r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 214

Time: 10 - 19 February 2003

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, 10-19 February 2003 – Cruise no. 214

Report: Gunni Ærtebjerg

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Summary
The Jutland Coastal Current (JCC) with lower salinity and temperature and high nutrient concentrations, especially nitrate, was evident along all the Danish North Sea and Skagerrak coasts. The JCC also influenced the northern Kattegat north of Læsø with nitrate concentrations up to 13-14 µmol/l in an intermediate layer at 20-40 m depth. In the Kattegat, the Sound and the Belt Sea the hydrography was dominated by outflow from the Baltic Sea, less vertical mixing and stronger stratification than normal for the season.

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 82 µmol/l), decreasing to the north and west. The nitrate concentrations in the Skagerrak waters and Baltic waters mixing in the Kattegat and Belt Sea were relatively high and about 1 µmol/l higher than in February last year. Therefore, the nitrate concentration in the bottom water of the Kattegat, the Sound and Great Belt was relatively high (9-10 µmol/l). Contrary, the nitrate concentration in the surface water in the Kattegat and the Belt Sea was normal to low, probably due to low runoff during winter, and because the phytoplankton spring bloom had started in the Belt Sea. Thus, nitrate concentrations in the Belt Sea surface waters do not represent the winter maximum values.

The DIN/DIP ratio varied from 50-60 in the German Bight and above 30 in the JCC to 8-15 at the north-western North Sea stations and central Skagerrak stations. In the Kattegat and the Belt Sea the DIN/DIP ratio was rather close to the Redfield ratio of 16 for phytoplankton uptake, as it varied from about 8 in the Arkona Sea to 16 in the northern Kattegat.

The phytoplankton spring bloom had not started yet in the North Sea, the Skagerrak, the Kattegat, the Sound and the Arkona Sea, and the chlorophyll concentrations were generally below 2 µg/l. However, the bloom had started in the Belt Sea, especially in Kiel Bight and Fehmarn Belt, where a chlorophyll maximum of 17 µg/l was observed in 10-15 m depths below the outflowing Baltic water. The minimum oxygen concentrations were about saturation level at all stations in the North Sea. At the deepest station in the central Skagerrak the lowest oxygen concentration of 5.2 ml/l was observed in 600 m depth. In the Kattegat, the Sound and the Belt Sea the lowest oxygen concentration of 4.8 ml/l was found in the Sound. Compared to February last year the minimum oxygen concentrations this year were generally lower, probably due to less water exchange and mixing.

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 (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 macrozoobenthos were sampled at 3 stations. Sediment samples for monitoring of radioactivity were sampled at 3 stations. Besides the monitoring measurements, sediments for pigment analyses were sampled at 8 stations.

Meteorology

Characteristics of the weather conditions since the last cruise at the beginning of November 2002 are given in *table 1*. The winter 2002-2003 (December-February) was generally cold and dry. In spite of normal temperature in December the winter temperature was on average 0.9°C and the precipitation 44% below normal. The wind conditions in January were rather normal with temporary strong wind from Southwest and West. However, both in November, December and February the dominating wind direction was East and Southeast, and the wind force was relatively low, especially in February.

***Table 1**. Deviations in monthly mean temperature and precipitation in November 2002 to February 2003 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
Nov. 02	-0.5	+10	4.7	E-SE
Dec. 02	-1.6	-55	5.3	E-SE
Jan. 03	+0.2	-16	5.6	SW-W
Feb. 03	-1.2	-68	3.8	E-SE

The North Sea and the Skagerrak

Hydrography

The Jutland Coastal Current (JCC) with lower salinity and temperature was evident along the Danish North Sea and Skagerrak coasts. West of the JCC the surface salinity was 34.0-34.5 (St. 1024-1027, 1071-1074, 1045-1046, 1056, 1064, 1085), and a tongue of high saline surface water (34.3-34.7) was observed in the central Skagerrak (St. 1102-1104, 1131-1133). Along the coast the salinity increased from 26.6-27.0 in the German Bight (St. 1080-1081) to 31.0 at Hanstholm (St. 1019), 31.8 at Hirtshals (St. 1013) and 31.0 at Skagen (St. 1005) (*figure 2*). The surface temperature ranged from 1.3-1.7°C at the coast-near stations (St. 1059, 1080-1081, 1086) in the German Bight to 5.0-5.8°C at the western stations in the North Sea (St. 1024-1027, 1073-1074, 1045-1046, 1056, 1064, 1085) and in the central Skagerrak (St. 1102-1104, 1133) (*figure 3*).

Nutrients
In the North Sea the nutrient concentrations, except 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 well-mixed water masses in the eastern North Sea, although TP's correlation to salinity is somewhat lower due to accumulation of particulate phosphorus in the bottom near water samples.

***Table 2**. Linear regression analyses of salinity and concentrations of nutrients at the 36 stations in the North Sea 12-14 February 2003. 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. n = number of samples.*

Nutrient	Slope	Intercept	34.5 psu	n	R^2
Nitrate	-8.19	290	7.35	240	0.97
Nitrite	-0.15	5.45	0.20	240	0.54
Ammonium	-1.07	36.7	0	240	0.96
DIN	-9.42	332	7.18	240	0.98
TN	-10.10	362	13.90	236	0.97
DIP	-0.11	4.41	0.43	240	0.92
TP	-0.14	5.77	0.78	240	0.74
Silicate	-4.55	161	3.70	240	0.97

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, 8, 9 and 10*). In the Skagerrak as much as 31.3 µmol/l nitrate was observed in the JCC at Hanstholm (St. 1019) and 22.1 µmol/l at Hirtshals (St. 1013) (*figure 5*).

The DIN/DIP ratio varied from 50-60 at the coast near stations in the German Bight and >30 in the JCC to 8-15 at the north-western North Sea stations (St. 1024-1027, 1073-1074, 1046) and the central Skagerrak stations (St. 1102-1104, 1031-1033) (*figure 11*).

Oxygen and chlorophyll-*a*
The minimum oxygen concentrations were about saturation level at all stations in the North Sea. At the deepest stations in the Skagerrak the lowest oxygen concentration of 5.19 ml/l (76%) was observed in 600 m depth at the central station 1006 (M6).

The mean chlorophyll-*a* concentration in the surface layer (0-10 m) varied from <0.5 µg/l in the central Skagerrak (St. 1013, 1101-1106, 1135) and at the north-western stations in the North Sea (St. 1025-1026, 1073-1074, 1046) to 1.1-2.0 µg/l at the coast-near stations in the North Sea (St. 1019, 1022, 1041, 1086, 1059, 1080) (*figure 12*). 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 <1°C in the Sound and the Belt Sea to 2.0-2.4°C in the northern and western Kattegat (St. 403, 415, 1007-1009) with a maximum of 4.1°C in Aalborg Bight (St. 409) (*figure 3*). The bottom water temperature ranged from 2.0-2.6°C in the southern Belt Sea and western Arkona Sea (St. 441, 449, 450, 952, 954, M2, N3) to 7.0-7.6°C in the Sound and south-eastern Kattegat (St. 431, 413, 921, 922) (*figure 13a*).

The surface salinity was relatively low for the season and ranged from 7.4-7.9 in the Sound and the Arkona Sea (St. 431, 441, 444, 449, 954) to 30.0 in the northern Kattegat (St. 1008) and 30.2 in the shallow Aalborg Bight (St. 409) (*figure 2*). The bottom water salinity at stratified stations ranged from 22.0-24.0 in the deep Arkona Basin and southern Belt Sea (St. 444, 954, 952, M2, N3) to 34.0 at the northern entrance to the Sound (St. 921) and 34.3 in the north-eastern Kattegat (St. 1001) (*figure 13b*). The salinity stratification was relatively strong for the season with 12-18 at the deeper stations in the Arkona Basin, the Belt Sea and the eastern Kattegat and with a maximum of 25 in the Sound.

Compared to long-term monthly means (Lightship observations 1931-1960) for February the surface temperature and salinity during the present cruise were lower, except in the western Kattegat. The bottom water temperature and salinity were higher than normal, except in the northern Kattegat.

Thus, the hydrography was dominated by outflow from the Baltic Sea, less vertical mixing and stronger stratification than normal for the season, and upwelling of saline and warmer bottom water in the shallow western Kattegat.

