



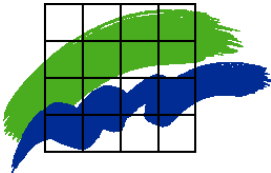
r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 210

Time: 16 - 19 September 2002

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



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Data Sheet

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Monitoring cruise with r/v Gunnar Thorson in the Sound, the Kattegat, the Belt Sea and the Arkona Sea, 16-19 September 2002. Cruise no. 210.

Report: Gunni Ærtebjerg

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

Summary

The following summary is based not only on the present cruise, but also on oxygen measurements made by the Danish counties, SMHI and Swedish and German coastal authorities. The report on oxygen deficiency is published at the address: <http://iltrapport.dmu.dk>

Since the last report on the oxygen situation at the end of August the oxygen deficiency in the Belt Sea and central Sound has developed to the most serious and widespread ever observed in these areas. In mid September the bottom water oxygen concentration was 0-2 mg/l at depths larger than 15-20 m in most of the Belt Sea. In parts of the sea north of the island of Funen, and in the southern Little Belt, Flensborg Fjord, the archipelago south of Funen, the southern Belt Sea including outer Kiel Fjord, Lübeck Bight and Mecklenburg Bight the bottom water was anoxic and contained toxic hydrogen sulphide released from the sediments.

In the southern and western Kattegat the oxygen situation was mid September more or less unchanged compared to mid August. The situation worsened during the beginning of September, but oxygen supply caused by changing wind forces and directions has later compensated the oxygen consumption in the bottom water. However, extensive oxygen deficiency (<4 mg/l) was still present in the southern and western Kattegat with serious oxygen deficiency (<2 mg/l) in certain coastal areas (Laholm Bight, Skälderviken, north of Sjællands Odde and in Hevring Bight). In the deep eastern Kattegat serious oxygen depletion has developed close to the bottom south-east of Anholt, and the oxygen depletion has spread to the north up to around Fladen. In the deeper parts of the Arkona Sea the oxygen concentration at the bottom has increased from <1 mg/l in August to >2 mg/l mid September.

In the southernmost Kattegat, the Sound and the Belt Sea oxygen deficiency is present in a very large water volume, and a very large oxygen debt is built up which has to be met before normal oxygen conditions can be established. It is normal that oxygen deficiency events in the Kattegat, the Sound and the Belt Sea culminate in late September or early October, and that autumn storms during October and November usually re-oxygenate the bottom water. Gales from south-west will create an inflow of oxygen rich water from the Skagerrak to the bottom water of the Kattegat, the Sound and the Belt Sea. However, there is a risk that the inflow can cause extensive fish death, especially at east-facing coasts in the Belt Sea. The inflow will raise the oxygen poor water towards the surface and press it into bights and estuaries, and the fish might be caught in these oxygen poor water masses. How dramatic the progress will be, or when it will happen, can not be predicted, as it depends on the meteorological development, which can not be predicted more than a week ahead.

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 (the Arkona Sea, the Sound, the Belt Sea, the 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*.

