



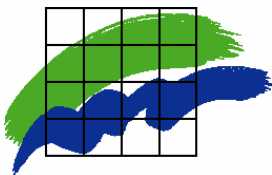
r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: GT 237

Time: 21 - 25 August 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, 21-25 August 2006

Cruise no. GT 237

Report: Gunni Ærtebjerg

Cruise leader: Kjeld Sauerberg

Participants: Dorete Jensen, Hanne Ferdinand, Peter Kofoed, Nina Thomsen (trainee), Jørgen Hansen (from Korsør to Frederikshavn)

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

Summary

The stratification of the water column was unusually strong for the season. The surface temperature was high, 19-20° C due to record high monthly average temperature in July. The surface salinity was 1-3 lower than long-term average due to water flowing out from the Baltic Sea, while the bottom water salinity was 0.5-3.5 higher than normal, probably due to unusually calm weather all year, except at the end of May, and therefore low water mixing and exchange.

Oxygen depletion (<2.8 ml/l) was observed in the Kiel Bight, Fehmarn Belt, Mecklenburg Bight and east of Falster (2.0-2.8 ml/l, 31-44% saturation). In the Arkona Sea the minimum oxygen concentration was 3.1 ml/l (44%). In the Sound, Great Belt, southern and eastern Kattegat the minimum oxygen concentrations were 3.2-4.5 ml/l (46-70%). In the north-western Kattegat unusually low oxygen concentrations of 3.3-3.7 ml/l (54-62%) were observed.

Practically no DIN was available in the surface layer in any area. Also DIP was exhausted at the surface, except in the Arkona Sea and northernmost Kattegat. Silicate was present in the surface of the Arkona Sea, southern Belt Sea, the Sound and northwestern Kattegat. In the bottom water the highest concentrations of nitrite, ammonium, phosphate and silicate were observed in the southern Belt Sea, where also the lowest oxygen concentrations were found. The bottom water nitrate concentration was low, except in the eastern Kattegat.

During the cruise large surface accumulations of cyanobacteria were observed in most areas, even in the southern and central Kattegat. At the sampling stations the highest average chlorophyll concentration of 10.4 µg/l in the uppermost 10 m was found in Mecklenburg Bight. In the Sound and Belt Sea the average surface concentration (0-10 m) varied from 3.3 to 6.3 µg/l. In the Arkona Sea and southern Kattegat the mean surface concentration was 2.0-2.9 µg/l. Contrary, in the northern Kattegat the surface chlorophyll concentration was low to normal for the season with 0.5-1.0 µg/l.

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 and respiration in the bottom water.

