r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 201

Time: 5 - 15 February 2001

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

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Data Sheet

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Monitoring cruise with r/v Gunnar Thorson in the Sound, Kattegat, Skagerrak, North Sea, Belt Sea and Arkona Sea, 5-15 February 2001. Cruise no. 201.

Report: Gunni Ærtebjerg

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5-12/2: Gunni Ærtebjerg, Peter Kofoed, Lars Renvald, Martin Larsen;
12-15/2: Hanne Ferdinand; 5/2: Ole Lund Jensen;
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Summary
The hydrographic situation was rather unusual compared to previous February cruises. As usual, the Jutland Coastal Current (JCC) with lower salinity and temperature was evident but relatively narrow along the Danish North Sea coast up to the entrance to Skagerrak. However, west of the JCC and in the central Skagerrak the surface salinity was unusually high, 34.5-34.9, probably due to an unusually large inflow of Atlantic water from the Biscay in late 2000 (Jan Aure, pers.com.). The Kattegat and Belt Sea area was characterised by out flowing low saline Baltic water at the surface, high saline bottom water, strong stratification and for the season relatively low oxygen concentrations in the bottom water. This is probably due to the prevailing relatively weak southerly wind in the months prior to the cruise.

In the North Sea the nutrient concentrations as usual varied inversely to the salinity. Due to the relation to the salinity the nutrient concentrations were generally highest in the south-eastern German Bight, decreasing to the north and west. However, the estimated nitrate concentration at salinities above 34 is higher than at earlier February cruises, which is in agreement with a higher dominance of Atlantic water. The estimated nitrate concentration in river water (0 psu) was lower than usual. The reason for this is yet unknown. The nitrate concentrations in the Kattegat and Belt Sea were relatively low compared to the 1980s, especially in the eastern Kattegat and the Arkona Sea.

The mean chlorophyll concentration in the uppermost 10 m varied from 0.2 µg/l in the central Skagerrak to 2.4 µg/l in the German Bight, 2.5 µg/l in Kiel Bight and 3.1 µg/l at Hanstholm. Generally, the phytoplankton spring bloom was not yet developed, but seemed just about to start in the southern Belt Sea, Arkona Sea and western Kattegat, and may be at Hanstholm. The lowest oxygen concentration of 4.3-4.8 ml/l (63-73% saturation) was observed in the Sound the 5 February in 20 to 50 m depth, but had 10 days later increased to 5.2 ml/l (78%). Otherwise, the minimum saturation was 80-100%. Compared to February last year and to mean for February in the 1980s the minimum oxygen concentrations were generally lower in the Kattegat-Belt Sea this year.

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 (Arkona Sea, Sound, Belt Sea, Kattegat), and the OSPARCOM monitoring programme for the Greater North Sea (Kattegat, Skagerrak, 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 was sampled at 3 stations. Sediment samples for monitoring of contaminants and radioactivity were sampled at 3 stations and 2 stations, respectively. Besides the monitoring measurements, surface water was sampled at 24 stations, and sediments at 5 stations for pigment analyses.

Meteorology
Characteristics of the weather conditions since the last cruise in the beginning of November 2000 are given in *table 1*. The whole period November-February was unusually mild, especially November to January, which was also dominated by rather weak wind from southerly directions. November was relatively wet, while December was about normal and January quit dry. In the beginning of February the weather changed, and the cruise began in a snowstorm from E-NE. Again 7 February we had 18-20 m/s from S-SW in Skagerrak, but during the rest of the cruise the wind was rather weak.

Table 1. Deviations in monthly mean temperature and precipitation in November 2000 to February 2001 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. 00	+2.2	+18	5.6	SE-S-SW
Dec. 00	+2.1	+5	4.9	SE-S-SW
Jan. 01	+1.7	-21	4.5	SE-S-SW
Feb. 01	+0.5	+26	5.5	SW-W-NW--NE

North Sea and Skagerrak

Hydrography
Actually, the hydrographic situation was quite unusual compared to previous February cruises. As usual, the Jutland Coastal Current (JCC) with lower salinity and temperature was evident but relatively narrow along the Danish North Sea coast up to the south-western entrance to Skagerrak. However, west of the JCC the surface salinity was unusually high, 34.5-34.9. High saline and relatively warm water also dominated the central Skagerrak with 34.7 psu observed at the coast off Hirtshals, establishing a very strong front to the Baltic water from Kattegat, probably close to Skagen. Along the coast the salinity increased from 30.1-30.5 in the German Bight to 33.0 at Limfjorden and 33.7 at Hanstholm, which was the lowest salinity observed at

the Skagerrak stations (*figure 2*). The surface temperature was relatively high and ranged from 1.5-1.8°C at the coast-near stations in the German Bight to 5.4-5.9°C at the western most station in the North Sea and 5.8-7.0°C in the central Skagerrak (*figure 3*).

The high salinity in the North Sea as well as parts of the Skagerrak surface water indicates inflow of North Atlantic water. According to information from Norway (Jan Aure, pers. com.) an unusually large inflow of Atlantic water from the Biscay through the English Channel to the North Sea took place in late 2000.

Nutrients

In the North Sea the nutrient concentrations as usual varied inversely to the salinity (*figure 4*). The results of linear regressions are shown in *table 2*. For ammonium, phosphate, total-P and silicate the concentrations were about constant at salinities above 34. Therefore, samples with salinity >34.1 were omitted from the analysis of these nutrients, as also 4 Total-N outliers. All regressions are highly significant, indicating well-mixed water masses in the eastern North Sea. Usually nitrite, phosphate and Total-P correlations to salinity are much less significant due to bio-geochemical processes.

Table 2. Linear regression analyses of salinity and concentrations of nutrients at the 36 stations in the North Sea 8-10 February 2001. 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	-5.0	184	10.2	238	0.88
Nitrite	-0.42	14.6	0.14	238	0.93
Ammonium	-0.56	19.1	0	118	0.81
Total-N	-8.4	310	18.9	234	0.93
Phosphate	-0.19	7.01	0.45	118	0.95
Total-P	-0.36	13.2	0.72	118	0.71
Silicate	-4.4	155	3.50	118	0.97

Due to the relation to the salinity the nutrient concentrations were generally highest in the south-eastern German Bight, decreasing to the north and west (*figures 5, 6, 7, 8, 9, 10 and 11*). However, the estimated nitrate concentration at salinities above 34 is higher than at earlier February cruises, which is in agreement with a higher dominance of Atlantic water. The estimated nitrate concentration in river water (0 psu) was lower than usual. The reason for this is yet unknown.

In the Skagerrak the high saline Atlantic water from the Biscay with nitrate concentrations above 8-10 µmol/l seems to dominate the surface water on the Danish site, while more normal central North Sea water is observed at the outermost stations at the transects.

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 concentrations of 5.47-5.65 ml/l (82-85%) were observed in 175-250 m depth at the stations 1106, 1006 (M6) and 1135, all in the middle of Skagerrak, but also at 20-50 m depth at the stations 1101 and 1102 outside Hirtshals.

The mean chlorophyll-*a* concentration in the surface layer (0-10 m) varied from 0.2 µg/l in the central Skagerrak to 2.4 at the island of Sylt in the German Bight and 3.1 at Hanstholm (*figure 12*). It can not be ruled out that a spring bloom was initiated outside Hanstholm.

Kattegat, Sound, Belt Sea and Arkona Sea

Hydrography

The surface temperature (1 m depth) was relatively high for the season and varied from 0.7-1.5°C in the northern Kattegat to 3.4°C in the Arkona Sea (*figure 3*). The bottom water temperature ranged from 4.0-5.0°C in the Arkona Sea to 8.9°C in the Sound.

The surface salinity was low for the season and ranged from 7.7-8.1 in the Arkona Sea (St. 441, 444) to 23.1-24.6 in the north-western Kattegat (St. 403, 1008, 1009) (*figure 2*). The bottom water salinity ranged from 15.7-17.9 in the Arkona Sea (St. 441, 444, 449) to 34.2-34.9 in the northern Kattegat (St. 403, 905, 1001, 1007, 1008, 1009). Also in the Sound, eastern and southern Kattegat the bottom water salinity was as high as 32.3-33.8 (*figure 13*). The salinity stratification was strong: 24 psu in the Sound, 10-15 psu in the deeper parts of Kattegat and 7.5-10 psu in the Belt Sea and Arkona Sea.

Compared to long term monthly means (Lightship observations 1931-1960) for February the water temperature during the present cruise was generally higher, except for lower surface temperature in the northern Kattegat. The surface salinity in Kattegat was lower than normal, but in the Belt Sea higher than normal. The bottom water salinity was higher than normal, except in Læsø Rende.

Nutrients

The nitrate concentrations were relatively low compared to the 1980s. Especially in the eastern Kattegat (St. 413) and the Arkona Sea (St. 441, 444) the concentrations were unusually low, 3.8 and 1.8 µmol/l, respectively (*figure 5*). In the bottom water a maximum of 9.4-10.7 µmol/l were observed in the southern Kattegat and the Sound (*figure 14*).

Rather high concentrations (>0.5 µmol/l) of nitrite (*figure 6*) and ammonium (*figure 7*) were found in the southern Belt Sea (*figure 15*). Also the concentrations of phosphate and silicate were highest in the Belt Sea (*figures 9, 11 and 16*).

Chlorophyll-*a*

The mean chlorophyll concentration in the uppermost 10 m was highest (2.5 µg/l) in Kiel Bight (St. N3), and above 1 µg/l in the western Kattegat, southern Belt Sea and Arkona Sea (*figure 12*). The chlorophyll was relatively homogeneously distributed in the uppermost 10 m (*figure 17*). The phytoplankton spring bloom had not yet started, but seemed just about to start in the southern Belt Sea, Arkona Sea and western Kattegat.

