r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 228

Time: 7 - 18 February 2005

Area: The Sound, the Kattegat, the Skagerrak, the North Sea, the Belt Sea and the Arkona Sea

Ministry of the Environment
National Environmental Research Institute
Frederiksborgvej 399
DK-4000 Roskilde
Denmark
Tel.: +45 4630 1200 ◇ Fax: +45 4630 1114
www.neri.dk

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, 7-18 February 2005 – Cruise no. 228

Report: Gunni Ærtebjerg

Cruise leader: Gunni Ærtebjerg/Kjeld Sauerberg

Participants:

- 7-18/2: Kjeld Sauerberg, Jan Damgaard, Dorete Jensen
- 7-14/2: Gunni Ærtebjerg, Lars Renvald, Peter Kofoed, Hanne Ferdinand
- 7-8/2: Thyge Dyrnesli, Danish Fishery Research Institute

Summary

The Jutland Coastal Current (JCC) with lower salinity and temperature and high nutrient concentrations, especially nitrate, was as usual evident but rather narrow along the Danish North Sea coast, but was not observed in the Skagerrak. DIN concentrations of 10-13.5 µmol/l found in some samples in the northern Kattegat at salinities of 32-33.9 were probably of local origin, or influenced by Atlantic deepwater, as the concentrations were much lower than at the same salinities in the JCC.

Generally, in the Kattegat, the Sound and the Belt Sea the temperature was above and the salinity below long-term means in the whole water column, and the stratification was relatively weak for the season, except in the Sound and northern Kattegat. The hydrographic situation witness on outflow from the Baltic Sea and relatively strong mixing of the water column in the Belt Sea.

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 57 µmol/l), decreasing to the north to 10 µmol/l at Hanstholm, and to the north-west to less than 5 µmol/l in the central North Sea water. In the Kattegat, the Sound, the Belt Sea and the Arkona Sea the DIN concentration was generally low, probably due to decreased washout from land, and the first signs of a beginning phytoplankton spring bloom. Phosphate and silicate concentrations were about normal.

The DIN/DIP ratio in the surface layer varied from 30-35 in the German Bight to less than10 at the north-western North Sea stations. In the Kattegat and the Belt Sea the DIN/DIP ratio varied from 7-9 in the southern Belt Sea to 15-20 in the northern Kattegat, but was as low as 4 in the Arkona Sea and the Sound.

The phytoplankton spring bloom had not yet started in the North Sea, the Skagerrak, the Sound and the Arkona Sea. However, signs of a beginning spring bloom were observed in parts of the Kattegat and the Belt Sea with surface chlorophyll concentrations of 2-3 µg/l.

The minimum oxygen concentrations were about saturation level at all stations in the North Sea and the Skagerrak. In the Kattegat, the Sound and the Belt Sea the lowest oxygen concentration of 6.6 ml/l was found in the eastern Kattegat. Compared to February last year, the minimum oxygen concentrations this year were generally higher and about normal for the season.

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 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 (12 stations).

Meteorology

Characteristics of the weather conditions since November 2004 are given in *table 1*. The winter 2004-2005 (December-February) was generally mild with a little more precipitation than normal. In spite of nearly normal temperature in February, the average winter temperature was 2.1°C above normal. Especially January was unusually warm. The precipitation was 10% above normal with the highest precipitation in December (70 mm), but showed the largest deviation from normal in February. The last half of December and 3 first weeks of January were dominated by rather strong wind from southwest and west. Two western storms past Denmark 8 January and 12 February, respectively.

Table 1 *Deviations in monthly mean temperature and precipitation in December 2004 to February 2005 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
Dec. 04	+2.5	+6	5.3	SW-W
Jan. 05	+3.6	+11	7.2	SW-W
Feb. 05	+0.2	+16	5.5	Changing

The North Sea and the Skagerrak

Hydrography

The Jutland Coastal Current (JCC) with lower salinity and temperature was as usual evident but rather narrow along the Danish North Sea coast, but was not observed in the Skagerrak. West of the JCC the surface salinity was 34.0-35.2 (St. 1023-1025, 1071-1074, 1035, 1043-1046, 1054-1056, 1063-1064, 1084-1085), highest at the north-western stations. At the North Sea – Skagerrak border the surface salinity was 34.2-35.0 (St. 1019, 1130-1133). Along the coast the salinity increased from 29.0-30.7 in the German Bight (St. 1059, 1080) to 33.6 at Thyborøn (St. 1022) and 34.2 at Hanstholm (St. 1019) (*figure 2*). The surface temperature ranged from 3.0-3.3°C at the coast-near stations in the German Bight (St. 1059, 1080, 1086) to 6.2-6.4°C at the westernmost stations in the North Sea (St. 1045-1046, 1056) (*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 33 stations in the North Sea 9-11 February 2005. 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	-8.12	289	8.24	0.96
Nitrite	-0.10	3.86	0.33	0.06
Ammonium	-0.28	9.62	0.11	0.60
DIN	-8.50	302	8.67	0.97
TN	-10.4	378	19.6	0.91
DIP	-0.17	6.48	0.59	0.68
TP	-0.62	22.1	0.80	0.65
Silicate	-4.64	165	5.08	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, 7 and 8*). In the Skagerrak about 10 µmol/l nitrate was observed at Hanstholm (St. 1019) and 7.8 µmol/l at Hirtshals (St. 1013) (*figure 5*).

The DIN/DIP ratio varied from 5.5-15 in the central North Sea water to 25-38 at the stations in the JCC (*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.

The mean chlorophyll-*a* concentration in the surface layer (0-10 m) varied from 0.4-0.7 µg/l at the westernmost stations in the North Sea (St. 1023, 1071-1073, 1045-1046, 1055-1056, 1064) to 3.0-7.0 µg/l at the coast-near stations in the German Bight (St. 1059, 1080-1081, 1086) (*figure 10*). The phytoplankton spring bloom had not yet started.

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

Hydrography

The surface temperature (1 m depth) varied from 2.0°C in the Fehmarn Belt (St. 952) to 3.0-3.3°C in the western Kattegat (St. 409, 403, 1009) (*figure 3*). The bottom water temperature ranged from 2.4-2.8°C in the central Great Belt (St. 443, 939) to 7.2°C in the eastern Kattegat (St. 905) (*figure 11a*).

The surface salinity was the same in the Arkona Sea and the Sound due to outflow from the Baltic, and ranged from 8.3-8.6 in these areas (St. 441, 444, 1728, 431) to 28.4-29.2 in the north-western Kattegat (St. 1008, 1009) (*figure 2*). The bottom water salinity at stratified stations ranged from 16.8 at Gedser Rev (St. 954) and as high as 18.4 in the deep Arkona Basin (St. 444) to 34.1-34.8 in the northern Kattegat (St. 403, 905, 1001, 1007, 1008, 1009) (*figure 11b*). The salinity stratification was relatively weak for the season, except in the Sound and northern Kattegat.

Compared to long-term monthly means (Lightship observations 1931-1960) for February, the temperature during the present cruise was higher than normal in the whole water column, except for 0.5°C lower temperature than normal in the bottom water of the northern Belt Sea (St. 925- 939). Generally the salinity was lower than normal in the whole water column, except for higher than normal bottom water salinity in the northern Kattegat.

