r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 234

Time: 6 - 16 February 2006

Area: The Sound, the Kattegat, the Skagerrak, the North Sea, 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 Skagerrak, the North Sea, the Belt Sea and the Arkona Sea, 6-16 February 2006 – Cruise no. 234

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Summary

The Jutland Coastal Current (JCC) with lower salinity and temperature and high nutrient concentrations, especially nitrate, was as usual evident but very narrow along the Danish North Sea and Skagerrak coasts. No significant inflow from the JCC to the Kattegat was observed at the cruise. Nitrite concentrations of 1.0-1.3 µmol/l found at 20-70 m depth in the northern Kattegat at high salinities (33.8-34.8) might originate from the more open North Sea.

Generally, in the Kattegat, the Sound and the Belt Sea the surface temperature and salinity were lower than long-term means, except in the central Great Belt, and the bottom water temperature and salinity were higher than-long term means in all areas. Thus, the stratification was unusually strong for the season. The hydrographic situation in the inner Danish waters indicated a relatively cold January, outflow from the Baltic Sea and low mixing of the water column due to unusually low wind activity.

In the North Sea the nutrient concentrations, except nitrite, as usual varied inversely to the salinity. Due to this the nutrient concentrations were generally highest in the south-eastern German Bight, nitrate up to 31 µmol/l, decreasing to the north to 10-11 µmol/l at Hanstholm, and to the west to less than 5 µmol/l in the central North Sea water. In the Kattegat and the Belt Sea the DIN concentration and partly also the phosphate and silicate concentrations in the surface water were low due to a very early phytoplankton spring bloom. Thus, the measured nutrient concentrations in the Kattegat and the Belt Sea do not represent the winter levels.

The phytoplankton spring bloom had not yet started in the North Sea, the Skagerrak, the Sound and the Arkona Sea. However, in most of the Kattegat and especially in the Belt Sea the spring bloom was well developed with surface chlorophyll concentrations of 5-22 µg/l. The counties of Fyn and Aarhus as well as SMHI have informed that *Chattonella* cf. *verruculosa* made up a large part of the spring bloom with cell concentrations up to 1.9 mill./l in the Great Belt, 4.3 mill./l in Odense Fjord, 4.98 mill./l in Aarhus Bight and >2 mill./l in the eastern Kattegat.

The minimum oxygen concentrations were about saturation level at all stations in the North Sea and most of the stations in the Skagerrak. However, in the Skagerrak a minimum of 85-87% saturation was observed at 200-300 m depth. In the Kattegat, the Sound and the Belt Sea the lowest oxygen concentration of 4.7 ml/l (71%) was found in the Sound. In the southern Kattegat and northern Belt Sea the minimum concentration was 5.2-5.8 m/l (78-87%). Compared to February last year, the minimum oxygen concentrations this year were generally lower, except in the northern 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 regional 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 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 (the Kattegat, the Skagerrak, the North Sea). The main scope of the cruise was to monitor the winter nutrient levels, but also the hydrography and the concentrations of oxygen and chlorophyll-*a*. The stations of the cruise are shown in *figure 1*. Also integrated phytoplankton and zooplankton samples were collected at 4 stations, and sediment was sampled for monitoring of macrozoobenthos (3 stations), contaminants (1 station), radioactivity (3 stations) and pigments (10 stations). The depth of the hydrogen sulphide front in the sediment was investigated at 12 stations in the southern Little Belt.

Meteorology

Characteristics of the weather conditions since November 2005 are given in *table 1*. The mean temperature during the winter 2005-2006 (December-February) was 0.7° C above normal, and the precipitation was 17% lower than normal. Especially, December and January were dry, while February was more wet than normal. The average wind force was about normal in December, while January and February were unusually calm. During the cruise northern gales prevailed on 8-10 February 2006.

Table 1 Deviations in monthly mean temperature and precipitation in December 2005 to February 2006 in Denmark compared to long-term monthly means 1961-90, monthly mean wind speed and dominating wind directions (based on data from the Danish Meteorological Institute).

Month	Temperature deviation °C	Precipitation % deviation	Mean wind speed m/s	Dominating wind direction
December 2005	+1.0	-26	5.3	W-NW
January 2006	-0.9	-42	4.5	E-SE-S
February 2006	+0.6	+36	4.2	Shifting

The North Sea and the Skagerrak

Hydrography

The Jutland Coastal Current (JCC) with lower salinity and temperature was evident but unusually narrow along the Danish North Sea coast. In the Skagerrak, JCC was only traceable at the stations nearest to the coast (1013, 1019). West of the JCC the surface salinity was 34.0-34.7 (St. 1024, 1071-1072, 1044-1045, 1054, 1062-1064, 1083-1085). At the North Sea - Skagerrak border the surface salinity was 35.0 at the station in the middle of the transect (St. 1131), but only 28.4-28.8 at the northernmost stations in the central Skagerrak (St. 1106, 1135). Along the coast no clear increasing trend in salinity from south to north was observed. The salinity at the coast-near stations varied from 30.3 to 32.7 (*figure 2*). The surface temperature ranged from 1.6-3.3° C at the coast-near stations to 5.8-6.0° C at the westernmost stations in the North Sea (St. 1045, 1064, 1071-1072) (*figure 3*).

Nutrients

In the North Sea the winter nutrient concentrations, except for nitrite, as usual varied inversely to the salinity (*figure 4*). The results of linear regressions are shown in *table 2*. All regressions, except for nitrite, are highly significant, indicating relatively well-mixed water masses in the eastern North Sea.

Table 2 Linear regression analyses of salinity and concentrations of nutrients at the 28 stations in the North Sea 9-11 February 2006. The intercept gives the estimated mean concentrations in fresh water entering the south-eastern North Sea. 34.5 psu gives the estimated concentrations in central North Sea water. Unit = µmol/l.

Nutrient	Slope	Intercept	34.5 psu	R^2
Nitrate	-6.19	215	1.53	0.85
Nitrite	0.54	-15.4	3.32	0.27
Ammonium	-1.17	40.3	0	0.89
DIN	-6.80	239	4.60	0.84
TN	-8.64	311	13.2	0.92
DIP	-0.22	7.88	0.41	0.87
TP	-0.39	14.1	0.66	0.62
Silicate	-4.70	166	4.27	0.89

Due to the relation to the salinity, the nutrient concentrations were highest in the south-eastern German Bight, decreasing to the north and west (*figures 5, 6 and 7*). In the Skagerrak 12.4-13.6 µmol DIN per litre was observed at Hirtshals and Hanstholm (St. 1013, 1019) (*figure 5*). The DIN/DIP ratio varied from 6.7-9.4 in the central North Sea water (St. 1024, 1064, 1071-1072) to 25-33 in the German Bight (St. 1080-1082) and 23 outside the Limfjorden (St. 1022) (*figure 8*).

Very high nitrite concentrations (>3 µmol/l) were observed in the German Bight at some distance from the coast and west of the JCC with the highest concentration of 4.1-4.2 µmol/l at the stations 1061 and 1082 (*figure 9*).

Oxygen and chlorophyll-*a*

The minimum oxygen concentrations were about saturation level at all the sampled stations both in the North Sea and the Skagerrak, except at the deepest Skagerrak station 1106. At this station the oxygen concentration in 200-300 m depth was 5.6-5.8 ml/l (84.7-86.9% saturation). At the bottom in 447 m depth the concentration was 6.4 ml/l (92%).