Oxygen

The lowest oxygen concentration of 4.3-4.8 ml/l (63-73% saturation) was observed in the Sound (St. 431) the 5 February in 20 to 50 m depth, but had 10 days later increased to 5.2 ml/l (78%). Otherwise, the minimum saturation was 80-95%. Compared to February last year and to mean for February in the 1980s the minimum oxygen concentrations were generally lower this year.

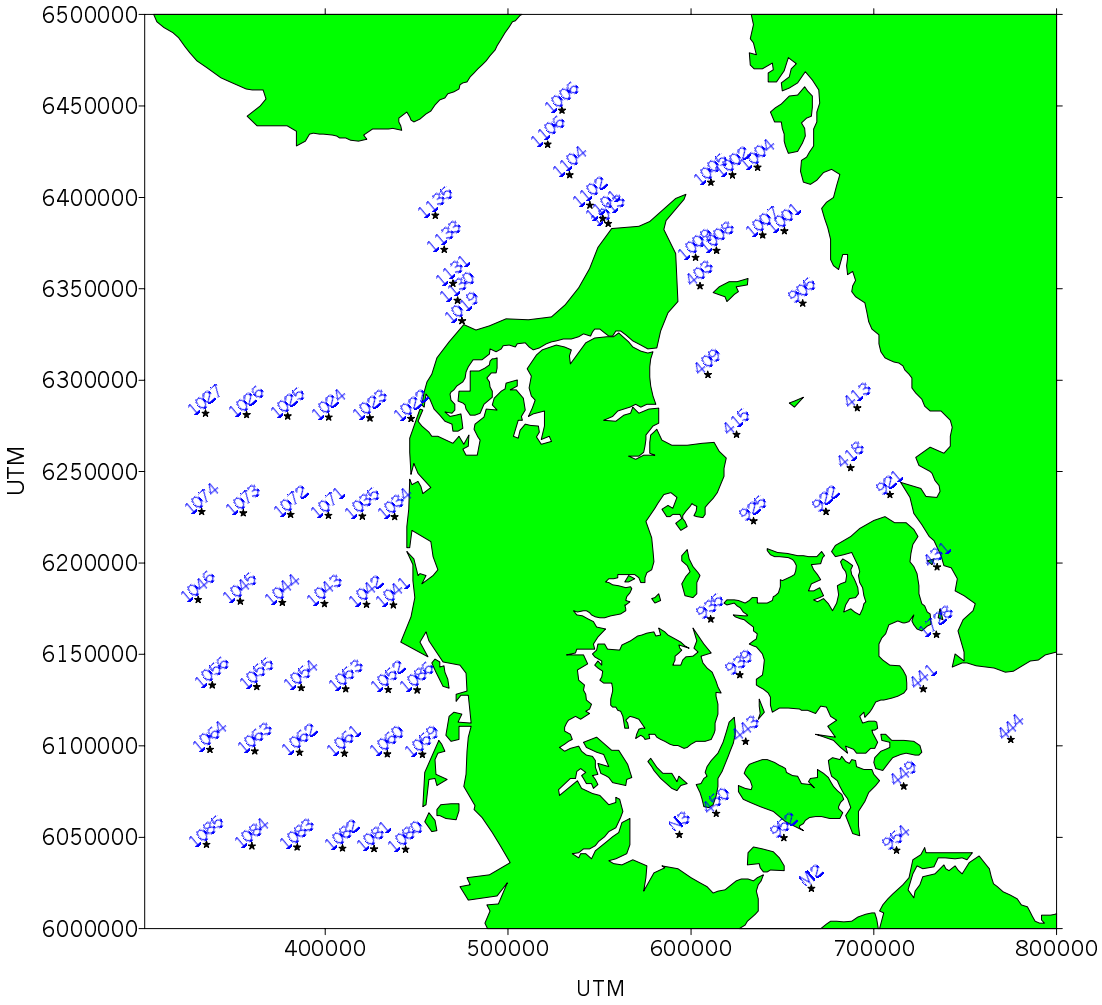


Figure 1. Stations of the monitoring cruise with r/v Gunnar Thorson 5-15 February 2001 in the Sound, Kattegat, Skagerrak, North Sea, Belt Sea and Arkona Sea. Gunnar Thorson cruise no. 201.

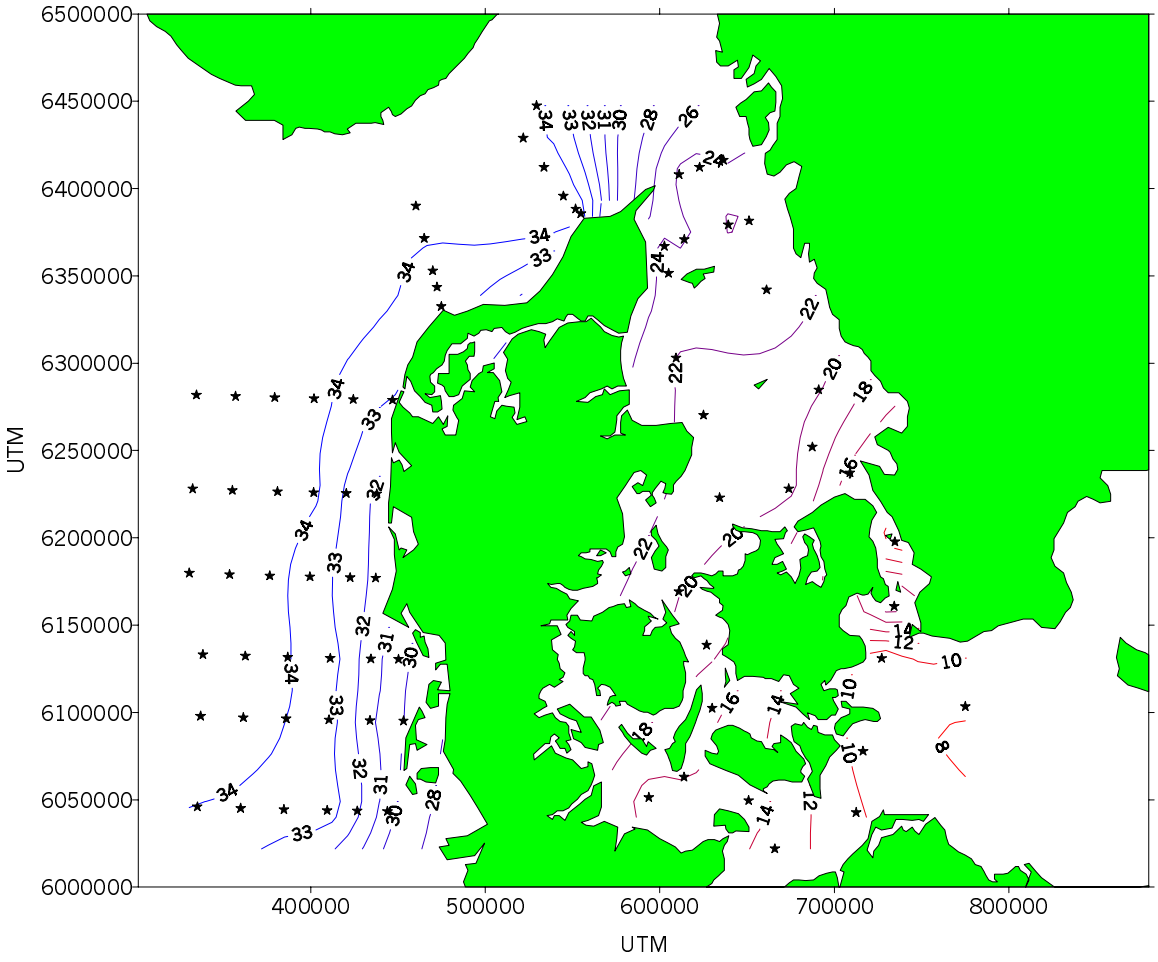


Figure 2. Interpolated distribution of surface salinity (mean 1, 5 and 10 m depth).

