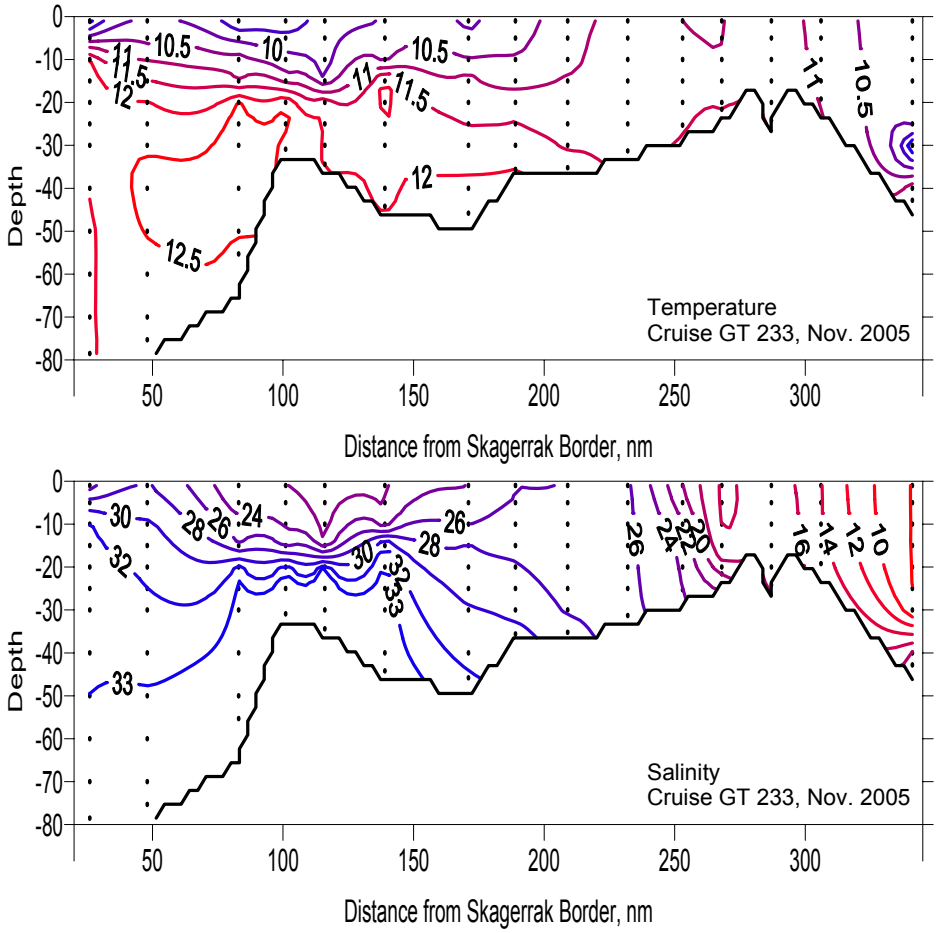

Figure 3 Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