The mean chlorophyll-*a* concentration in the surface layer (0-10 m) varied from 0.7-0.9 µg/l at the westernmost stations in the German Bight (St. 1063-1064, 1082-1085) to 2.5-6.3 µg/l at the coast-near stations with the highest concentration at the northern transect in the North Sea (St. 1022) (*figure 10*). The relatively high chlorophyll-*a* concentration along the coast was probably due to resuspension of sediments during gales 8-10 February, and the phytoplankton spring bloom had not yet started in the North Sea and Skagerrak.

The Kattegat, the Sound, the Belt Sea and the Arkona Sea

Hydrography

The surface temperature (1 m depth) varied from 0.6-1.0° C in the Sound, southern Kattegat and Fehmarn Belt (St. 431, 921, 922, 925, 418, 413, 905, 952, 954, M2) to 2.2-3.3° C in the north-western Kattegat (St. 403, 1007, 1008, 1009) (*figure 3*). The bottom water temperature ranged from 1.9-2.1° C in the Arkona Sea (St. 441, 444, 449) to 8.3-8.7° C in the south-eastern Kattegat and the Sound (St. 431, 921, 922) (*figure 11a*).

The surface salinity ranged from 7.8-9.2 in the Arkona Sea and the Sound (St. 441, 444, 449, 1728, 431) to 26.9-31.8 in the northern Kattegat (St. 1007, 1008, 1009) (*figure 2*). The bottom water salinity at stratified stations ranged from 15.3-16.8 in the Arkona Sea (St. 441, 444, 449) to 34.1-34.8 in the northern and eastern Kattegat (St. 403, 418, 413, 905, 1001, 1007, 1008, 1009) (*figure 11b*). The salinity stratification was very strong for the season.

Compared to long-term monthly means (Lightship observations 1931-1960) for February, the surface temperature and salinity during the present cruise were lower than normal, except for higher than normal temperature and salinity in the surface water of the central Great Belt and Læsø Rende (St. 939, 403). The bottom water temperature and salinity was higher than long-term monthly means in all areas. The hydrographic situation indicated a relatively cold January, outflow from the Baltic Sea and relatively low mixing of the water column due to unusually low wind activity.

Nutrients

The surface DIN concentration was low (<5 µmol/l) in the Belt Sea and the Kattegat, and even zero in the surface of the central Great Belt, due to an ongoing very early phytoplankton spring bloom (*figure 5* and *13a*). In the bottom water the highest nitrate concentration of 8.8-9.1 µmol/l was observed in the Sound, southern Kattegat and northern Belt Sea (St. 431, 418, 922, 925, 935) (*figure 12a*). No significant inflow from the JCC to the Kattegat was observed at the cruise. Relatively high concentrations of nitrite (1.0-1.3 µmol/l) were observed at 20-70 m depth in the northern Kattegat (St. 905, 1001, 1007, 1009) at high salinities (33.8-34.8) and probably originated from the North Sea (*figure 12b*). The highest concentrations of ammonium (1.0-1.7 µmol/l) were observed in the surface layer (10-25 m depth) of the northern Kattegat (St. 905, 1001, 1002, 1005, 1007, 1008). Also at the bottom of the southern Little Belt and Kadetrenden at Gedser Rev ammonium concentrations of 1.1-1.2 µmol/l were found (St. 447, 954) (*figure 12c*). The total-N concentration varied from <15 µmol/l in the bottom water of the north-eastern Kattegat to >25 µmol/l in the whole water column in the Belt Sea.

Also the phosphate concentration was relatively low in the surface of the southern Kattegat and the Belt Sea with the lowest concentrations of 0.3-0.4 µmol/l in the central Great Belt (*figure 6* and *13b*). The highest phosphate concentrations (1.0-1.1 µmol/l) were observed at the bottom of the northern Belt Sea (*figure 13b*). The total-P concentration varied from <0.75 µmol/l in the northern Kattegat to 1.3 µmol/l at the bottom of the northern Belt Sea. The DIN/DIP ratio in the surface layer was in the Kattegat and Belt Sea very low due to the spring bloom, but in the bottom layer 8-13, highest in the northern Kattegat (*figure 8* and *13c*). However, in the Arkona Sea and the Sound it was as low as 3-4. The silicate concentration was 6-8 µmol/l in the surface of the Belt Sea and in the bottom water of the northern Kattegat, but 14-15 µmol/l in the Arkona Sea (*figures 7* and *14a*).

Chlorophyll-*a*

In the Kattegat and Belt Sea the phytoplankton spring bloom had already started. The mean chlorophyll concentration in the uppermost 10 m varied in the Belt Sea from 3.6 µg/l in the Fehmarn Belt (St. 952) to 22.3 µg/l in the central Great Belt (St. 939). In the Kattegat the concentration varied from 6-8 µg/l in the southern part to 2-3 µg/l in the northern part. In the Arkona Sea and the Sound the mean concentration in the uppermost 10 m was 1.0-1.6 µg/l (*figure 10* and *15*).

The counties of Fyn and Aarhus as well as SMHI have informed, that *Chattonella* cf. *verruculosa* made up a large part of the spring bloom with cell concentrations up to 1.9 mill./l in the Great Belt, 4.3 mill./l in Odense Fjord, 4.98 mill./l in Aarhus Bight and >2 mill./l in the eastern Kattegat.

Oxygen

The lowest oxygen concentrations of 4.68-4.75 ml/l (65-71% saturation) were observed in the Sound (St. 431) and Aalborg Bight (St. 409). In the southern Kattegat and northern Belt Sea the minimum concentration was 5.2-5.8 ml/l (78-87%) (St. 418, 921, 922, 925, 935, 939) (*figure 14b*). Compared to February last year, the minimum oxygen concentrations this year were generally lower, except in the northern Kattegat.