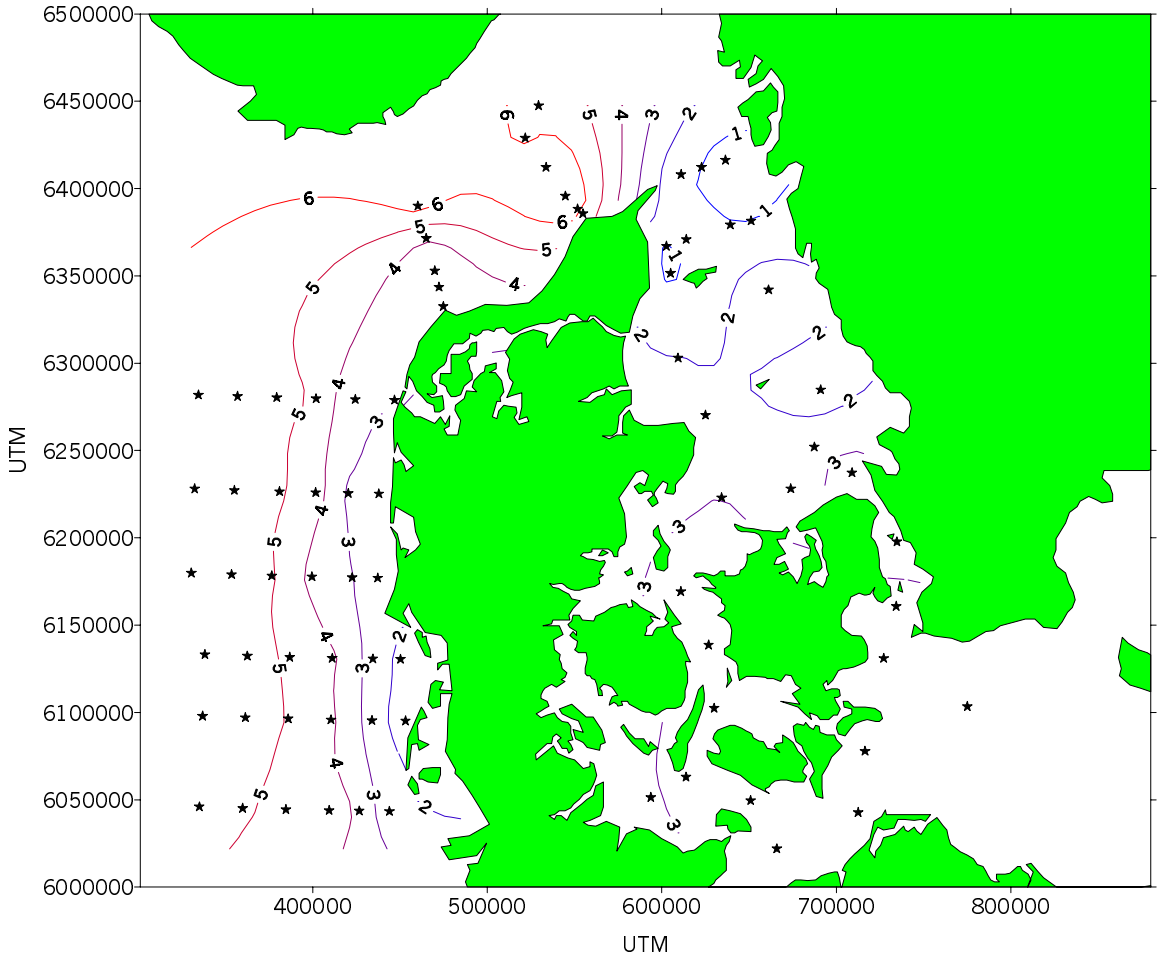


Figure 3. Interpolated distribution of surface temperature (mean 1, 5 and 10 m depth).

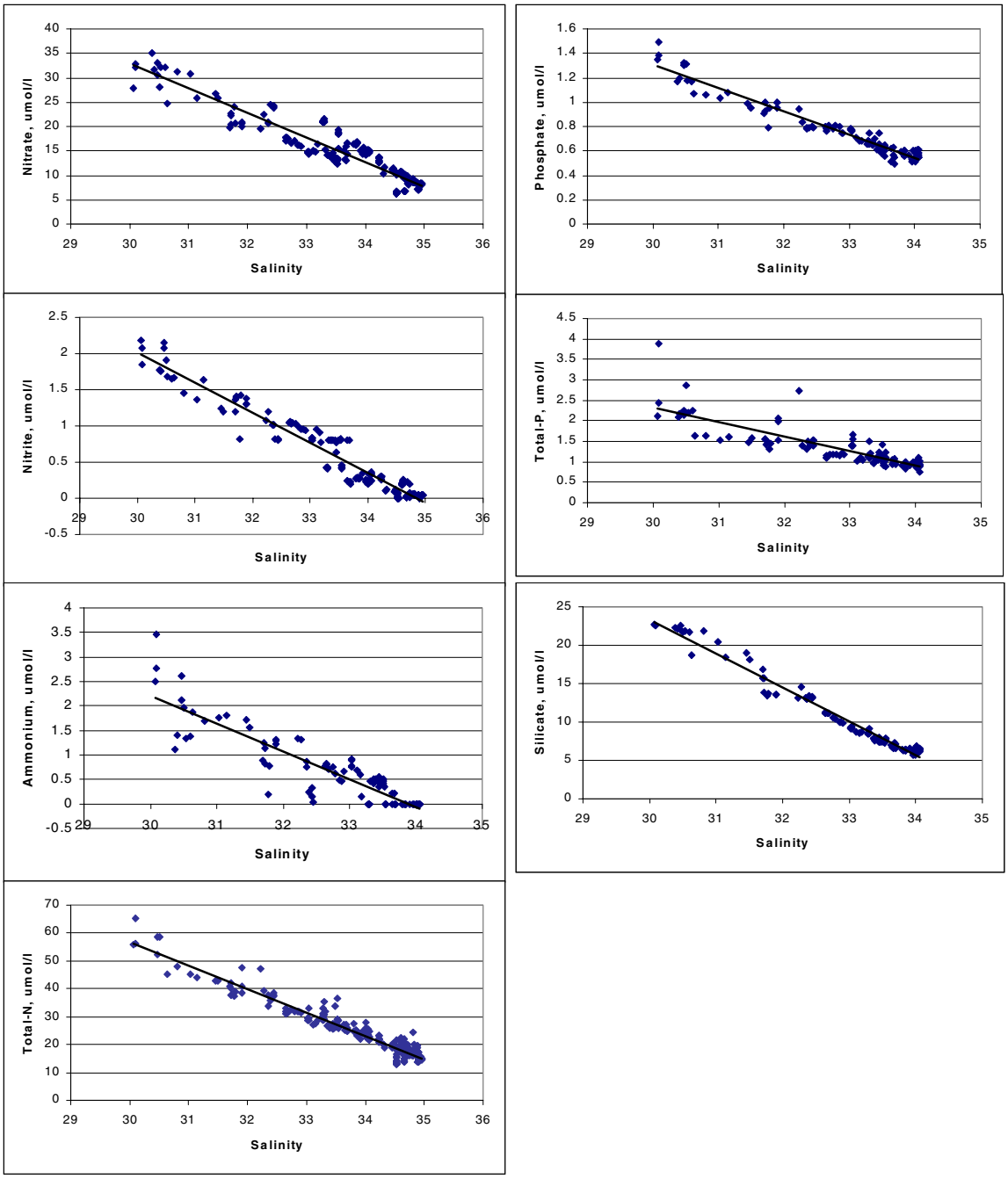


Figure 4. Correlation between salinity and nutrient concentrations at the 36 stations in the North Sea, 8-10 February 2001.

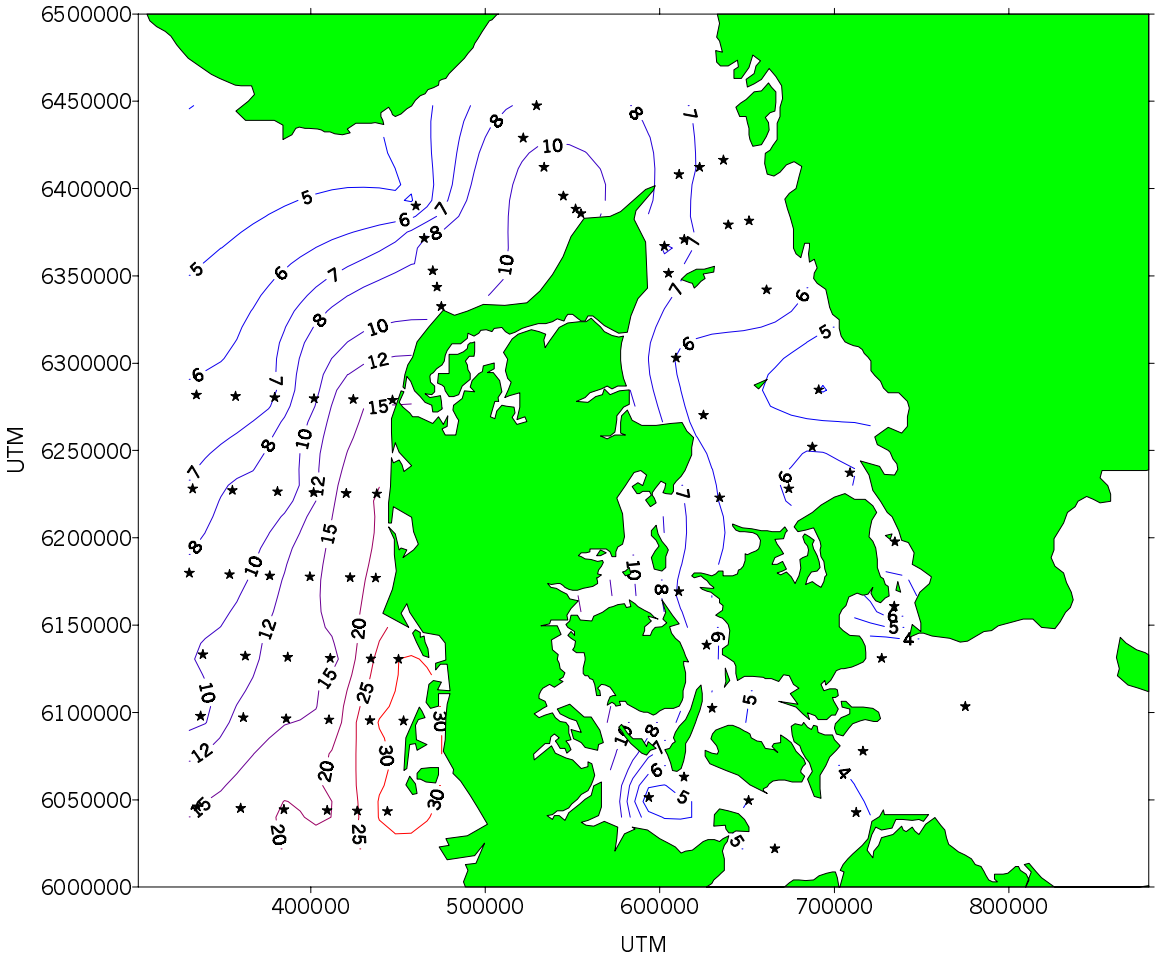


Figure 5. Interpolated distribution of surface nitrate concentrations (mean 1, 5 and 10 m depth).

