r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 195

Time: 7 - 18 February 2000

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, 7-18 February 2000. Cruise no. 195.

Report: Gunni Ærtebjerg

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7/2: Ole Lund Jensen

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

Summary
The unusually high wind activity during this winter had mixed the water column well. Practically no stratification was present in the North Sea, and the inner Danish waters were unusually homogenous. In the Arkona Sea a primary halocline was found at 39 m depth due to saline bottom water flowing in from the Sound and Belt Sea. A pycnocline was also present in the deeper parts of the Kattegat, but relatively weak and generally situated in more than 20 m depth.

The surface temperature was relatively high due to the mild winter. In the inner Danish waters both the water temperature and salinity was higher than long term means for February in the whole water column, except for lower bottom water temperature and salinity in the southern Kattegat.

In the North Sea the inverse linear relationship between salinity and nutrients (except for nitrite) was as usually observed mirroring the river based nutrient load to the south-eastern North Sea. The Jutland Coastal Current with relatively low temperature and salinity, and high nutrient concentrations was narrow along the Danish coast up to Hanstholm at the entrance to the Skagerrak and could be traced at Hirtshals, but not in the Kattegat.

In the western Kattegat relatively high nitrate concentrations of 10-13 µmol/l not originating from the North Sea was observed. In the Arkona Sea the nitrate concentration in the surface was 3.8-4.9 µmol/l. In the rest of the inner Danish waters the nitrate concentrations were between 7 and 9 µmol/l in the whole water column.

The phytoplankton spring bloom had not yet started in any area. The minimum oxygen concentrations were high and most often close to saturation.

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 OSPAR 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*.

Meteorology
Characteristics of the weather conditions since the last cruise in the beginning of November 1999 are given in *table 1*. The whole period November-February was unusually mild, especially January and February. November was dry and relatively calm. December was very wet and windy. The strongest storm ever recorded past over Denmark 3 December, and another 17 December. Also January and February were very windy, including the first week of the cruise, and 10 planed stations in the North Sea were not sampled due to stormy weather. In January the precipitation was about normal, while February was very wet.

Table 1. Deviations in monthly mean temperature and precipitation in November 1999 to February 2000 in Denmark compared to long term monthly means 1961-90, monthly mean wind speed and dominating wind direction (based on data from the Danish Meteorological Institute).

Month	Temperature deviation °C	Precipitation % deviation	Mean wind speed m/s	Dominating wind direction
Nov. 99	+0.8	-60	5.2	S-SW
Dec. 99	+0.6	+106	6.4	SW
Jan. 00	+3.0	+2	6.6	SW-W
Feb. 00	+3.6	+92	6.6	SW-W

North Sea and Skagerrak

Hydrography
The Jutland Coastal Current (JCC) with lower salinity and temperature was evident but relatively narrow along the Danish North Sea coast, and traces were also observed at the most coast near stations in the Skagerrak. Central North Sea water with salinity above 34 was found at the western stations at all transects in the North Sea and in a tongue into the south-western Skagerrak (*figure 2*). The surface temperature was high and ranged from 4.3-4.6°C at the coast-near stations in the German Bight to 5.9-6.4°C at the western most station in the North Sea and into the south-western Skagerrak (*figure 3*). Along the coast the salinity increased from 28.4-29.5 in the German Bight to 33.2 at Limfjorden and 33.3-34.4 at Hirtshals, as the German Bight water within the JCC is mixed with North Sea water. However, at Hanstholm a patch of JCC water was observed with a salinity of 31.9 and a nitrate concentration of 25 µmol/l. In the Skagerrak the surface salinity was lowest in the central part (33.1-33.4 at the

stations 1006, 1102, 1104, 1106 and 1135), probably due to out-flowing Baltic influenced water from the Kattegat.

Nutrients
In the North Sea the nutrient concentrations varied inversely to the salinity. The results of linear regression on measurements of nutrients and salinity from the 26 stations at the 5 transects in the North Sea are shown in *table 2*. For nitrite the significance is absent, as often seen in the area. For Total-P and phosphate the concentrations are relatively high and scattered at salinities above 34. Deleting these samples increases R^2 to 0.62 and 0.93, respectively.

Table 2. Linear regression analyses of salinity and concentrations of nutrients at the 26 stations in the North Sea 9-14 February 2000. The intercept gives the estimated mean concentrations in the river water entering the south-eastern North Sea. 34.5 psu gives the estimated concentrations in central North Sea water. N = number of observations. Unit = µmol/l.

Nutrient	Slope	Intercept	34.5 psu	N	R^2
Nitrate	-8.23	290	6.5	161	0.97
Nitrite	-0.08	2.87	0.25	160	0.13
Ammonium	-0.08	2.82	0	160	0.35
Total-N	-11.3	409	19.0	159	0.93
Phosphate	-0.12	4.50	0.51	160	0.67
Total-P	-0.25	9.57	0.93	159	0.43
Silicate	-5.11	180	3.9	162	0.89

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 4, 5, 6, 7 and 8*). This is not true for the nitrite concentrations. Here the highest concentrations (0.7-1.05 µM) were observed in the German Bight three stations from the coast (*figure 6*) at salinities up to 33.8.

Oxygen and chlorophyll-*a*
The minimum oxygen concentrations were about saturation level (97-100%) at all stations, except at the deepest stations in the Skagerrak. The lowest oxygen concentrations of 5.4-5.7 ml/l (81-86%) were observed in 150-300 m depth at station 1006 (M6) and at 400 m depth at station 1106, both in the middle of the Skagerrak. The mean chlorophyll-*a* concentration in the surface layer (0-10 m) was 1.6-3.4 µg/l within the JCC from the German Bight and up to Hanstholm (*figure 9*), probably due to resuspension of sediments. The well mixed water was very turbid. No signs of spring bloom were observed.

Kattegat, Sound, Belt Sea and Arkona Sea

Hydrography
Due to the stormy weather prior to and during the cruise the water column was unusually well mixed. Only in the deeper parts of Kattegat a distinct but rather weak pycnocline was observed, generally situated deeper than 20 m. The surface temperature (1 m depth) was relatively high for the season and varied from 3.2°C in the western Arkona Sea to 4.6-4.8°C in the northern Kattegat (*figure 3*). The bottom water temperature ranged from 3.0°C in the Sound (St. 431) to 5.1-5.3°C in the eastern Kattegat with the bottom water up to 1.7°C warmer than the surface water.

The surface salinity was relatively high and ranged from 9.0 in the Arkona Sea (St. 444) to 33.0-33.2 in the north-western Kattegat (St. 1007, 1008, 1009) (*figure 2*). The bottom water salinity ranged from 16.3-18.6 in the Arkona Sea (St. 441, 444, 449) to 34.1 in the north-eastern Kattegat (St. 1001) (*figure 10*). The salinity stratification was strongest (7.9-8.7 psu) in the Arkona Sea due to inflow of bottom water from the Sound and Belt Sea. Otherwise the stratification was 7.8 psu in the Sound and 3.8-5.4 in the eastern Kattegat.

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

Nutrients

Unusually high concentrations of nitrate (>10 µmol/l) were observed in the surface in the western Kattegat (*figure 4*) with up to 12.9 µmol/l in Laesoe Rende (St. 403). This nitrate seems not to stem from the JCC but of more local origin as the concentration in relation to salinity is only about half of that in the North Sea. In the Arkona Sea the nitrate concentration in the surface was 3.8-4.9 µmol/l (St. 441, 444, 449). Otherwise, the nitrate concentrations were between 7 and 9 µmol/l in the whole water column (*figure 11*).

Rather high concentrations of nitrite (*figure 5*) and ammonium (*figure 6*) were found in the Belt Sea (*figure 11*). Relatively high concentrations of phosphate were observed at the bottom in the south-eastern Kattegat (*figures 7 and 12*). The silicate concentrations were highest in the Belt Sea (*figures 8 and 12*).