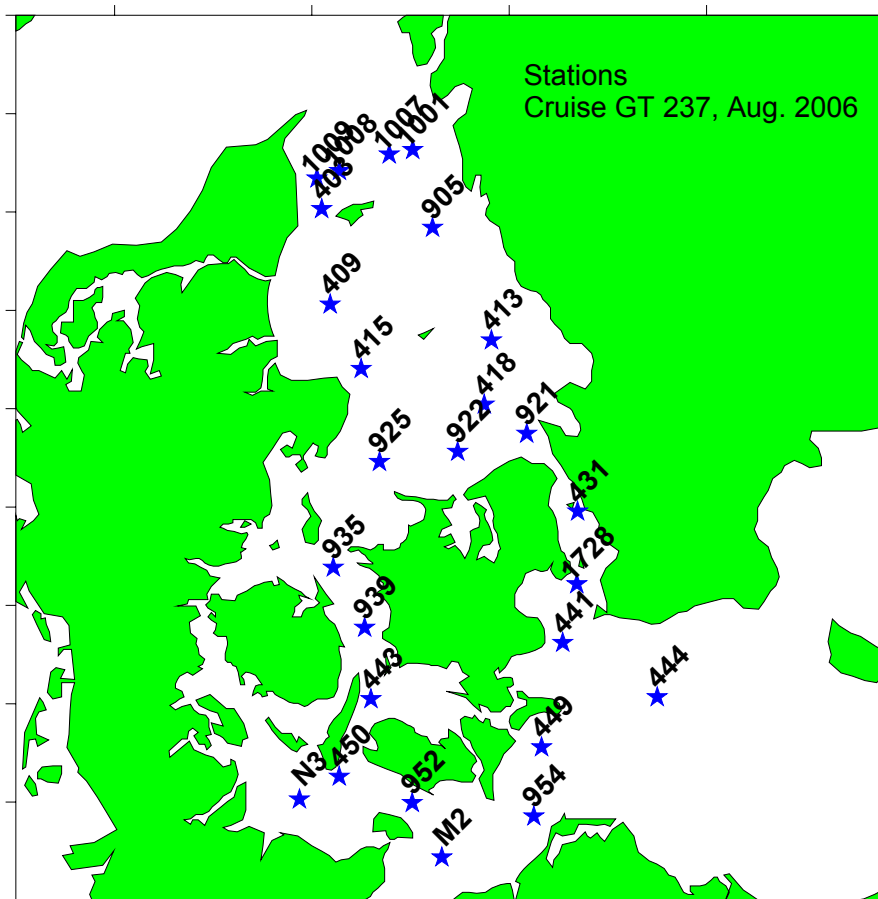


Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 21-25 August 2006 in the Sound, the Arkona Sea, the Belt Sea and the Kattegat. Gunnar Thorson cruise no. GT 237.

Meteorology

Characteristics of the weather conditions from March to August 2006 are given in *table 1*. March was rather cold, April to June a little warmer than average, while July was record warm. The precipitation was above average in April and May, but below average in March, June and July, while the precipitation in August was record high. The accumulated precipitation through the

first half year of 2006 was close to long-term average. The weather was very calm the whole period from March to August, except at the end of May (Week 21, *figure 2*). March was dominated by easterly winds, but at the end of the month the wind turned to southwest and west, which dominated the wind directions the whole period from April to August.

Table 1 Deviations in monthly mean temperature and precipitation in the months March-August 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
March	-2.3	-13	4.5	NE-E/SW-W
April	+0.4	+32	4.8	W
May	+0.6	+58	5.1	SW-W
June	+0.7	-53	3.9	SW-W
July	+4.2	-50	3.4	SW-W
August	+1.4	+121	3.5	W

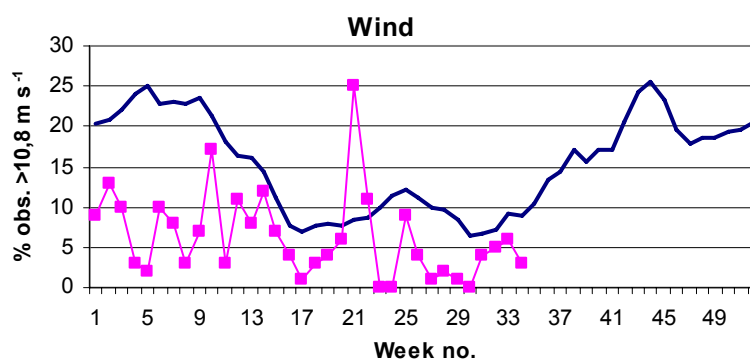


Figure 2 Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2006 (connected points) compared to 3-weeks running mean for the period 1994-2004 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m depth) was relatively high and varied from 17.5° C at Gedser Rev and 18.2-18.6° C in the western Arkona Sea (St. 441, 449) to 19.1-20.0° C in all other areas. The bottom near temperature ranged from 6.4-7.0° C in the south-eastern Kattegat (St. 413, 418, 921, 922) to 11-13° C in the Belt Sea, and 16.1° C east of Frederikshavn (*figure 3*).

The surface salinity ranged from 7.4-7.7 in the Arkona Sea (St. 441, 444, 449) to 20.5-22.1 in the northern Kattegat (St. 403, 1001, 1007, 1008, 1009). The bottom water salinity ranged from 19.9 in the deep Arkona Sea (St. 444) to 34.0-34.9 in the eastern and northern Kattegat (St. 413, 418, 905, 1001, 1007, 1008) (*figure 3*).

Compared to long-term monthly means (Lightship observations 1931-1960) for August, the surface temperature was 0.9-3.1° C above average in all areas. In the southern Kattegat the bottom water temperature was 0.1-3.6° C lower than normal, but in the Belt Sea and northern Kattegat a little above average. The surface salinity was 1-3 lower than average, except in the Great Belt. The bottom water salinity was in all areas 0.5-3.8 above normal. Thus the stratification of the water column was in all areas stronger than long term average.

