



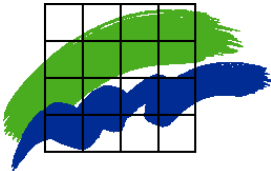
r/v Gunnar Thorson

# Monitoring Cruise Report

**Cruise no.: 211**

**Time: 14 - 18 October 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, 14-18 October 2002 – Cruise no. 211

**Report:** Gunni Ærtebjerg

**Cruise leader:** Kjeld Sauerberg

**Participants:** Dorete Jensen, Lars Renvald, Peter Kofoed, Lene Christiansen (NERI)  
Lars Lund-Hansen, Rikke Holm (Århus University)  
Morten Kongsfelt (trainee)

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

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## 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>

After dramatic fish kills at the beginning of October at several localities along the Jutland east-coast, due to upwelling of bottom water containing hydrogen sulphide or low oxygen concentration, the oxygen conditions have improved in large areas of the Danish waters. In mid October the distribution of oxygen deficiency in the Kattegat, the northern Belt Sea and the Great Belt was considerably reduced compared to late September. Contrary, the oxygen situation in the Sound, the southern Little Belt, Kiel Bight, Fehmarn Belt and Mecklenburg Bight was generally unchanged, with continuing extensive and severe oxygen deficiency. Hydrogen sulphide was observed in the bottom water in large areas of the southern Little Belt, the archipelago south of Funen, Flensborg Fjord and parts of Kiel Bight.

The wind activity increased in October compared to August and September. Strong short-lasting westerly wind caused an upwelling of oxygen poor bottom water along the Jutland east-coast in Ålborg Bight on the 1st of October. The result was a widespread death of fish and bottom fauna, which was washed ashore. The same happened on the 5th of October in the inner parts of Vejle Estuary, and on the 6th of October in Kalø Vig, Ebeltøft Vig and at the east-coast of Djursland.

Frequent strong winds from east and north-east the next couples of weeks forced out the oxygen deficiency from the western Kattegat. The oxygen deficiency became concentrated to the south-eastern part of the Kattegat in a large area between Anholt, Hesselø, northern Zealand and Sweden. North of the entrance to the Sound severe oxygen depletion (< 2 mg/l) was present from 13 m depth to the bottom, and extended into the Sound to south of the island of Ven. In the Great Belt, the area north of Funen, Århus Bight and along the Jutland east-coast the oxygen deficiency was restricted to greater depth by mid October, and the distribution reduced considerably compared to the beginning of the month.