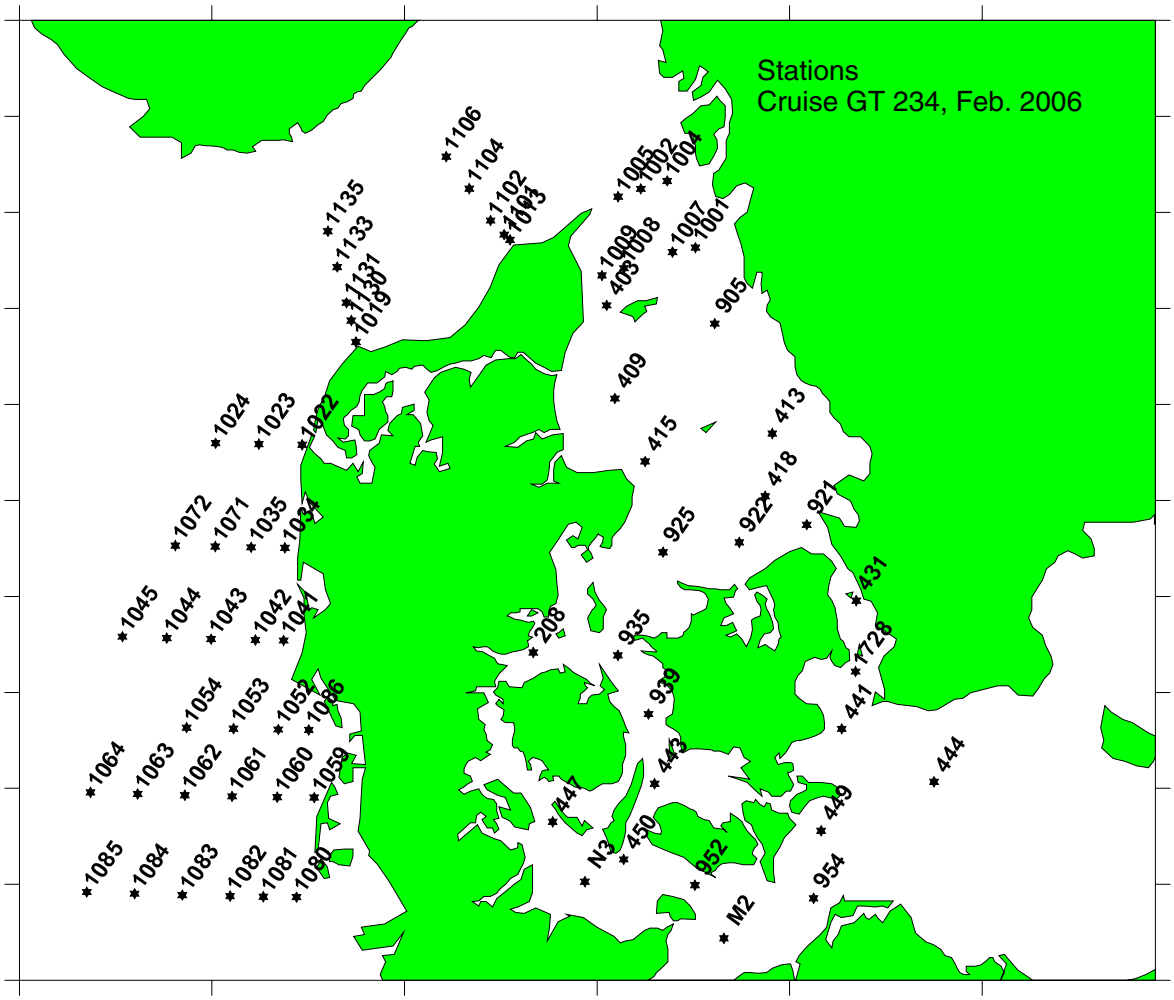

Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 6-16 February 2006 in the Sound, the Kattegat, the Skagerrak, the North Sea, the Belt Sea and the Arkona Sea. Gunnar Thorson cruise no. 234.

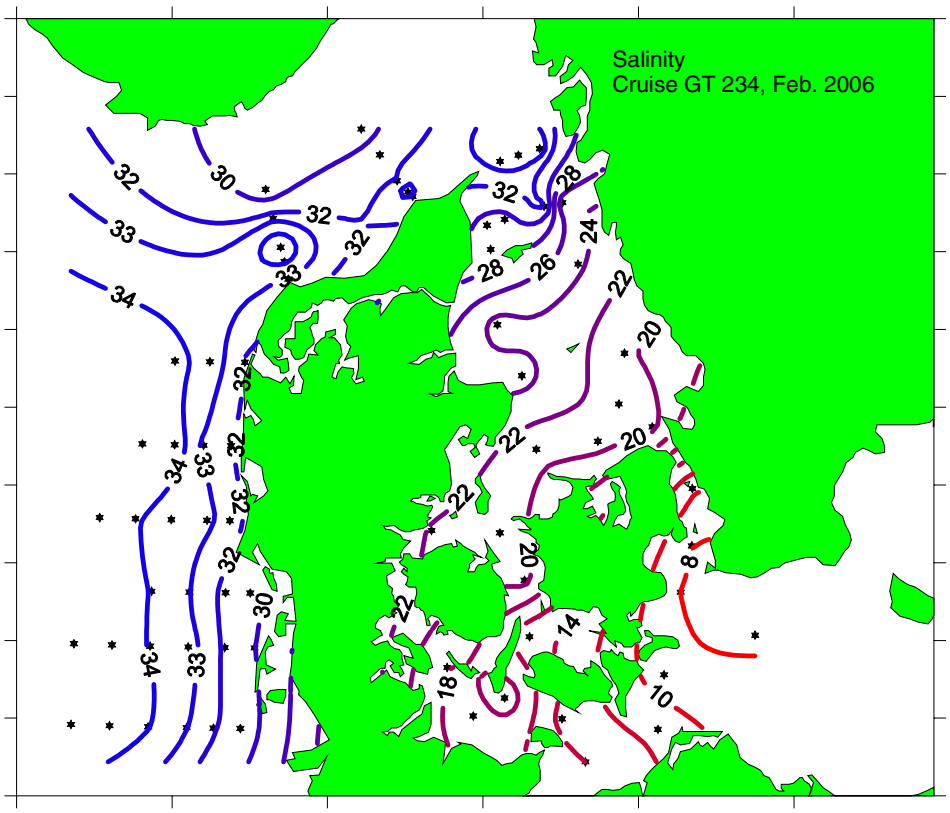

Figure 2 Interpolated distribution of surface salinity (mean 0-10 m depth).

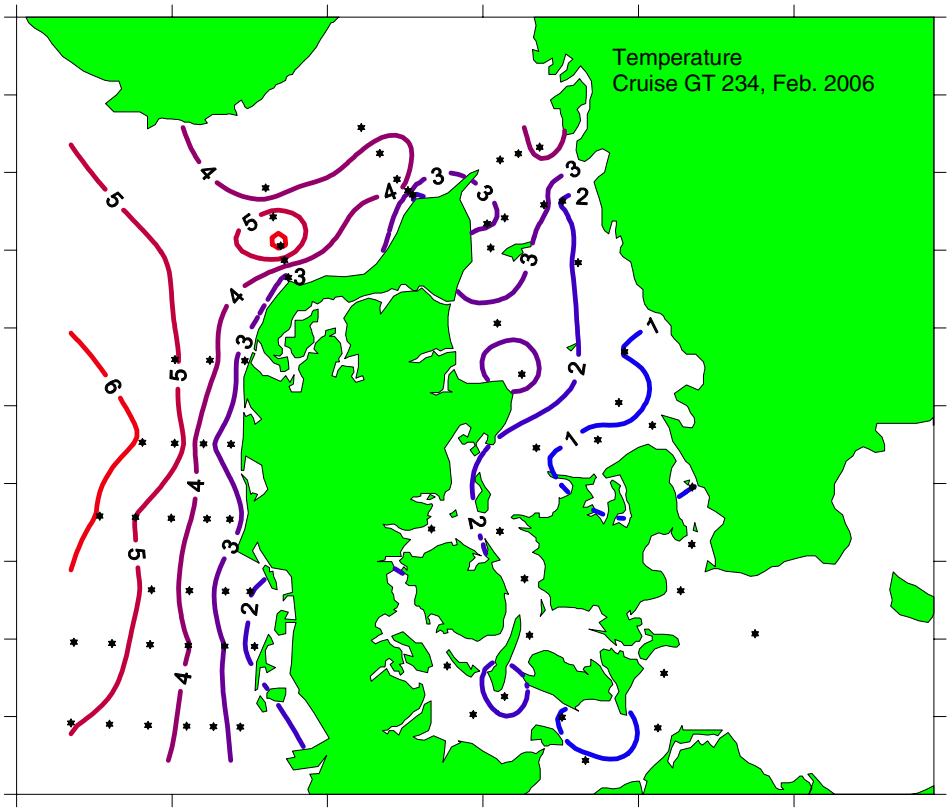

Figure 3 Interpolated distribution of surface temperature (mean 0-10 m depth).