Nutrients

Practically no nitrogen nutrients were available in the surface layer in any area (*figure 4a*). The nitrate concentration in the bottom layer was very low in the Sound and Belt Sea (0.3-3.1 $\mu\text{mol/l}$), while nitrate concentrations above 8 $\mu\text{mol/l}$ were observed in the eastern Kattegat (St. 413, 418, 905). The highest nitrite concentrations of $>0.3 \mu\text{mol/l}$ were observed at the bottom in the southern Belt Sea (St. M2, 952, 954) and the Arkona Sea (St. 444, 449), but also in the northernmost Kattegat (St. 403, 1001, 1008) (*figure 4b*). Very high ammonium concentrations of $>3 \mu\text{mol/l}$ and up to 5.5 $\mu\text{mol/l}$ were observed at the bottom in the Sound (St. 431), southern Belt Sea (St. 443, 450, 952, 954, M2), and also in the northernmost Kattegat (St. 403, 1001, 1008) (*figure 4c*).

Generally also phosphate was exhausted in the surface layer in most areas, except for the Arkona Sea (St. 441, 444, 449, 954, 1728) and north-western Kattegat (St. 403, 1009) where concentrations $>0.1 \mu\text{mol/l}$ were found. In the bottom layer the highest phosphate concentration of 1.1 $\mu\text{mol/l}$ was observed in the Fehmarn Belt (St. 952) (*figure 5a*). Also the silicate concentrations were low ($<1 \mu\text{mol/l}$) in the surface layer of most of the Kattegat and Great Belt, but higher in the Sound, north-western Kattegat, southern Belt Sea and the Arkona Sea. In the bottom water above 25 $\mu\text{mol/l}$ and up to 34 $\mu\text{mol/l}$ were found in the southern Belt Sea (St. M2, N3, 952, 954) and central Arkona Sea (St. 444) (*figure 5b*).

Chlorophyll a

During the cruise large surface accumulations of cyanobacteria were observed in most areas, even in the southern and central Kattegat. At the sampling stations the highest average chlorophyll concentration of 10.4 $\mu\text{g/l}$ in the uppermost 10 m was found in Mecklenburg Bight (St. M2). In the Belt Sea the average surface concentration (0-10 m) of chlorophyll varied from 3.3 to 6.3 $\mu\text{g/l}$ (*figure 6*). In the central Sound 4.1 $\mu\text{g/l}$ was observed, and in the Arkona Sea and southern Kattegat the mean surface concentration was 2.0-2.9 $\mu\text{g/l}$. Contrary, in the northern Kattegat the surface chlorophyll concentration was low to normal for the season with 0.5-1.0 $\mu\text{g/l}$.

Oxygen

The lowest oxygen concentrations of 2.0-2.8 ml/l (31-44% saturation) were observed in the Kiel Bight, Fehmarn Belt, Mecklenburg Bight and east of Falster (St. N3, 952, M2, 954, 449). In the Arkona Sea (St. 444) the minimum oxygen concentration was 3.1 ml/l (44%). In the Sound, Great Belt and the southern and eastern Kattegat the minimum oxygen concentrations were 3.2-4.5 ml/l (46-70 %). In the north-western Kattegat (St. 403, 1008) unusually low oxygen concentrations of 3.3-3.7 ml/l (54-62%) were observed (*figure 7*).

Compared to mean for August in the 1980s, the minimum oxygen concentrations this year were higher, and generally equal the concentrations in August last year.

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 observed in the Kiel Bight, Fehmarn Belt, Mecklenburg Bight and east of Falster, while severe oxygen depletion was not observed during the cruise. *Figure 8* shows the stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of August 2006, and where oxygen depletion or severe oxygen depletion was observed.