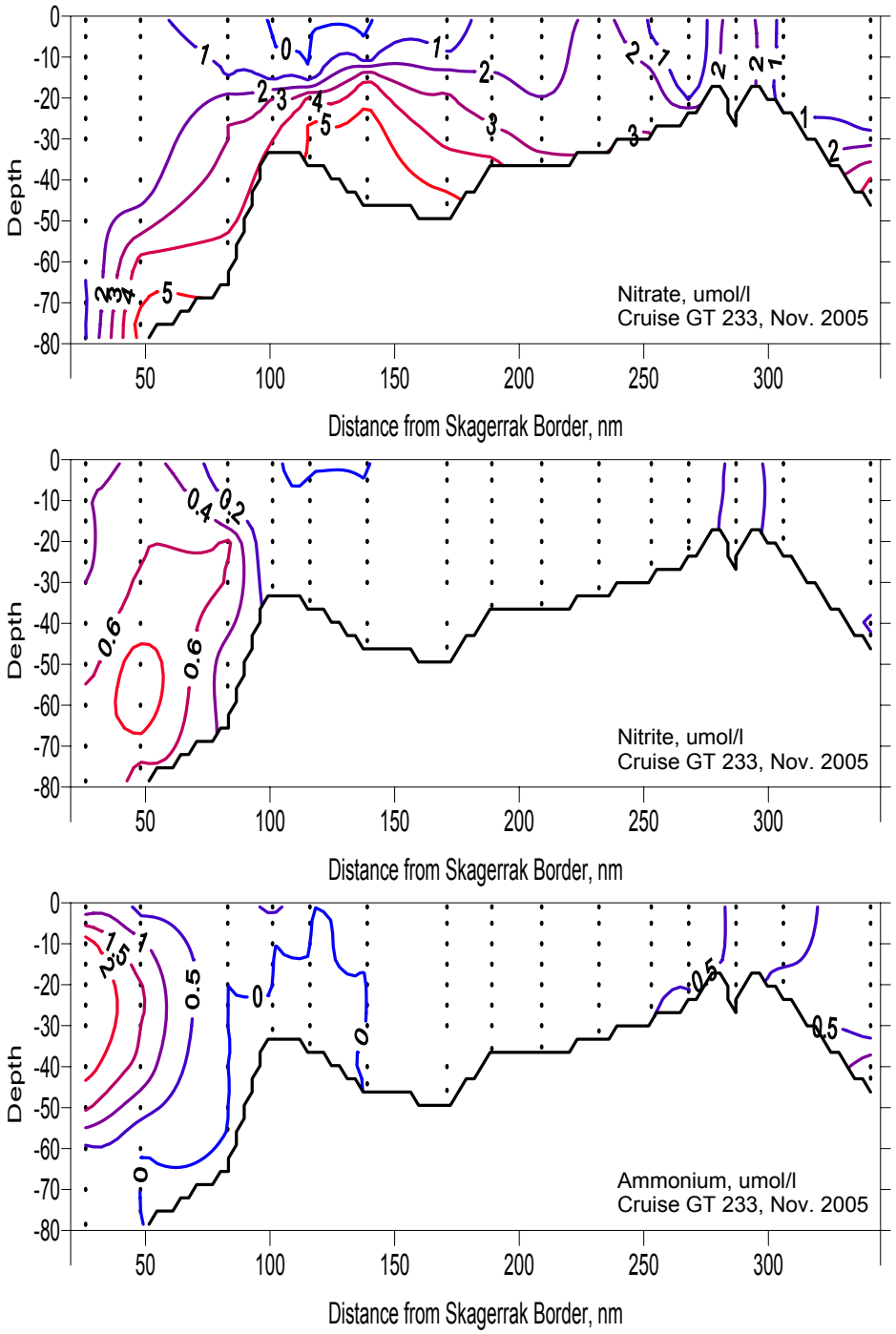

Figure 4 Nitrate (top), nitrite (middle) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