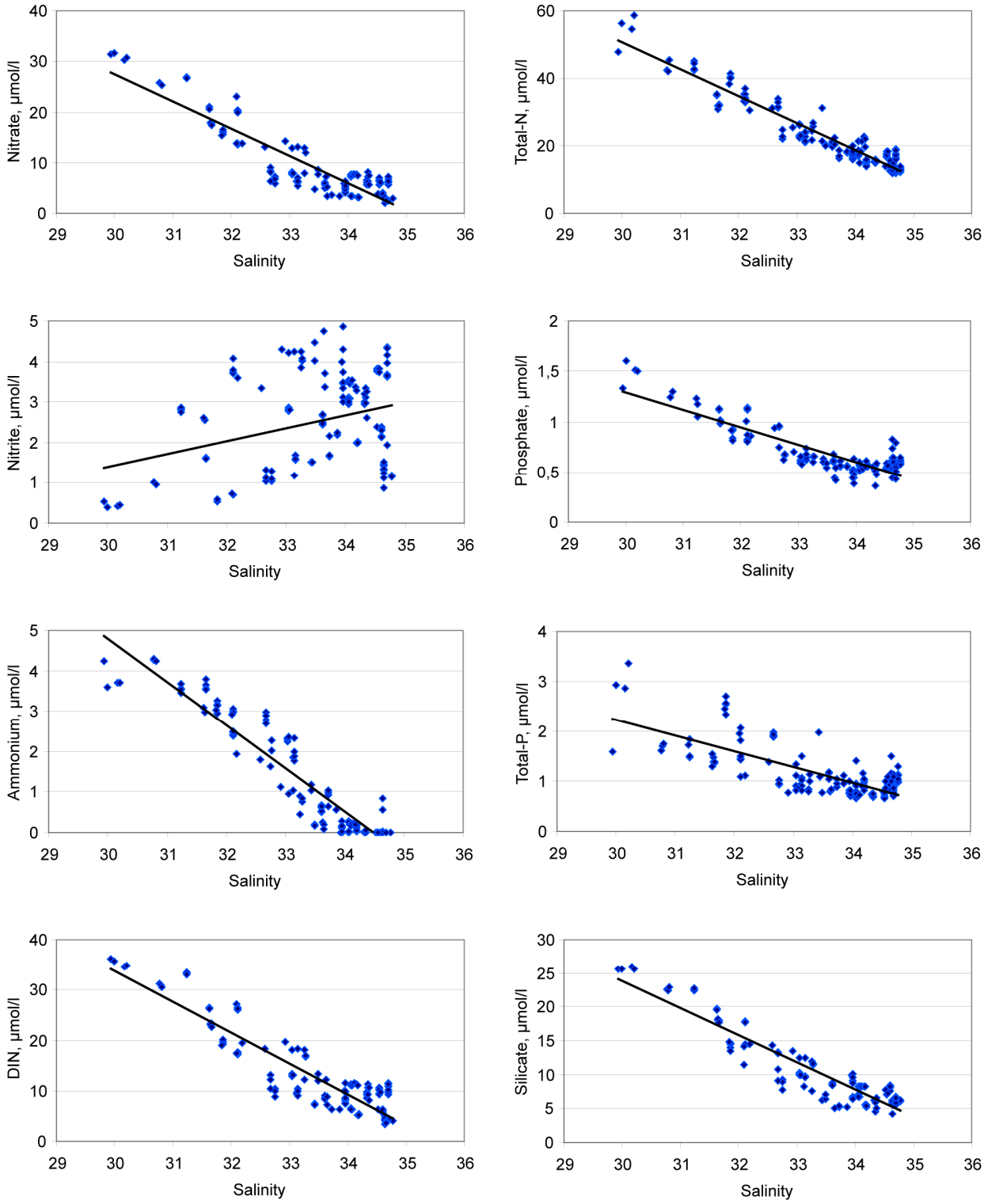

Figure 4 Correlations between salinity and nutrient concentrations at the 28 stations in the North Sea 9-11 February 2006.

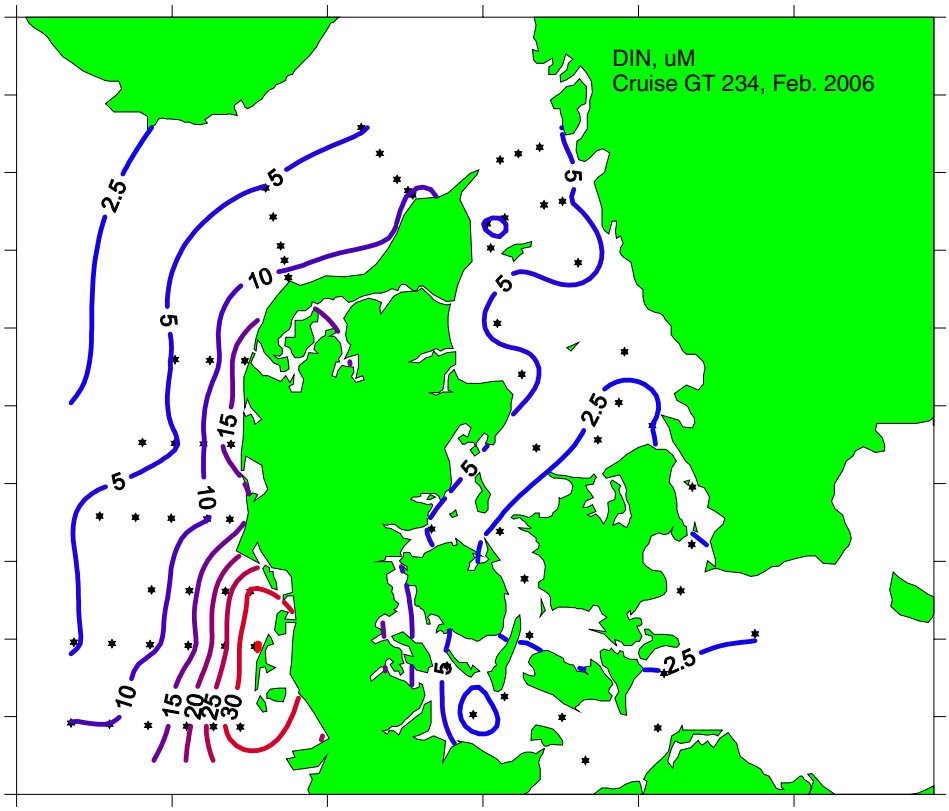

Figure 5 Interpolated distribution of surface DIN concentrations (mean 0-10 m depth).