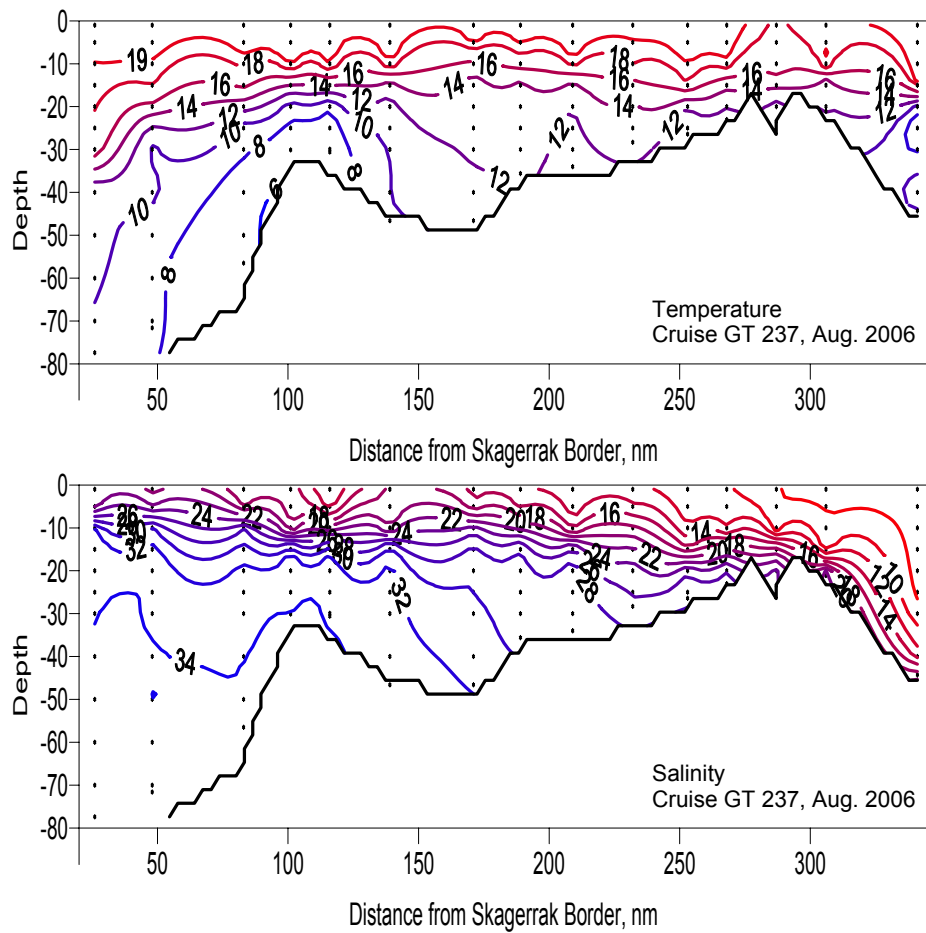


Figure 3 Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

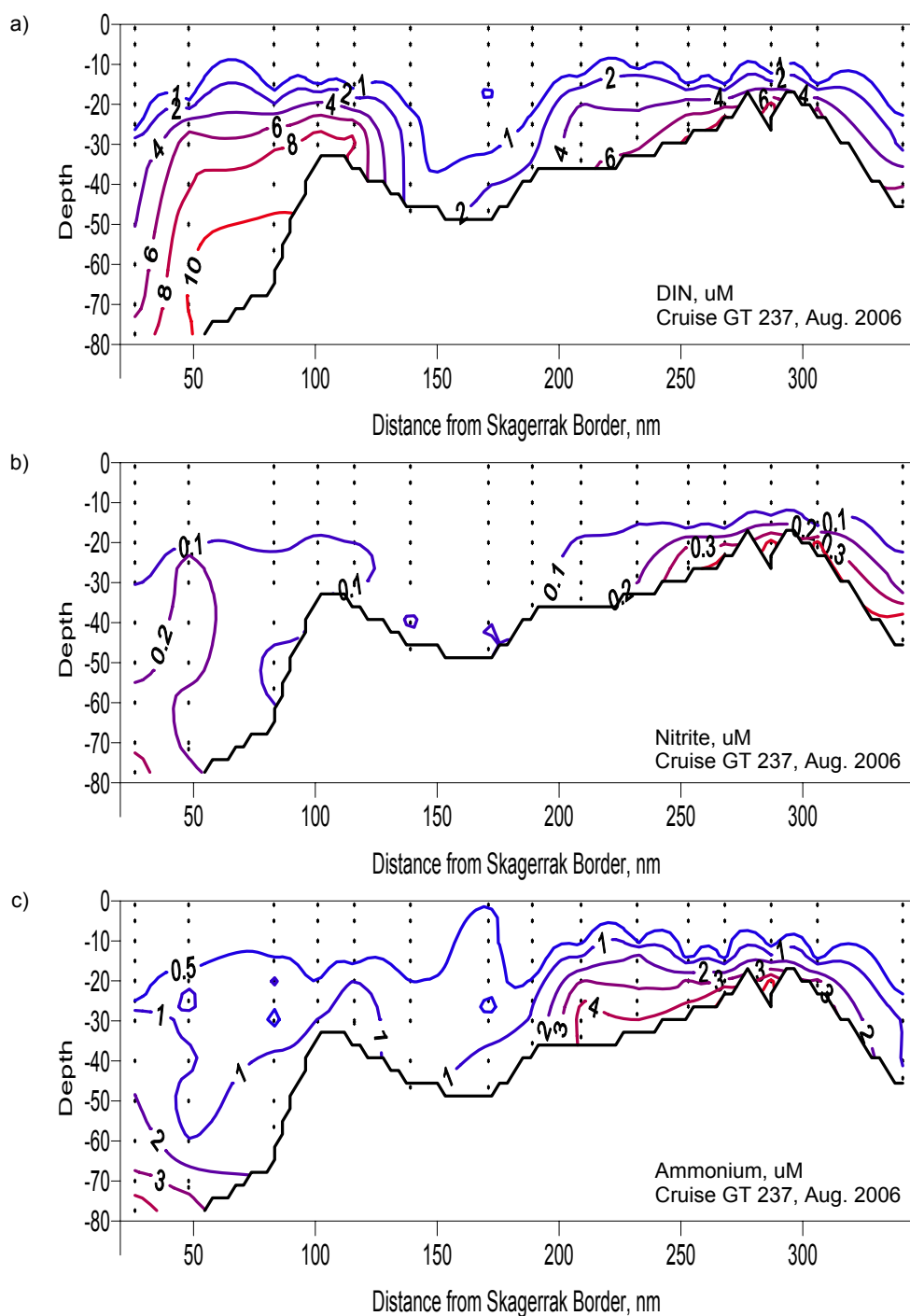


Figure 4 Dissolved inorganic nitrogen, DIN (top), nitrite (middle) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