The hydrographic situation witness on outflow from the Baltic Sea and relatively strong mixing of the water column in the Belt Sea.

Nutrients

Relatively high DIN concentrations of 10.0-13.5 µmol/l were observed in the northern Kattegat and east of Anholt (St. 413, 1002, 1004, 1005, 1007-1009), but not at the stations east and west of Læsø (St. 403, 905, 1001). East of Skagen (St. 1005) 10.2-10.8 µmol/l were found in the surface at salinities of 33.1-33.5. Further east and south (St. 1002, 1008-1009) 10.0-13.1 µmol/l were observed in 15-20 m depth at salinities of 32.8-33.9. Northeast of Læsø (St. 1007) 10.9 µmol/l occurred at 30 m depth at a salinity of 32. East of Anholt (St. 413) 10.9-12.0 µmol/l occurred in the bottom water (40-55 m depth) at salinities of 32.0-32.3. Finally, outside Marstrand (St. 1004) 11.0 and 10.5 µmol/l were observed at 25 m and 40 m depth, respectively, at salinities of 31.8 and 33.8. All these samples might be influenced by earlier inflows from the JCC. However, the samples do not fit the DIN-salinity correlation found in the North Sea during the cruise, but have much lower DIN concentrations than seen at the same salinities in the JCC. Therefore, the enhanced DIN concentrations might stem from local loads, as DIN concentrations of 10.9-13.2 observed in the surface at some stations (St. 1002, 1004, 1008) at salinities of 29.2-31.0, or influenced by Atlantic deepwater. Thus, no significant inflow from the JCC to the Kattegat was observed at the cruise. With the exception of the samples mentioned above, the nitrate and DIN concentrations were relatively low in the Kattegat, the Sound, the Belt Sea and the Arkona Sea (*figure 5*, *6*, *12a* and *13a*). The relatively low surface nitrate concentration might partly be due to a decreased washout of nitrate from land, and in some areas partly due to a beginning phytoplankton spring bloom.

The highest concentrations of nitrite (>0.4 µmol/l) and ammonium (>1 µmol/l) were found in the southern Belt Sea (*figure 12b* and *12c*). The phosphate concentration was about normal with the highest concentrations (>1.0 µmol/l) in the bottom water of the south-western Kattegat (St. 925) (*figure 7* and *13b*). The DIN/DIP ratio in the surface layer was in the Kattegat and Belt Sea rather close to the Redfield ratio for phytoplankton uptake, as it varied from about 7-9 in the southern Belt Sea to 15-20 in the northern Kattegat (*figure 9* and *13c*). However, in the Arkona Sea and the Sound it was as low as 4. The concentration of silicate was highest (>14 µmol/l) in the Arkona Sea bottom water (*figures 8* and *14a*).

Chlorophyll-*a*

The phytoplankton spring bloom was about to start in parts of the Belt Sea and Kattegat. The mean chlorophyll concentration in the uppermost 10 m varied from 2.9 µg/l in the eastern Kattegat (St. 905) to 0.6 µg/l at Kullen (St. 921). Concentrations above 2 µg/l were observed in the north-western Kattegat (St. 403, 1009), the eastern Kattgat (St. 413, 418, 905), the northern Great Belt (St. 925, 935), the Kiel Bight (St. N3) and the Mecklenburg Bight (St. M2) (*figure 10* and *15*).

Oxygen

The lowest oxygen concentration of 6.6 ml/l (95-97% saturation) was observed in the eastern Kattegat (St. 413, 905) (*figure 14b*). Compared to February last year, the minimum oxygen concentrations this year were generally higher and about normal for the season.

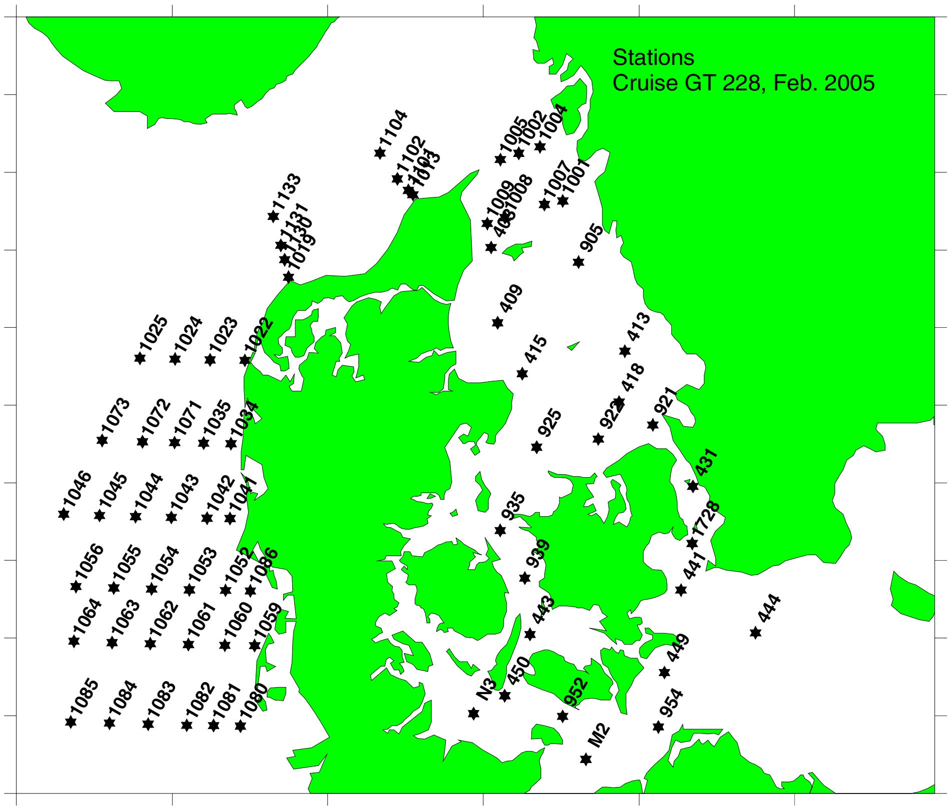

Figure 1 *Stations of the monitoring cruise with r/v Gunnar Thorson 7-18 February 2005 in the Sound, the Kattegat, the Skagerrak, the North Sea, the Belt Sea and the Arkona Sea. Gunnar Thorson cruise no. 228.*