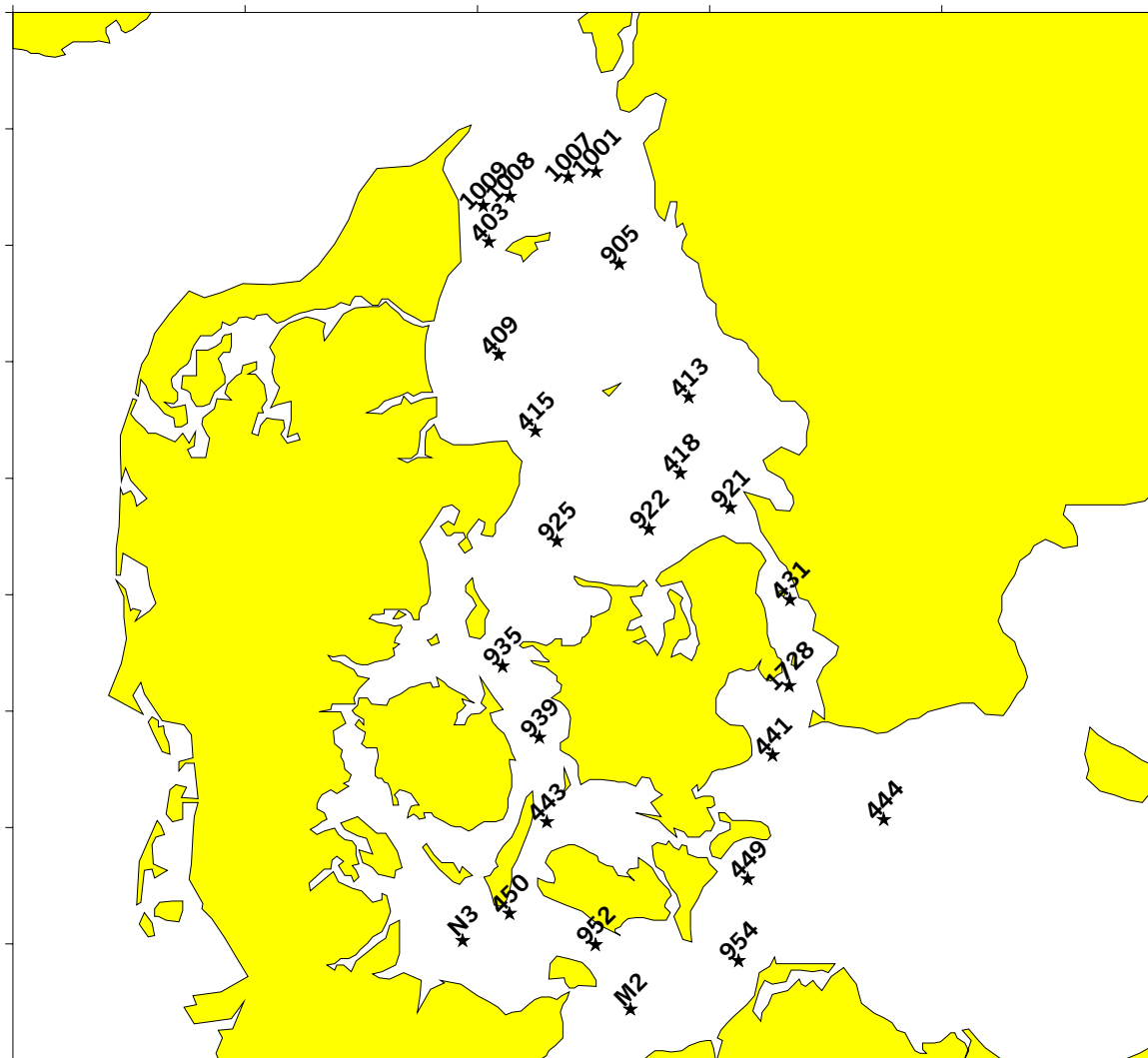
Highly saline and cold North Atlantic water rich in nitrate had penetrated from the Skagerrak as bottom water into the north-eastern Kattegat.

## 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*. Bottom fauna was sampled in the Great Belt, the Fehmarn Belt and the Arkona Sea (St. 939, 952, 444).



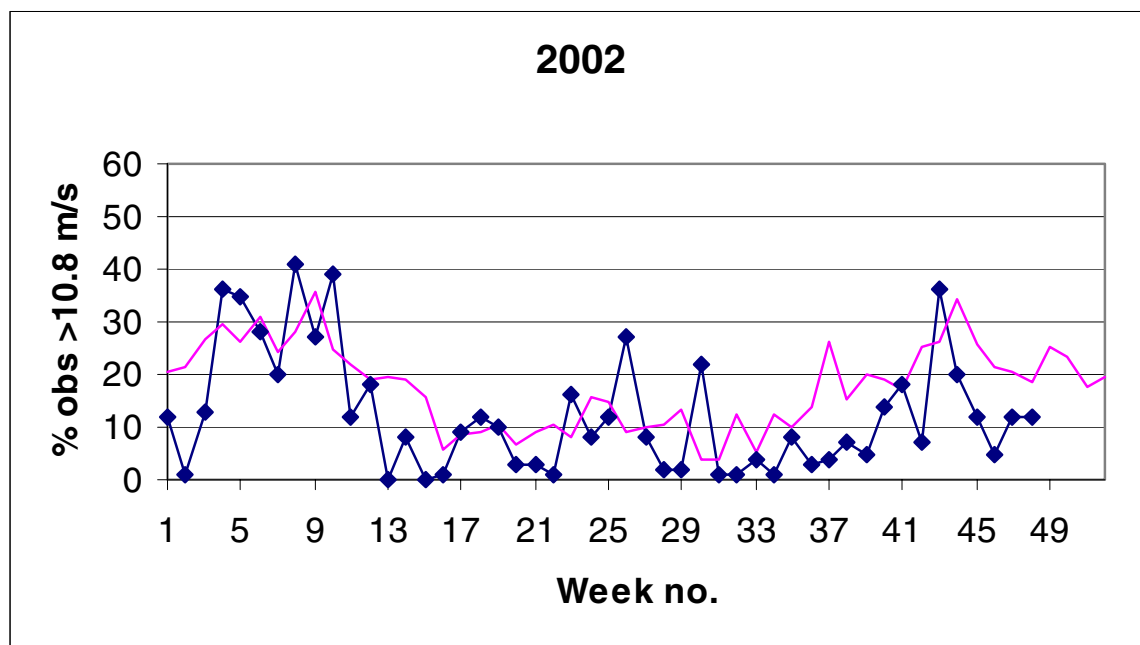
**Figure 1** Stations of the monitoring cruise with *r/v Gunnar Thorson* 14-18 October 2002 in the Sound, the Kattegat, the Belt Sea and the Arkona Sea. *Gunnar Thorson* cruise no. 211.