Nutrients
The JCC influenced the northern-most Kattegat with nitrate and DIN concentrations of 12-18 µmol/l in an intermediate layer (20-40 m depth) north of Læsø. The DIN concentrations in both the Skagerrak water and Baltic Sea water mixing in the Kattegat-Belt Sea area were relatively high and about 1 µmol/l higher than at the same time last year. The origin of this nitrate is not clear. It might partly stem from internal load following the oxygen depletion last autumn, and partly from inflow of more than usual Skagerrak deep water. Due to this the bottom water nitrate concentrations in the Kattegat, the Sound and Great Belt were relatively high (9-10 µmol/l) (*figure 5, 14a* and *15a*). However, in the surface the nitrate concentration was about normal to relatively low, partly due to a beginning phytoplankton spring bloom in the Belt Sea and probably partly due to low precipitation and runoff during winter.

Rather high concentrations of nitrite (>0.5 µmol/l) were found in the Arkona Sea bottom water. High concentrations of ammonium (>1 µmol/l) were observed in the Great Belt, the southern Belt Sea and the Arkona Sea bottom water as well as in the JCC water in the northern-most Kattegat (*figure 14b* and *14c*). Also the concentration of silicate was highest in the Belt Sea and the Arkona Sea bottom water (*figures 10* and *16a*), while the phosphate concentrations were highest (>0.9 µmol/l) in the Kattegat and Great Belt bottom water (*figure 8 and 15b*).

The DIN/DIP ratio was rather close to the Redfield ratio for phytoplankton uptake, as it varied from about 8 in the Arkona Sea to 16 in the northern Kattegat, but up to 22 in the JCC water north of Læsø (*figure 11* and *15c*)

Chlorophyll-*a*
The phytoplankton spring bloom had already started in the Belt Sea. The mean chlorophyll concentrations in the uppermost 10 m were very high in Kiel Bight (14.5 µg/l), Fehmarn Belt (7.3 µg/l) and the northern Belt Sea (7.2 µg/l) (*figure 12*). In the Kiel Bight and Fehmarn Belt the

maximum chlorophyll concentration was found at 10-15 m depth below the out-flowing Baltic water (*figure 17*). In the Kattegat, the Sound and the Arkona Sea the phytoplankton spring bloom had not yet started.

Oxygen

The lowest oxygen concentration of 4.8 ml/l (70% saturation) was observed in the Sound, and 5-6 ml/l (74-83%) was found in the southern Kattegat and northern Great Belt (*figure 16b*). Compared to February last year the minimum oxygen concentrations this year were generally a little lower, probably due to less water exchange and mixing.

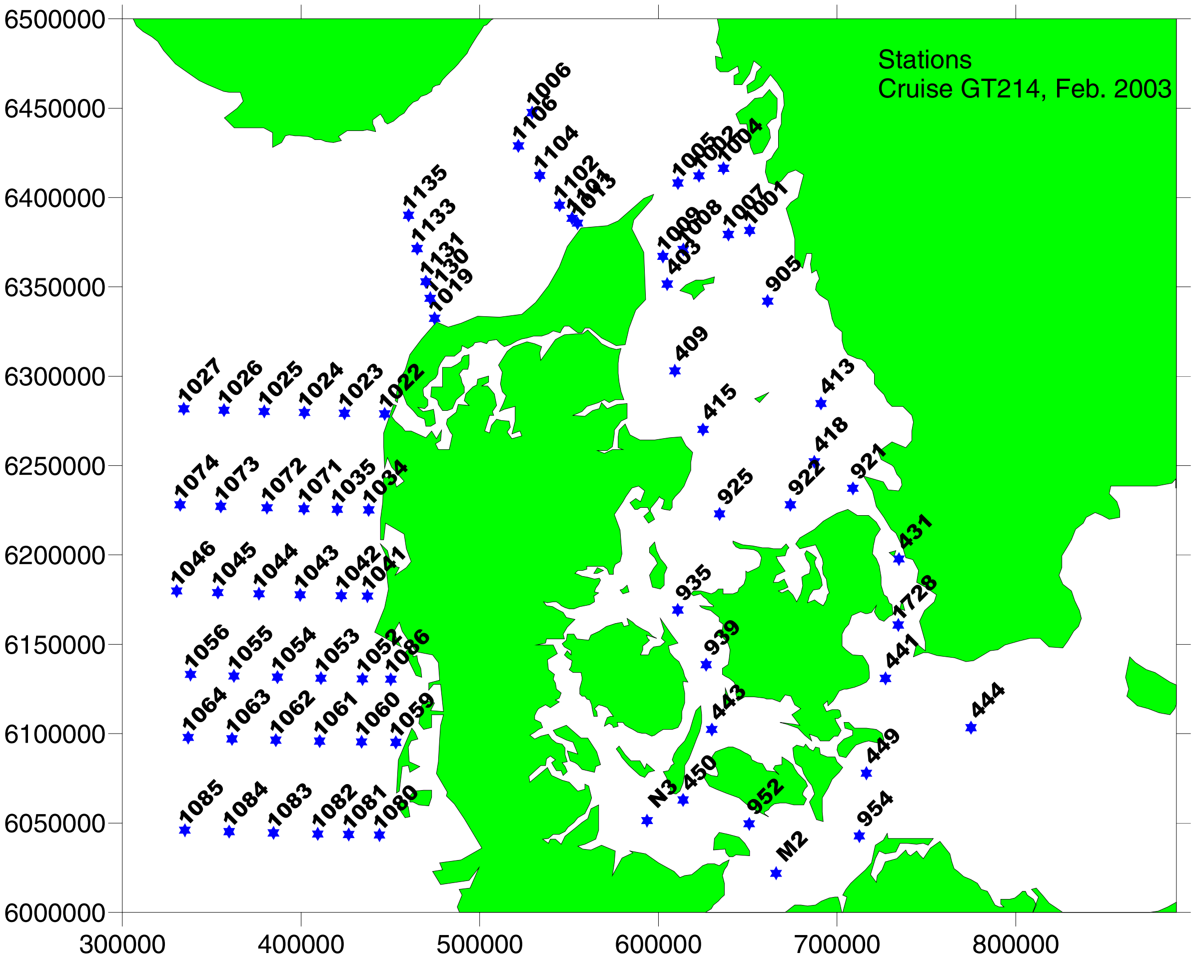

***Figure 1**. Stations of the monitoring cruise with r/v Gunnar Thorson 10-20 February 2003 in the Sound, the Kattegat, the Skagerrak, the North Sea, the Belt Sea and the Arkona Sea. Gunnar Thorson cruise no. 214.*