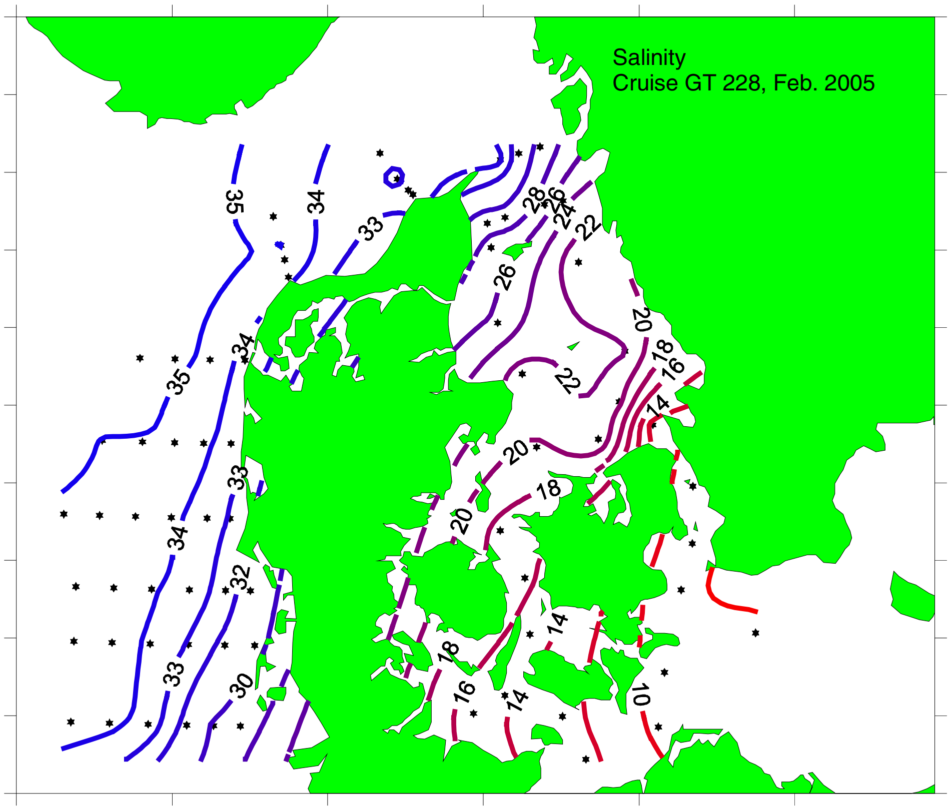

Figure 2 *Interpolated distribution of surface salinity (mean 0-10 m depth).*
Note: The lines in the Little Belt area are interpolation artefacts. There are no stations.