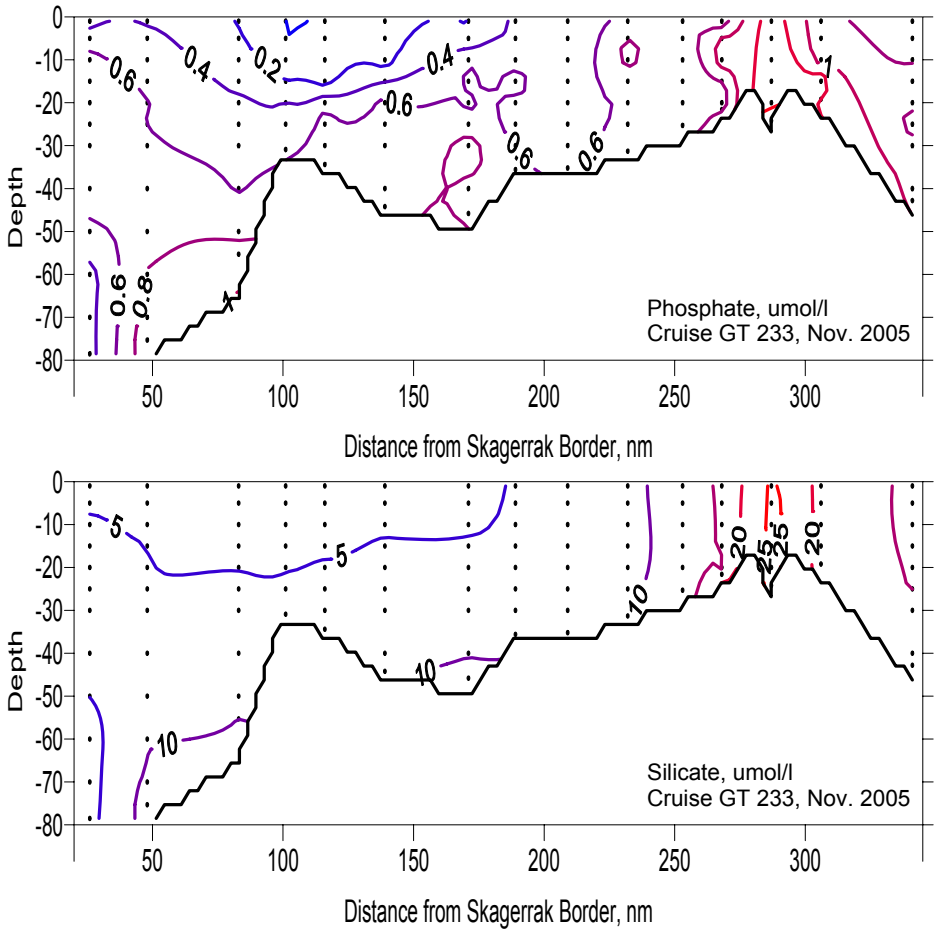

Figure 5 Phosphate (top) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

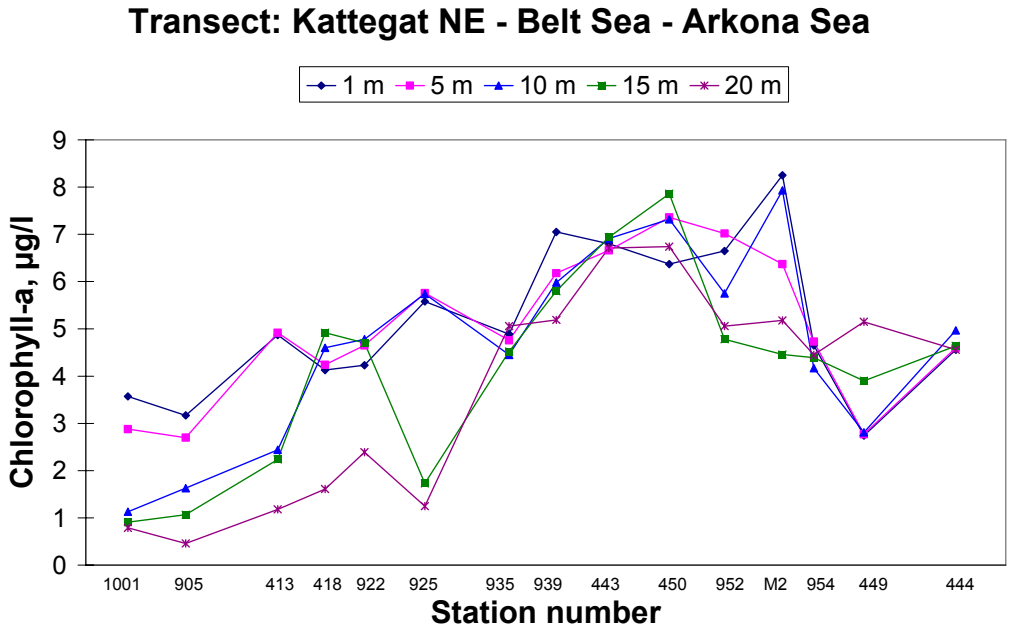

Figure 6 Chlorophyll-*a* at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

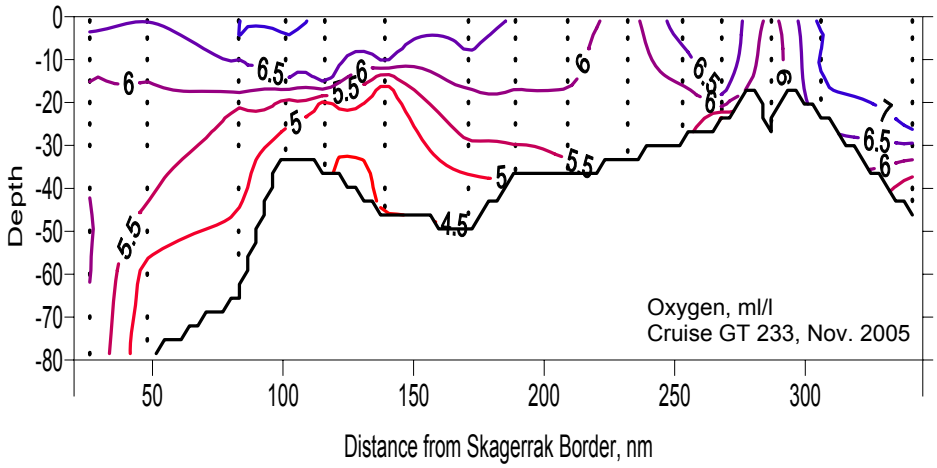