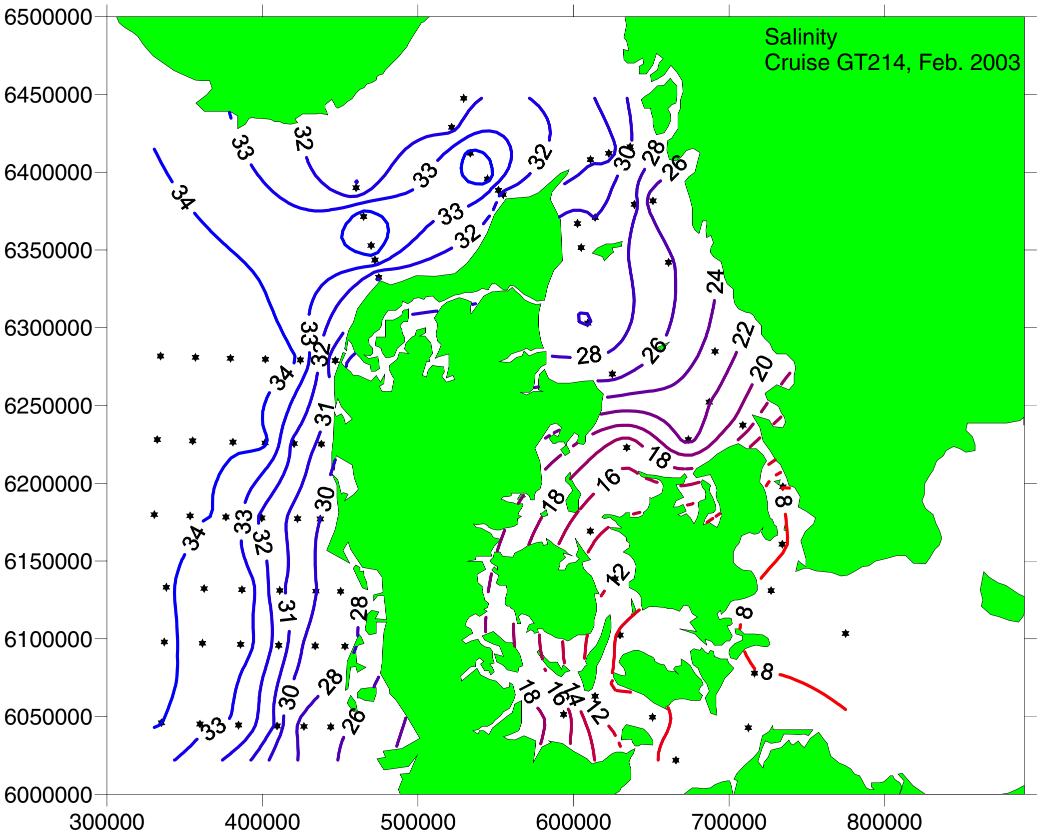

Figure 2. *Interpolated distribution of surface salinity (mean 0-10 m depth).*

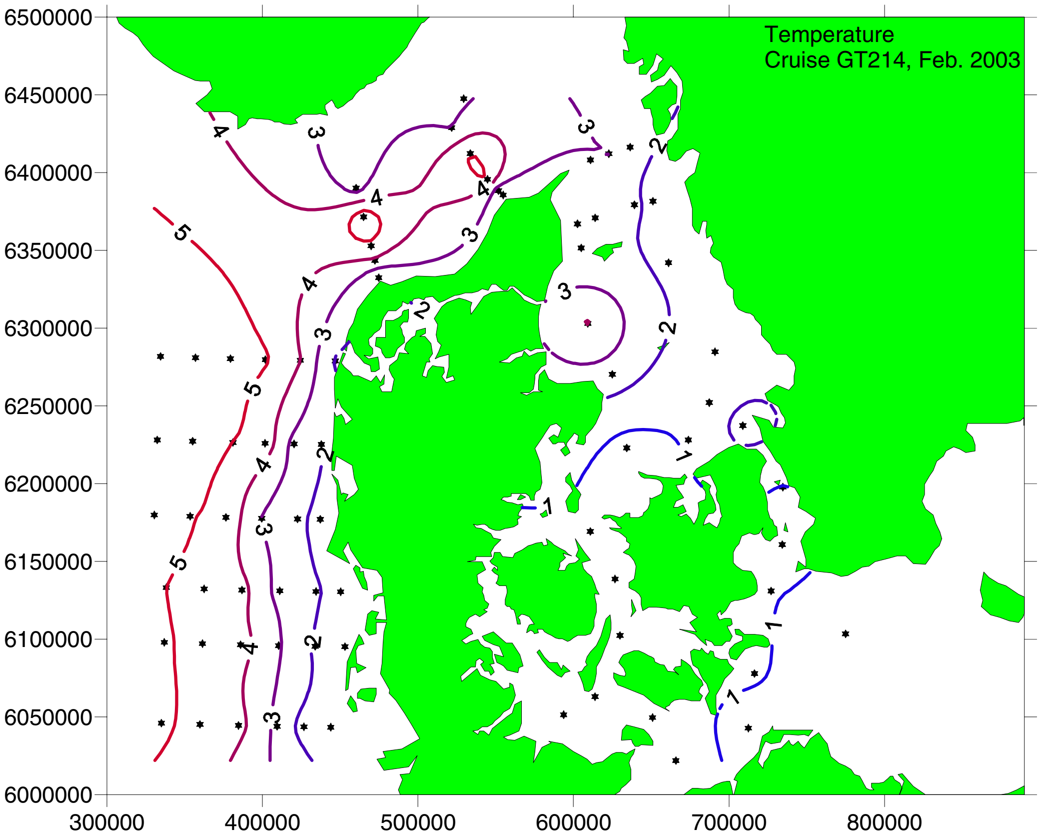

Figure 3. *Interpolated distribution of surface temperature (mean 0-10 m depth).*

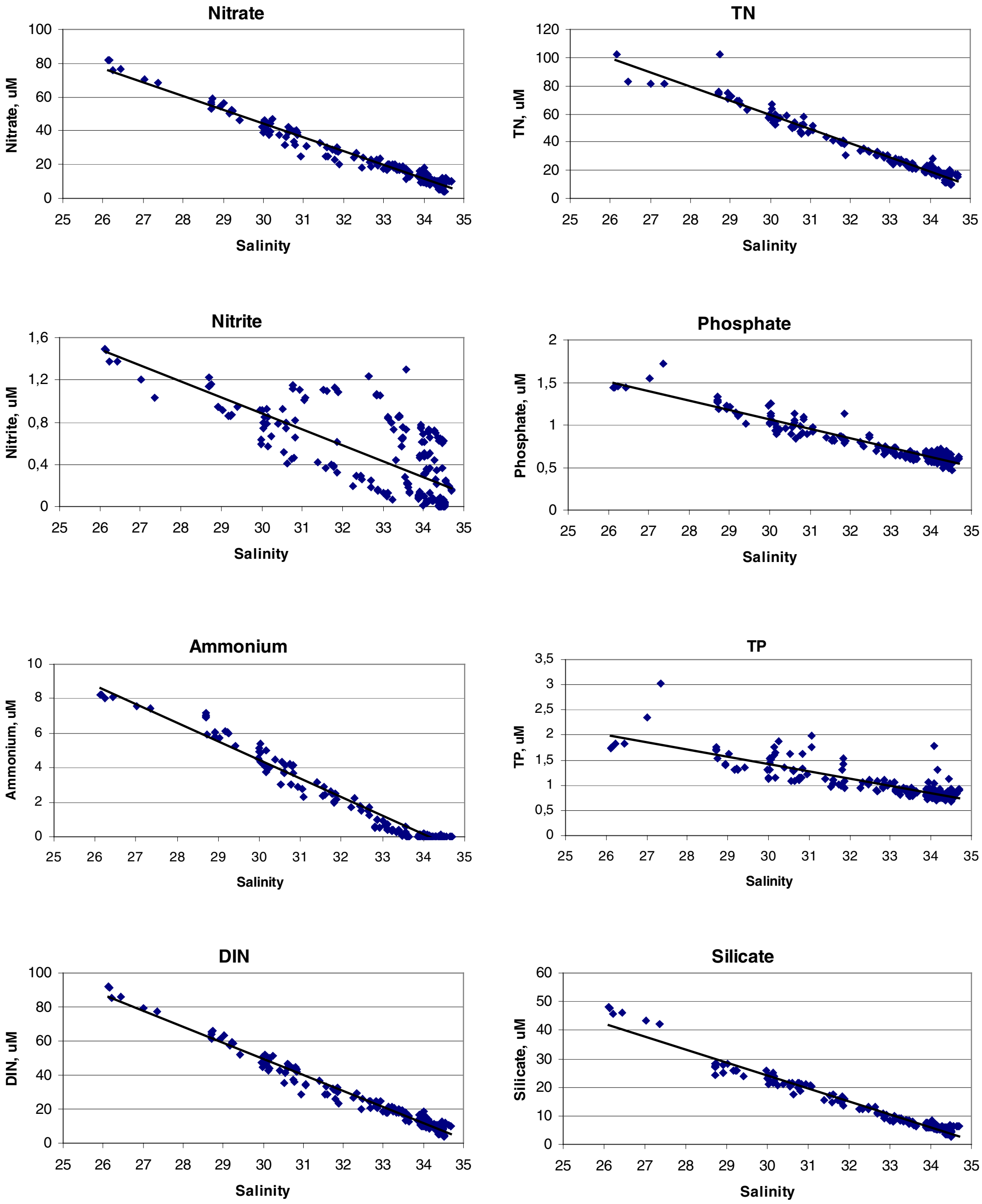

***Figure 4**. Correlations between salinity and nutrient concentrations at the 36 stations in the North Sea 12-14 February 2003.*