Chlorophyll-*a*

The mean chlorophyll concentration in the uppermost 10 m was highest (2.0 µg/l) in the western Kattegat (St. 409), and 1.2-1.4 µg/l in Laesoe Rende, northern Belt Sea, Mecklenburg Bight and western Arkona Sea. In the rest of the area the mean chlorophyll concentrations were below 1.0 µg/l. The chlorophyll was homogeneously distributed in the uppermost 10 to 15 m of the water column, except at Gedser Rev (St. 954) and in the Arkona Sea (*figure 13*). The phytoplankton spring bloom had not yet started, but seemed just about to start in the Gedser Rev area.

Oxygen

The lowest oxygen concentration of 6.5 ml/l (89% saturation) was observed in the southern Kattegat (St. 922). Otherwise, the minimum saturation was 91-100% due to intensive water mixing and exchange.

Compared to February last year and to mean for February in the 1980’s the minimum oxygen concentrations this year was higher.

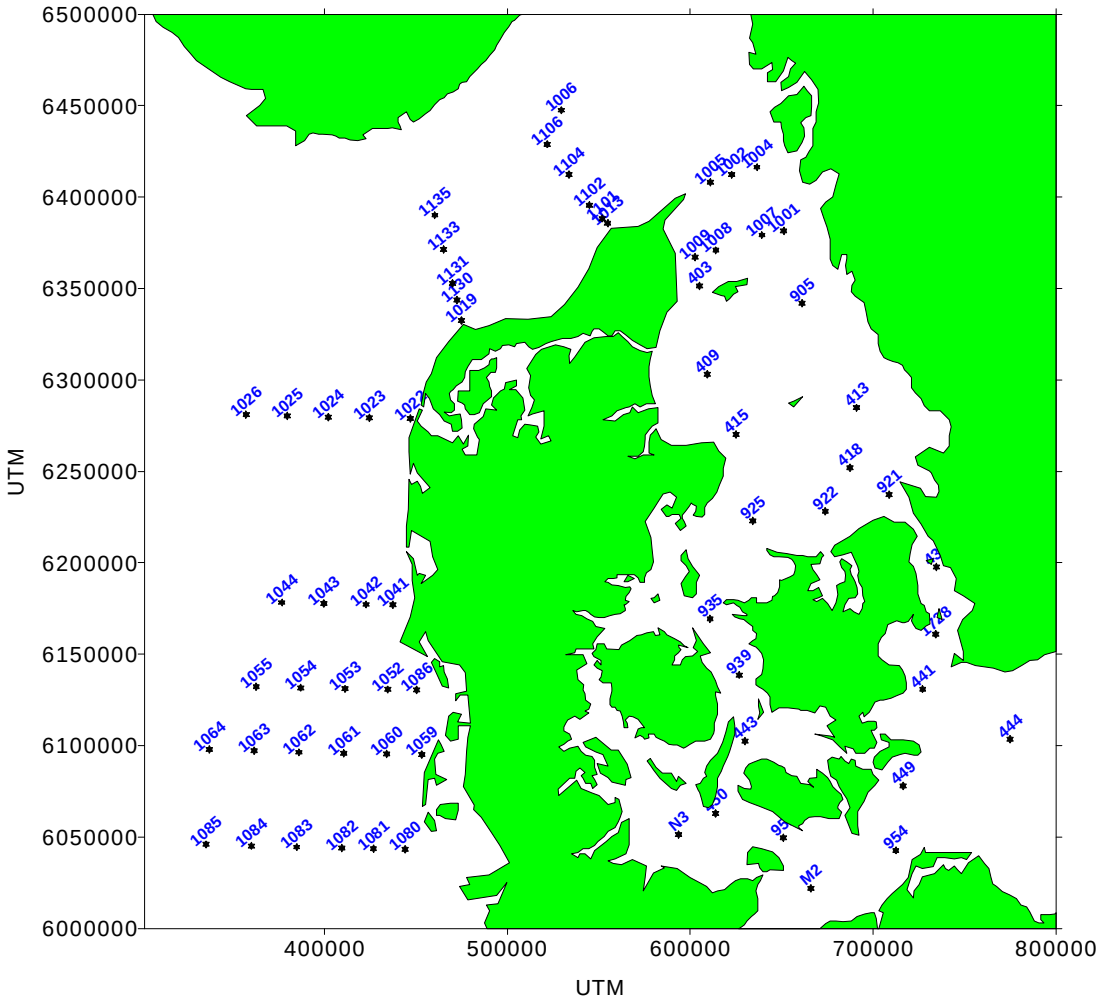


Figure 1. Stations of the monitoring cruise with r/v Gunnar Thorson 7-18 February 2000 in the Sound, Kattegat, Skagerrak, North Sea, Belt Sea and Arkona Sea. Gunnar Thorson cruise no. 195.

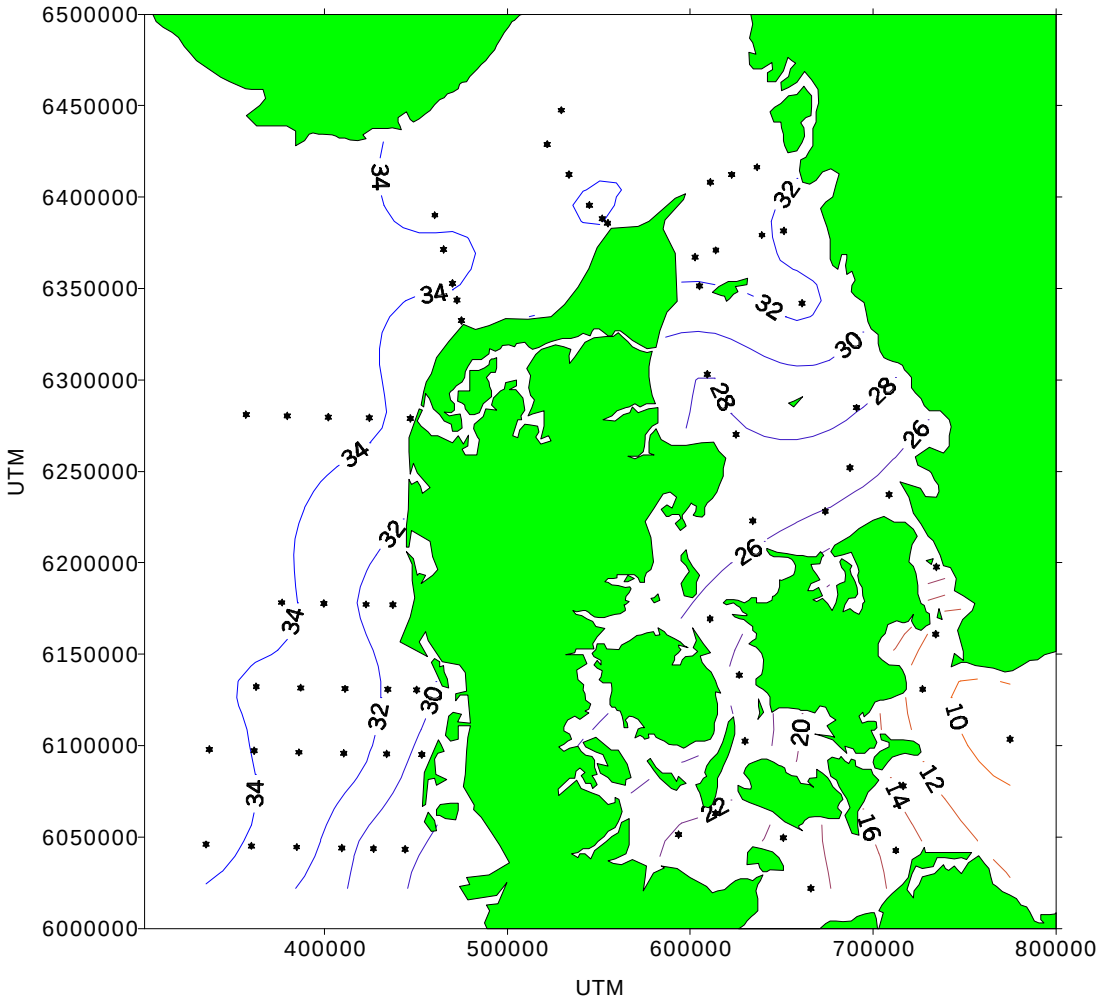


Figure 2. Interpolated distribution of surface salinity (mean 1, 5 and 10 m depth).