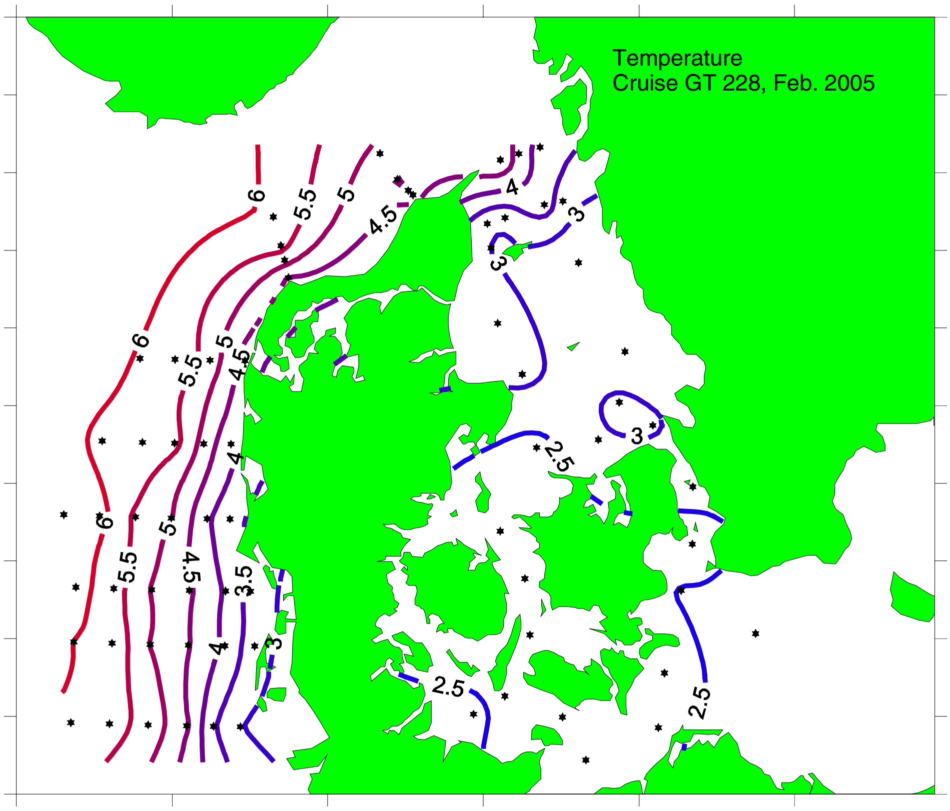

Figure 3 *Interpolated distribution of surface temperature (mean 0-10 m depth).*

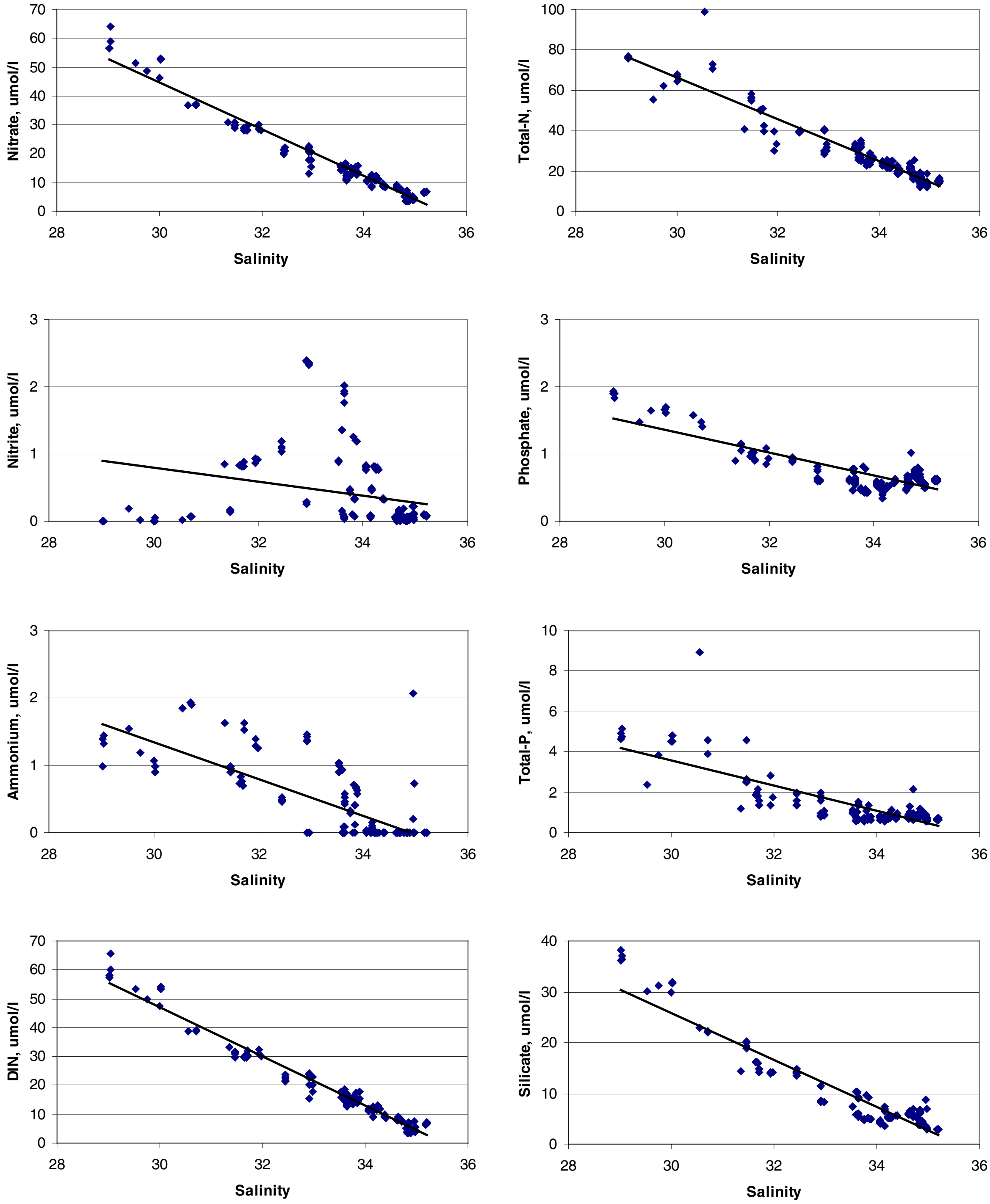

Figure 4 *Correlations between salinity and nutrient concentrations at the 33 stations in the North Sea 9-11 February 2005.*

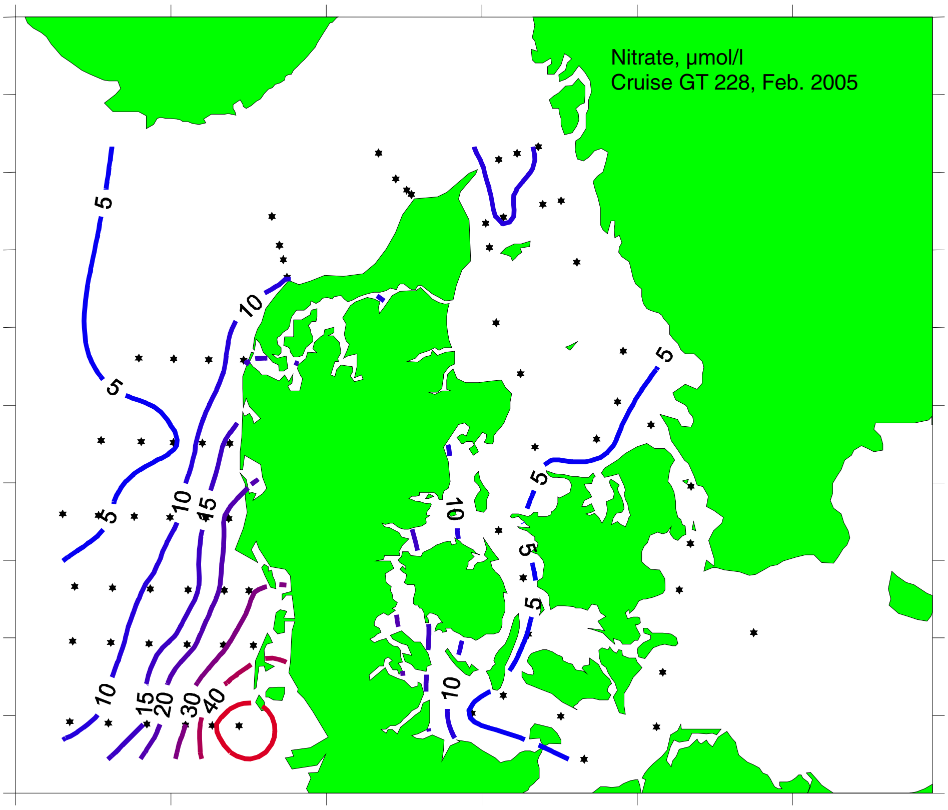

Figure 5 *Interpolated distribution of surface nitrate concentrations (mean 0-10 m depth). Note: The lines in the Little Belt area are interpolation artefacts. There are no stations.*

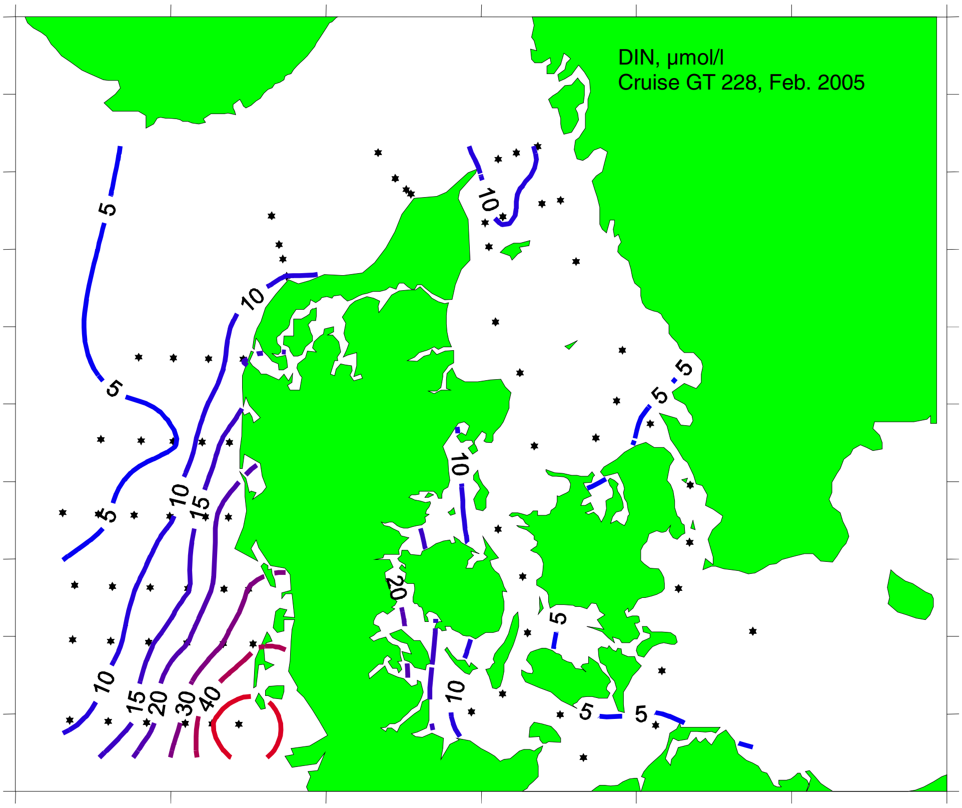

Figure 6 *Interpolated distribution of surface DIN concentrations (mean 0-10 m depth). Note: The lines in the Little Belt area are interpolation artefacts. There are no stations.*