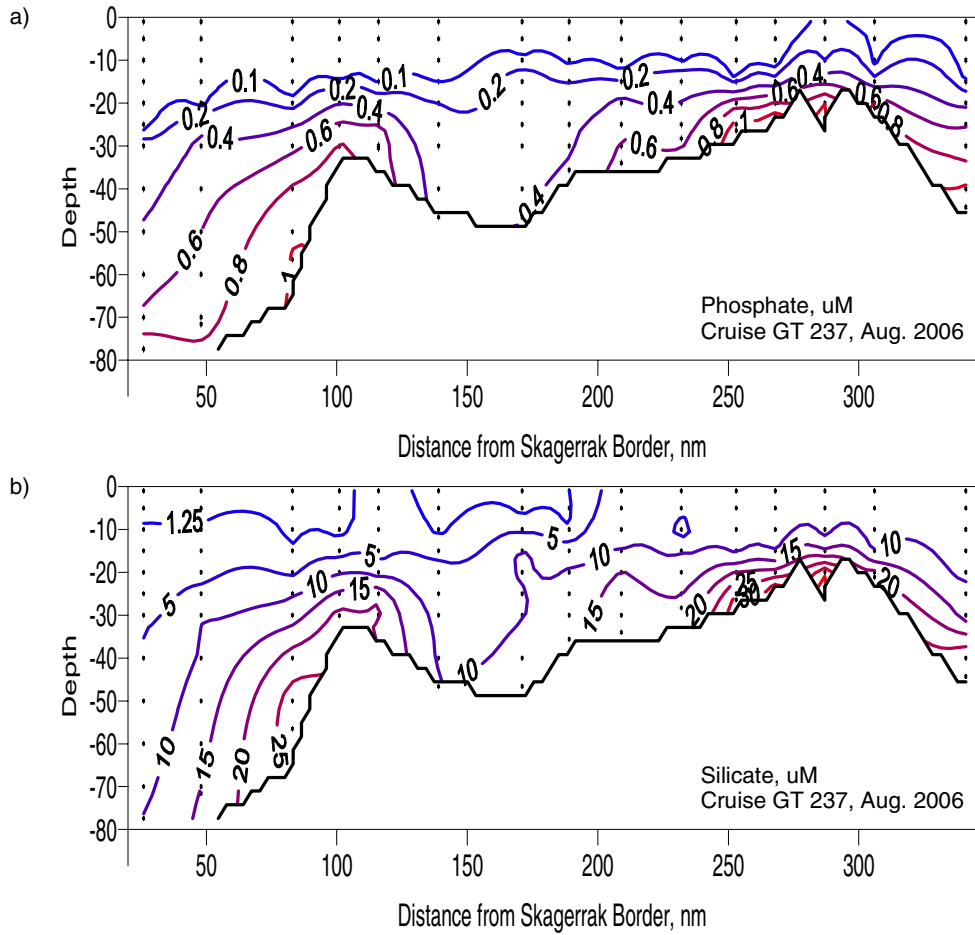


Figure 5 Phosphate (top) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

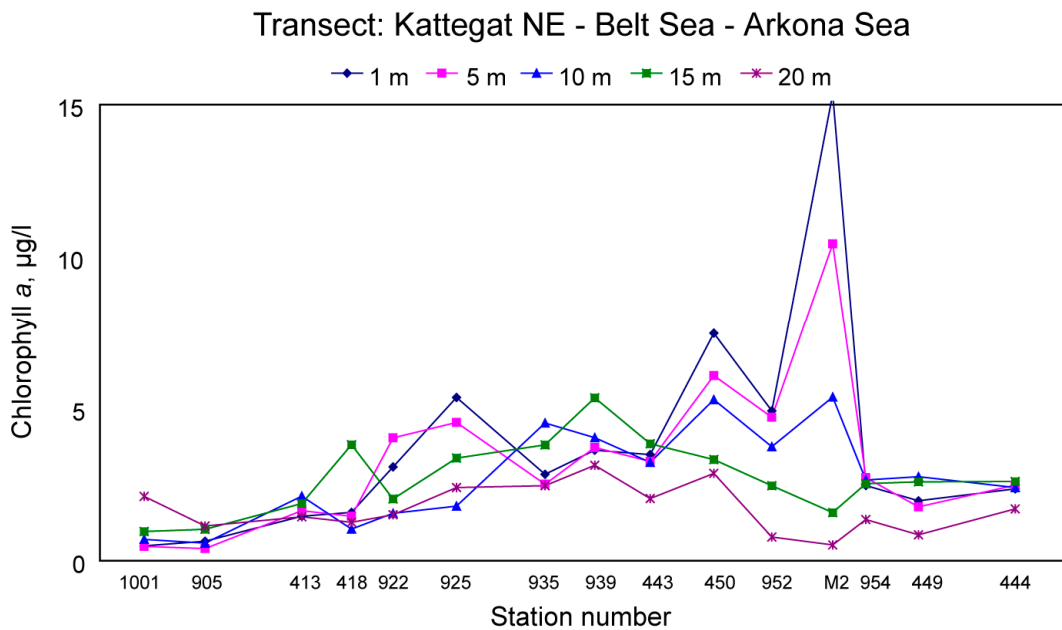


Figure 6 Chlorophyll a at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

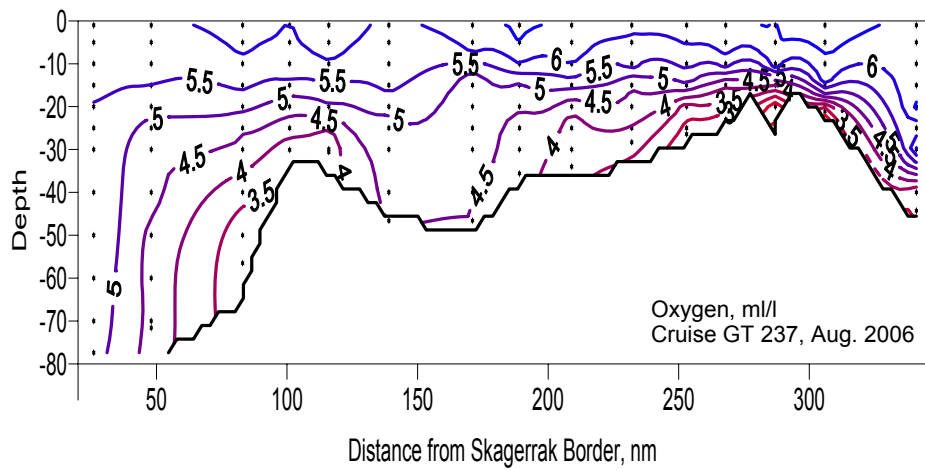