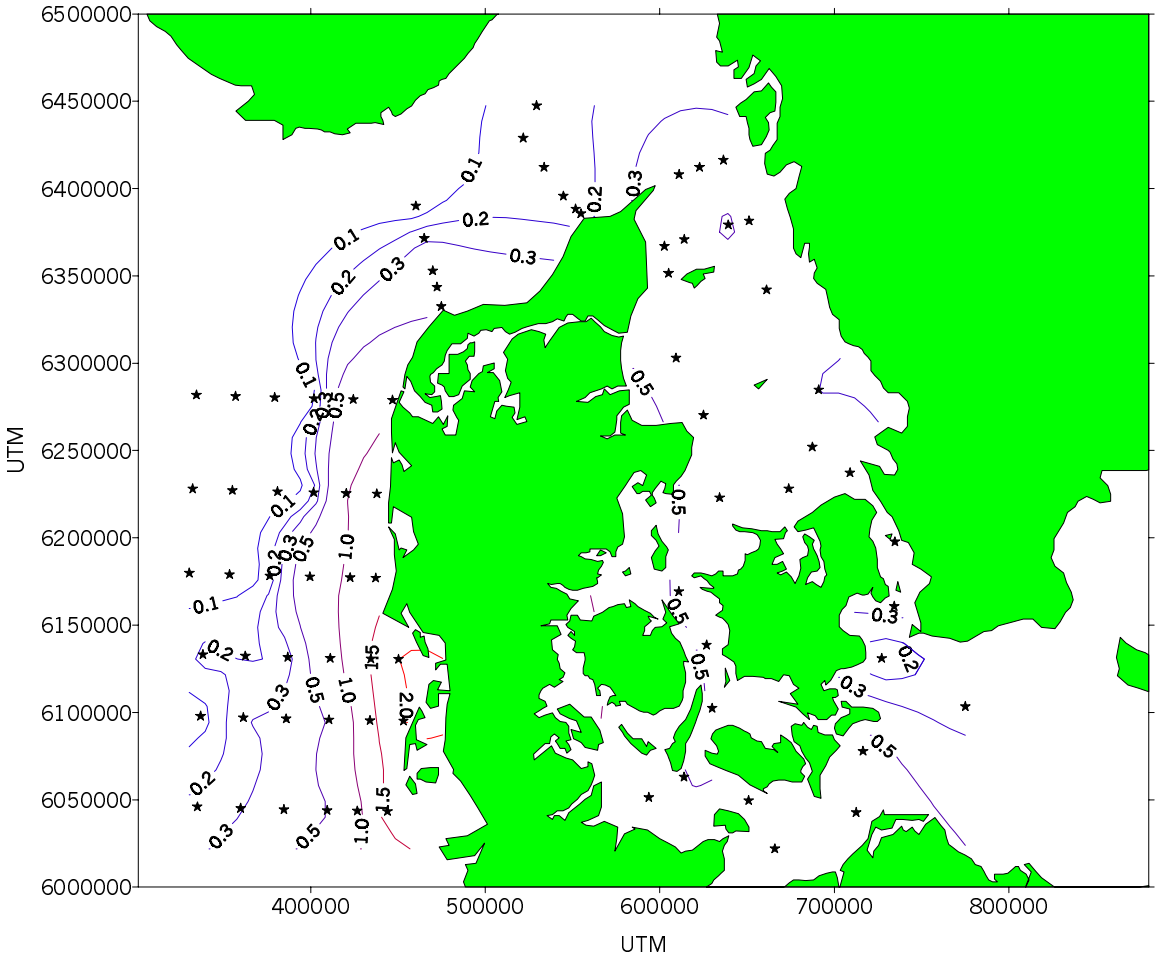


Figure 6. Interpolated distribution of surface nitrite concentrations (mean 1, 5 and 10 m depth).

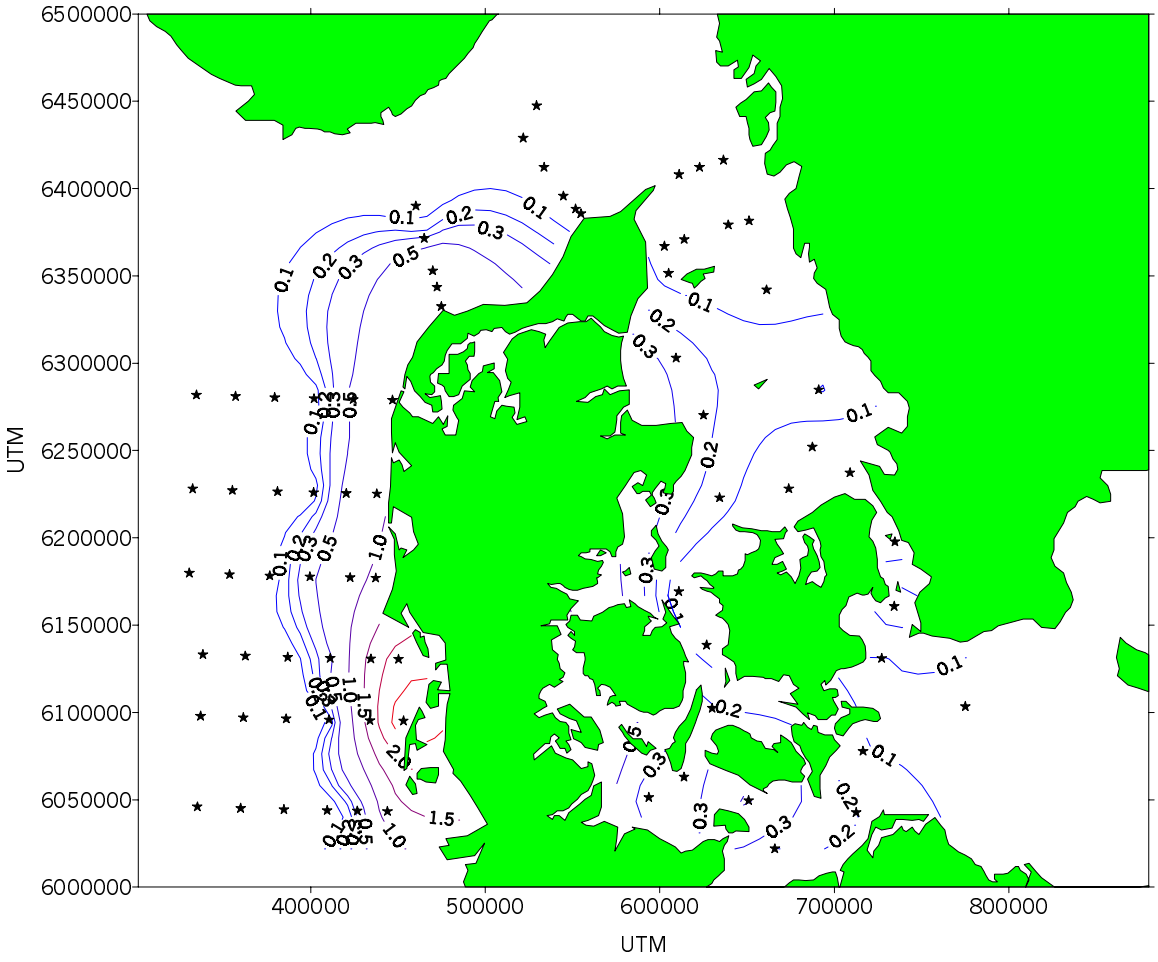


Figure 7. Interpolated distribution of surface ammonium concentrations (mean 1, 5 and 10 m depth).

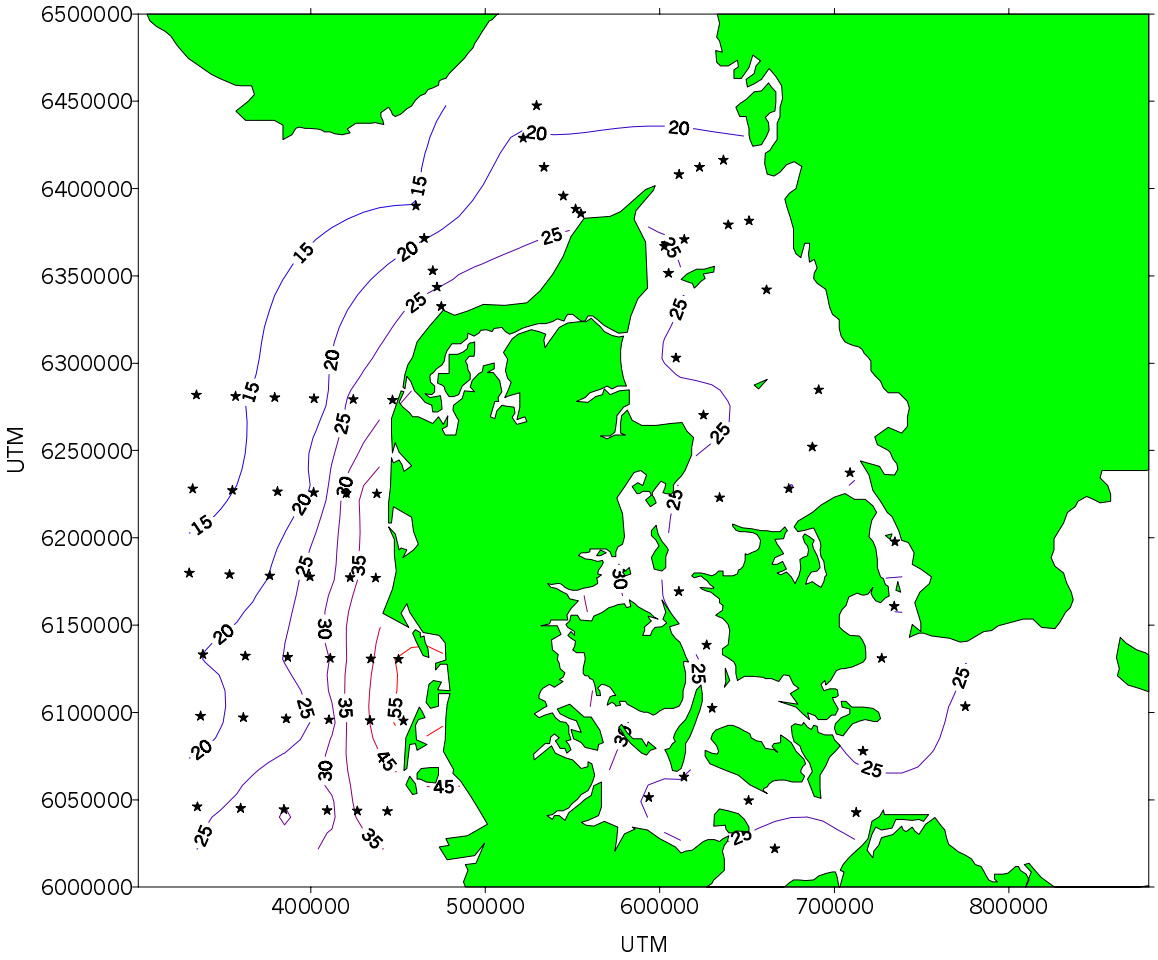


Figure 8. Interpolated distribution of surface Total-N (mean 1, 5 and 10 m depth).