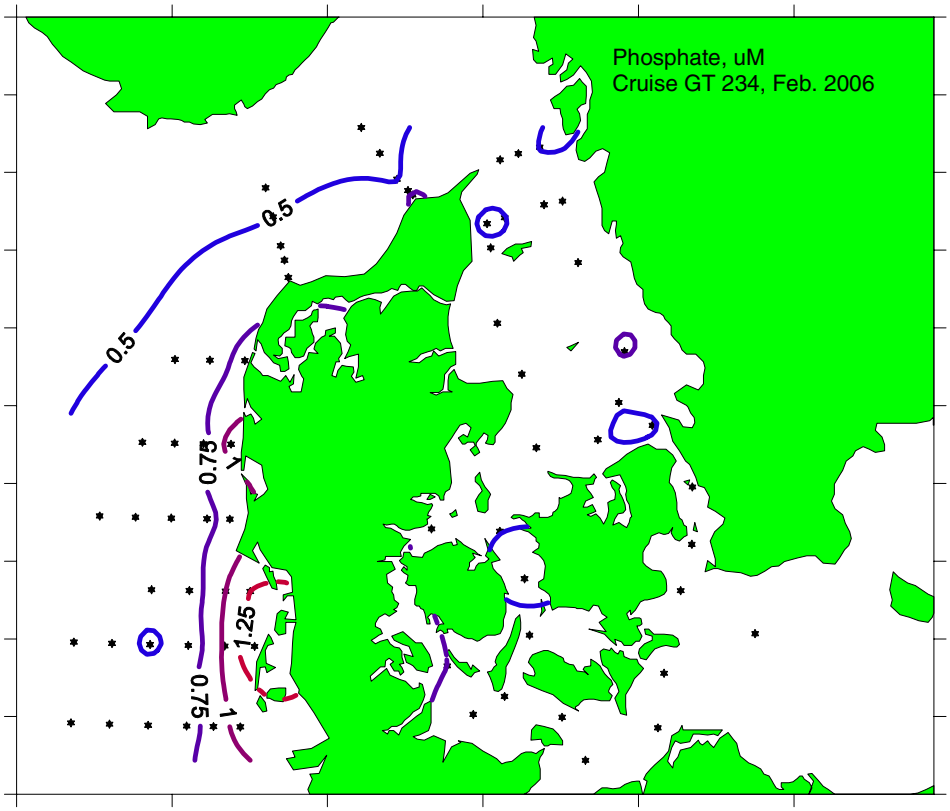

Figure 6 Interpolated distribution of surface phosphate concentrations (mean 0-10 m depth).

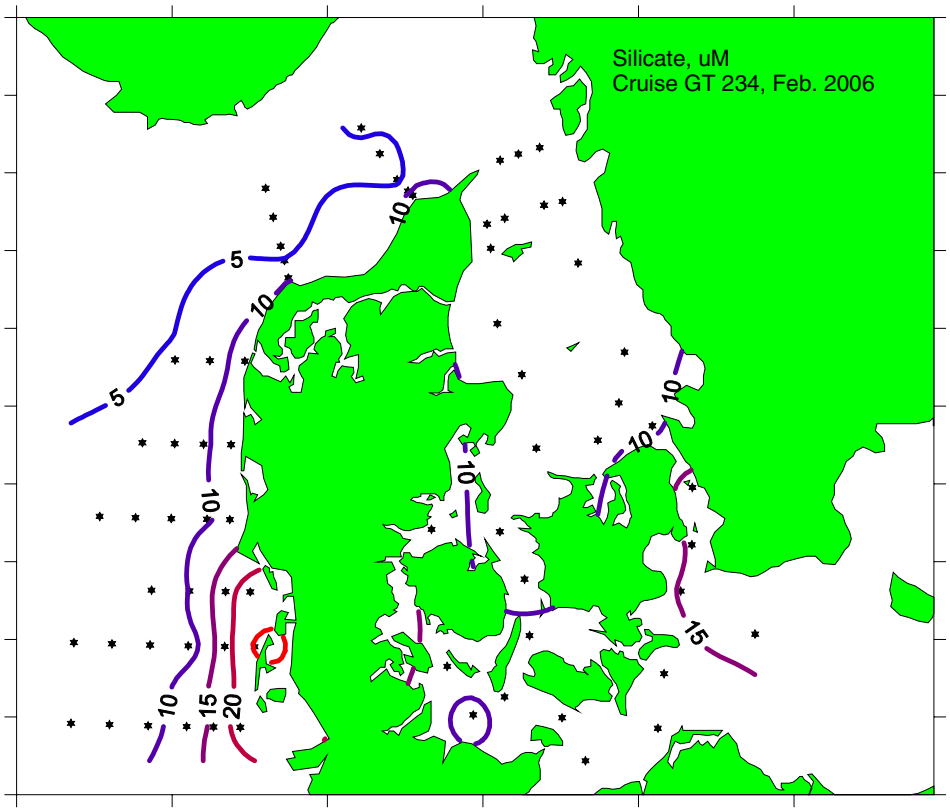

Figure 7 Interpolated distribution of surface silicate concentrations (mean 0-10 m depth).

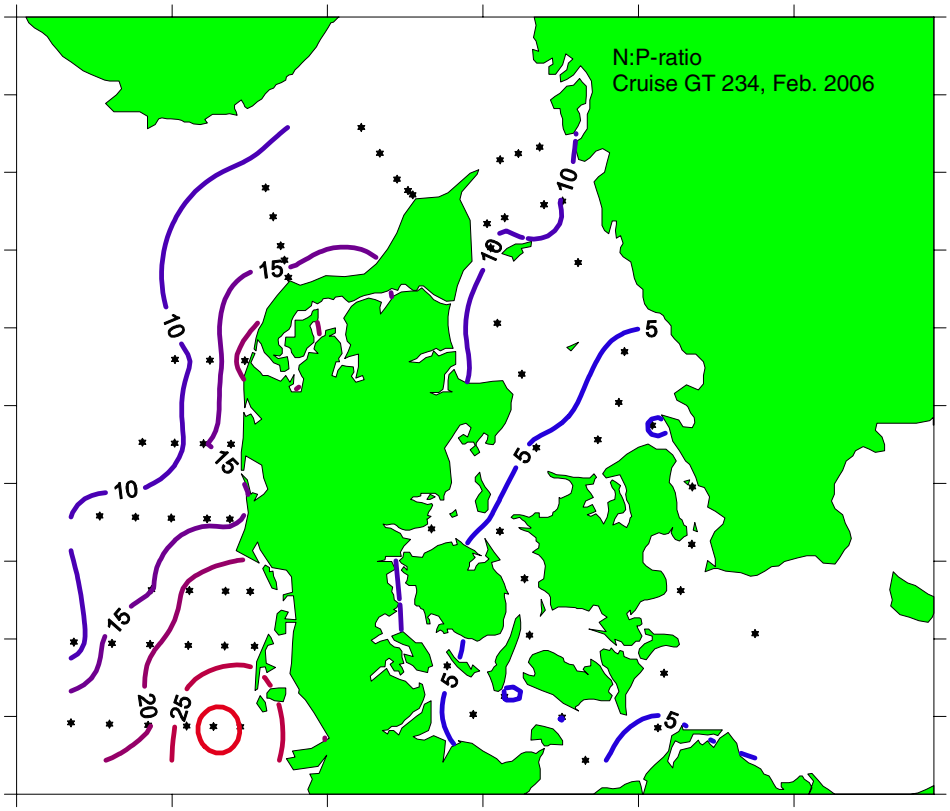

Figure 8 Interpolated distribution of surface DIN:DIP ratio (mean 0-10 m depth).