Figure 7 Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

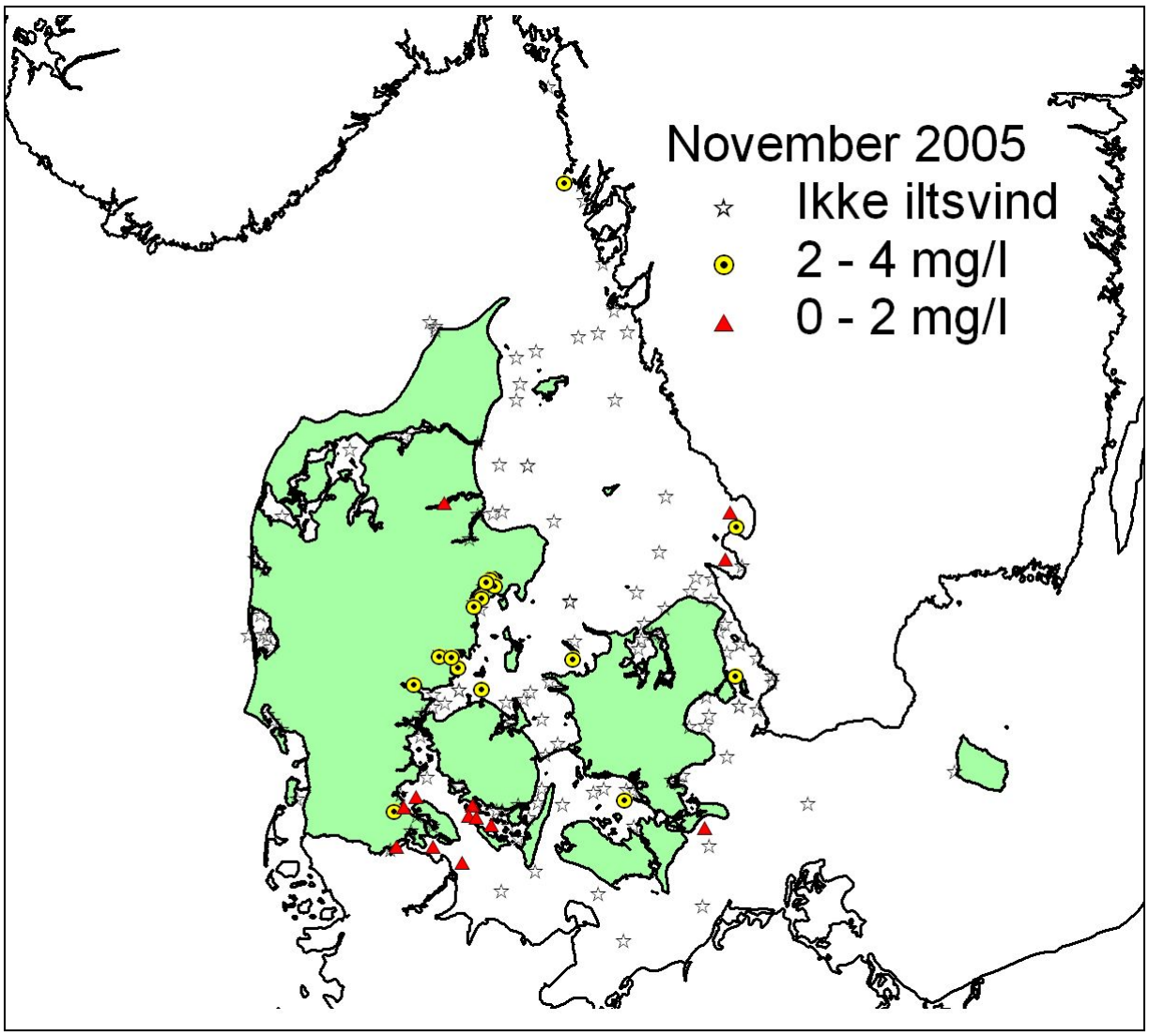

Figure 8 Stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of November 2005, and where oxygen depletion (<4.0 mg/l) and severe oxygen depletion (<2.0 mg/l) was observed.