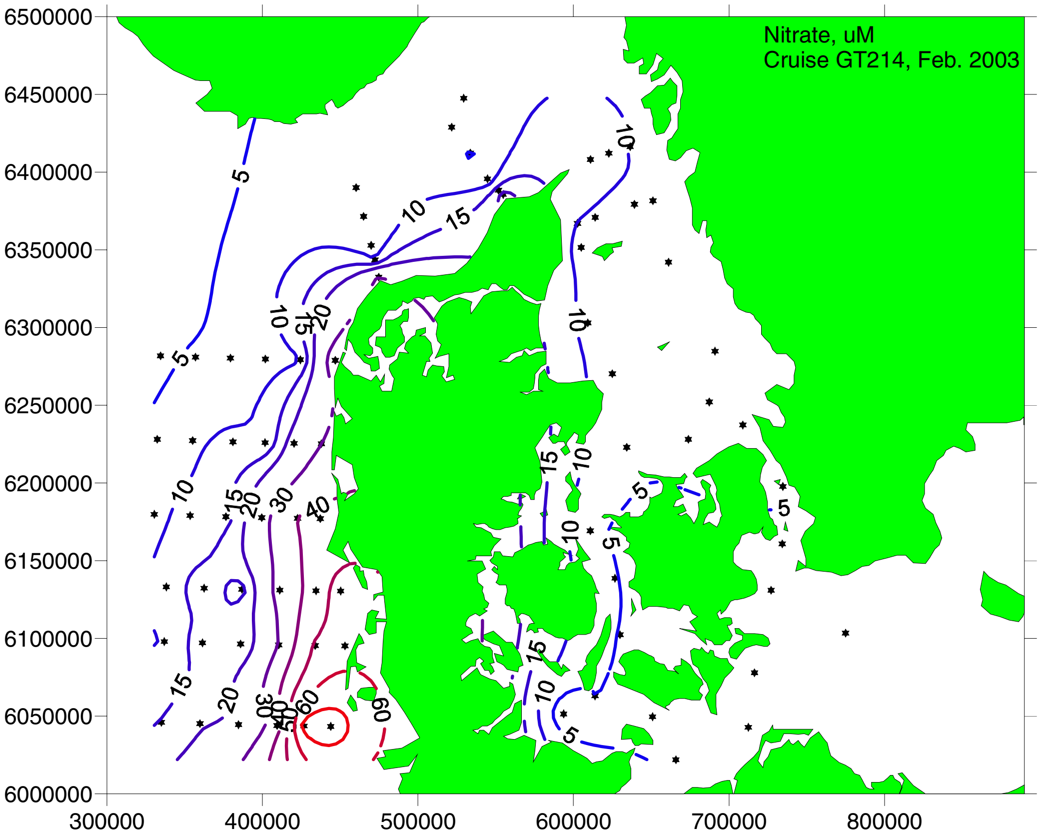

Figure 5. *Interpolated distribution of surface nitrate concentrations (mean 0-10 m depth).*

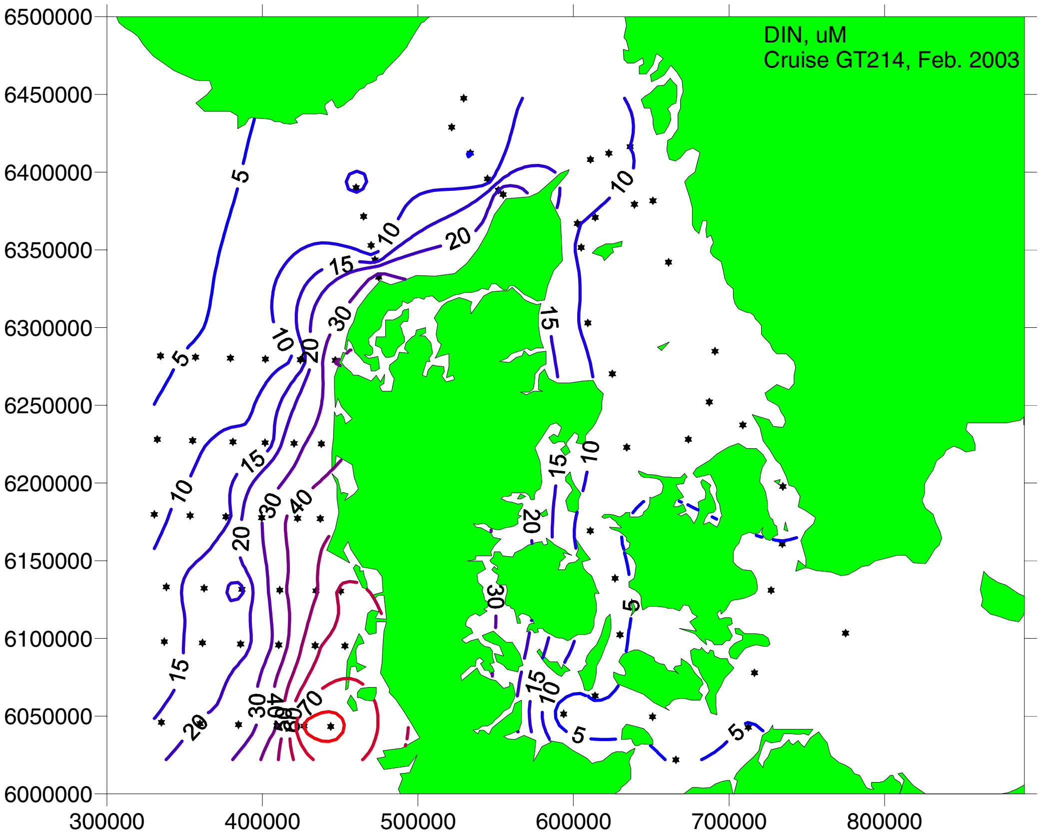

Figure 6. *Interpolated distribution of surface DIN concentrations (mean 0-10 m depth).*