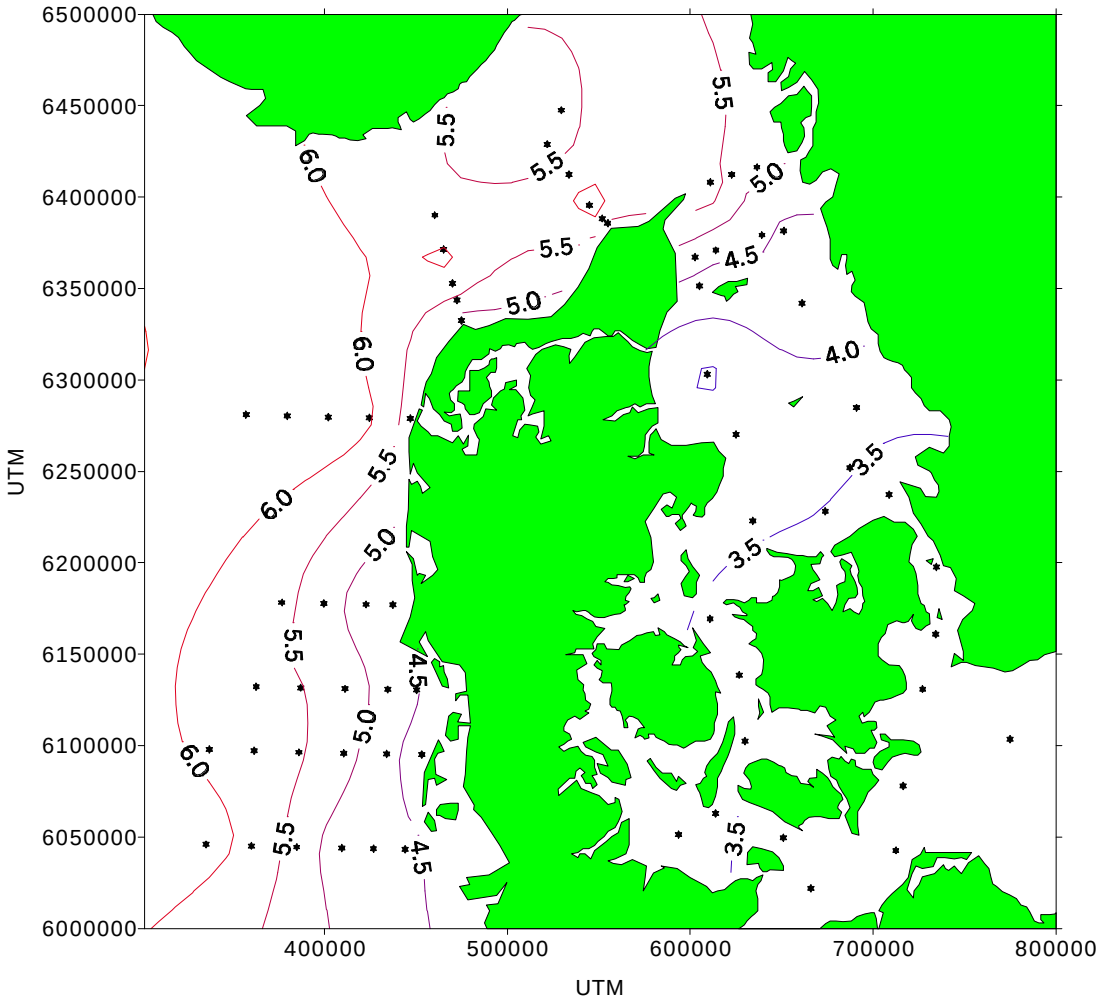


Figure 3. Interpolated distribution of surface temperature (mean 1, 5 and 10 m depth).

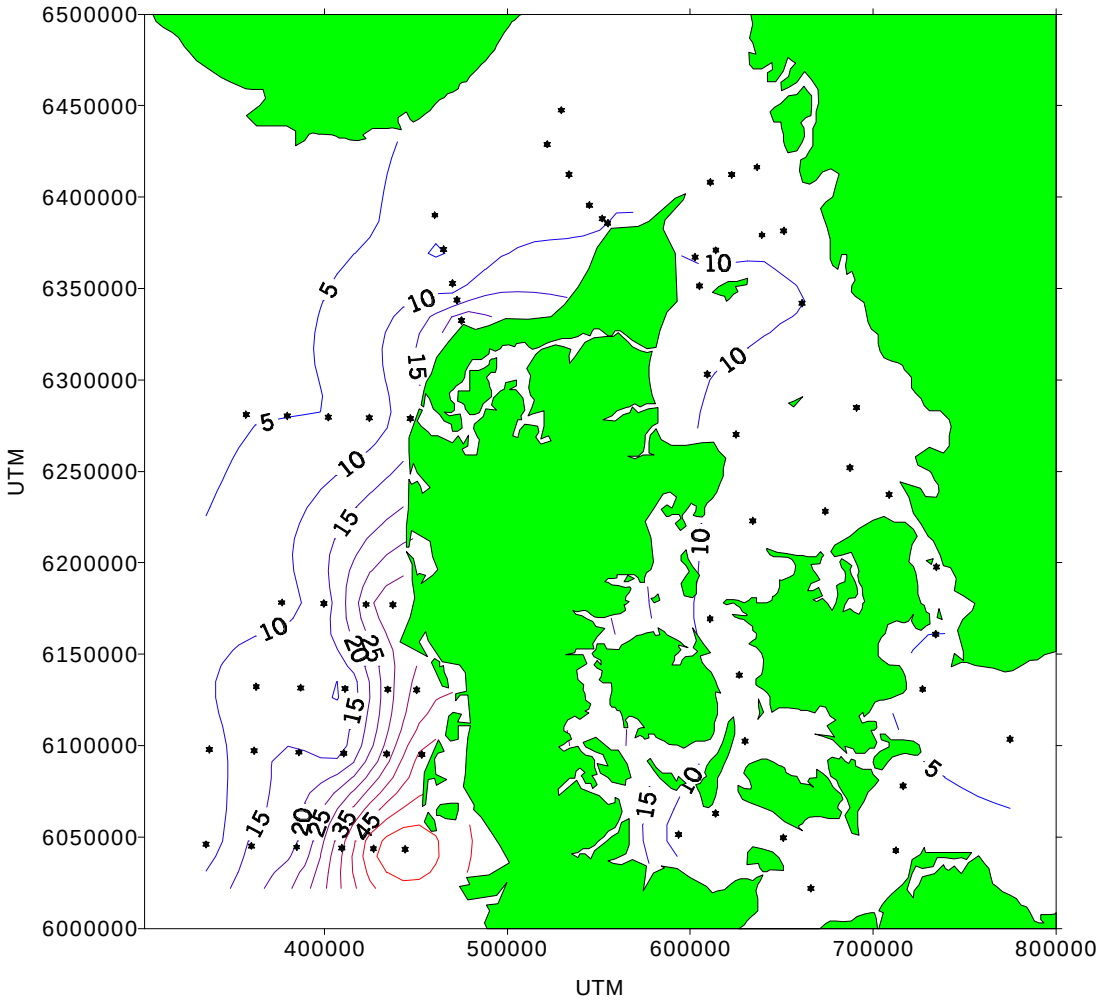


Figure 4. Interpolated distribution of surface nitrate concentrations (mean 1, 5 and 10 m depth).