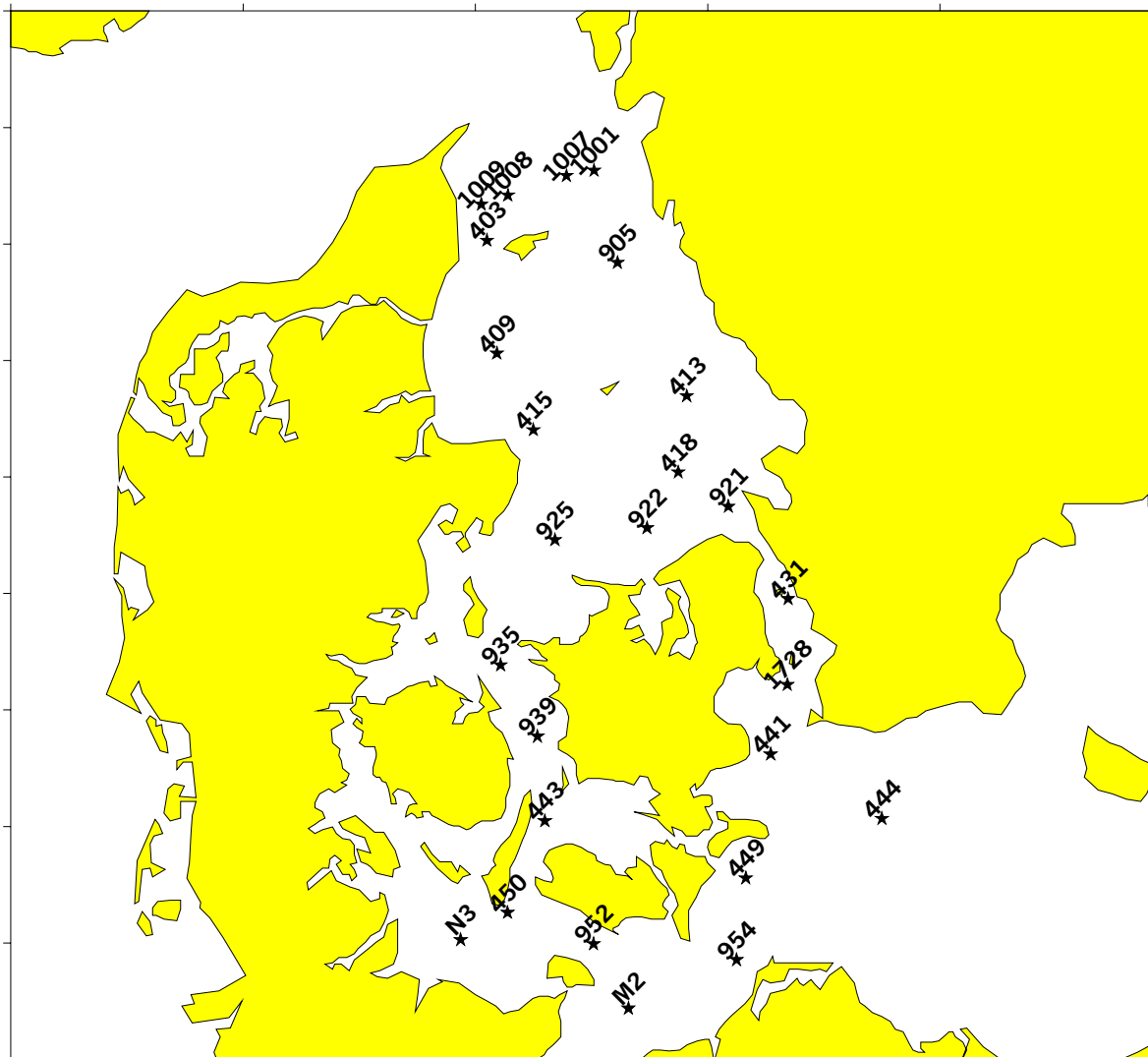


Figure 1. Stations of the monitoring cruise with r/v Gunnar Thorson 16-19 September 2002 in the Sound, the Kattegat, the Belt Sea and the Arkona Sea. Gunnar Thorson cruise no. 210.

Meteorology

Characteristics of the weather conditions in August and September 2002 are given in *table 1*. Both months were warmer than normal, August nearly 4°C above average. The precipitation

was about normal in August, but very low in September. Both months were unusually calm with very few and short incidents of gale forces (*figure 2*).

Table 1. Deviations in monthly mean temperature and precipitation in August and September 2002 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 directions
August	+3,9	+6	3.8	S-SW-W
September	+1.8	-56	3.8	E-SW-W-NW