## Meteorology

Characteristics of the weather conditions in October 2002 are given in *table 1*. The month was colder and more wet than normal. The wind activity increased in October with strong short-lasting westerly winds at the beginning of the month followed by frequent strong winds from east and north-east (week 41). At the end of the month (week 43), there were days with gales from west (*figure 2*).

**Table 1** Deviations in monthly mean temperature and precipitation in October 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
October	-2.1	+47	5.0	NE-E--SW-W

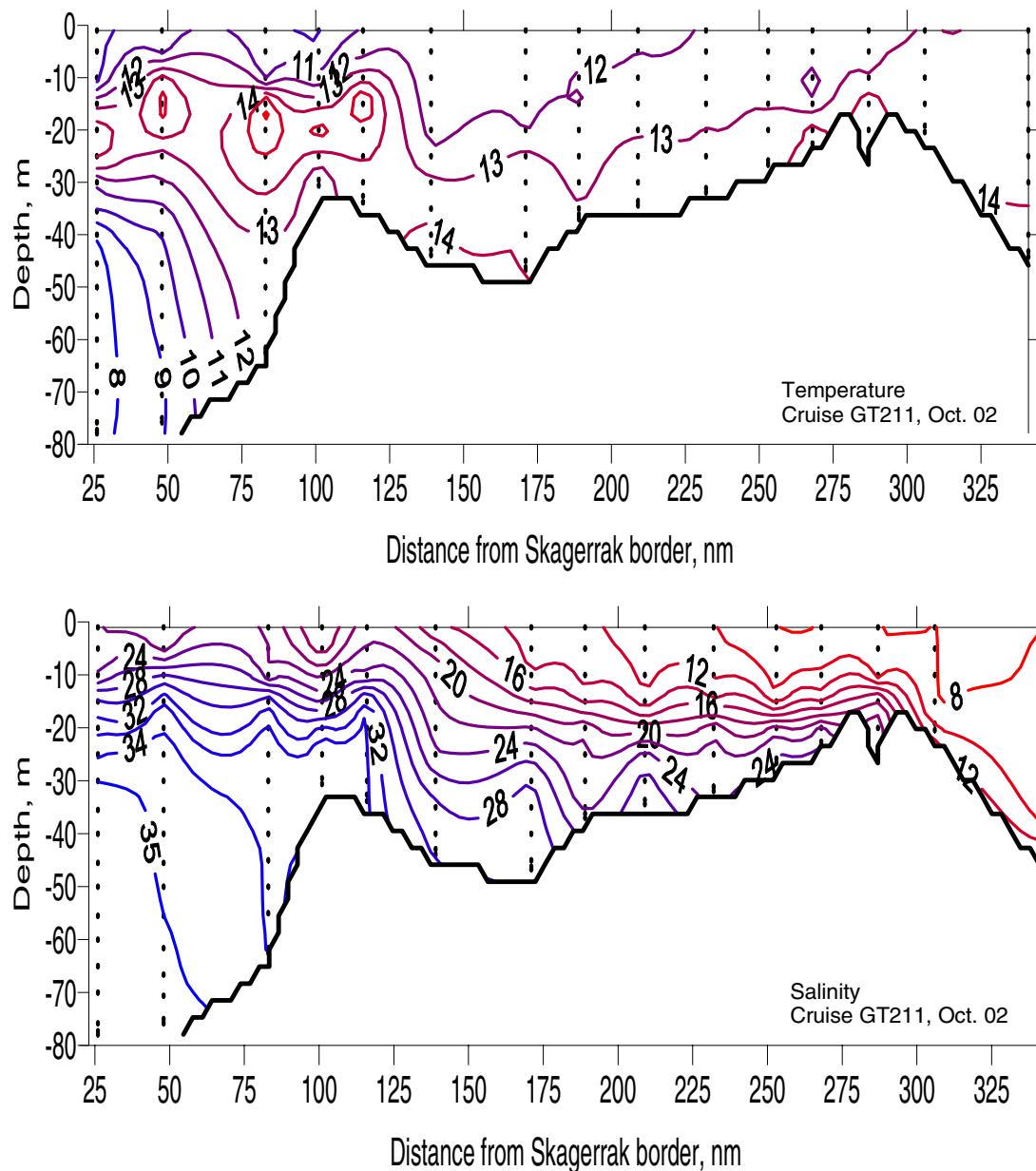


**Figure 2** Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2002 (connected points) compared to mean for the period 1994-2000 (thin line). Based on data from the Danish Meteorological Institute.

## Hydrography

The surface temperature (1 m depth) varied from 9.4-10.5°C in the Sound and the Kattegat to 13.1-13.4°C in the Arkona Sea (St. 441, 444, 449). The bottom water temperature ranged from 7.8-9.0°C in the north-eastern Kattegat (St. 905, 1001, 1007) to 14.0-14.2°C in the south-western Kattegat and northern Belt Sea (St. 415, 925, 935) and 15.0°C in the deep Arkona Sea (St. 444). In the Kattegat the highest temperatures were observed in an intermediate layer at 15-20 m depth (figure 3).

The surface salinity ranged from 7.7-8.3 in the Arkona Sea (St. 1728, 441, 444, 449), Mecklenburg Bight (954, M2) and Fehmarn Belt (952) to 22.2-24.8 in the northern and western Kattegat (St. 1001, 1007, 1008, 1009, 403, 409). The bottom water salinity ranged from 14.5 in the Arkona Sea (St. 444) to the unusually high values of 35.1-35.2 in the north-eastern Kattegat (St. 905, 1001, 1007) (figure 3). Thus high saline and cold water (North Atlantic water) had from the Skagerrak penetrated as bottom water into the north-eastern Kattegat. The salinity stratification was still unusually strong (10.0-21.8) in all areas (strongest in the Sound), except in the shallow Ålborg Bight (3.8) and the Arkona Sea (0.4-6.5).