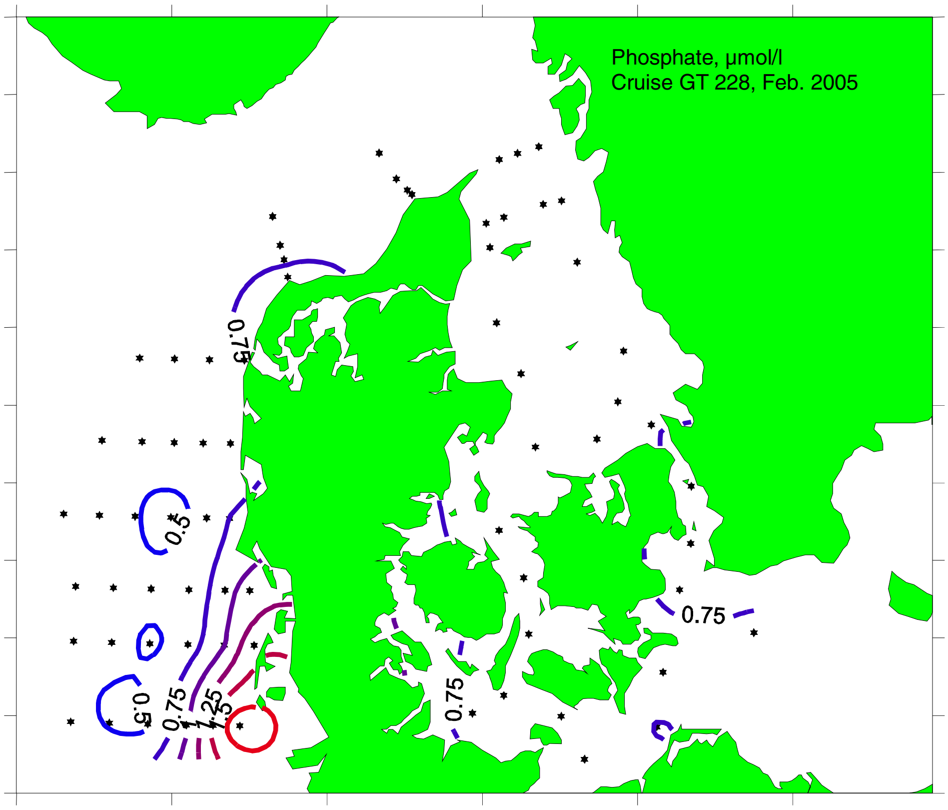

Figure 7 *Interpolated distribution of surface phosphate concentrations (mean 0-10 m depth). Note: The lines in the Little Belt area are interpolation artefacts. There are no stations.*

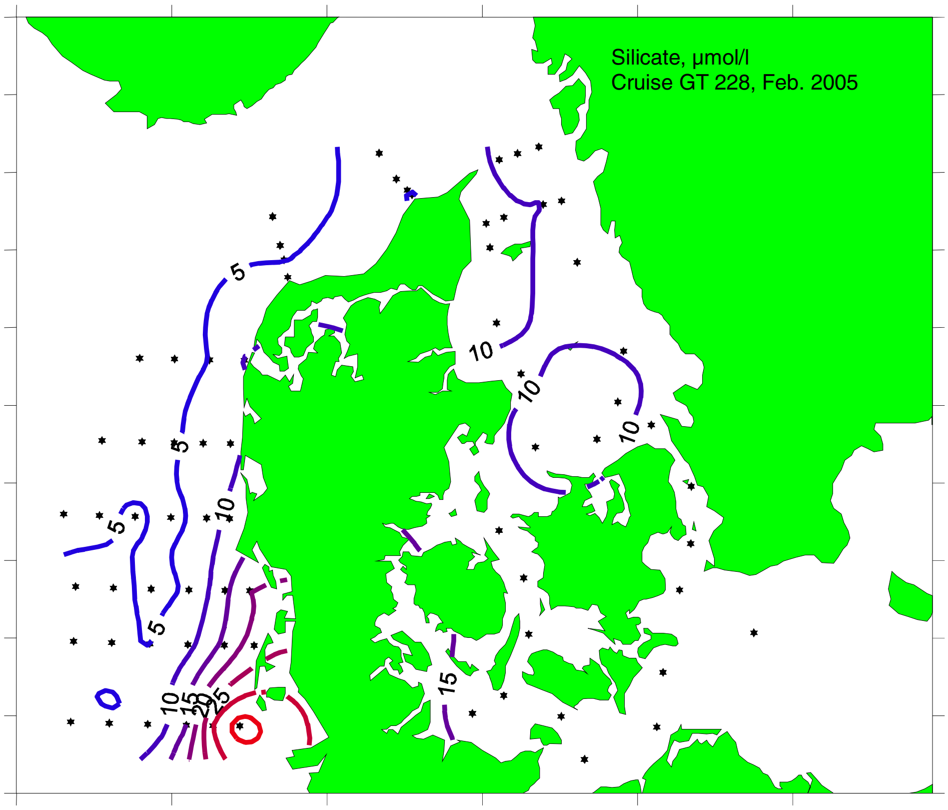

Figure 8 *Interpolated distribution of surface silicate concentrations (mean 0-10 m depth). Note: The lins in the Little Belt area is an interpolation artefact. There are no stations.*

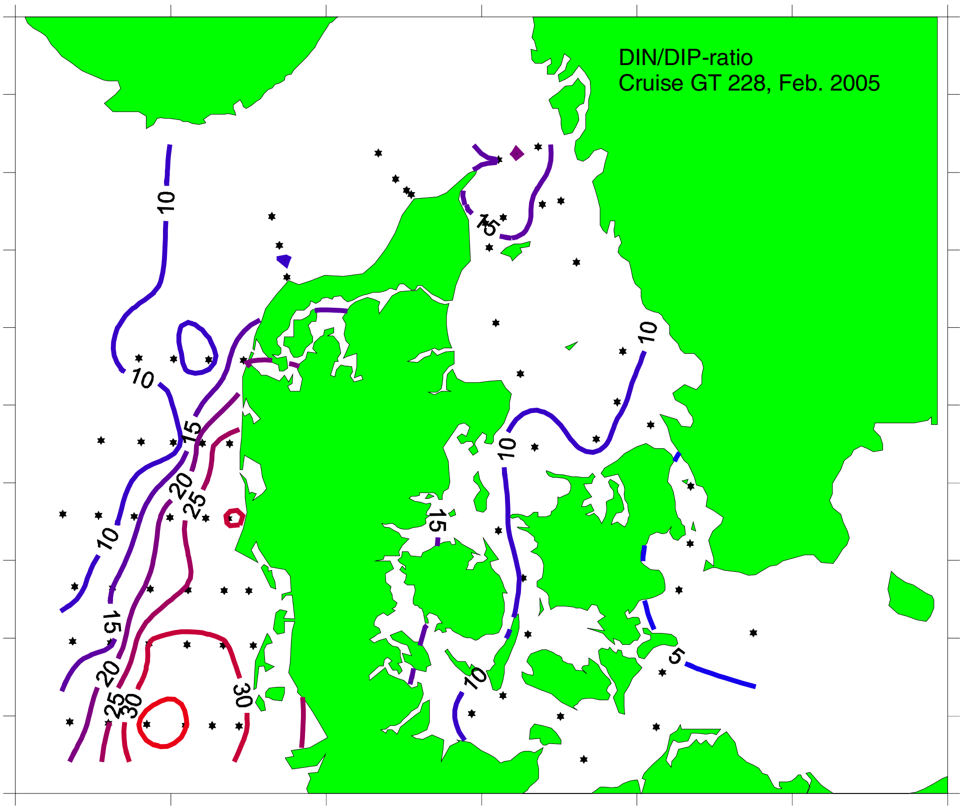

Figure 9 *Interpolated distribution of surface DIN:DIP ratio (mean 0-10 m depth). Note: The lins in the Little Belt area is an interpolation artefact. There are no stations.*