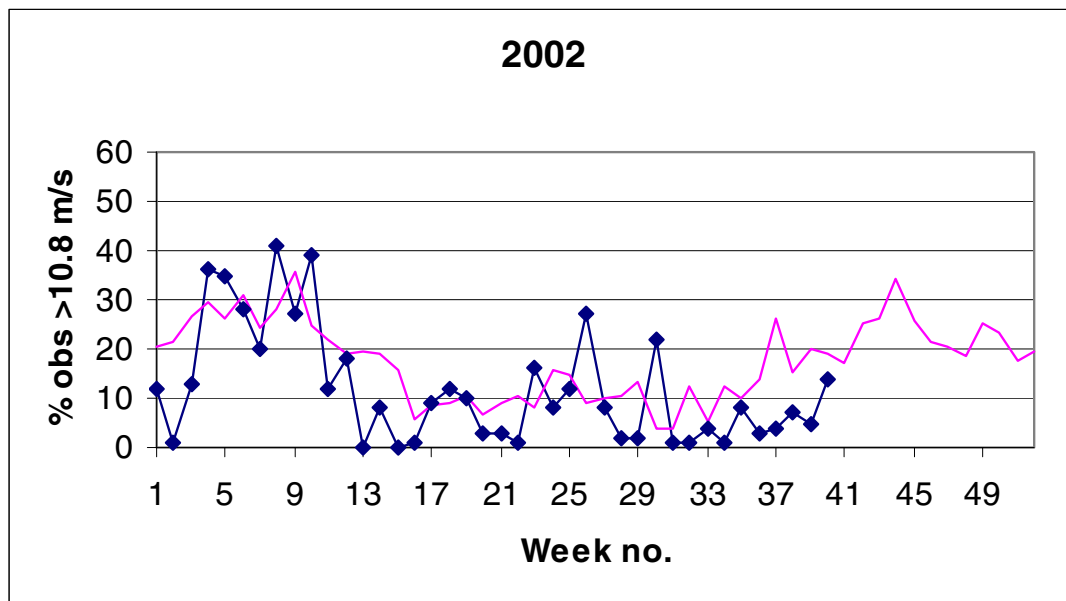


Figure 2. Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2002 (connected points) compared to mean for the period 1994-2000 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m depth) varied from 17.1-17.9°C in the Kattegat, the Sound and the Great Belt to 18.2-19.4°C in the southern Belt Sea and the Arkona Sea. The bottom water temperature ranged from 8.1°C in the north-eastern Kattegat (St. 1001) and 9.7°C in the Sound (St. 431) to 15.4-16,0°C in the shallow western Kattegat (St. 409, 415) and deep Arkona Sea (St. 444) (*figure 3*).

The surface salinity ranged from 7.4-8.3 in the Arkona Sea (St. 441, 444, 449) to 21.5-25.5 in the northern Kattegat (St. 1001, 1007, 1008, 1009, 905). The bottom water salinity ranged from 18.4-21.5 in the Arkona Sea (St. 444, 449) to 34.4-34.9 in the north-eastern Kattegat (St. 905, 1001, 1007, 1008) (*figure 3*). The salinity stratification was still unusually strong (8.7-17.2 psu) in all areas (strongest in the Sound), even in the shallow Ålborg Bight (9.7 psu).

Compared to long term monthly means (Lightship observations 1931-1960) for September the surface temperature was still 2-3°C higher than normal. Also the bottom water temperature was higher than normal (0.5-2.5°C). The surface salinity during the present cruise was generally lower than normal, except in the northern Kattegat and central Great Belt. Contrary,

the bottom water salinity was 0.7-3.6 higher than normal, and in Ålborg Bight 4.3 higher than normal (St. 409).

Nutrients

In the surface layer generally no inorganic nitrogen nutrients were present (*figure 4*). In the bottom water nitrate concentrations above 8 $\mu\text{mol/l}$ were observed in all the eastern Kattegat (St. 1001, 905, 413, 418, 921) and Læsø Rende (St. 403, 1009). In the Belt Sea the nitrate concentration in the bottom water was unusually low (*figure 4a*).

High nitrite concentrations (0.5-1.1 $\mu\text{mol/l}$) were observed at 15-25 m depth in the eastern Kattegat and in the bottom water in the southern Kattegat and the Great Belt (*figure 4b*). High ammonium concentrations (>3 $\mu\text{mol/l}$) were found in the bottom water in the Great Belt and very high concentrations (5.0-8.9 $\mu\text{mol/l}$) were observed in the area from Fehmarn Belt over Gedser Rev to the deep Arkona Sea (*figure 4c*).