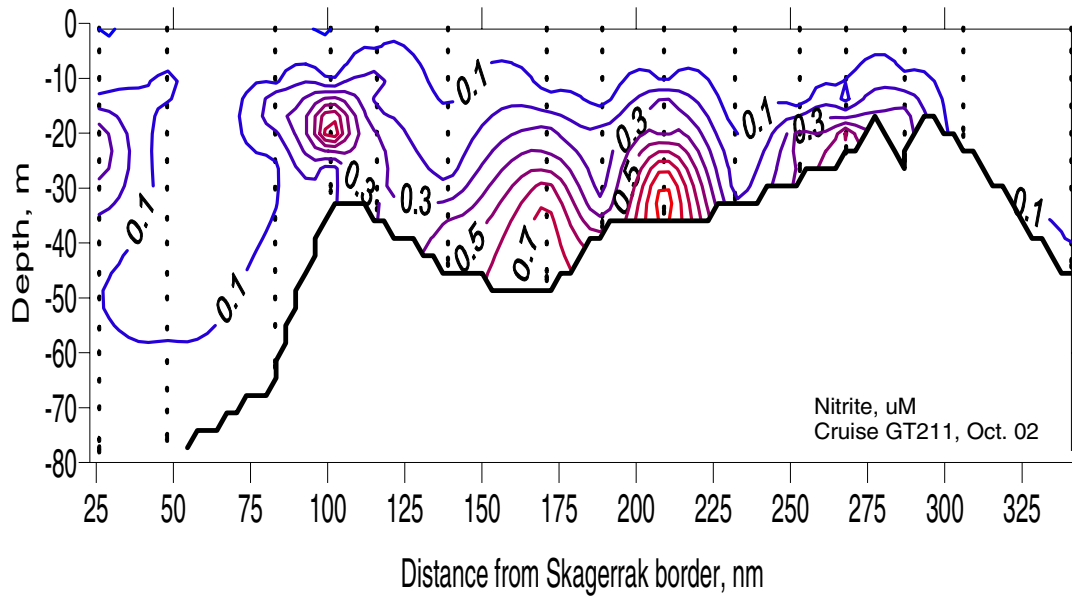


**Figure 3** Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

Compared to long-term monthly means (Lightship observations 1931-1960) for October the surface temperature was 1-2°C lower than normal in the Kattegat, but about normal in the Belt Sea. Also the bottom water temperature was lower than normal (1.3-1.7°C) in the northern and western Kattegat, but higher than normal (0.6-2.4°C) in the southern Kattegat and the Belt Sea. The surface water salinity during the present cruise was lower than normal in all areas. The bottom water salinity was 0.8-2.5 