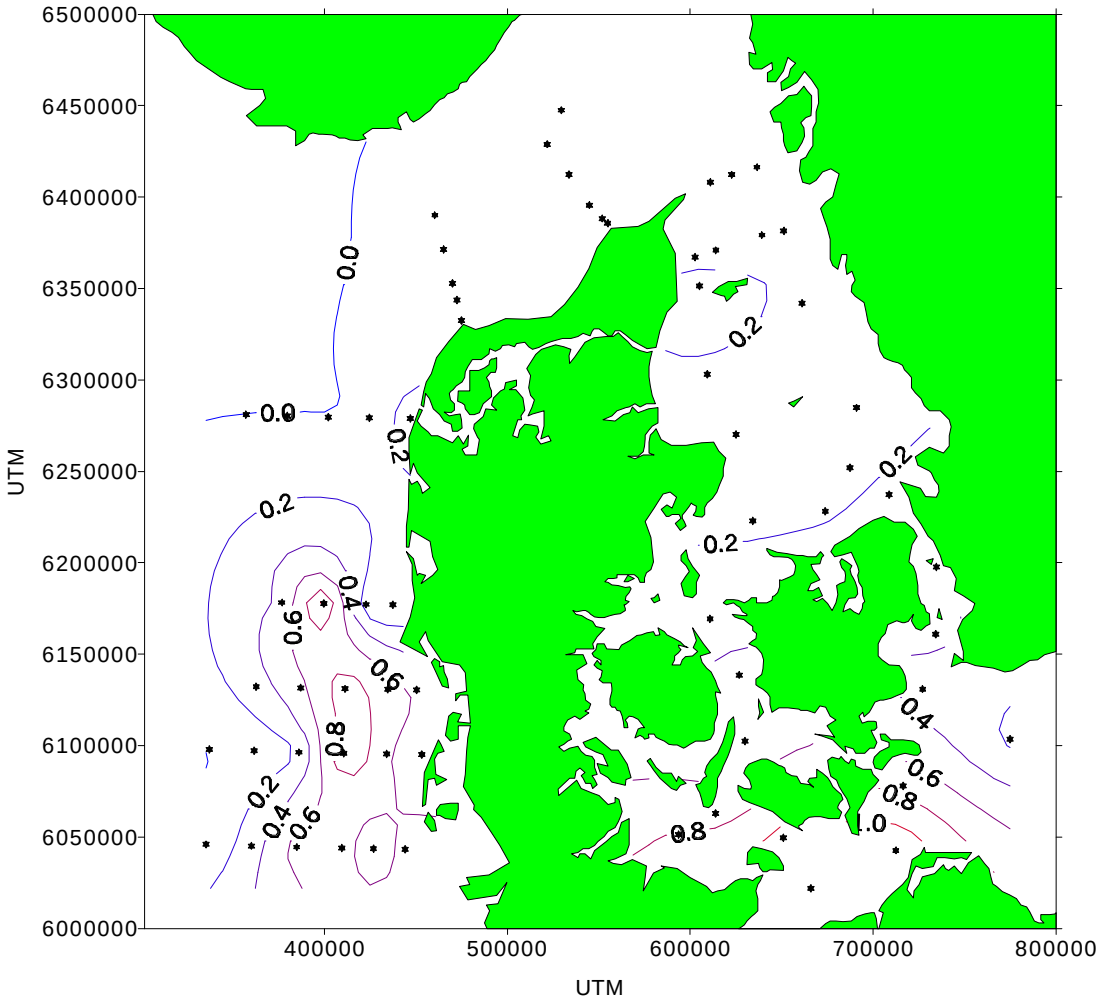


Figure 5. Interpolated distribution of surface nitrite concentrations (mean 1, 5 and 10 m depth).

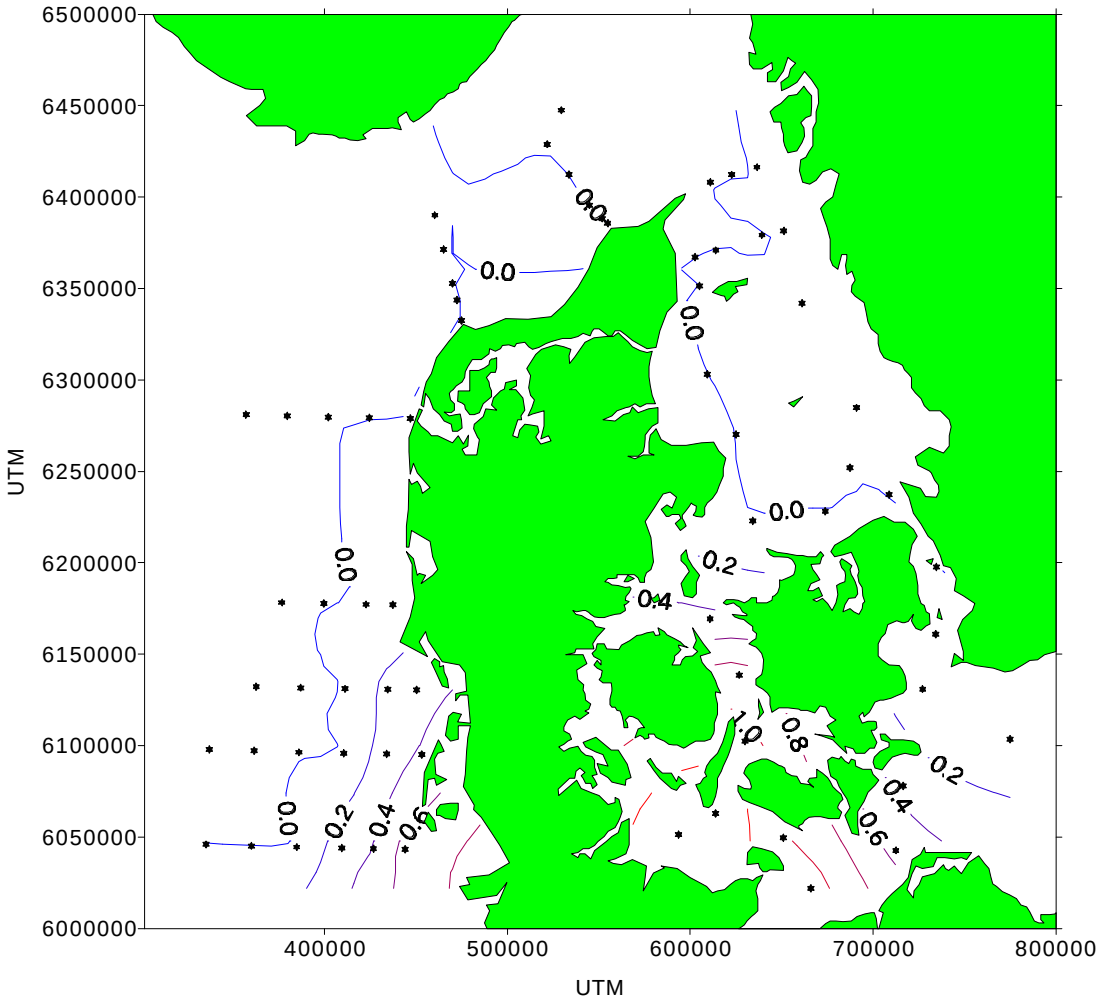


Figure 6. Interpolated distribution of surface ammonium concentrations (mean 1, 5 and 10 m depth).