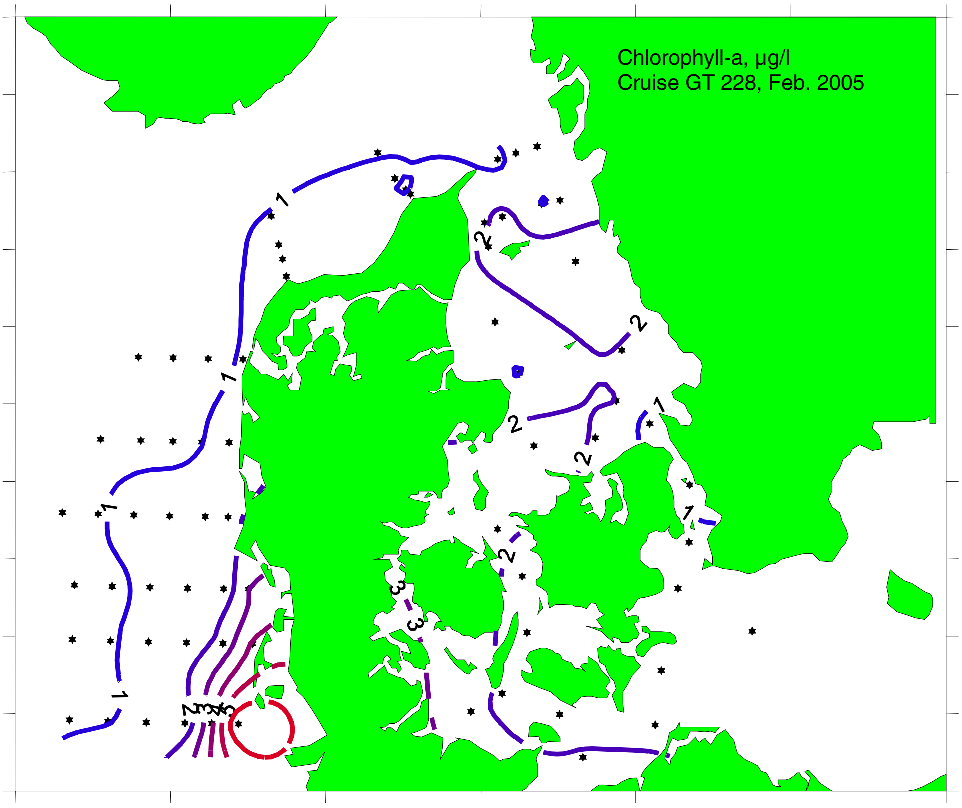

Figure 10 *Interpolated distribution of surface chlorophyll-a concentrations (mean 0-10 m depth). Note: The line in the Little Belt area is an interpolation artefact. There are no stations.*

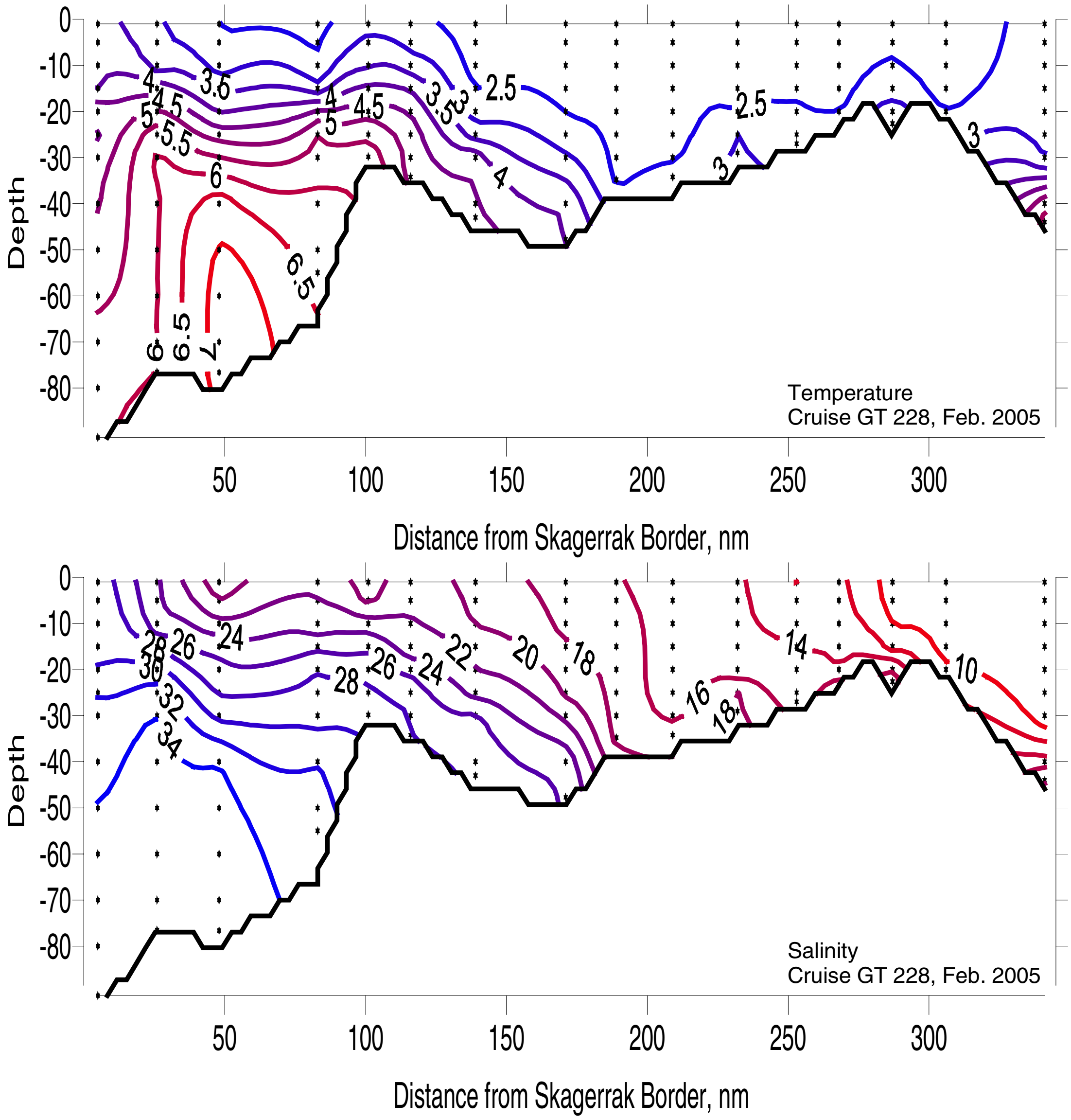

Figure 11 *Temperature (top) and salinity (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