Traces of phosphate was present in the surface water in all areas, lowest in the eastern and northern Kattegat (0.02-0.06 $\mu\text{mol/l}$), and higher (generally 0.1-0.3 $\mu\text{mol/l}$) in the Sound, the Belt Sea and the Arkona Sea. In the bottom water 1.4-2.5 $\mu\text{mol/l}$ phosphate was observed in the Fehmarn Belt, Gedser Rev and Arkona Sea area (*figure 5a*), and 5.9 $\mu\text{mol/l}$ was found at the bottom in Mecklenburg Bight. Silicate concentrations above 1 $\mu\text{mol/l}$ and up to 12 $\mu\text{mol/l}$ were present in the surface water in all areas, lowest in the north-eastern Kattegat. High concentrations (>30 $\mu\text{mol/l}$) were observed in the bottom water in the eastern Kattegat, and from the central Great Belt through the Fehmarn Belt to the Arkona Sea (*figure 5b*).

Chlorophyll-a

The chlorophyll-a concentration was relatively low, generally 0.5-2.5 $\mu\text{g/l}$ in the Kattegat with the highest concentrations around the pycnocline at 10-15 m depth. In the south-eastern Kattegat (St. 921) a pronounced subsurface bloom (6.9 $\mu\text{g/l}$) was observed at 12 m depth, and in the Sound (St. 431) 3.5-3.8 $\mu\text{g/l}$ was found at 15-20 m depth. Contrary, in the Belt Sea and Arkona Sea the chlorophyll-a concentration was somewhat higher (2.5-3.0 $\mu\text{g/l}$) and quite homogeneously distributed in the surface layer, that is in the uppermost 10 m (*figure 6*).

Oxygen

Since the cruise in August, when the oxygen situation was characterised as unusually critical, the minimum oxygen concentration has increased about 1 ml/l in the deeper Arkona Sea (St. 444) to 1.5 ml/l. In the southern and western Kattegat the oxygen situation was about unchanged (1.4-2.2 ml/l), but the concentrations had decreased in the deeper eastern part to 1.5-2.9 ml/l. In the Sound and especially in all the Belt Sea the oxygen concentration in the bottom water had decreased significantly since August, and the observed minimum concentrations were now 0.2-1.4 ml/l.

In Denmark oxygen depletion is defined as minimum oxygen concentrations below 2.8 ml/l (4 mg/l), and serious oxygen depletion as below 1.4 ml/l (2 mg/l). From these definitions oxygen depletion was observed in all areas, except the north-eastern Kattegat and shallow parts of the Arkona Sea, and serious oxygen depletion occurred in the western Arkona Sea, the Sound and the Belt Sea, except the northern Great Belt (Samsø Belt). In *figure 7* are shown the stations visited by Danish counties, NERI, SMHI, Swedish and German coastal authorities within the first three weeks of September 2002, and where oxygen depletion or serious oxygen depletion was observed.