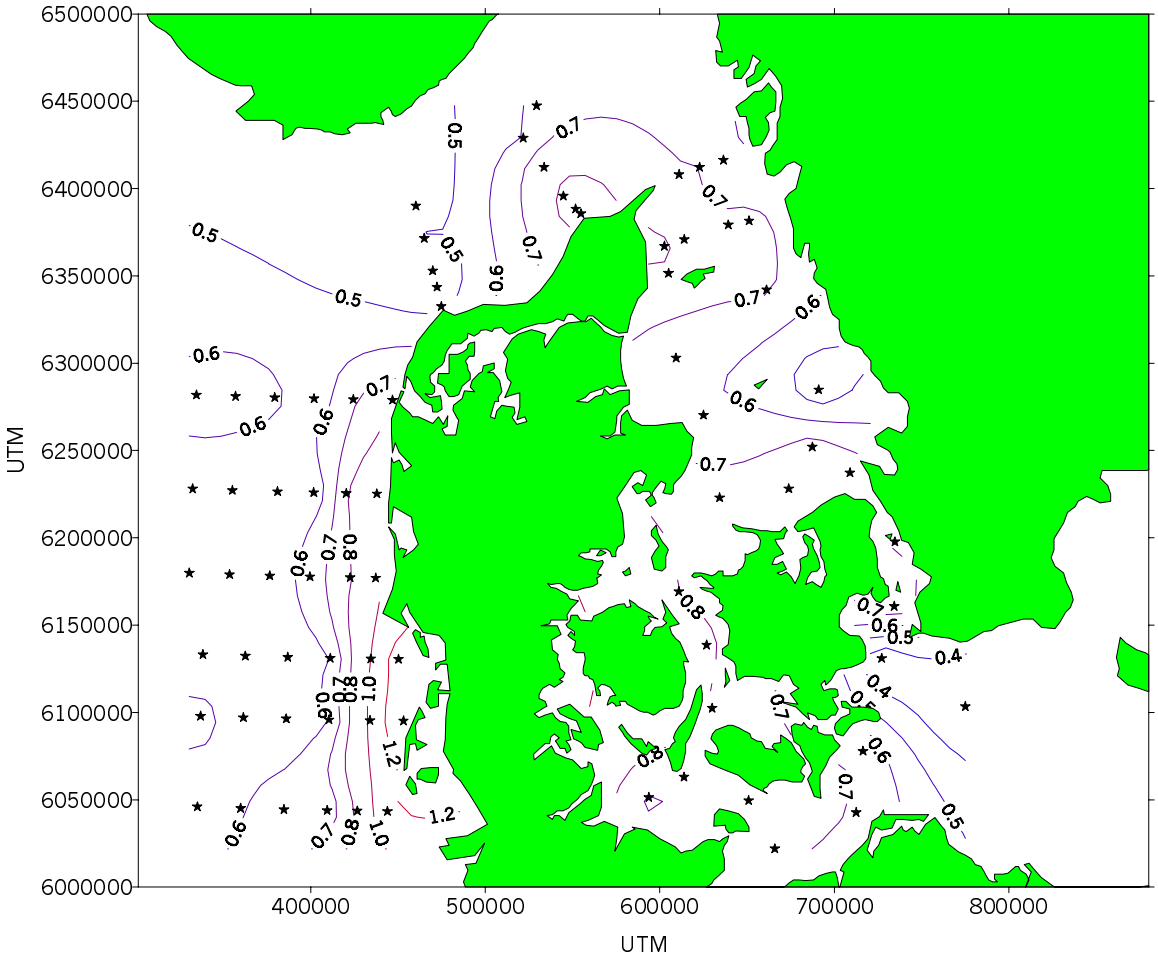


Figure 9. Interpolated distribution of surface phosphate concentrations (mean 1, 5 and 10 m depth).

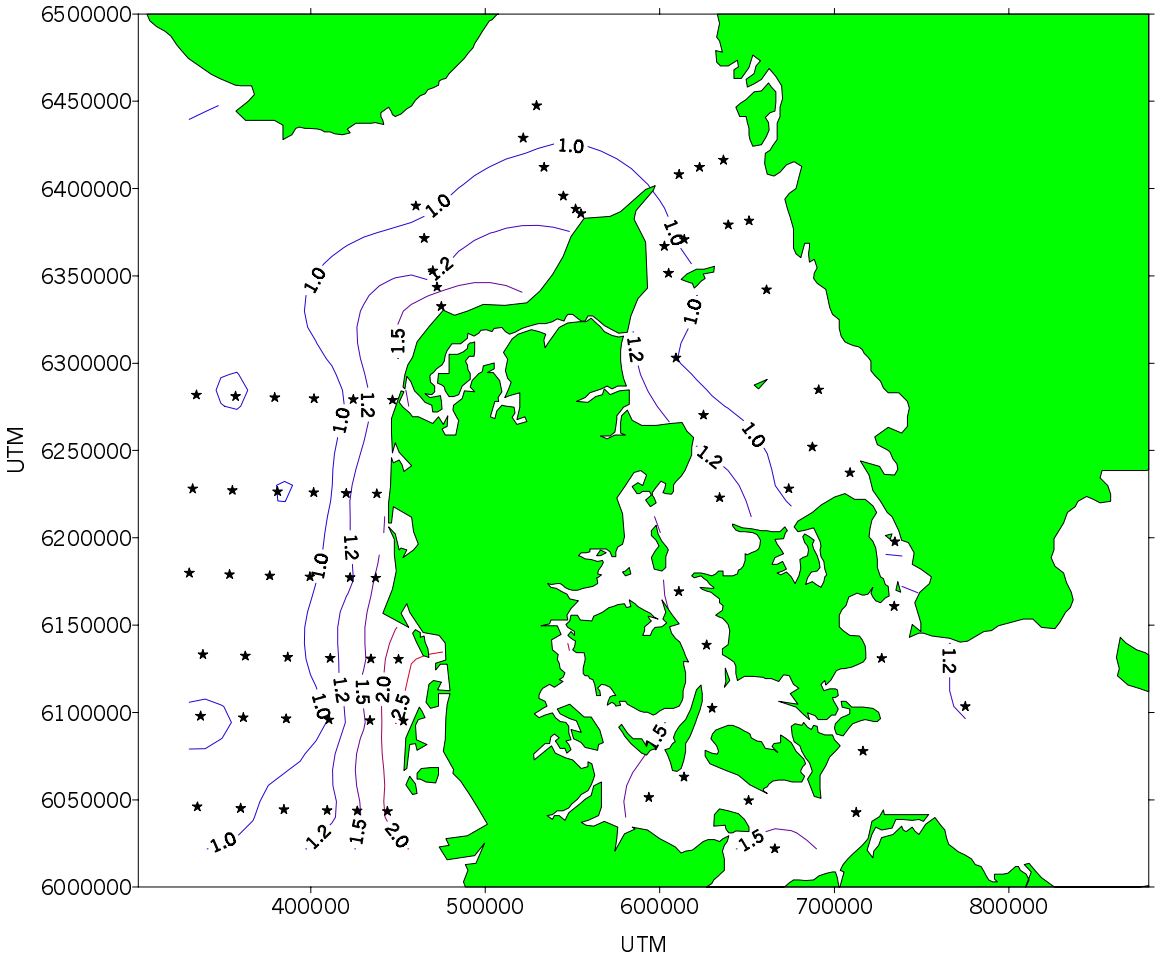


Figure 10. Interpolated distribution of surface Total-P concentrations (mean 1, 5 and 10 m depth).