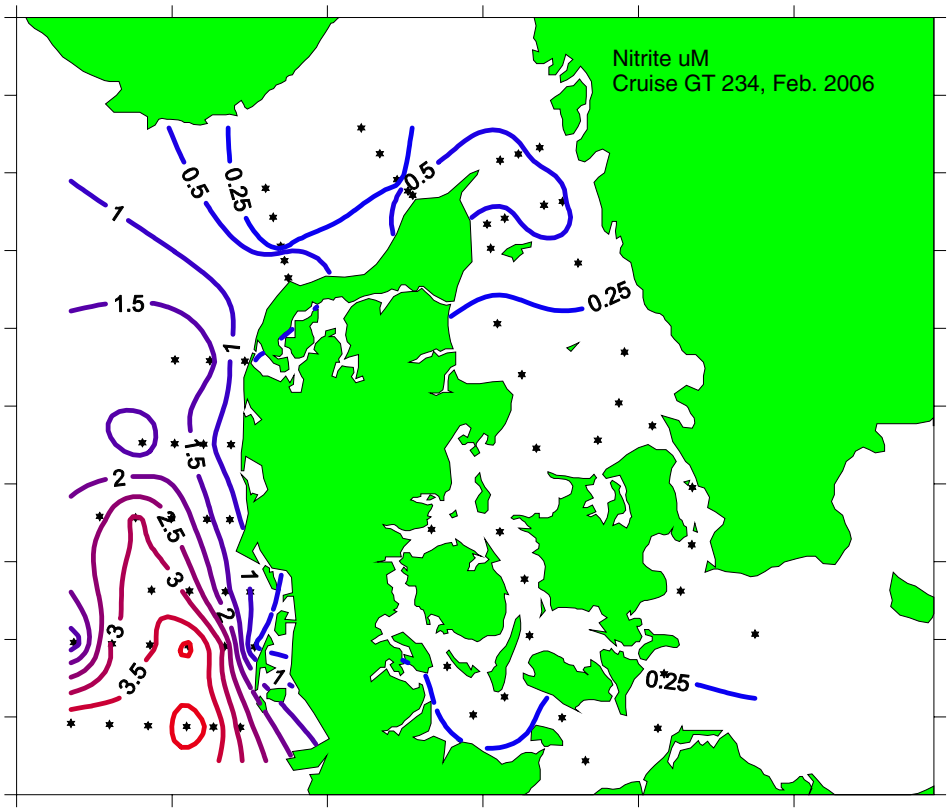

Figure 9 Interpolated distribution of surface nitrite concentrations (mean 0-10 m depth).

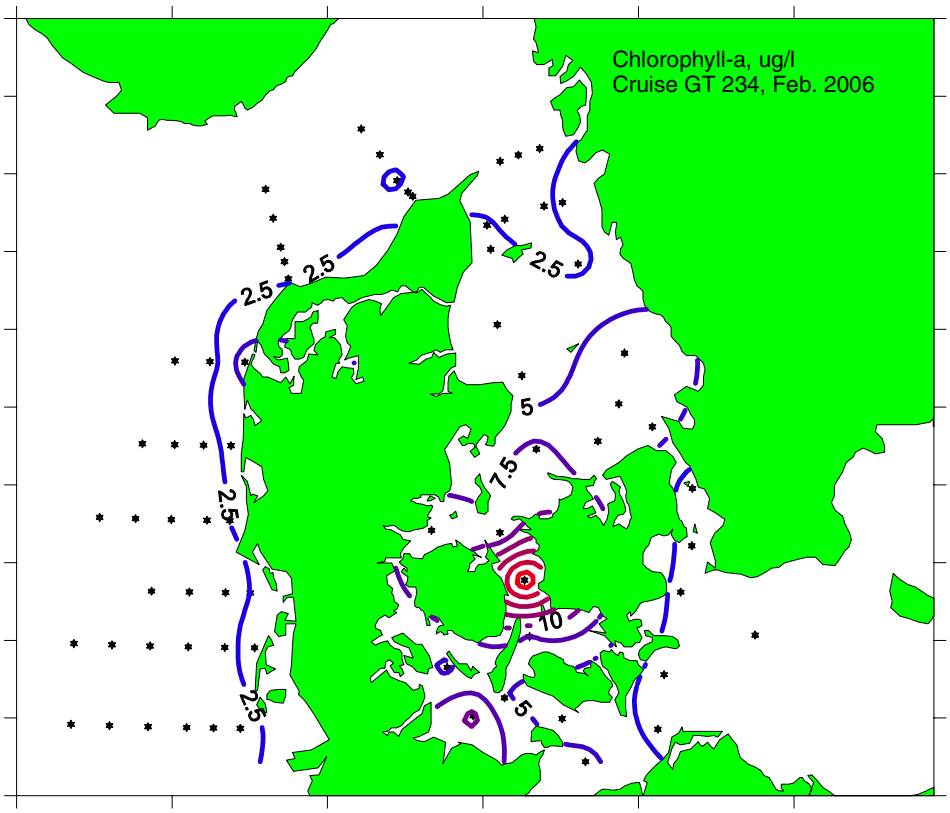

Figure 10 Interpolated distribution of surface chlorophyll-a concentrations (mean 0-10 m depth).

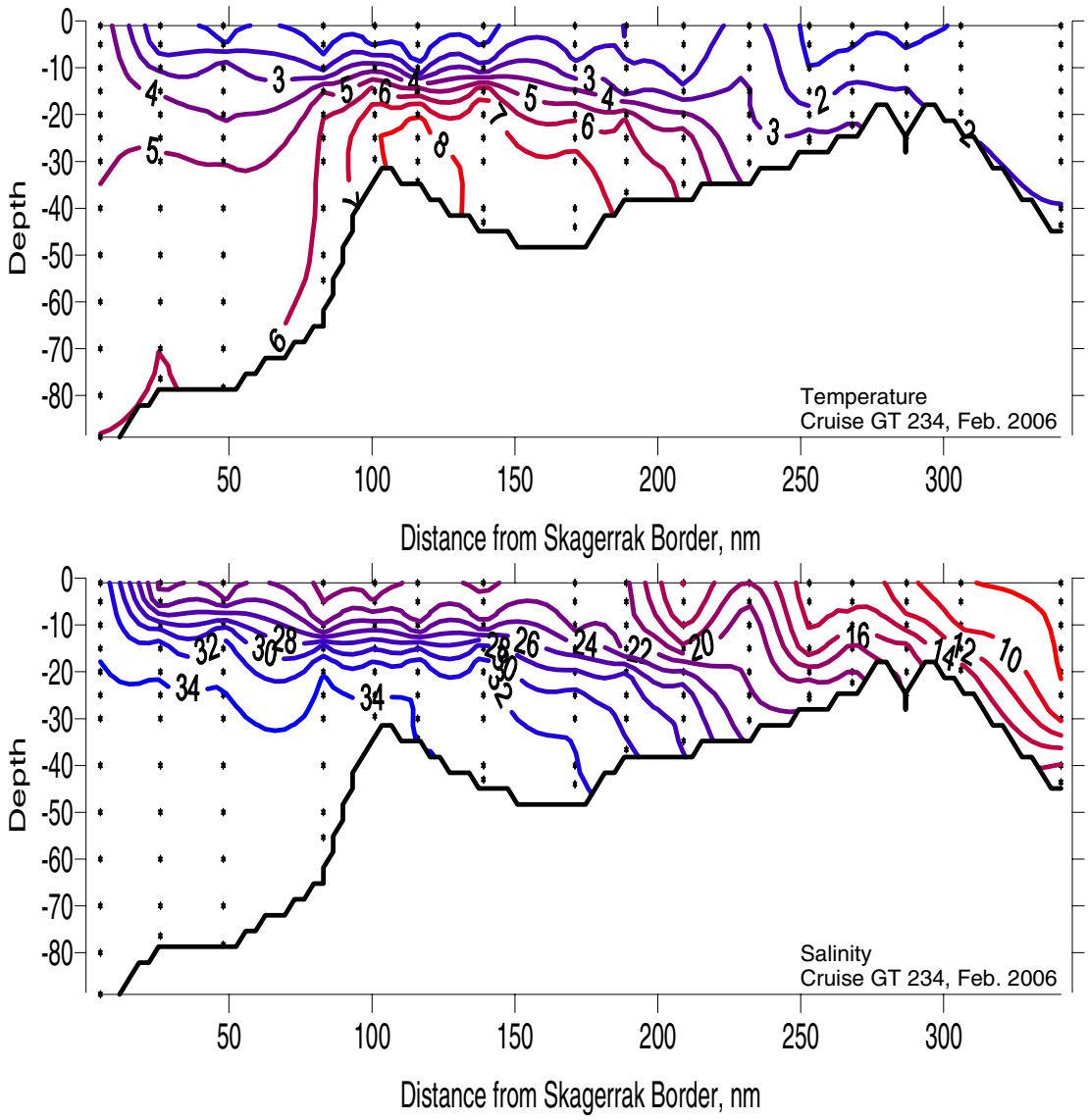

Figure 11 Temperature (top) and salinity (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