higher than normal in the northern and eastern Kattegat, but lower than normal in the Belt Sea, except at Gedser Rev (St. 954).

### Nutrients

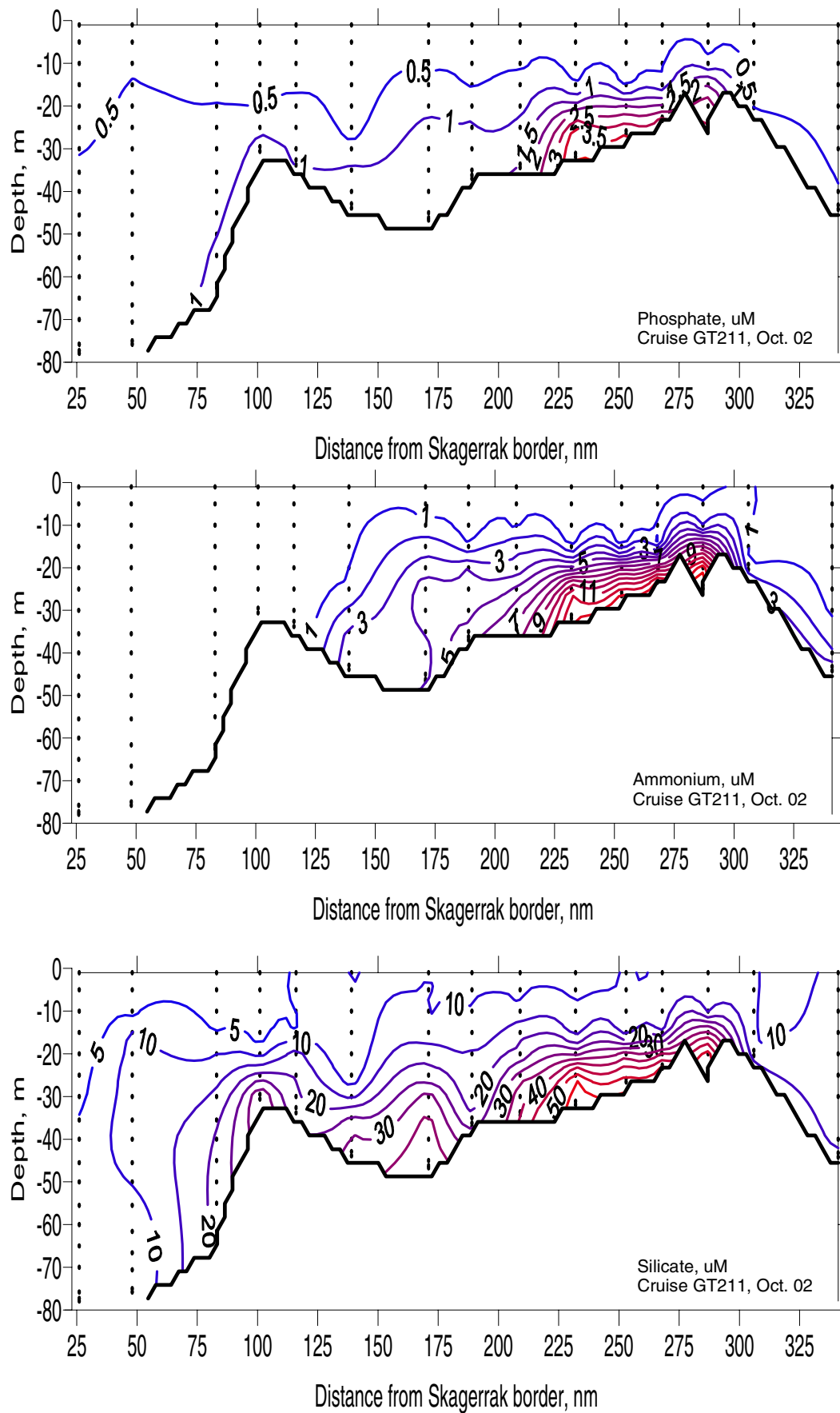
In the surface layer the concentrations of inorganic nitrogen nutrients were generally below 0.5  $\mu\text{mol/l}$  (figure 4). In the bottom water high nitrate concentrations (9.0-11.8  $\mu\text{mol/l}$ ) were observed in the North Atlantic water in the north-eastern Kattegat. The concentration was also high (9.0-15.3  $\mu\text{mol/l}$ ) in the old bottom water in the south-eastern Kattegat and the Sound (figure 4).