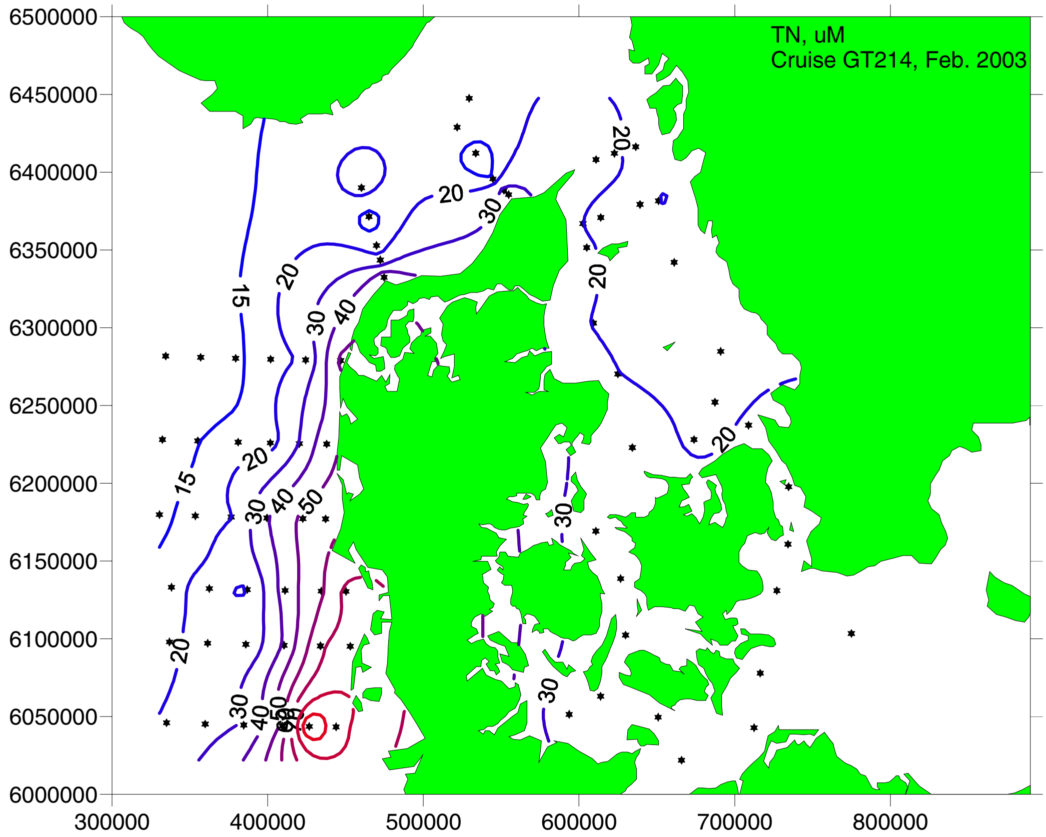

***Figure 7**. Interpolated distribution of surface Total-N (mean 0-10 m depth).*

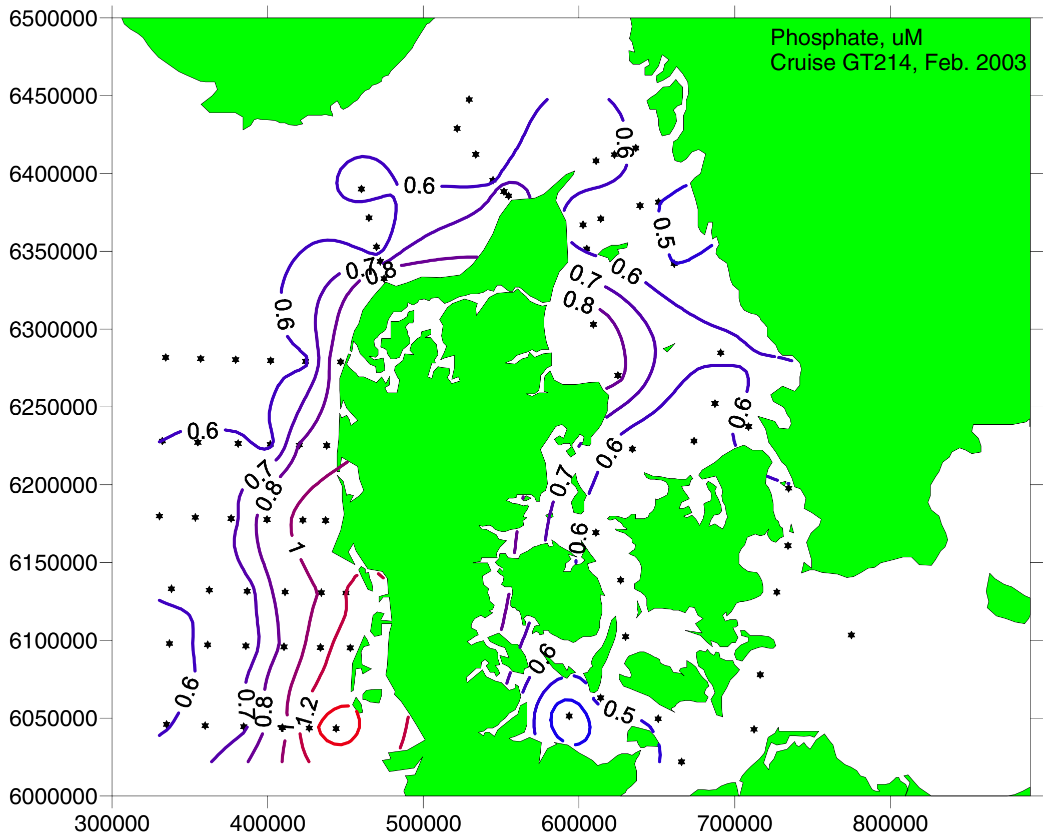

***Figure 8**. Interpolated distribution of surface phosphate concentrations (mean 0-10 m depth).*

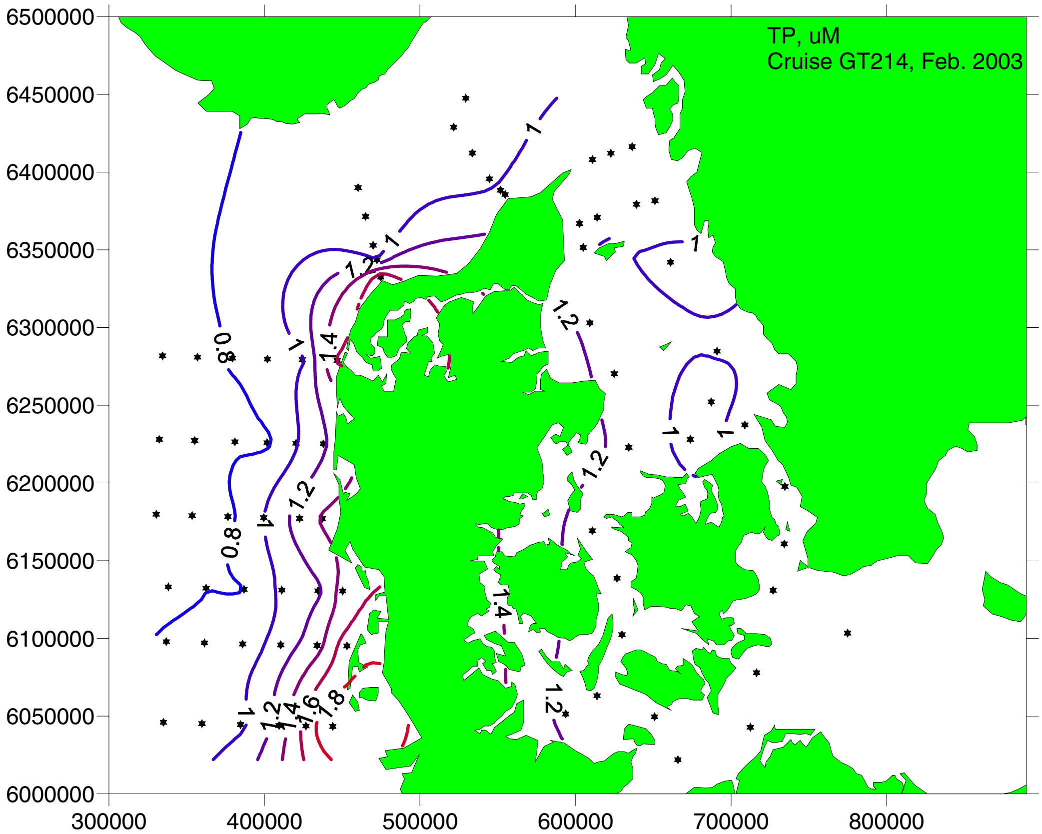

Figure 9. *Interpolated distribution of surface Total-P concentrations (mean 0-10 m depth).*

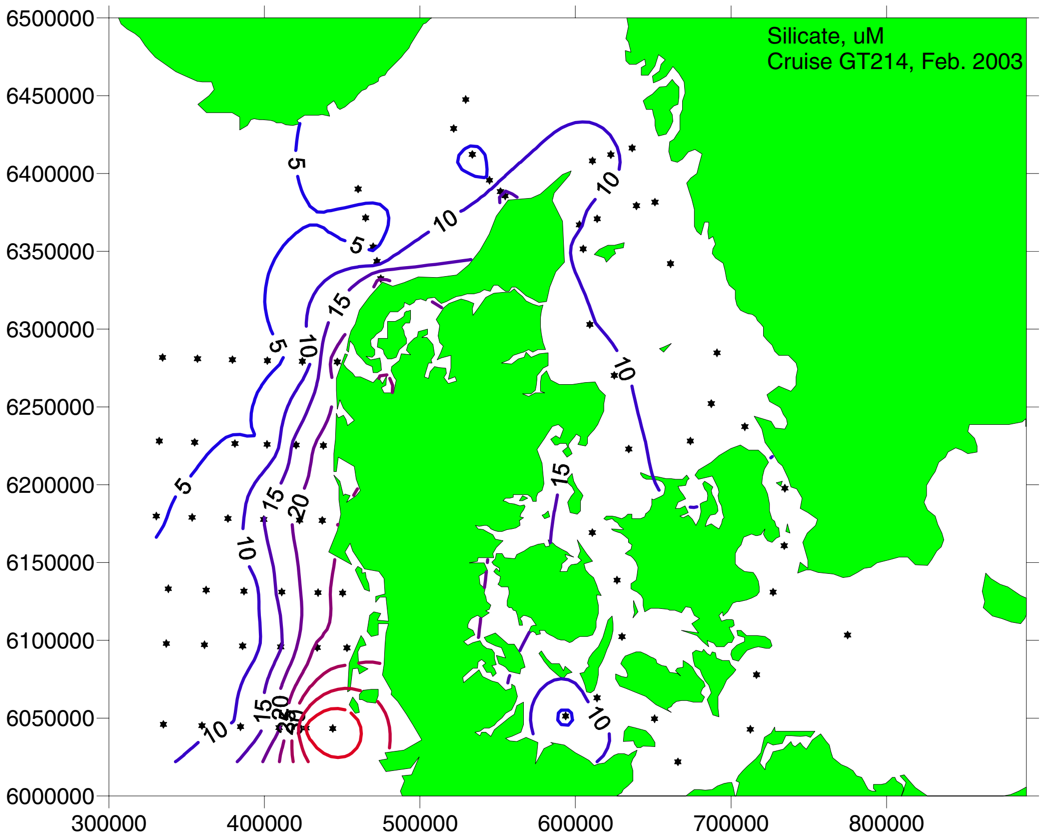

Figure 10. *Interpolated distribution of surface silicate concentrations (mean 0-10 m depth).*