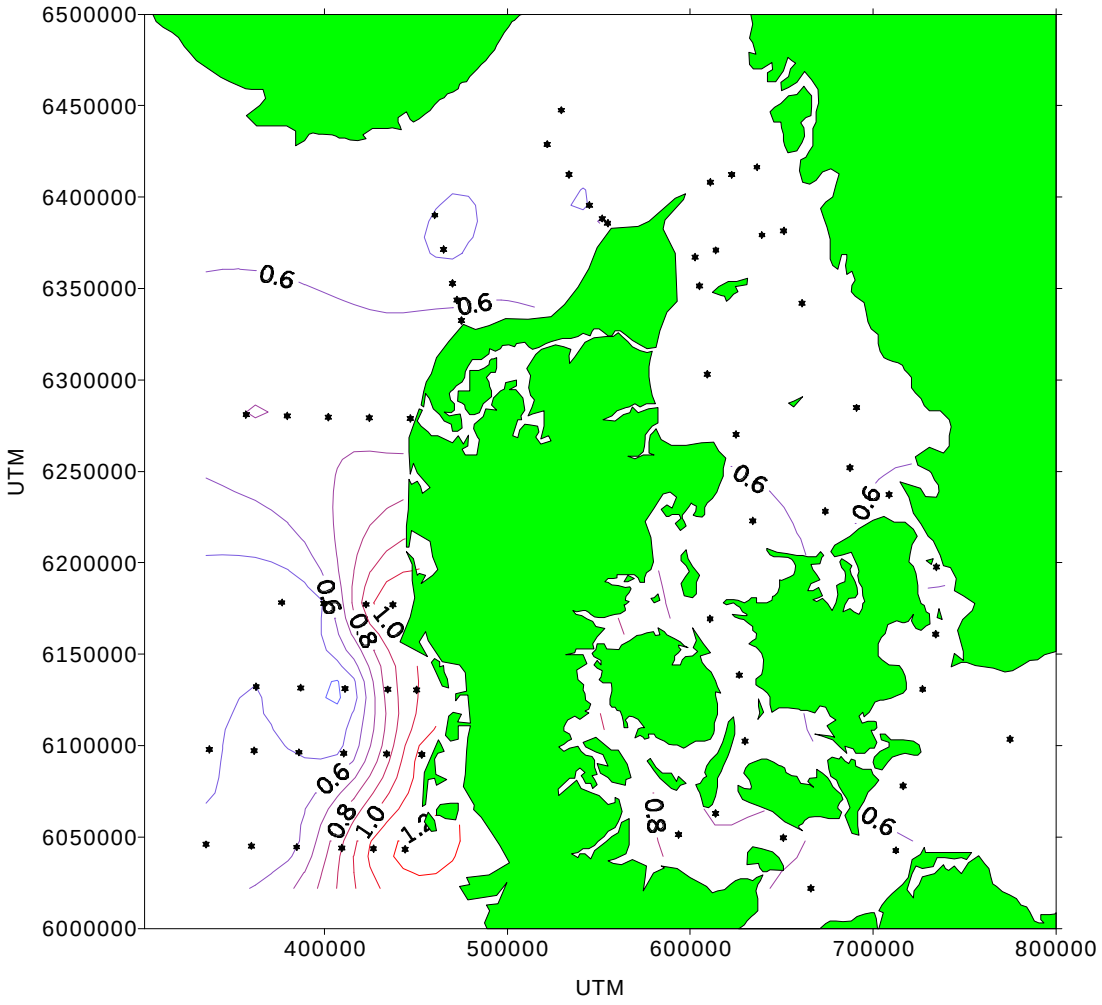


Figure 7. Interpolated distribution of surface phosphate concentrations (mean 1, 5 and 10 m depth).

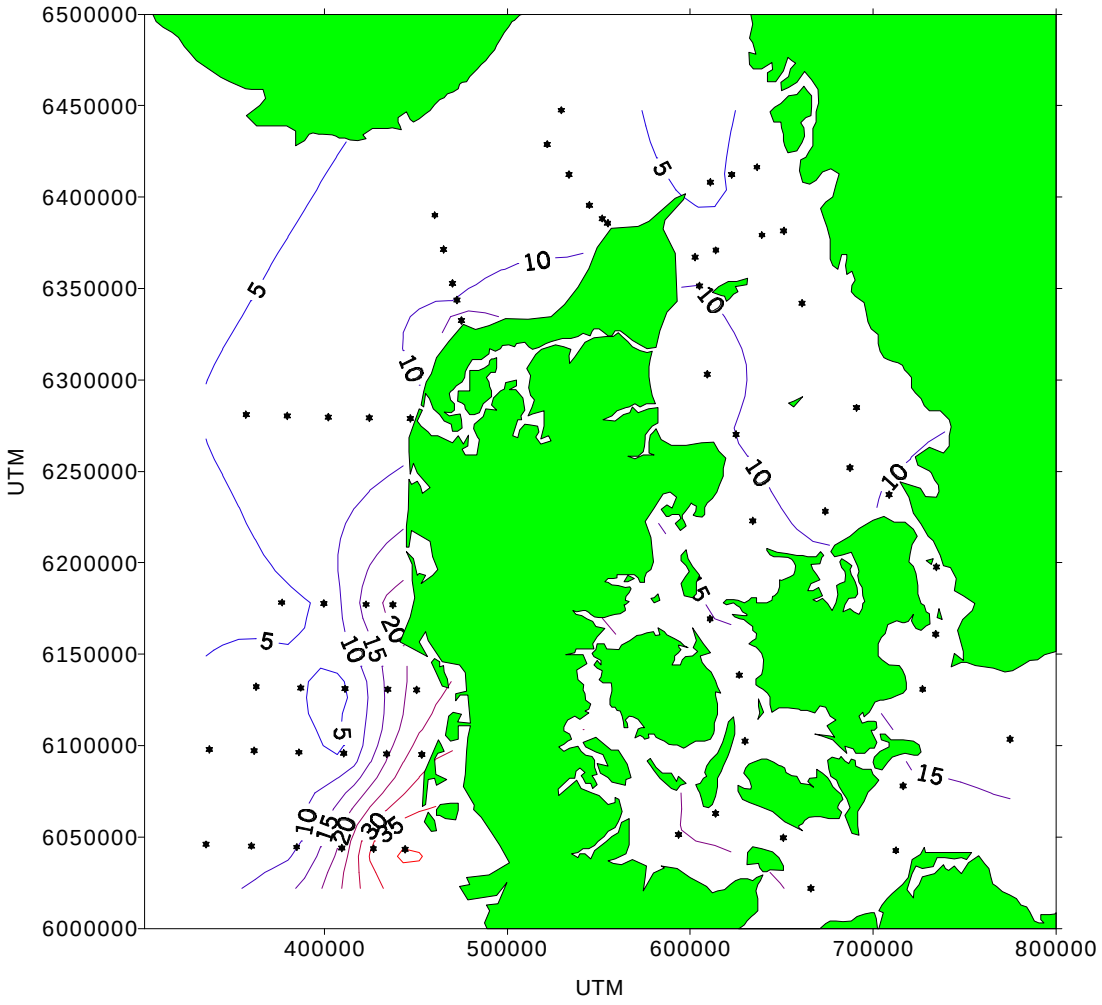


Figure 8. Interpolated distribution of surface silicate concentrations (mean 1, 5 and 10 m depth).