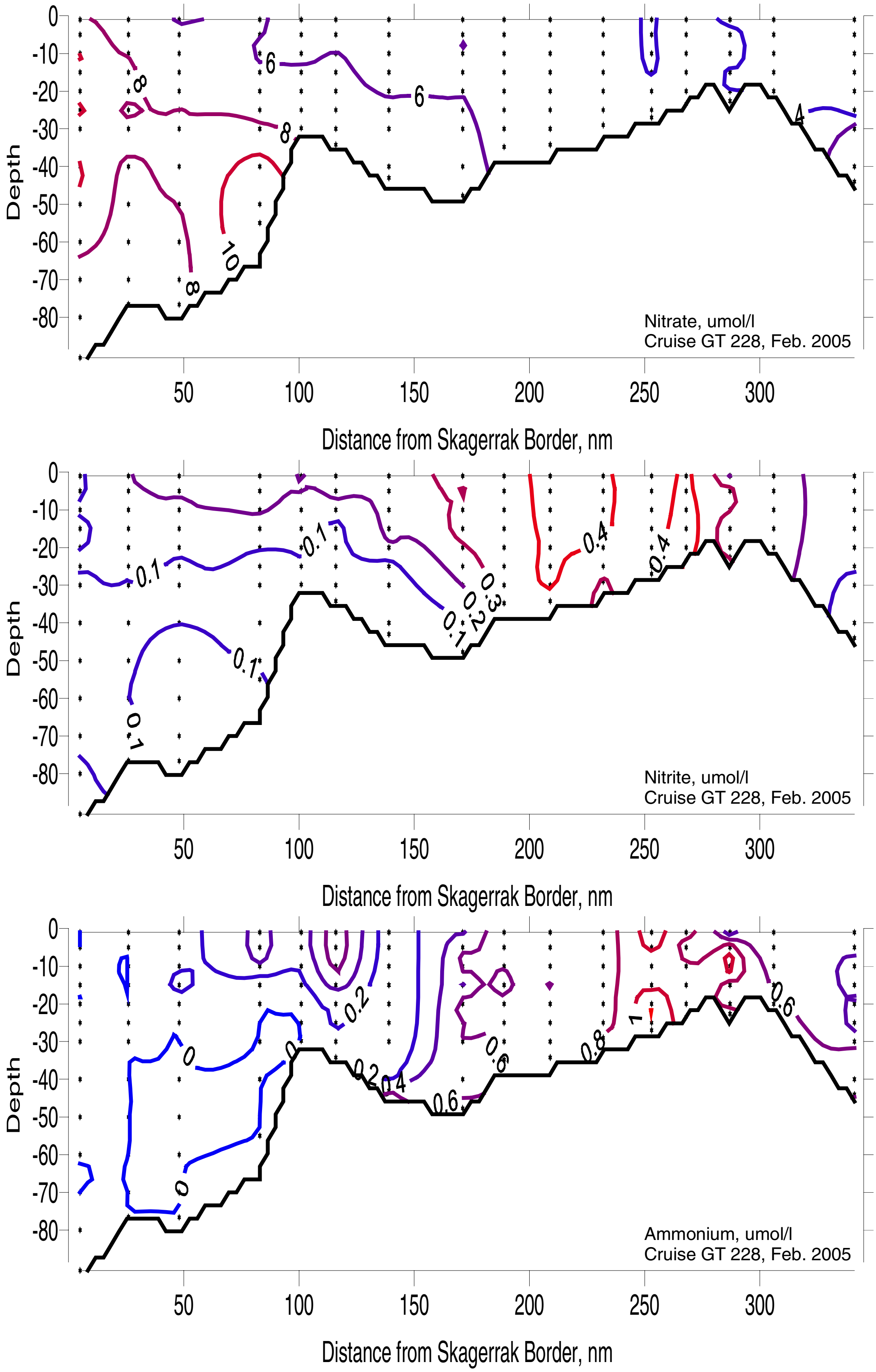

Figure 12 *Nitrate (top), nitrite (mid) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

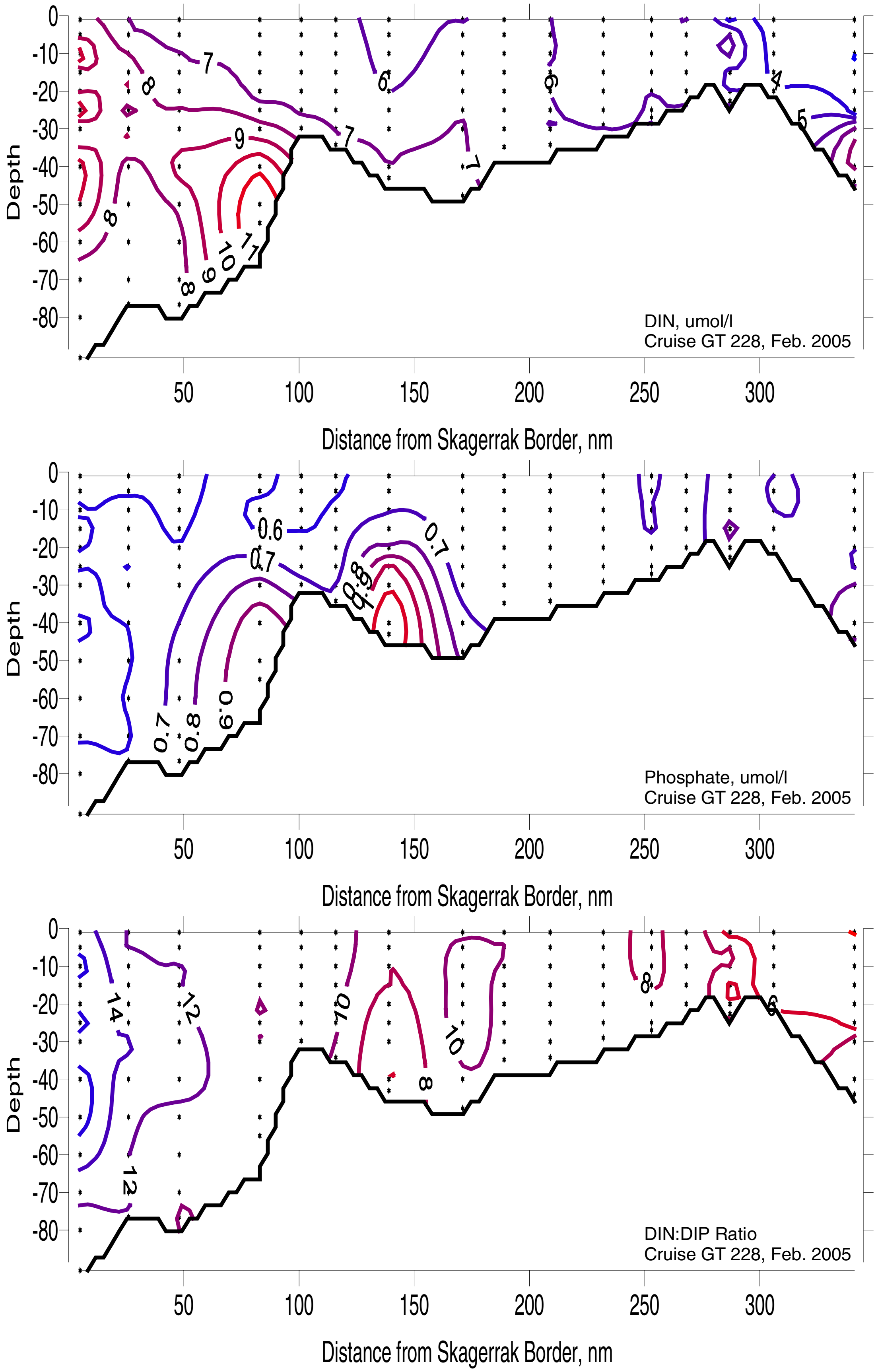

Figure 13 *DIN (top), phosphate (mid) and DIN/DIP ratio (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