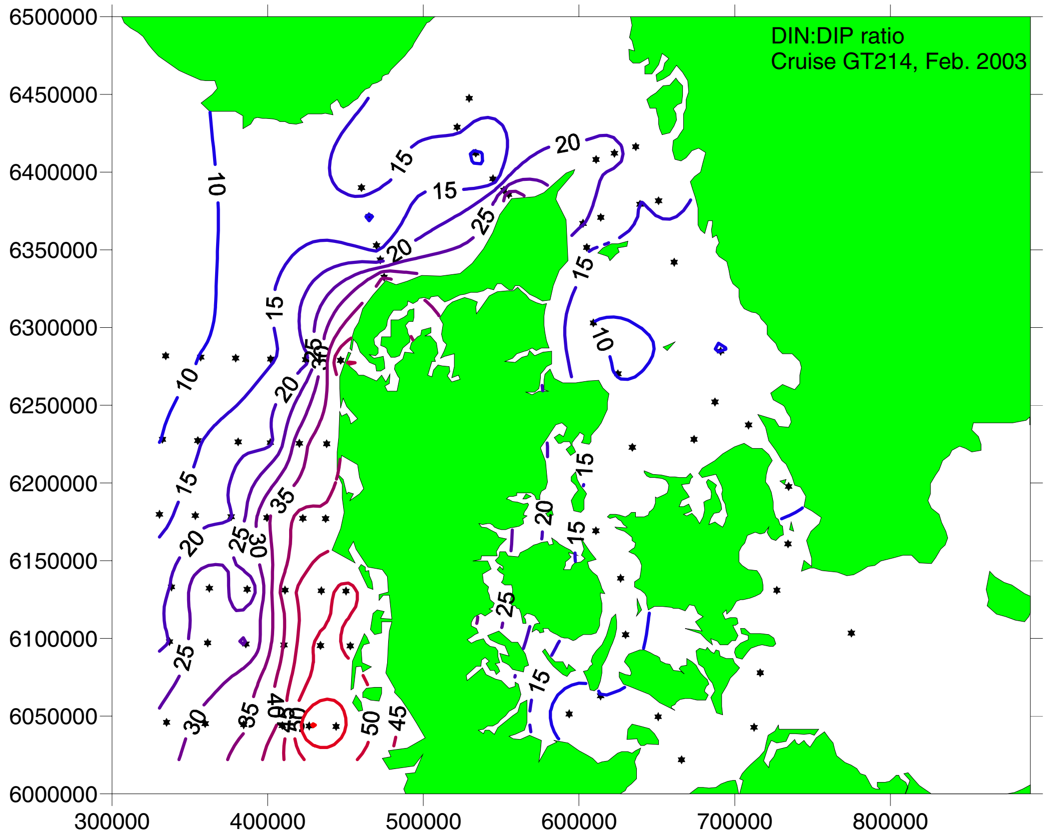

Figure 11. *Interpolated distribution of surface DIN:DIP ratio (mean 0-10 m depth).*

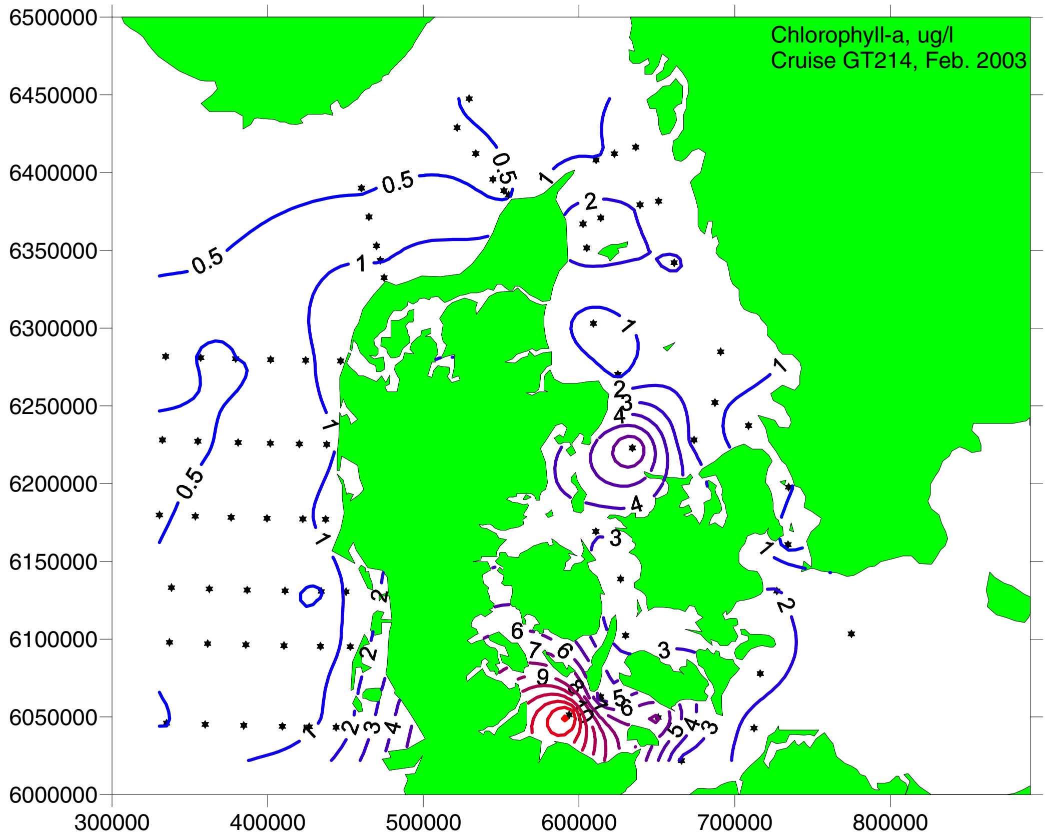

Figure 12. *Interpolated distribution of surface chlorophyll-a concentrations (mean 0-10 m depth).*