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

High nitrite concentrations ( $0.5\text{--}1.0\ \mu\text{mol/l}$ ) were observed at 15–20 m depth in the eastern Kattegat (St. 418) and in the bottom water in the Great Belt (St. 935, 939, 443) as well as in the Mecklenburg Bight (figure 4).

Phosphate and silicate were present in the surface water in all areas, lowest in the north-eastern Kattegat. In the bottom water extremely high concentrations of phosphate ( $3\text{--}4\ \mu\text{mol/l}$ ), ammonium ( $12\text{--}15\ \mu\text{mol/l}$ ) and silicate ( $50\text{--}57\ \mu\text{mol/l}$ ) were observed in the oxygen depleted bottom water in the southern Belt Sea (St. 450, 952, M2, 954) (figure 5). High concentration of silicate ( $>30\ \mu\text{mol/l}$ ) was also observed in the bottom water in the eastern Kattegat (St. 418), and in the Great Belt (figure 5).



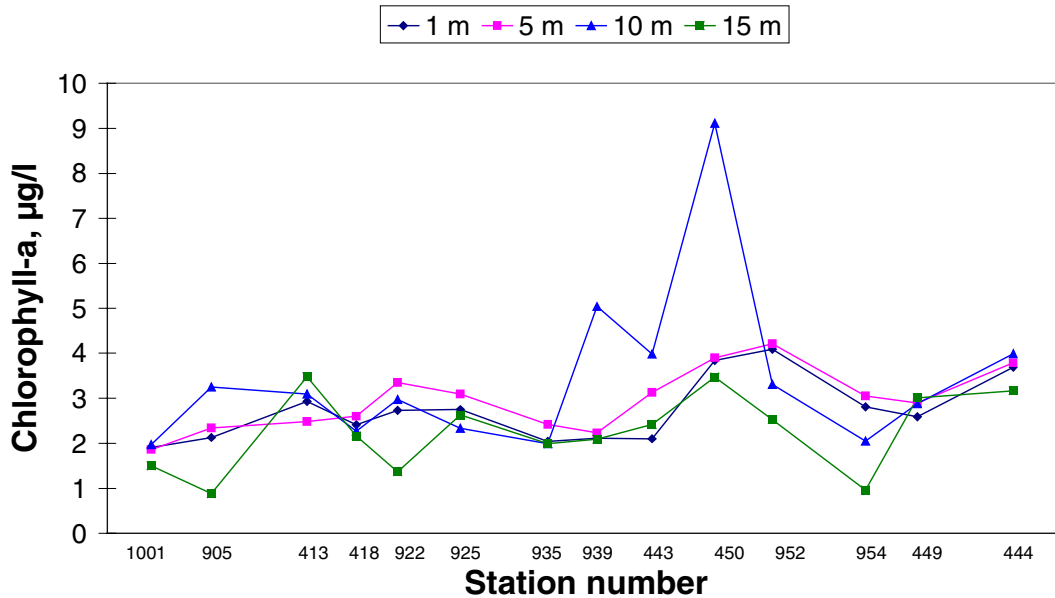
**Figure 5** Phosphate (top), ammonium (mid) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



### Chlorophyll-*a* and phytoplankton

The mean chlorophyll-*a* concentration in the uppermost 10 m was relatively low (1.2-3.9 µg/l) in most areas, somewhat higher in the western Kattegat (4.4-4.9 µg/l), and highest in the Kiel Bight (4.4-4.9 µg/l). The chlorophyll-*a* concentration was relatively homogeneously distributed in the uppermost 15 m, except for a subsurface maximum around 10 m depth in the Great Belt (*figure 6*).