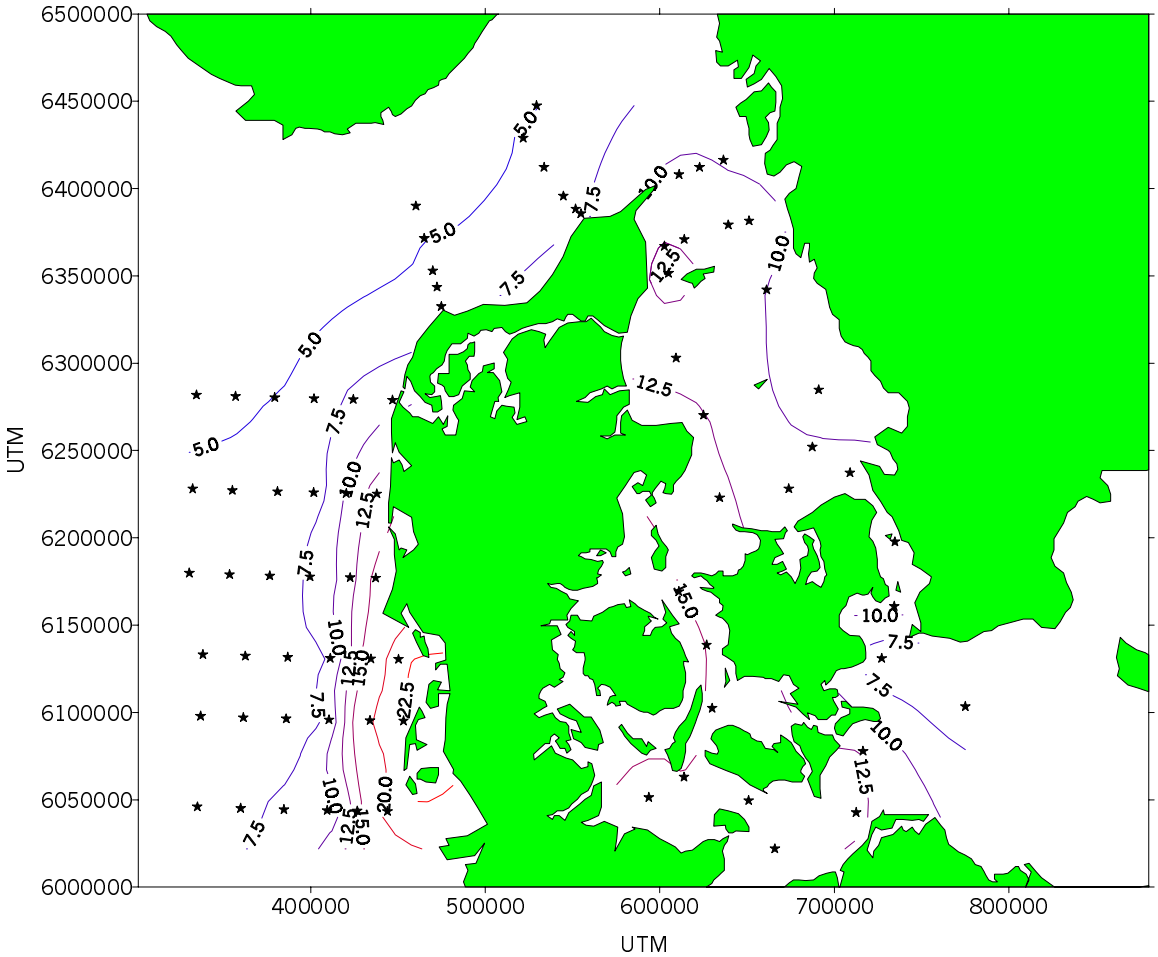


Figure 11. Interpolated distribution of surface silicate concentrations (mean 1, 5 and 10 m depth).

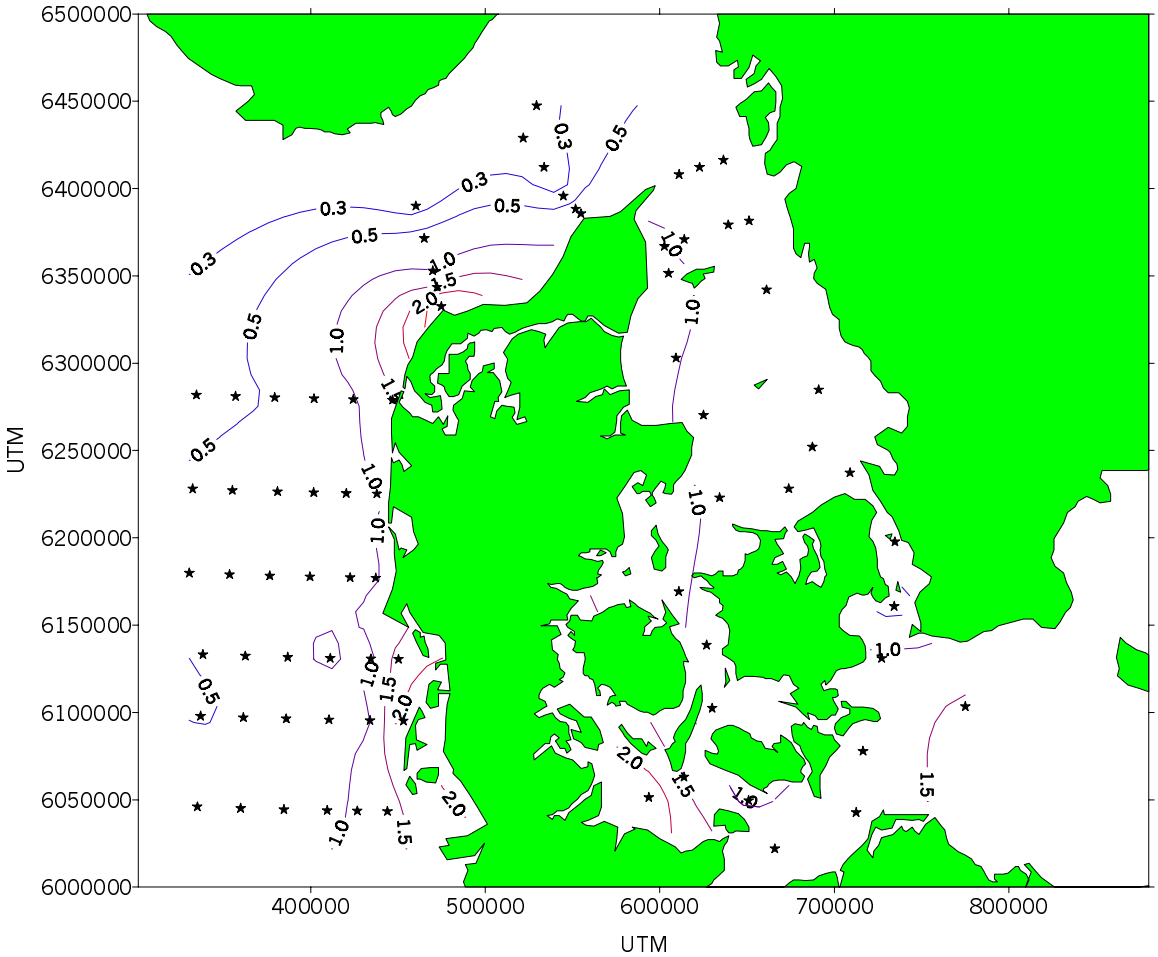


Figure 12. Interpolated distribution of surface chlorophyll-*a* concentrations (mean 1, 5 and 10 m depth).

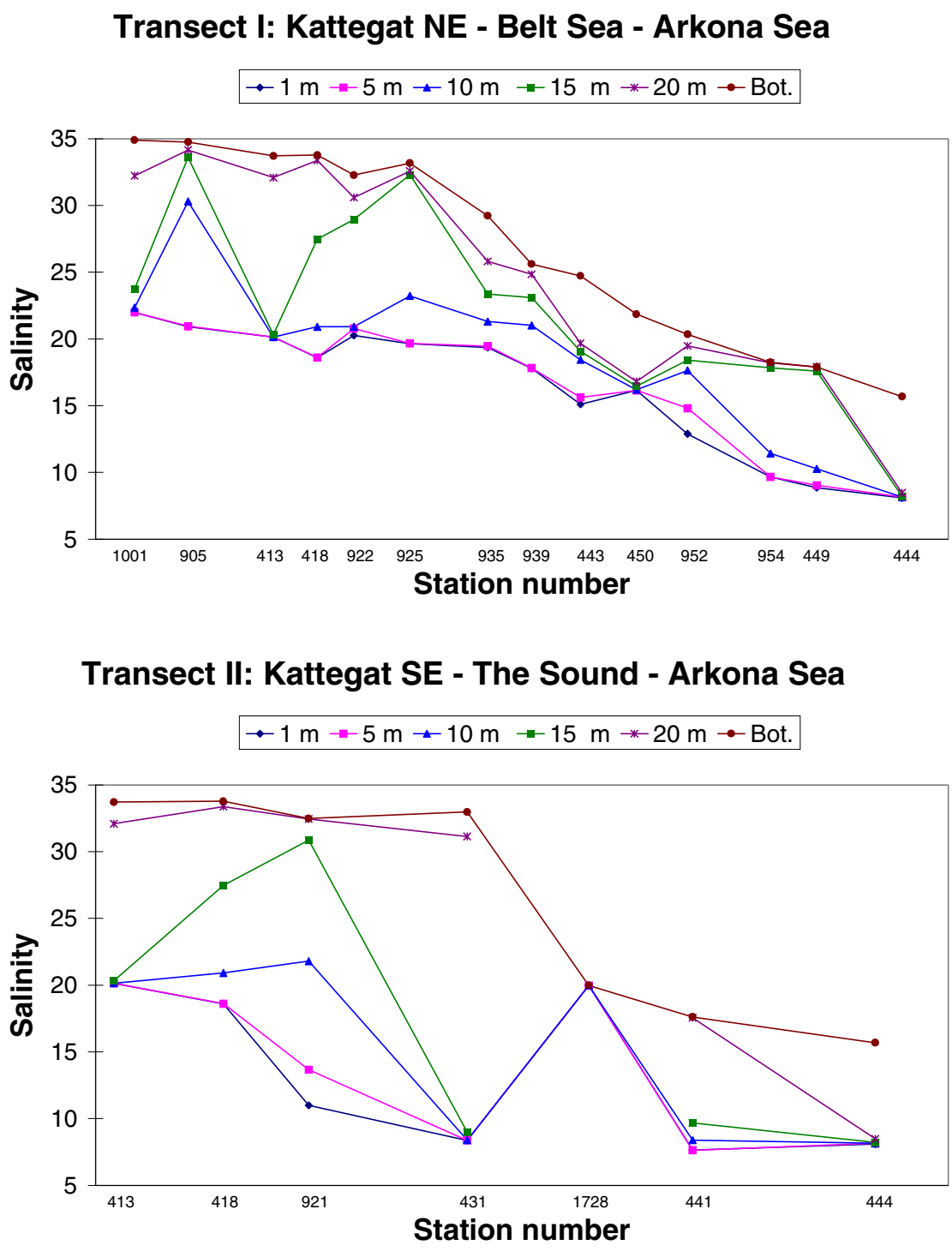
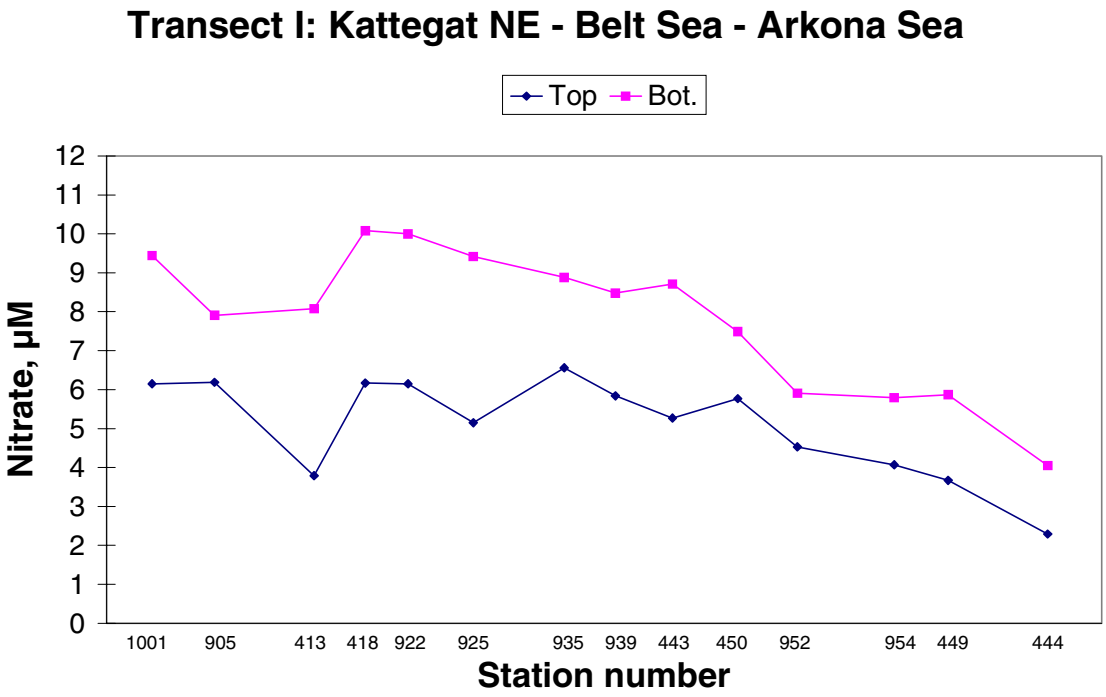