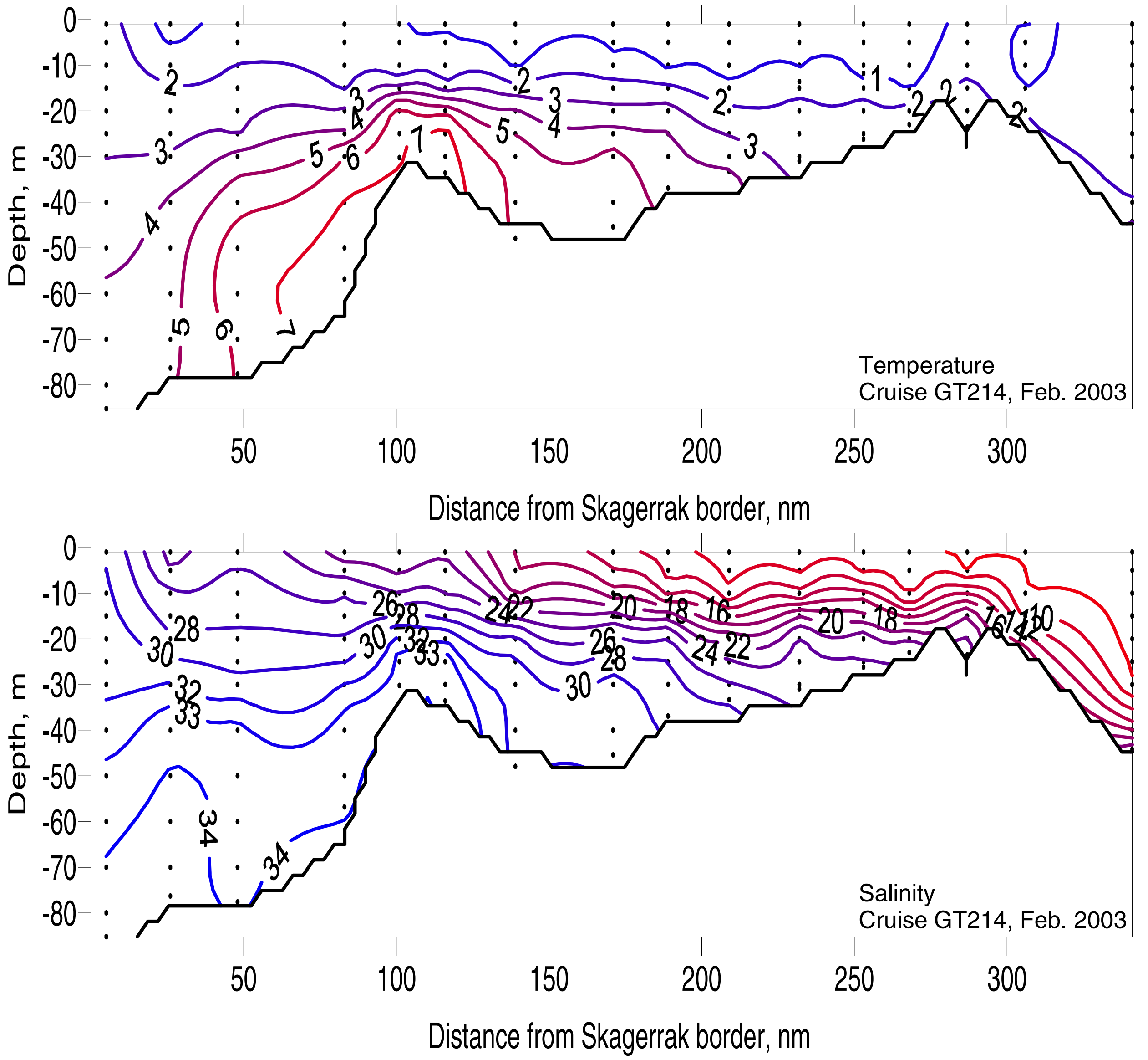

***Figure 13**. Temperature and salinity distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

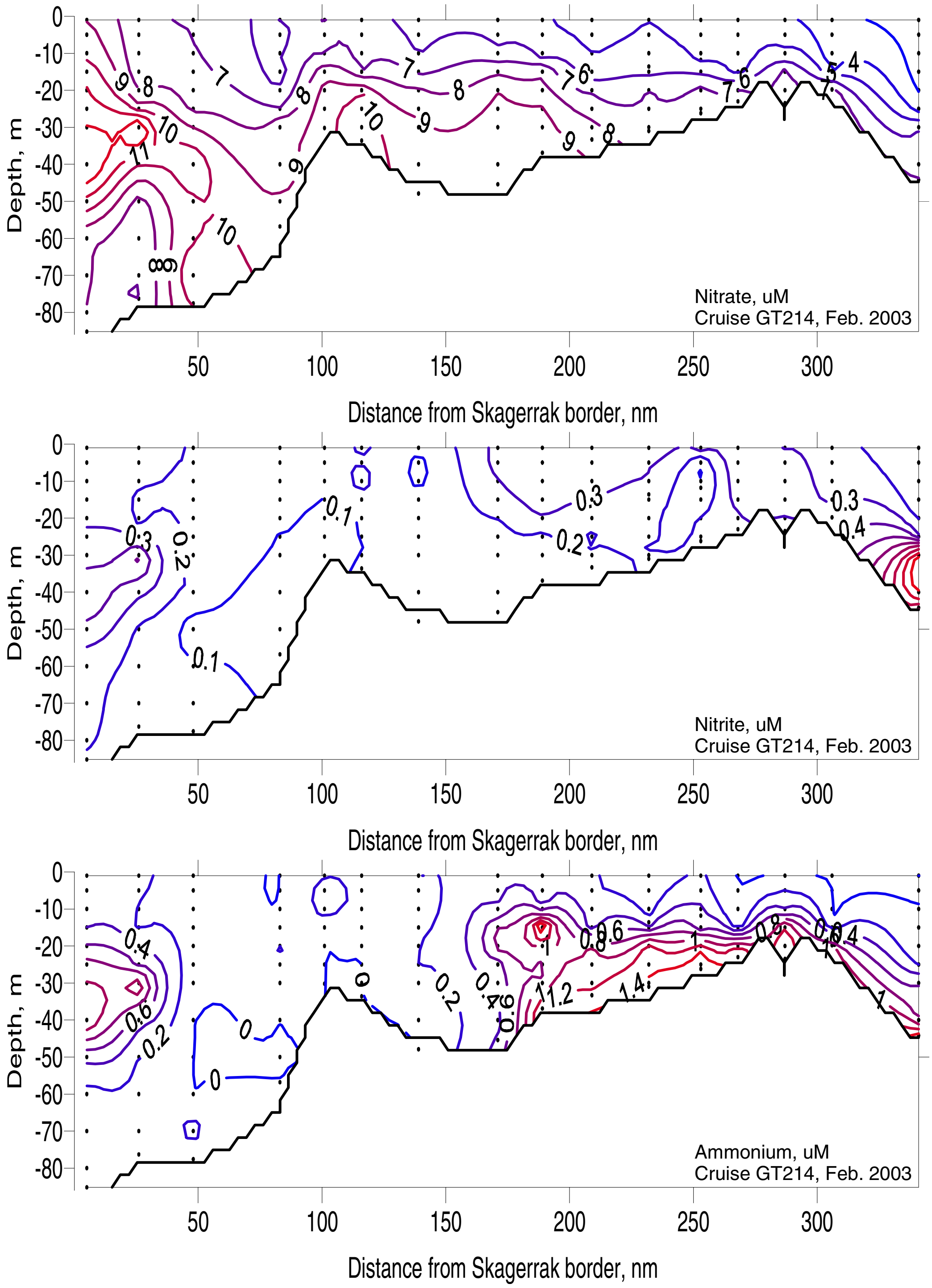

***Figure 14**. Nitrate, nitrite and ammonium distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

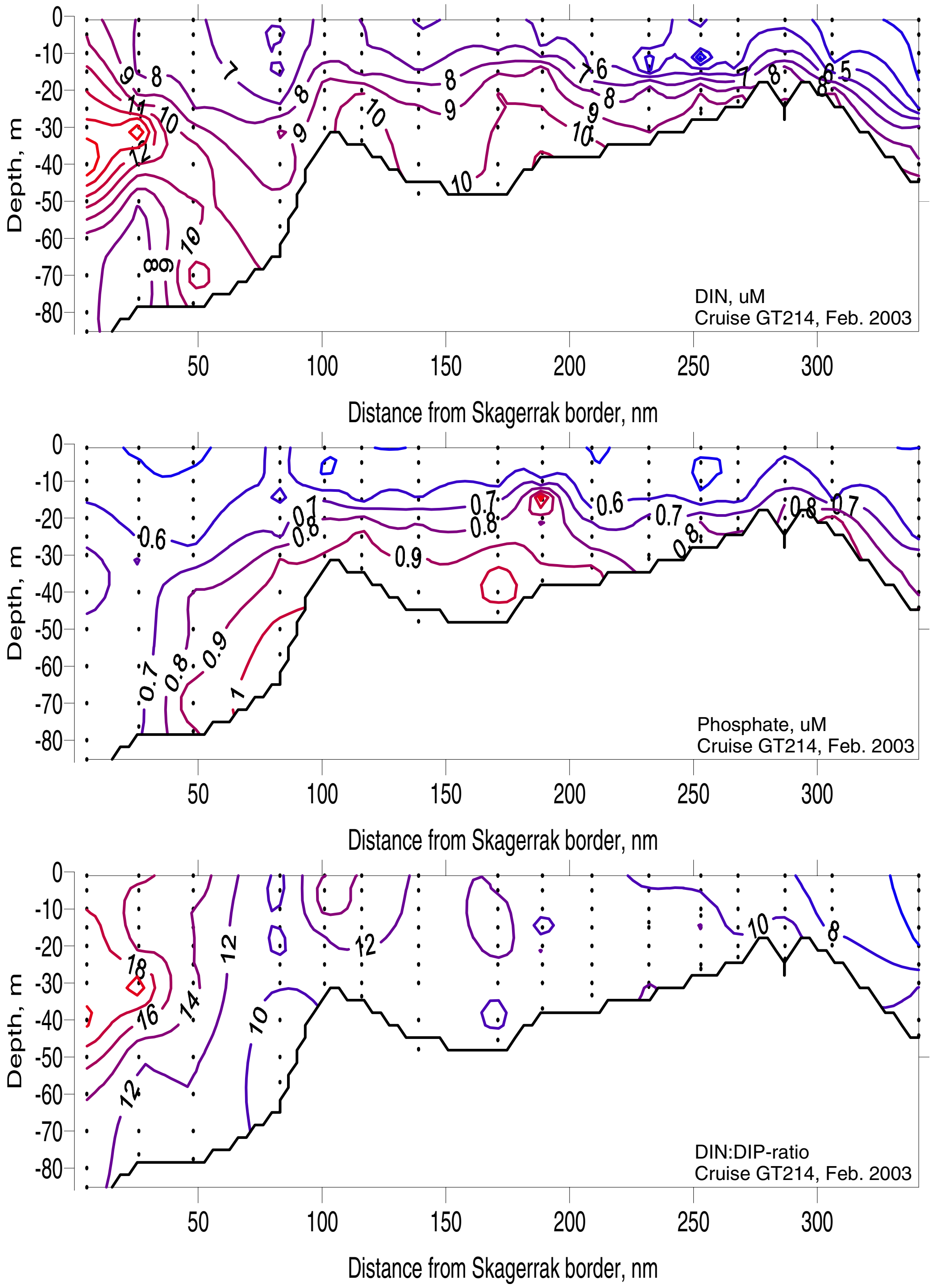