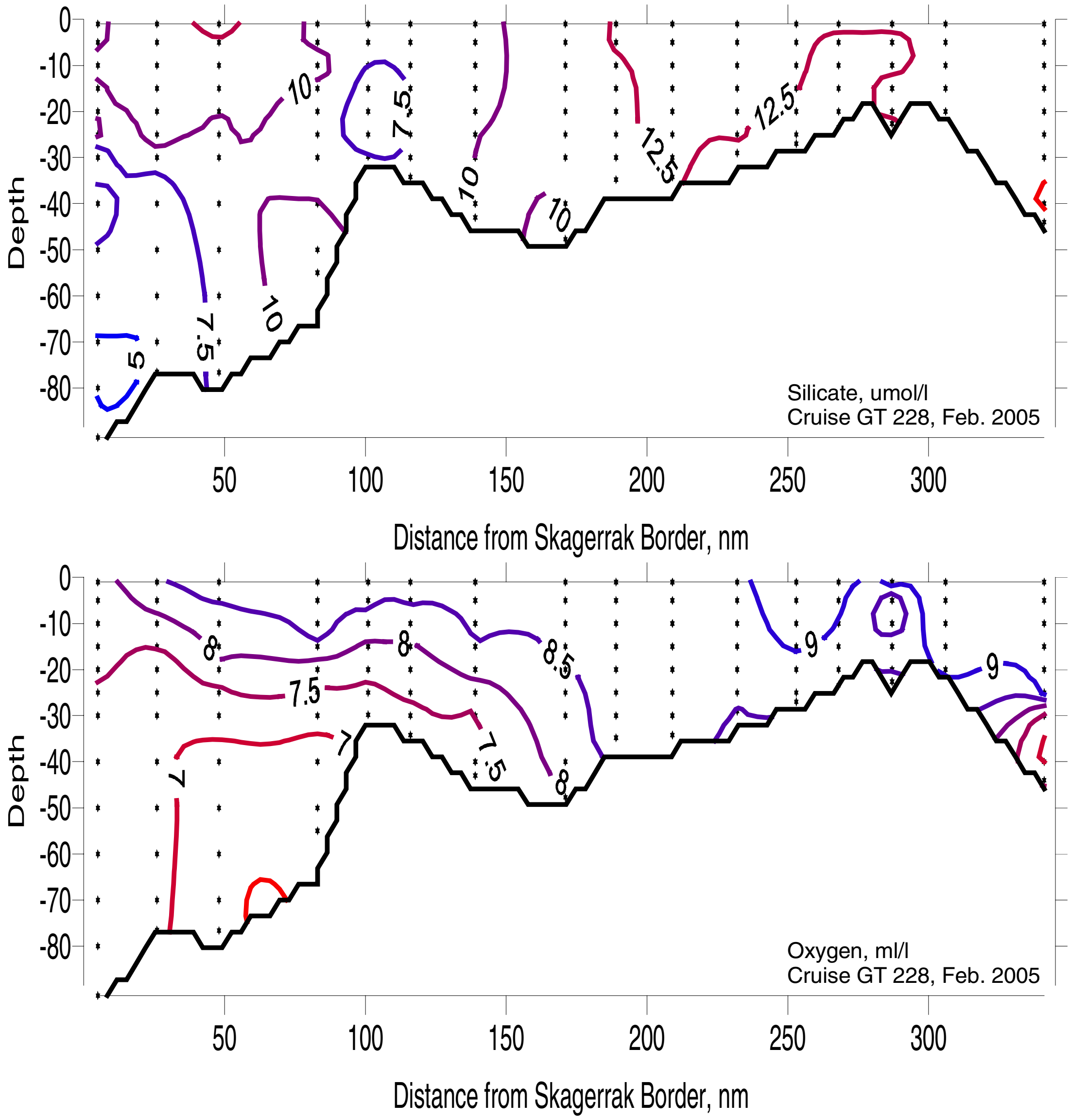

Figure 14 *Silicate (top) and oxygen (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

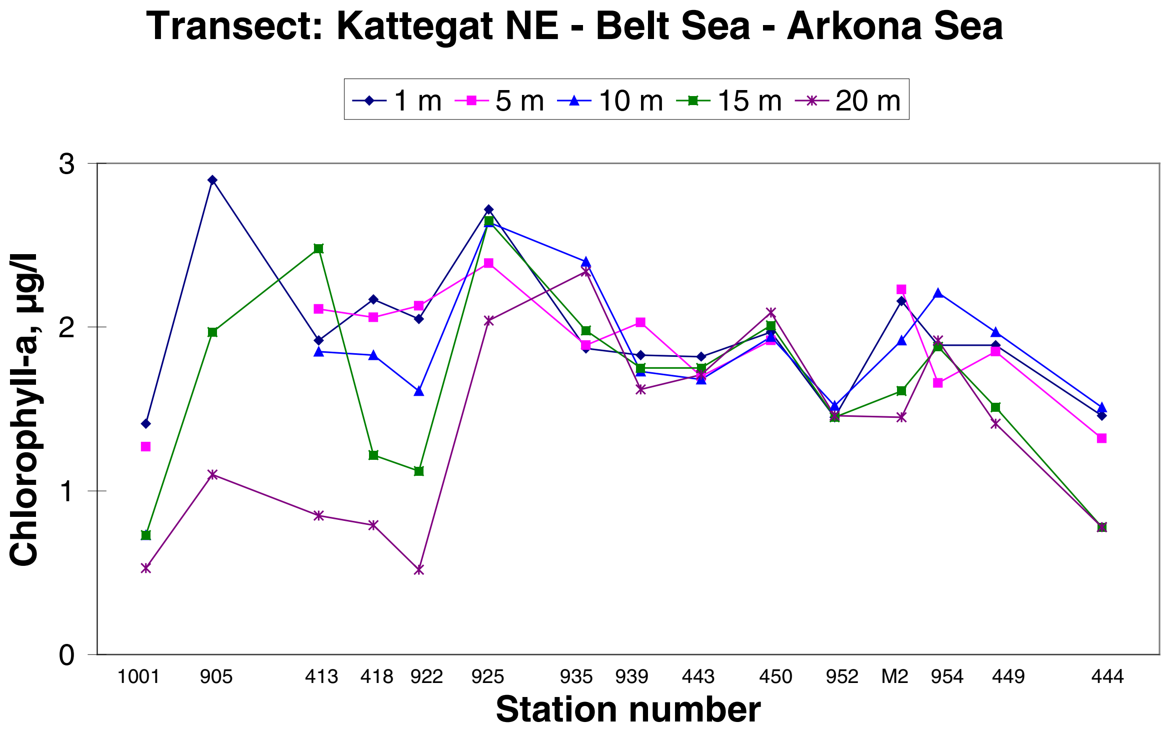

Figure 15 *Chlorophyl-a at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*