Figure 7 Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

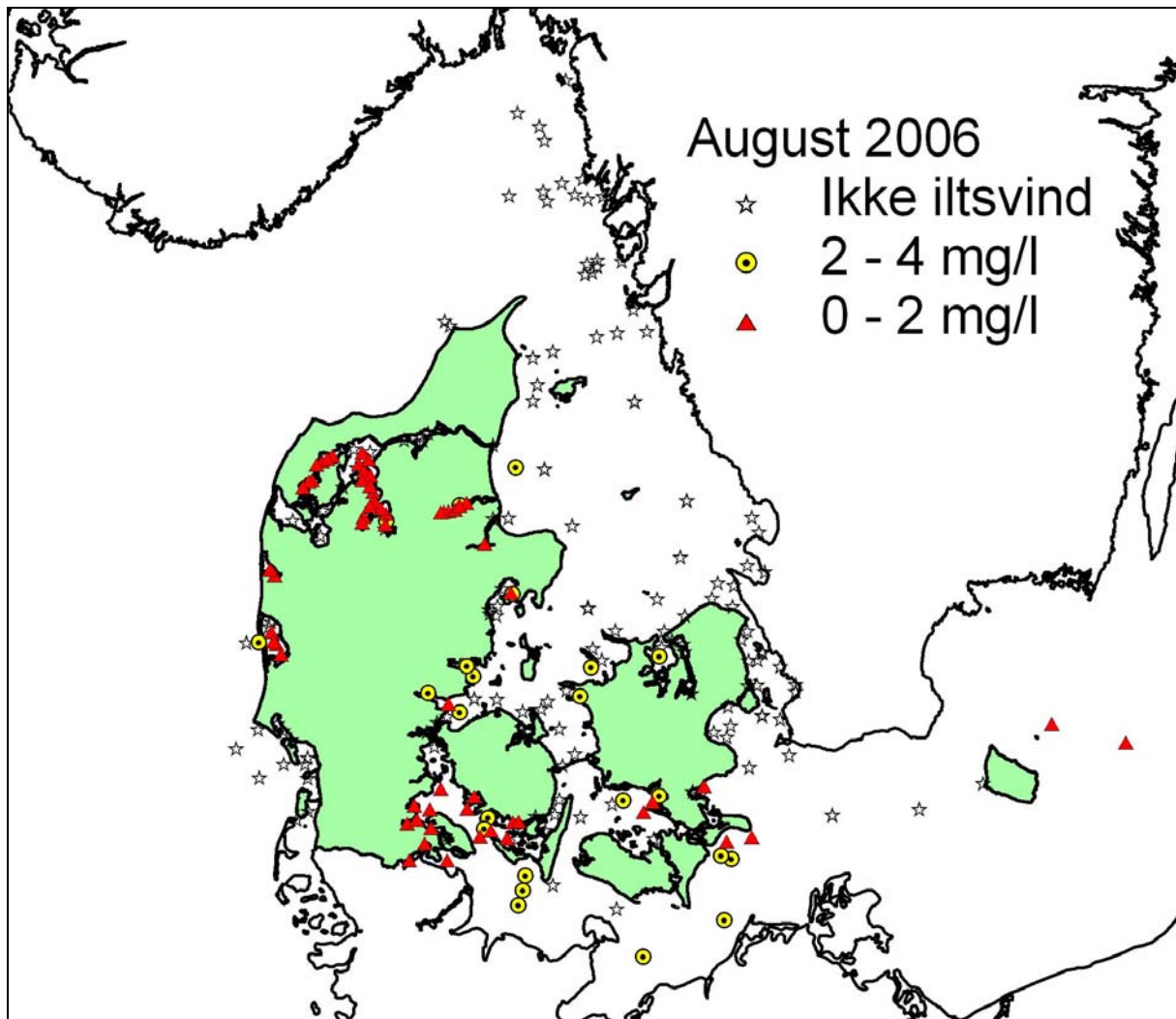


Figure 8 Stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the period 1-25 August 2006, and where oxygen depletion (<4.0 mg/l) and severe oxygen depletion (<2.0 mg/l) was observed.