Figure 15. *DIN, phosphate and DIN/DIP ratio distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

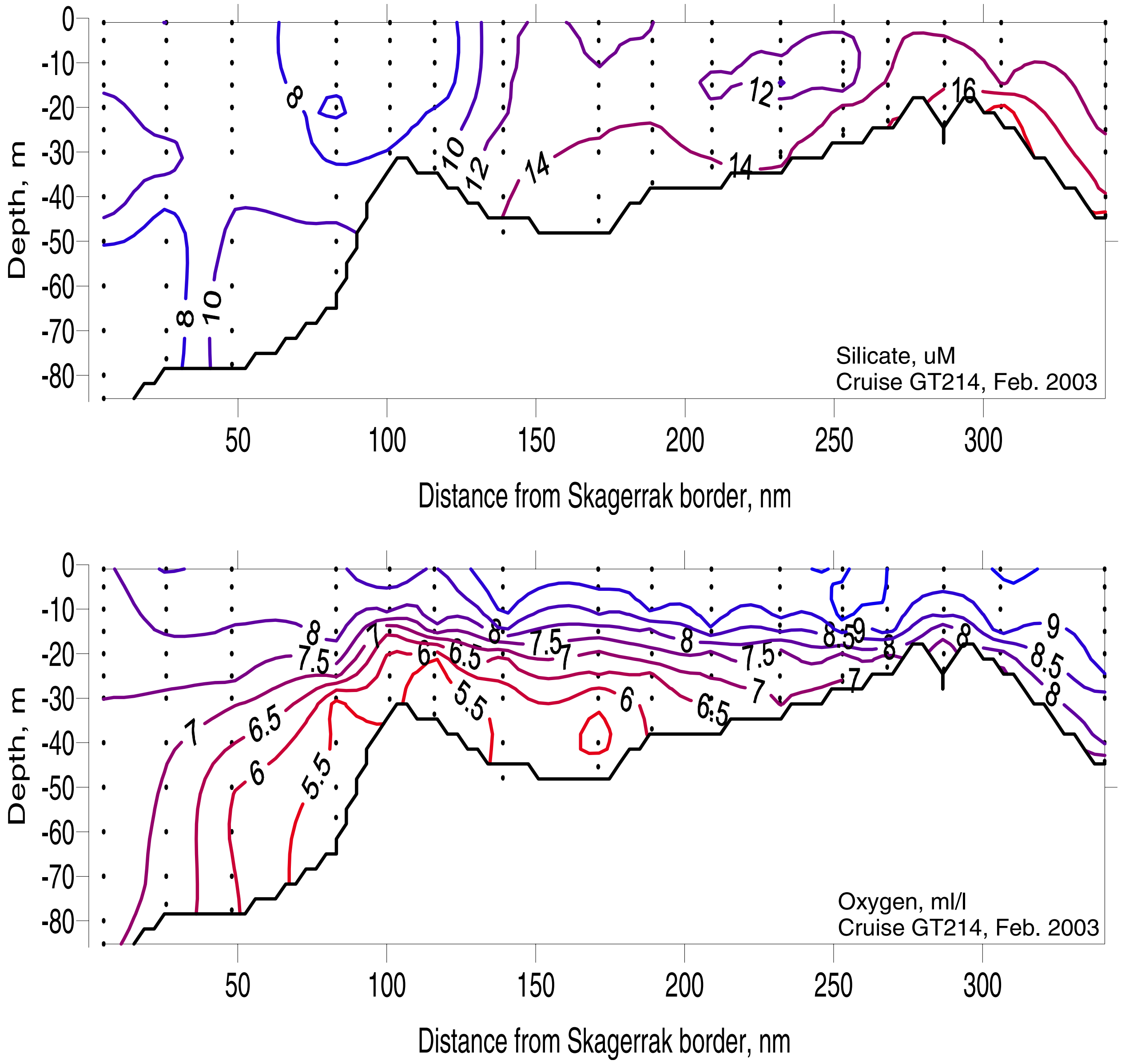

Figure 16*.* *Silicate and oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*

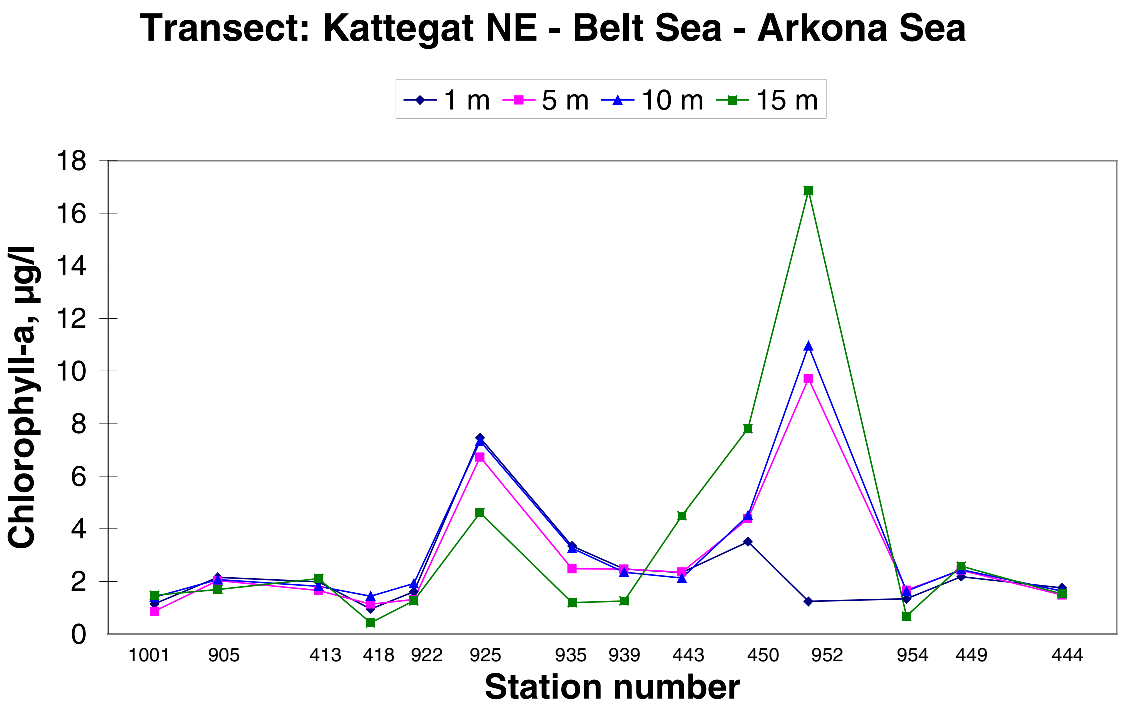

Figure 17. *Chlorophyl-a at 1 m, 5 m, 10 m and 15 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.*