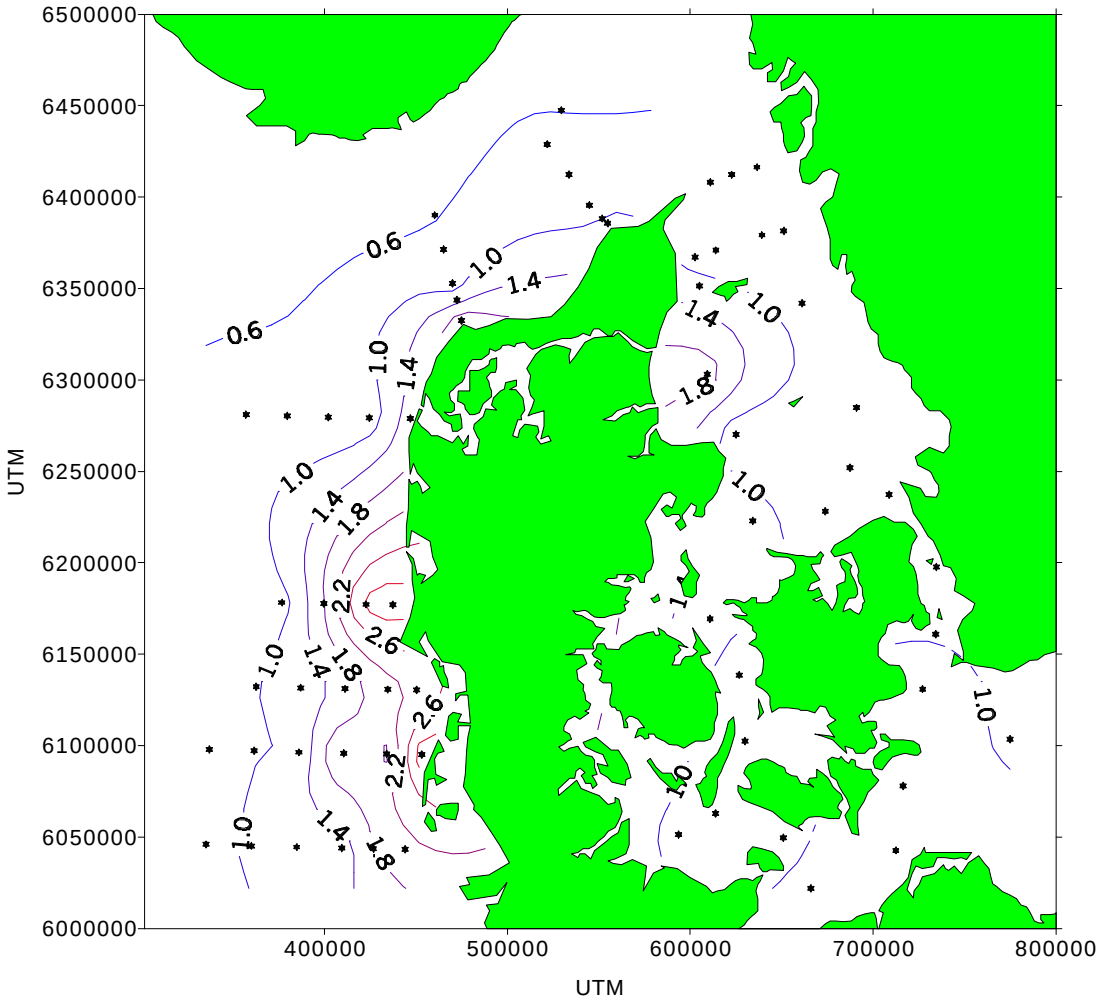


Figure 9. Interpolated distribution of surface chlorophyll-*a* concentrations (mean 1, 5 and 10 m depth).

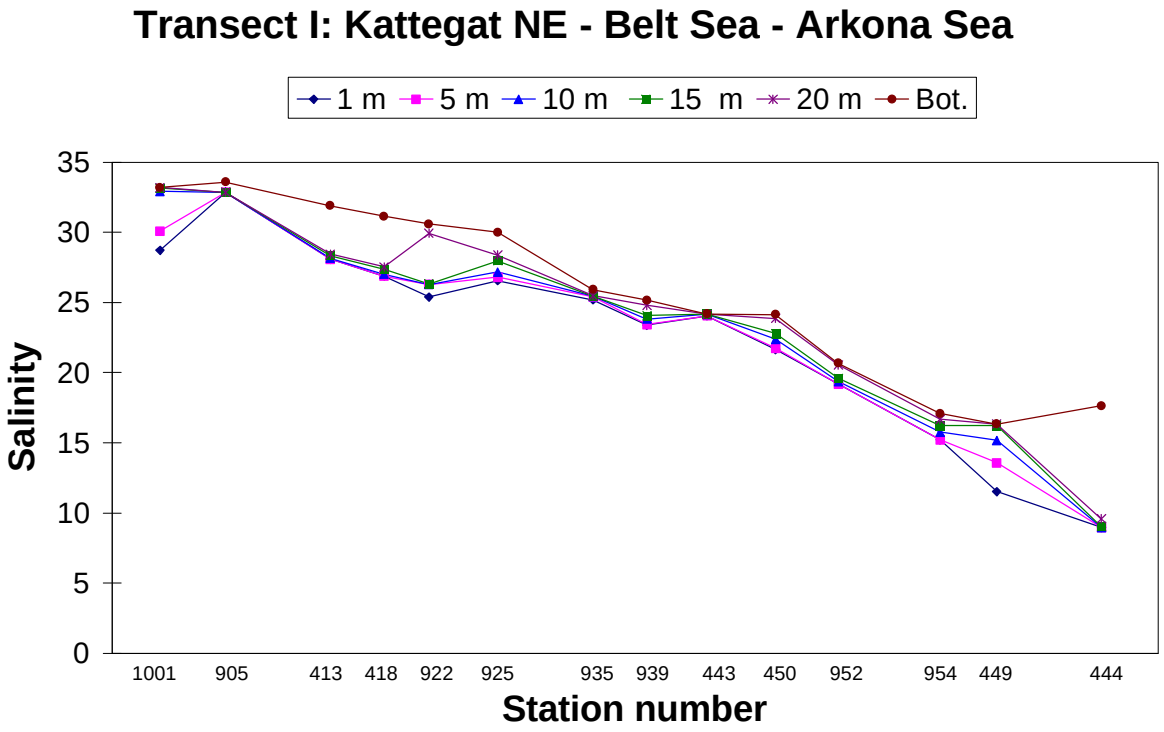
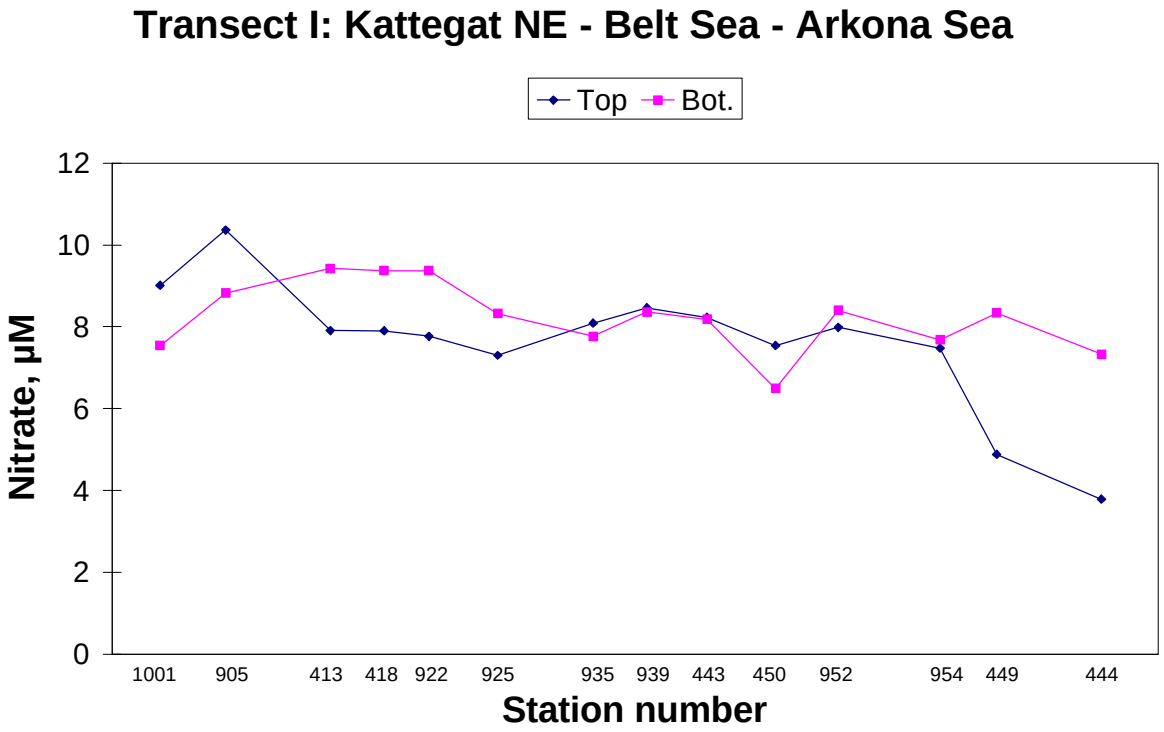
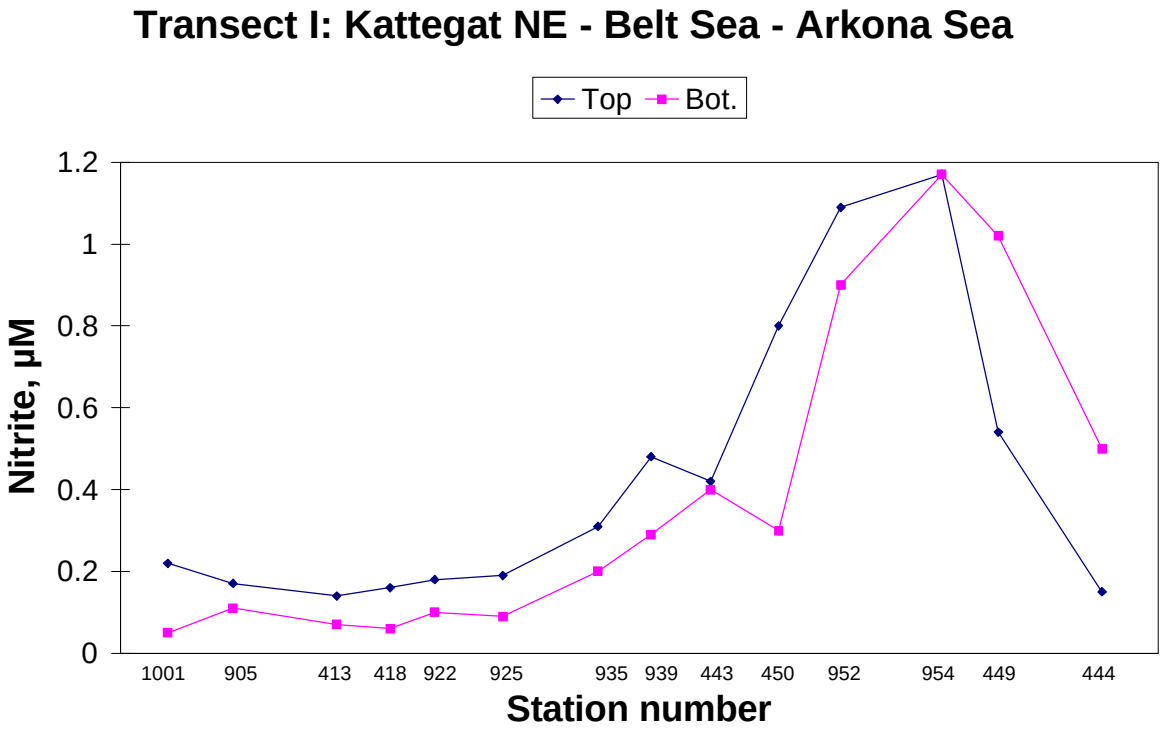