Figure 13. Salinity in 1 m, 5 m, 10 m, 15 m, 20 m depth and near bottom along transect I from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea, and along transect II from the eastern Kattegat through the Sound to the Arkona Sea.



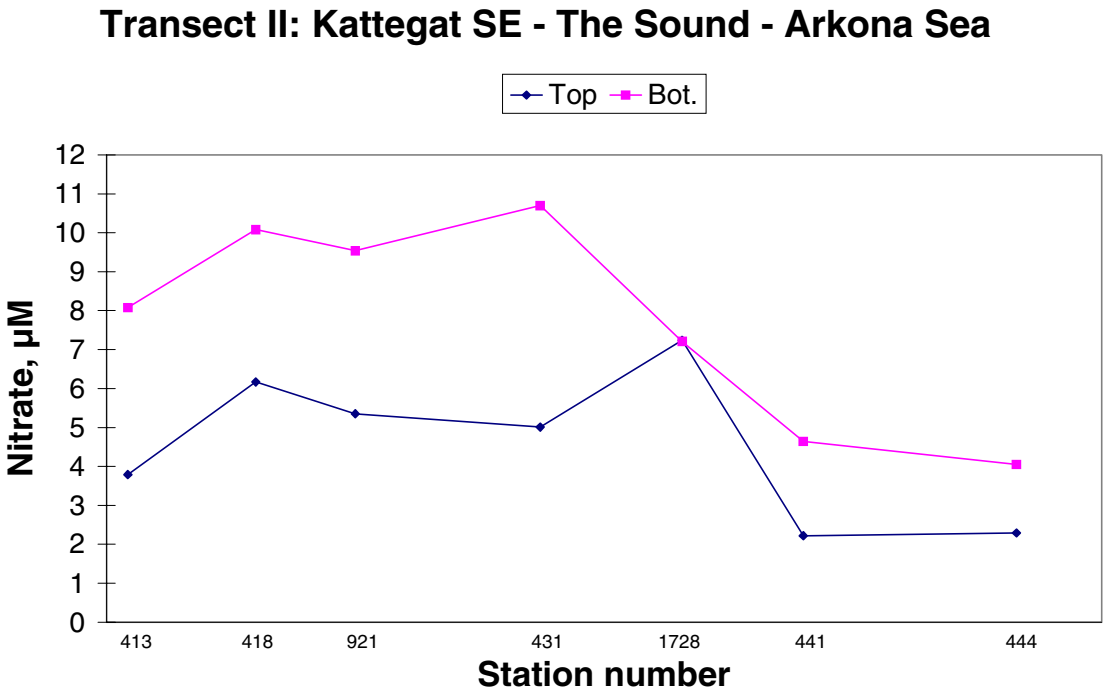
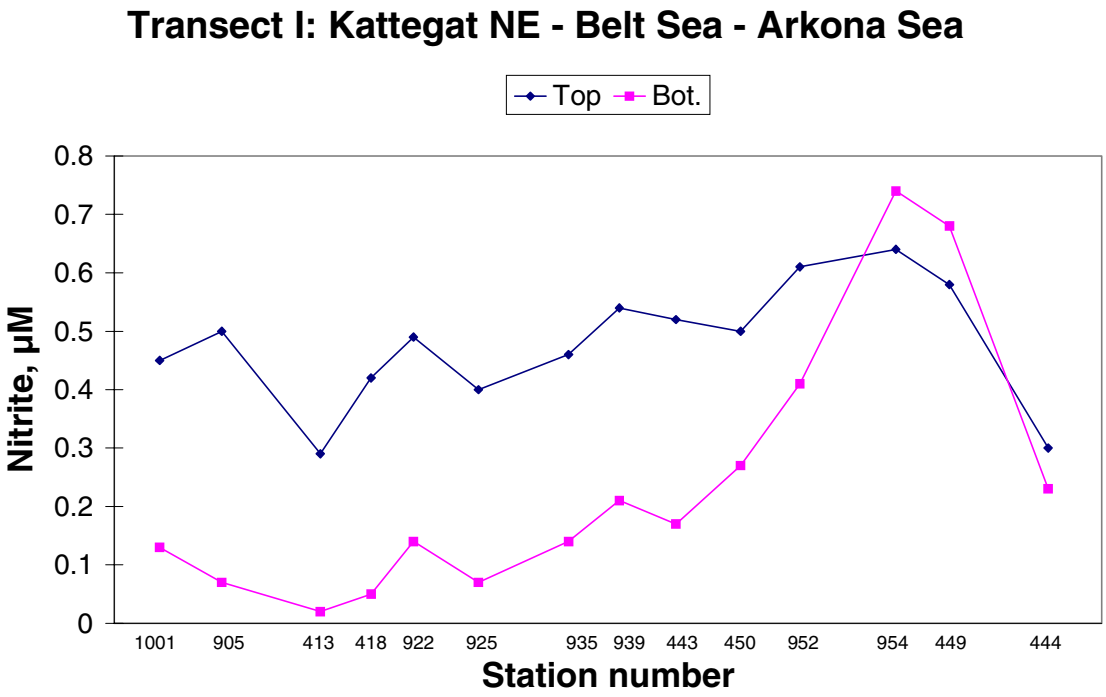


Figure 14. Surface and near bottom concentrations of nitrate along transect I and II.