### Transect: Kattegat NE - Belt Sea - Arkona Sea

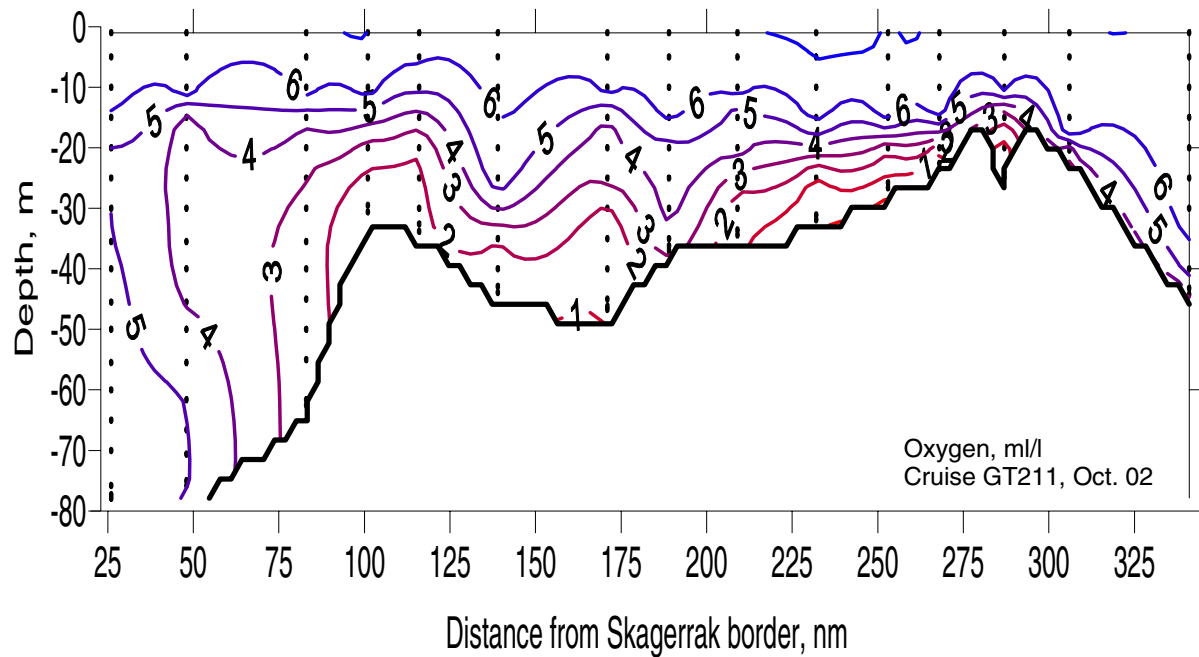


**Figure 6** Chlorophyll-*a* at 1 m, 5 m, 10 m and 15 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

In the Kattegat (St. 413) the phytoplankton was dominated by diatoms (*Coscinodiscus* sp., *Pseudo-nitzschia* spp., *Rhizosolenia setigera*, *Chaetoceros* spp., *Proboscia alata*), with some dinoflagellates also present (*Dinophysis* spp., *Ceratium tripos*). The high phytoplankton biomass in Kiel Bight (St. N3) was dominated by dinoflagellates (*Ceratium tripos*, *C. fusus*, *Dinophysis* spp.) and some centric diatoms. In the Mecklenburg Bight (St. M2) and the Arkona Sea (St. 444), the phytoplankton was dominated by large centric diatoms.