Figure 10. Salinity in 1 m, 5 m, 10 m, 15 m, 20 m depth and near bottom along transect I from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.





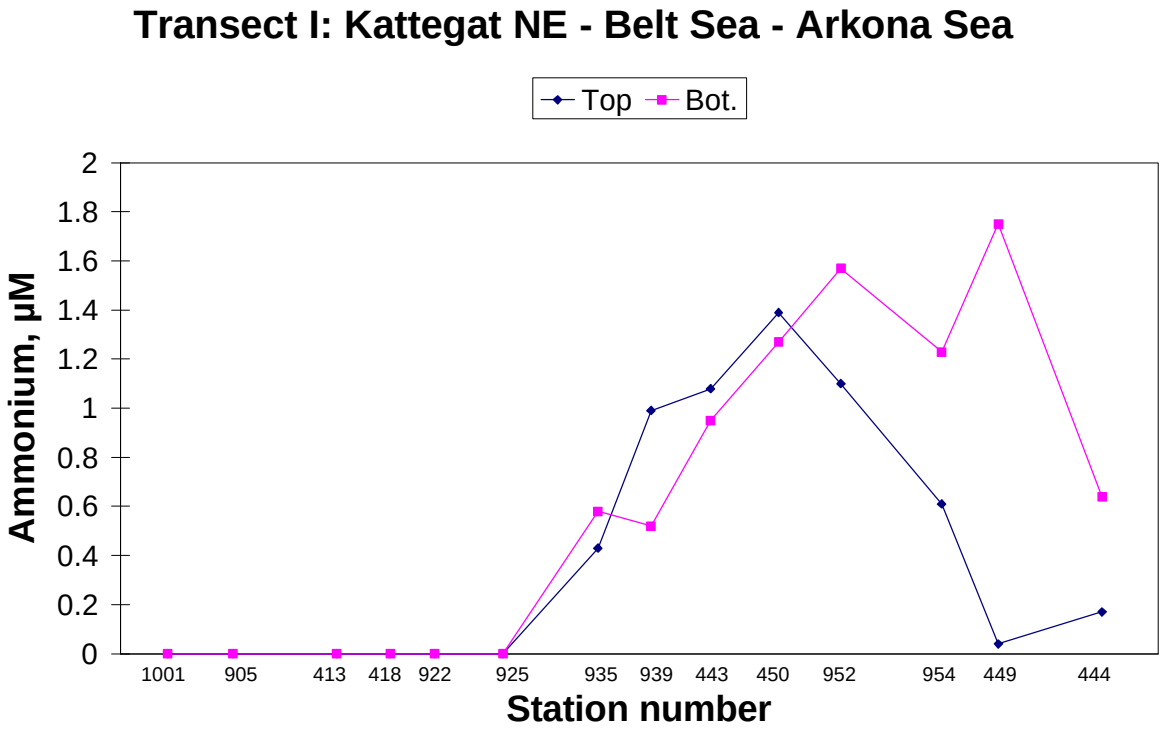
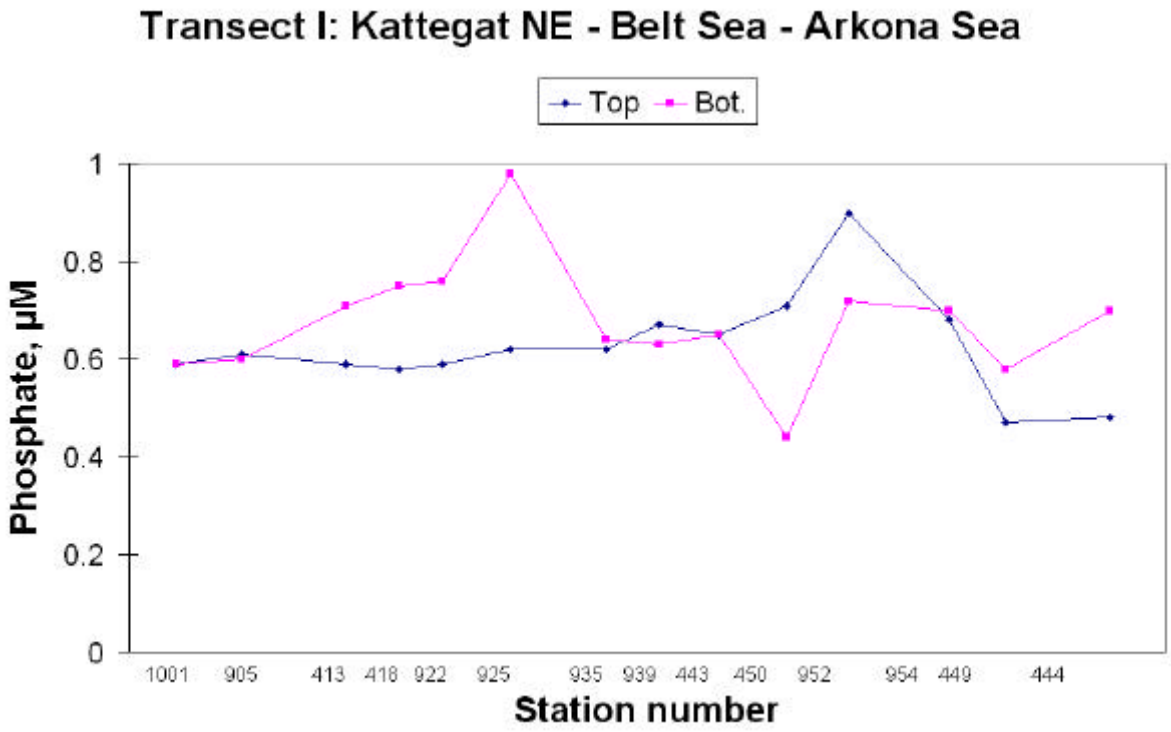