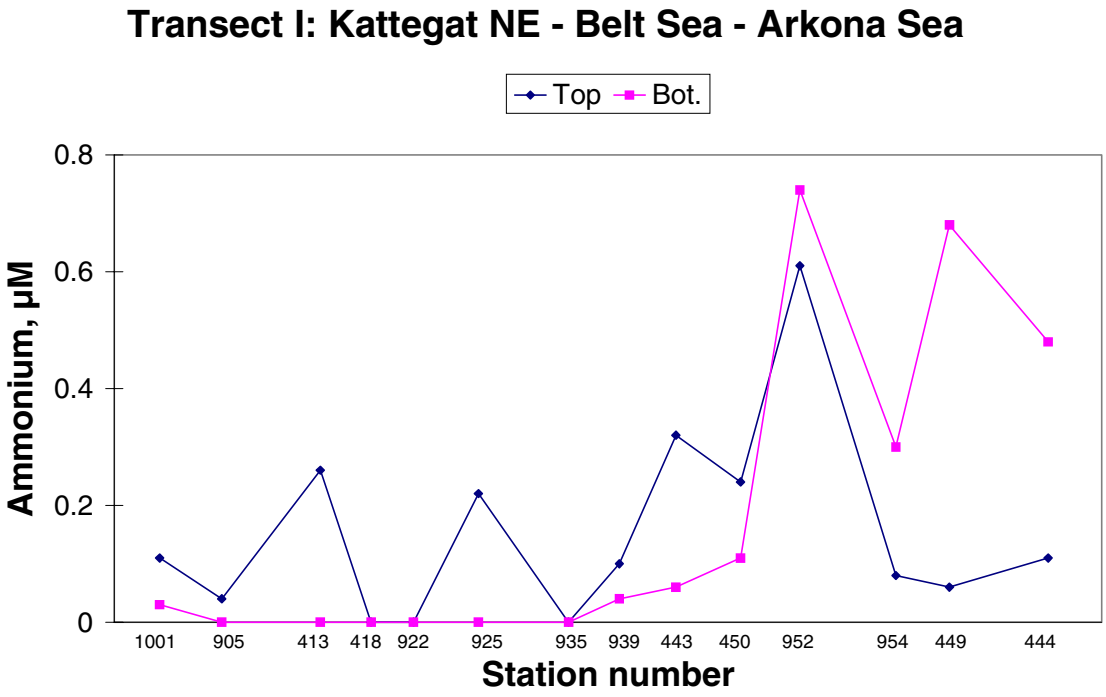
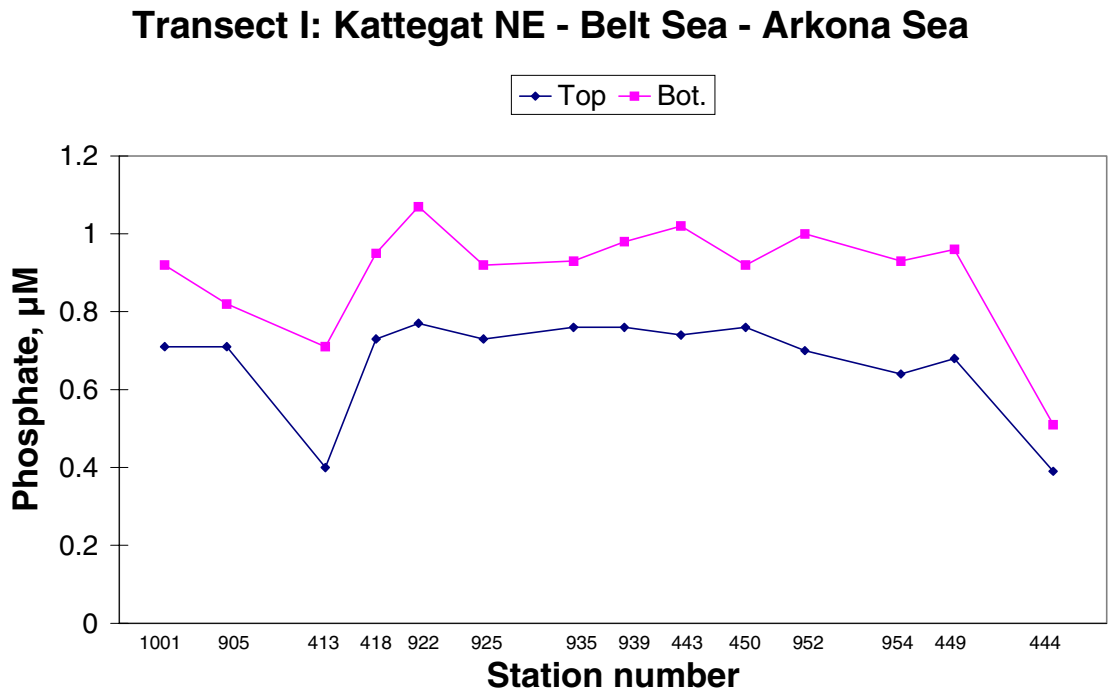


Figure 15. Surface and near bottom concentrations of nitrite and ammonium along transect I.



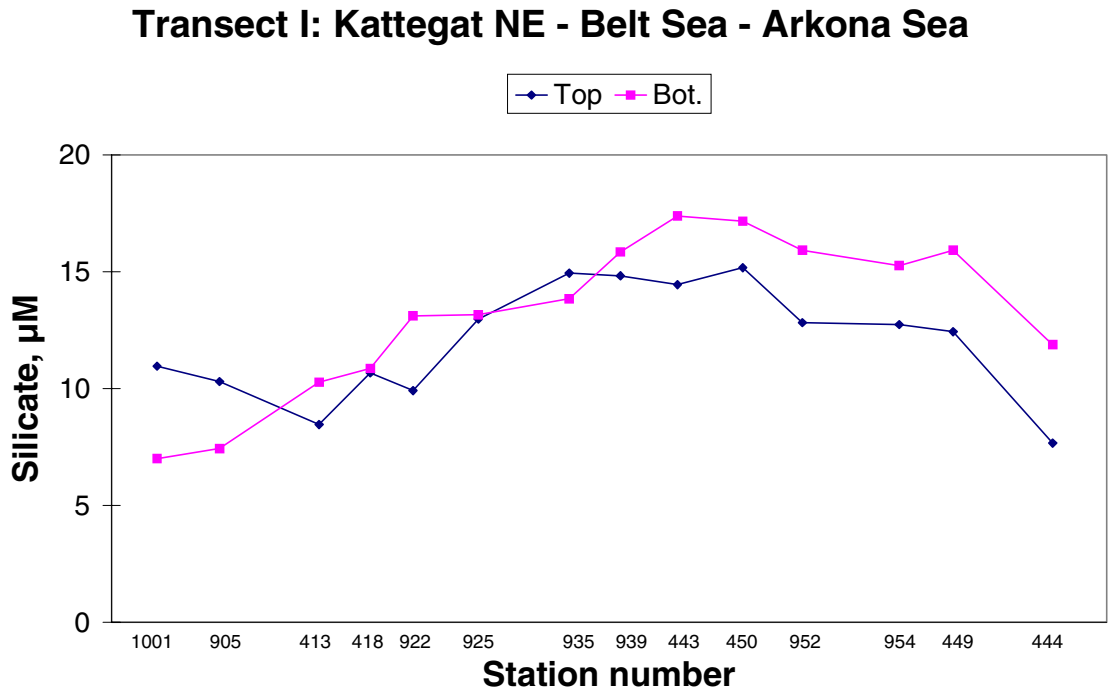


Figure 16. Surface and near bottom concentrations of phosphate and silicate along transect I.

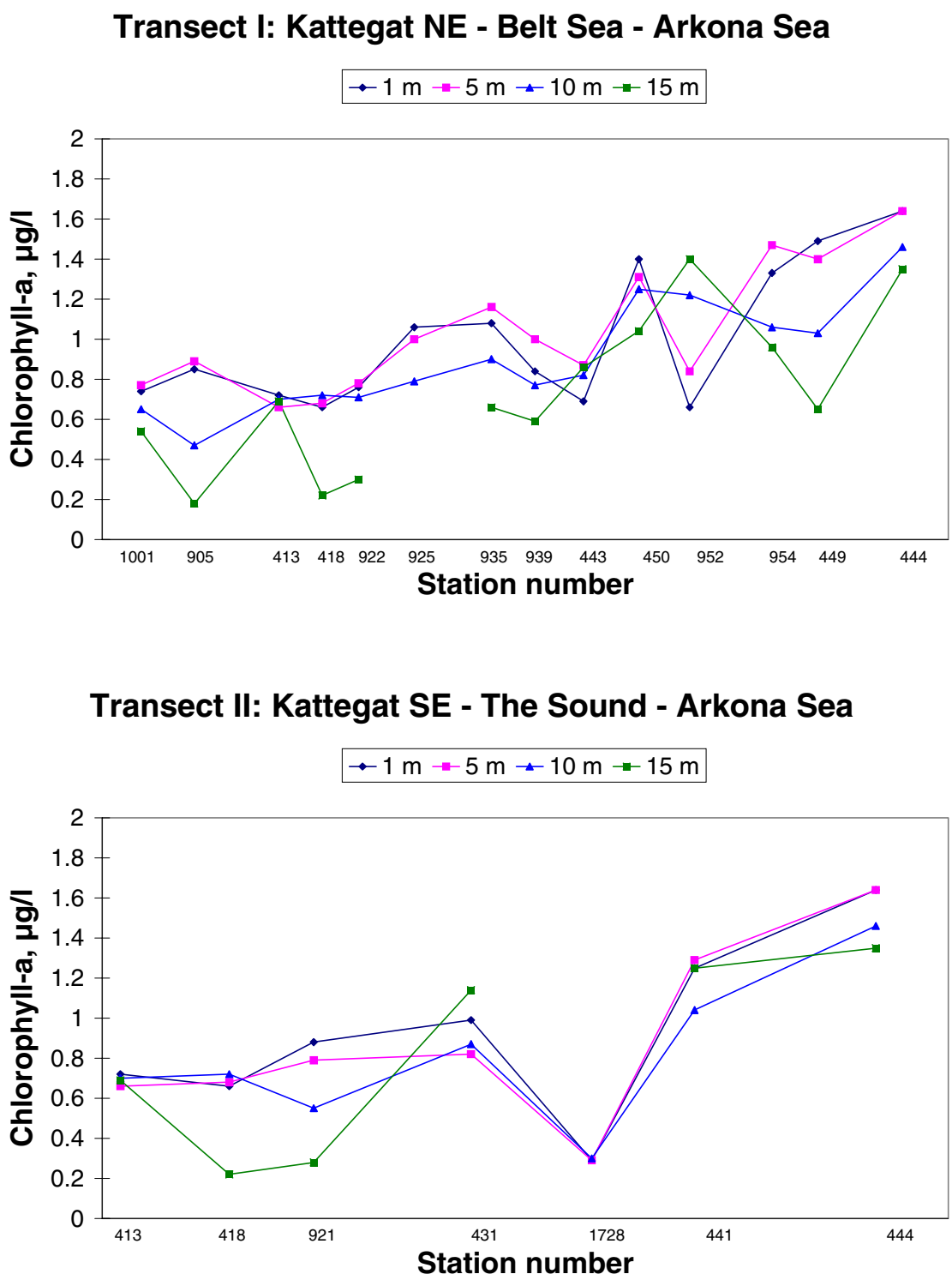


Figure 17. Chlorophyll-*a* concentrations in 1 m, 5 m, 10 m and 15 m depths along transect I and II.