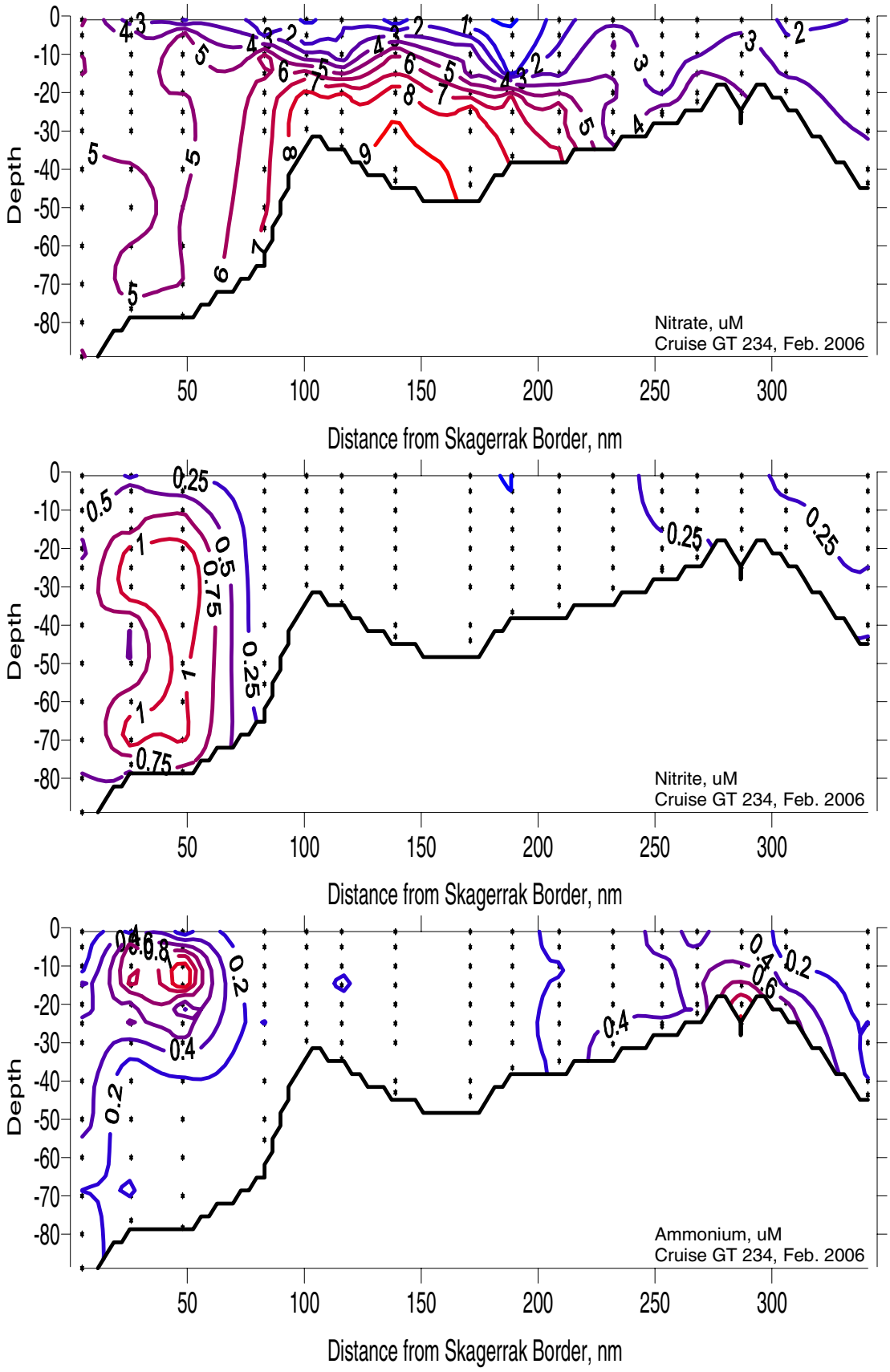

Figure 12 Nitrate (top), nitrite (mid) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

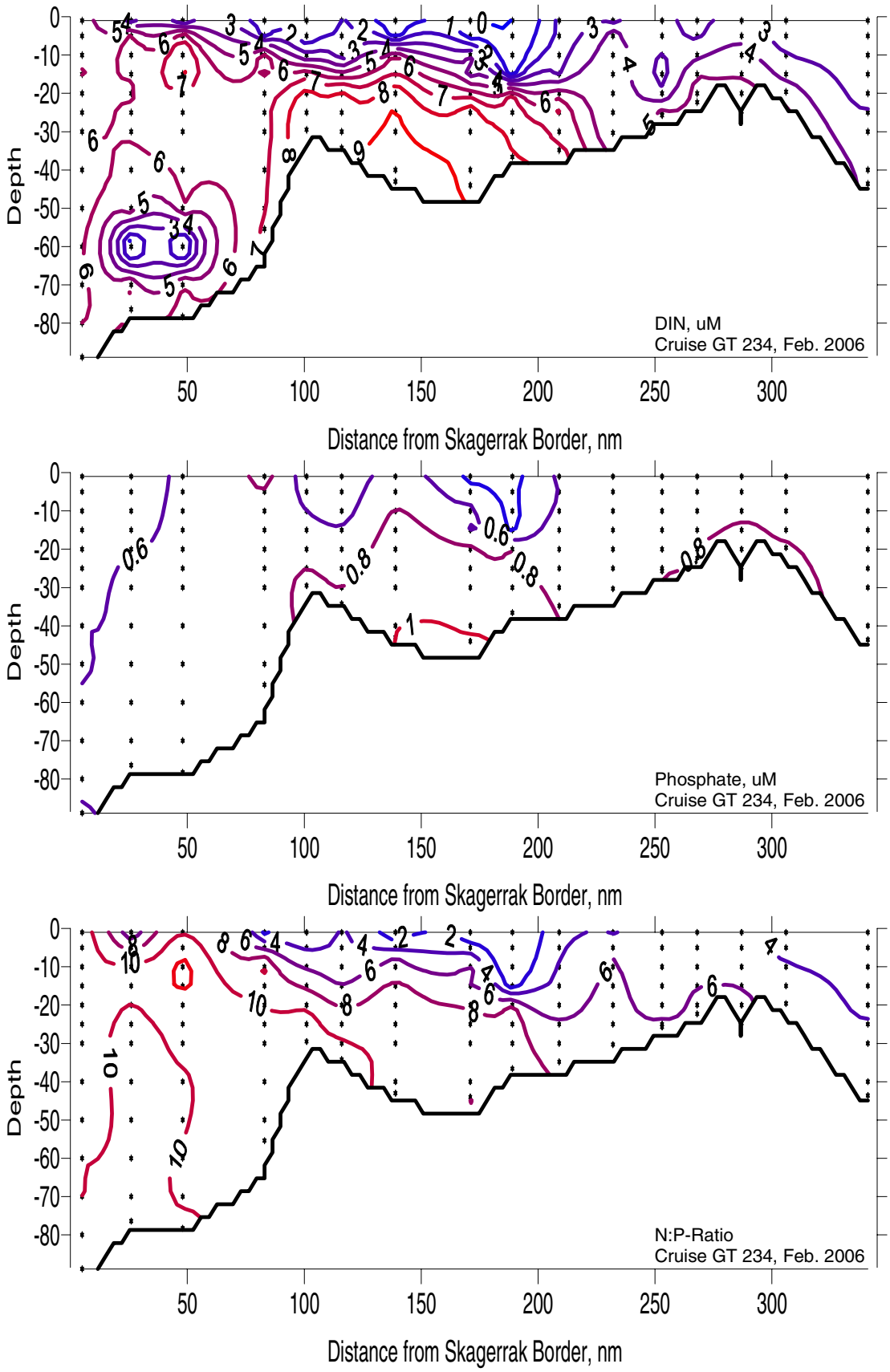

Figure 13 DIN (top), phosphate (mid) and DIN/DIP ratio (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