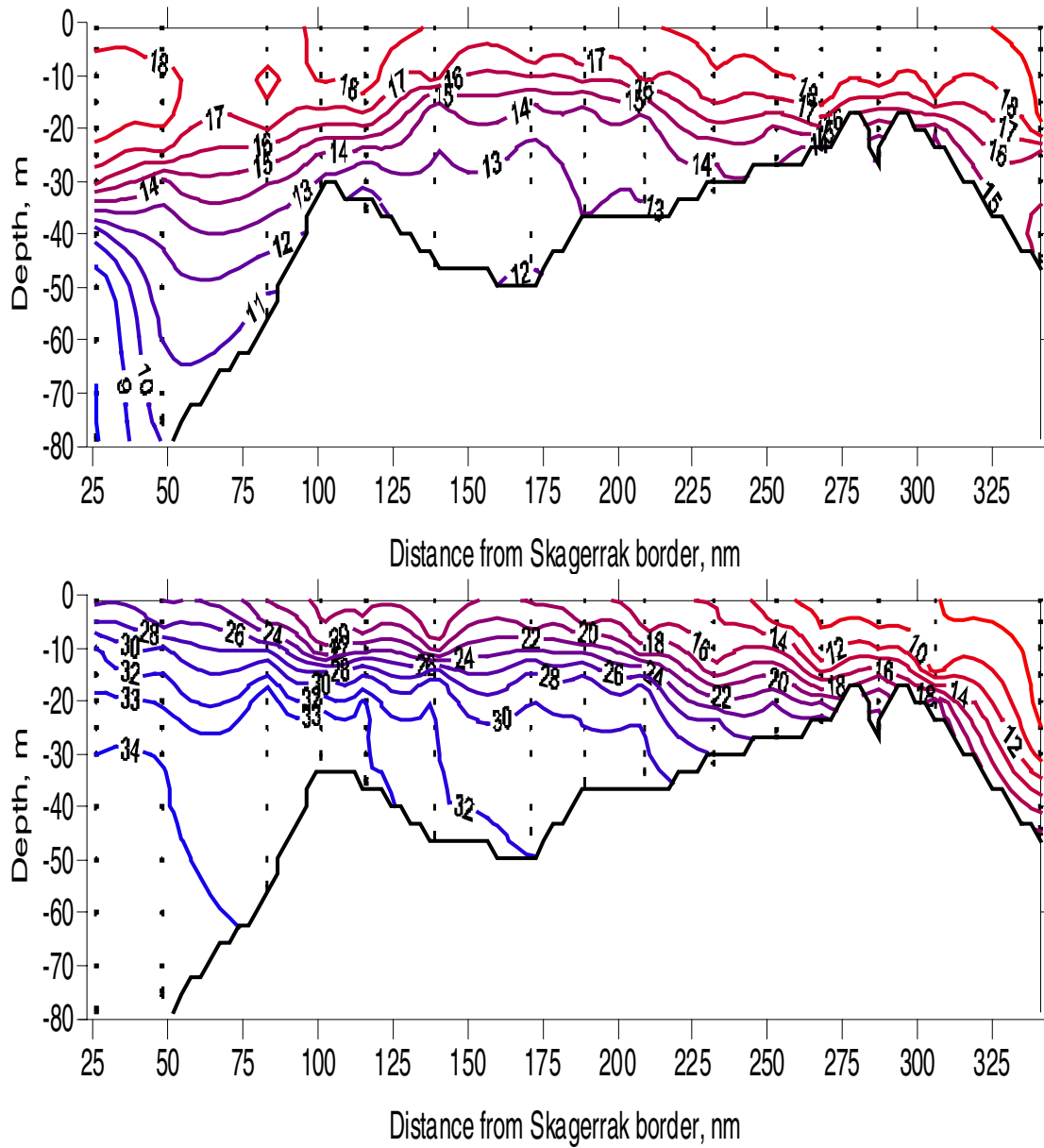


Figure 3. Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

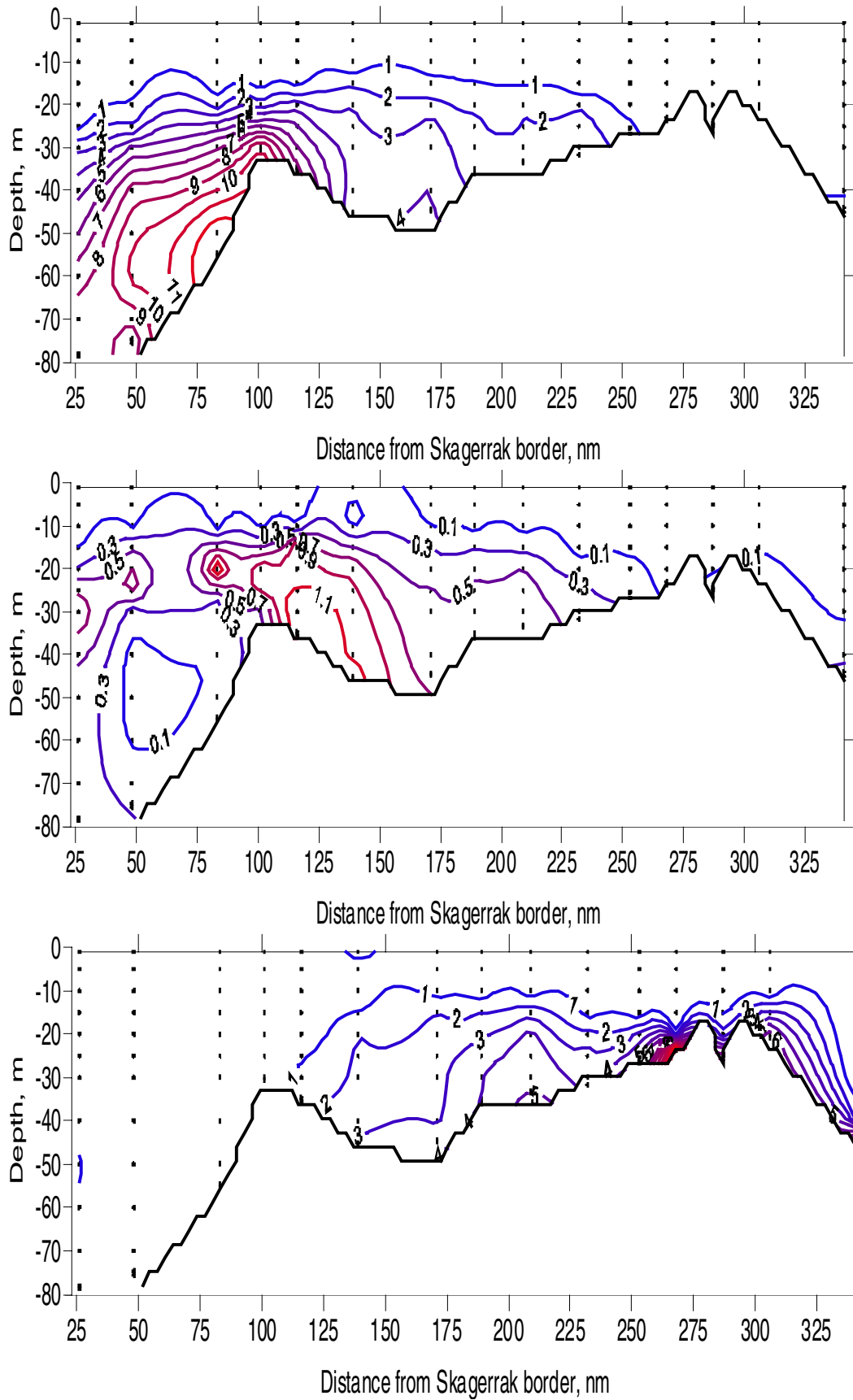


Figure 4. Nitrate (top), nitrite (mid) and ammonium (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