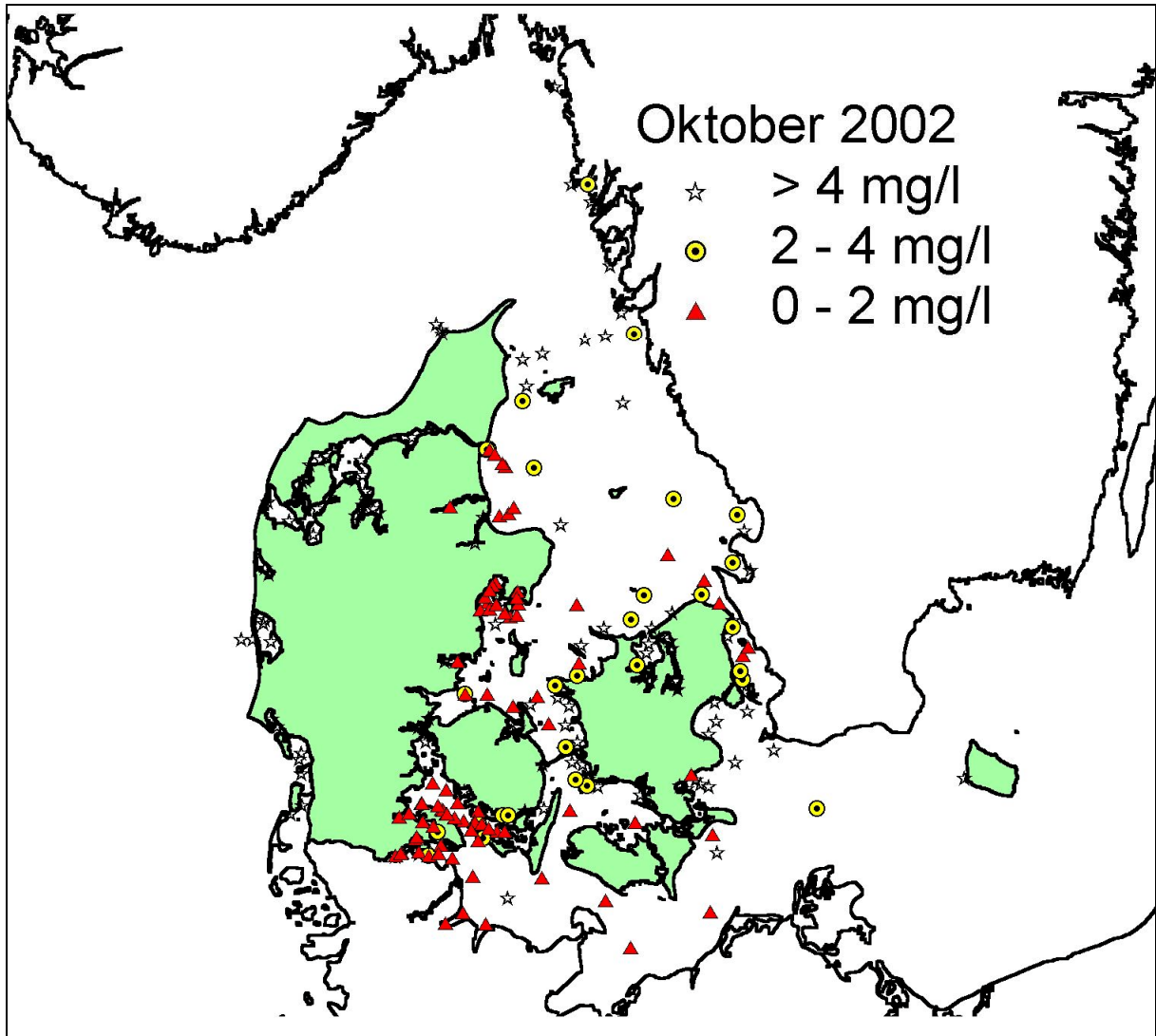
## Oxygen

Since the cruise in September, when the oxygen deficiency was widespread and the severity in the Belt Sea area the worst recorded, the minimum oxygen concentration has increased in most areas, except in the south-eastern Kattegat, the northern Belt Sea and the Fehmarn Belt. The lowest concentrations of 0.2-0.5 ml/l were found in the Fehmarn Belt and Mecklenburg Bight, including the Kadetrende in the Darss sill (St. 450, 952, M2, 954). Minimum oxygen concentrations of 1.1-1.8 ml/l were observed in the Sound, southern Kattegat and Great Belt (St. 431, 921, 922, 925, 935, 443) (figure 7). The highest minimum concentrations of 4.6-4.8 ml/l were found in the north-eastern Kattegat (St. 1001, 1007) in the North Atlantic water.



**Figure 7** Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the 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 observed in the Sound, south-eastern Kattegat, Great Belt, Fehmarn Belt, Mecklenburg Bight and the Kadetrende. Figure 8 shows the stations visited by Danish counties, NERI, SMHI and Swedish and German coastal authorities within the first three weeks of October 2002, and where oxygen depletion or severe oxygen depletion was observed.



**Figure 8** Stations visited by Danish counties, NERI, SMHI and Swedish and German coastal authorities within the first three weeks of October 2002, and where oxygen depletion (<4 mg/l) and severe oxygen depletion (<2 mg/l) was observed.