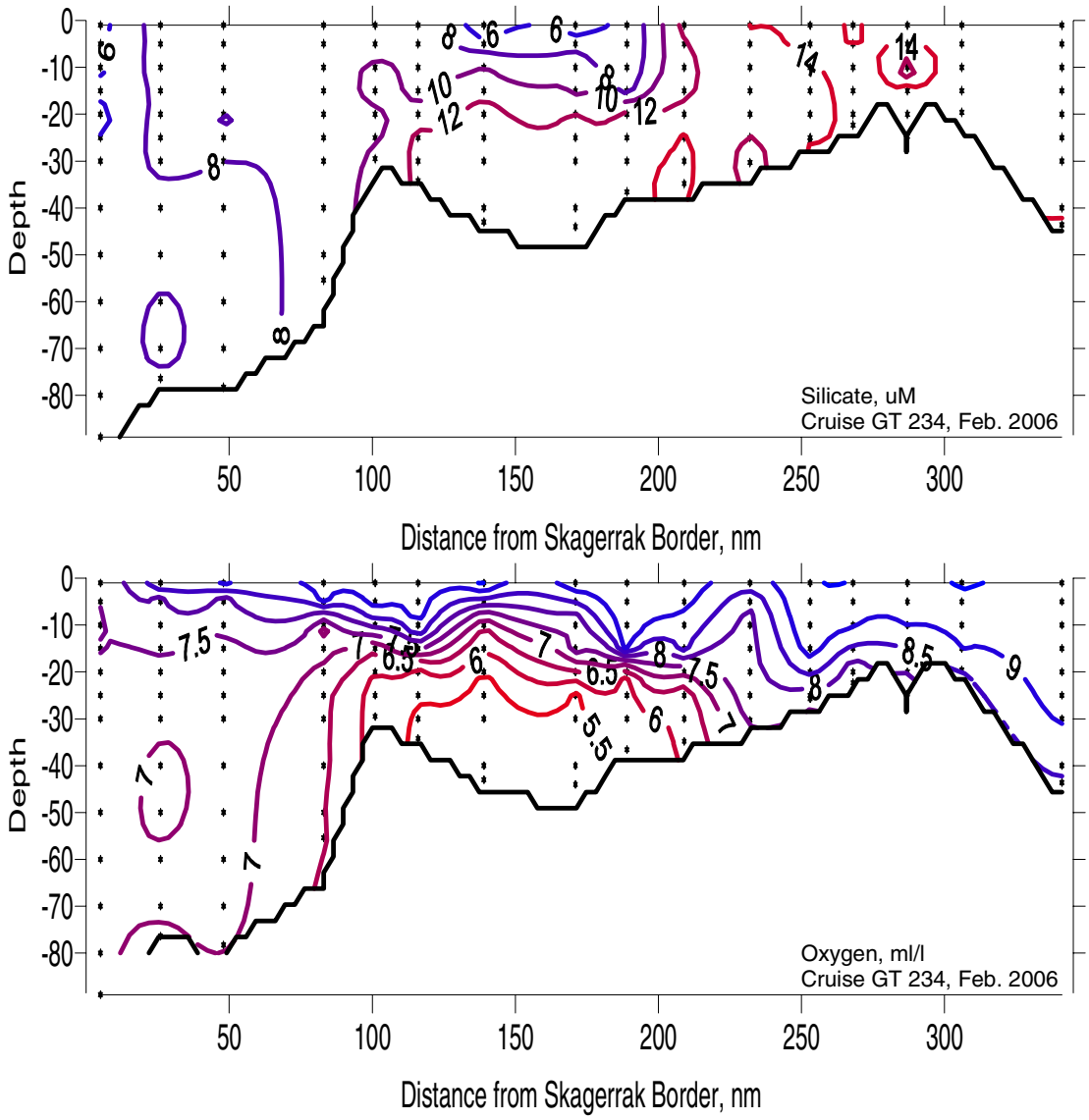

Figure 14 Silicate (top) and oxygen (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.

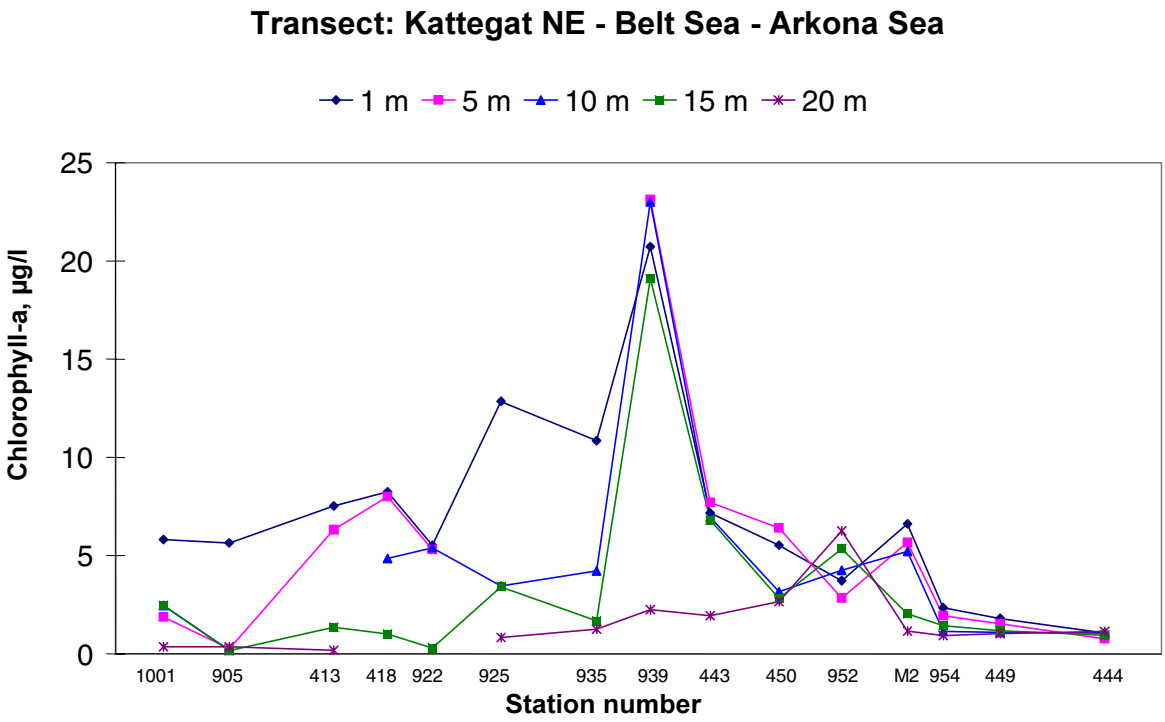

Figure 15 Chlorophyll-a at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.