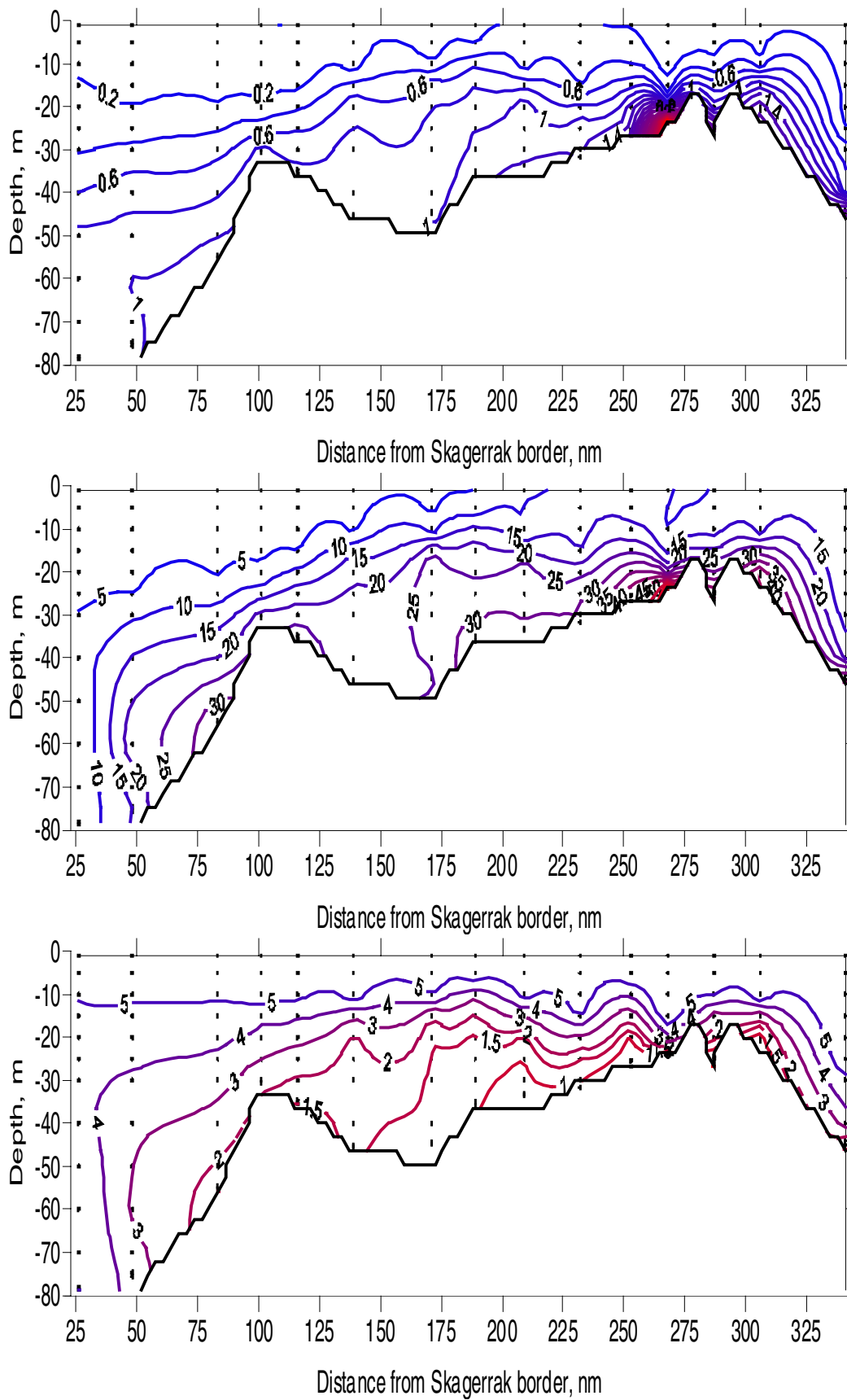


Figure 5. Phosphate (top), silicate (mid) and oxygen (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

Transect: Kattegat NE - Belt Sea - Arkona Sea

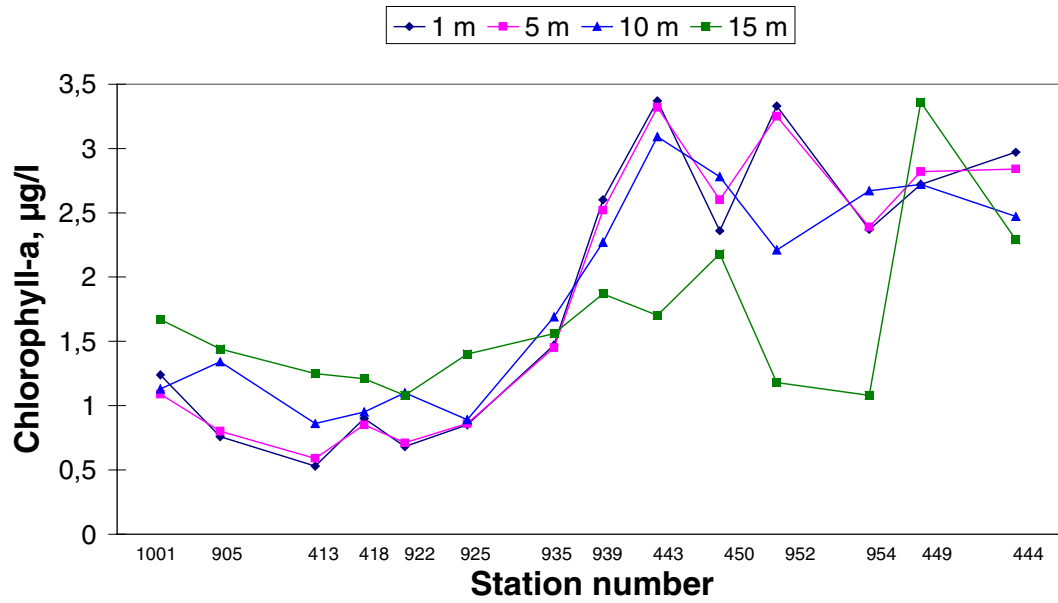


Figure 6. Chlorophyll-a at 1 m, 5 m, 10 m and 15 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

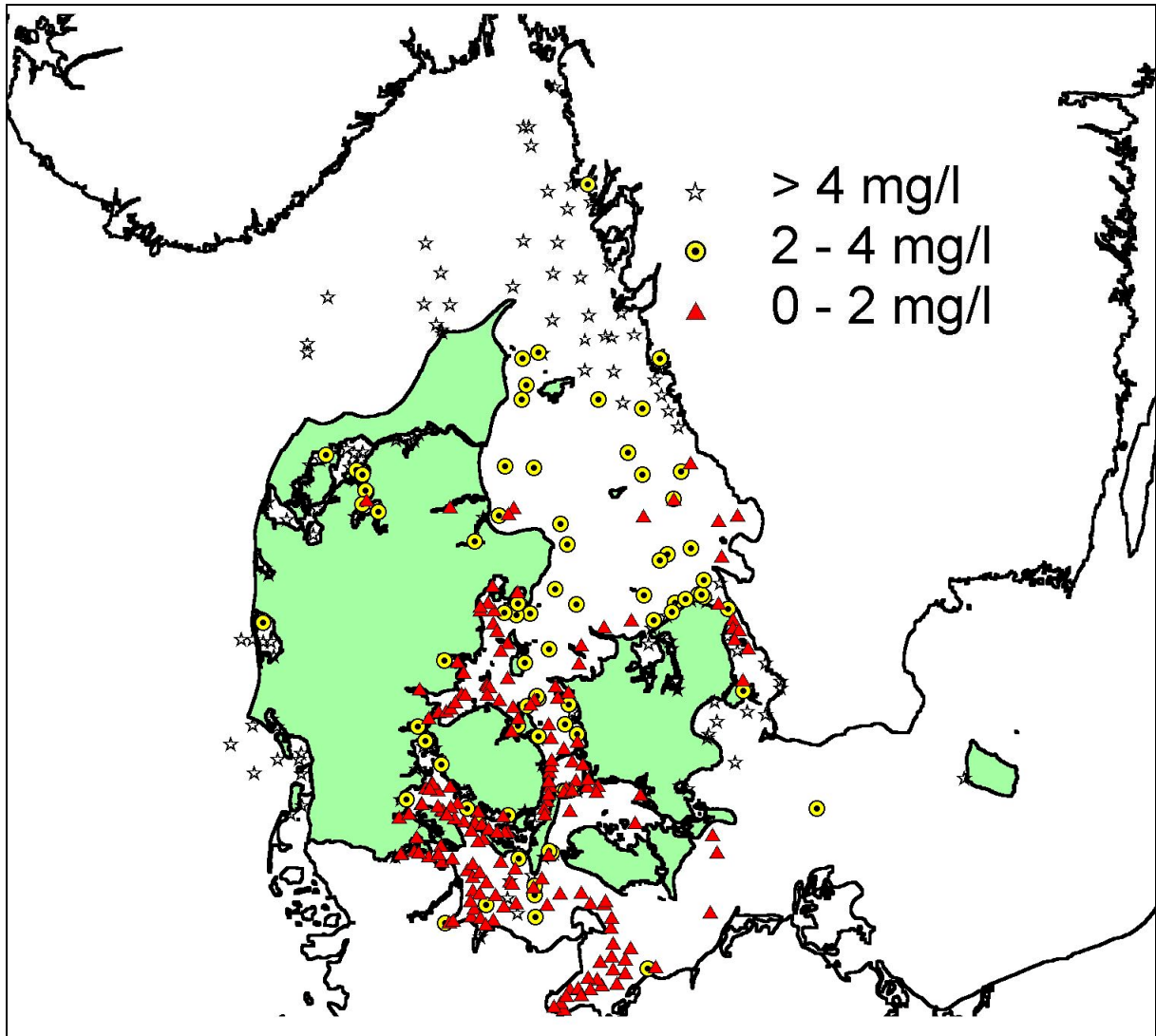


Figure 7. Stations visited by Danish counties, NERI, SMHI, Swedish and German coastal authorities within the first three weeks of September 2002, and where oxygen depletion (<4 mg/l) and serious oxygen depletion (<2 mg/l) was observed.