Figure 11. Surface and near bottom concentrations of nitrate, nitrite and ammonium along transect I.



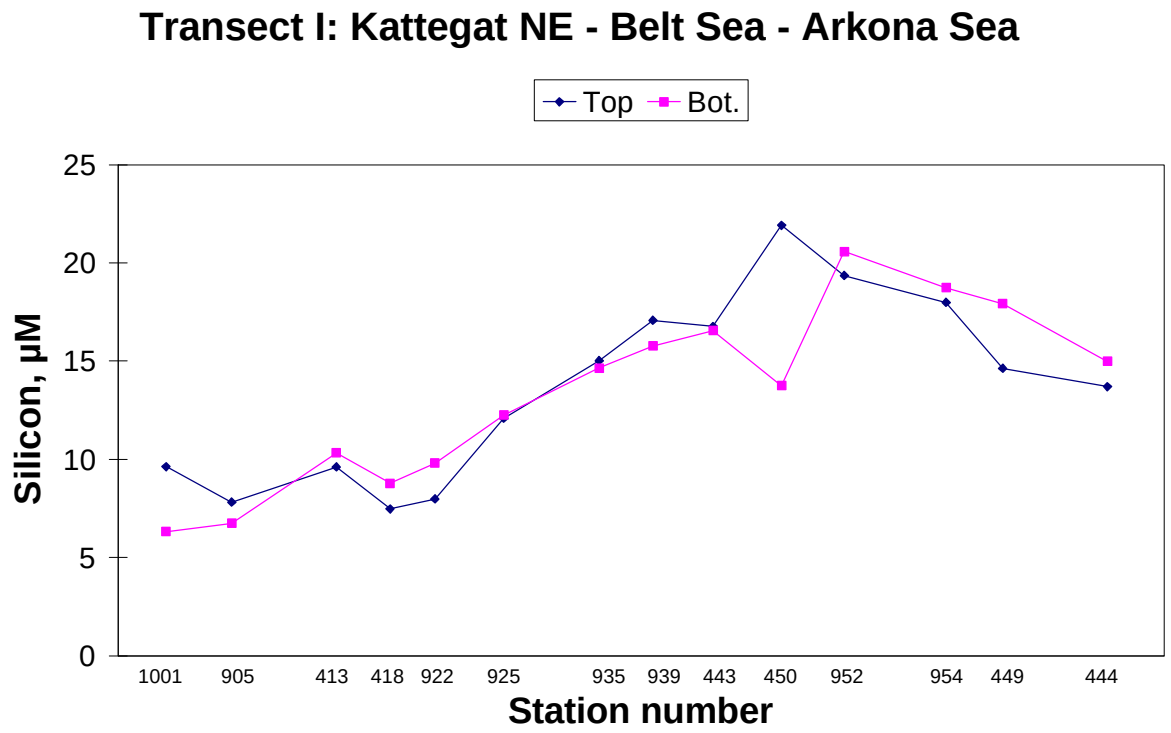


Figure 12. Surface and near bottom concentrations of phosphate and silicate along transect I.

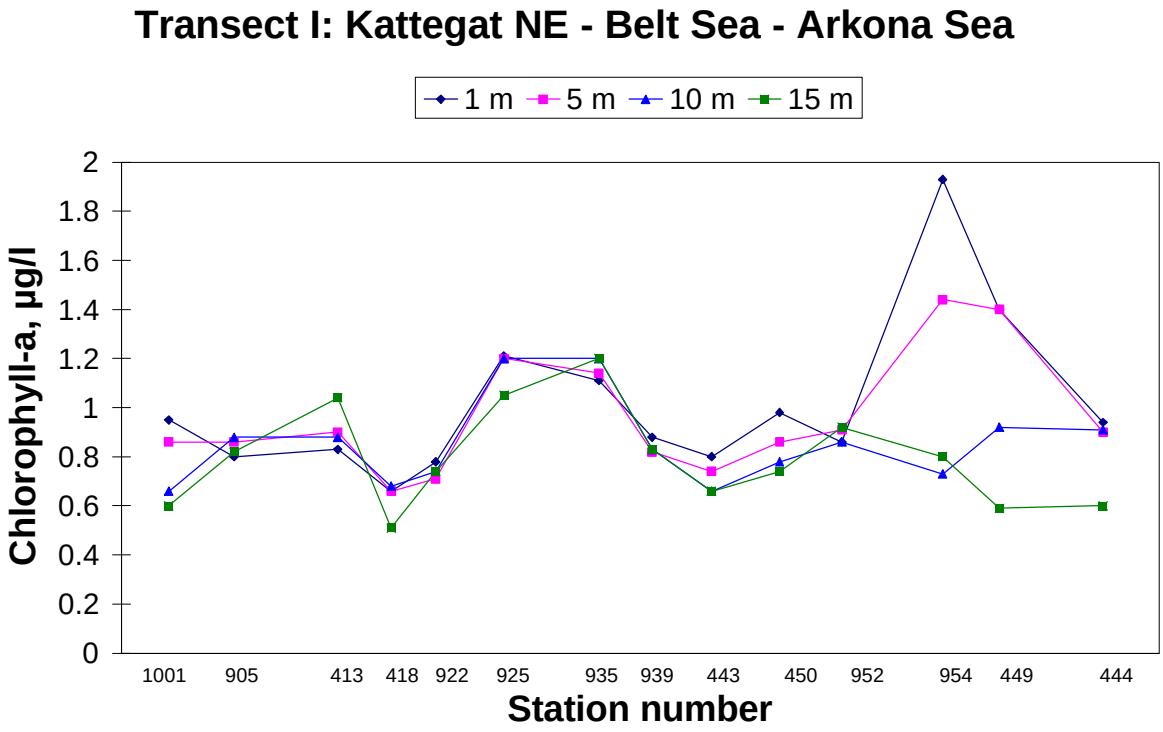


Figure 13. Chlorophyll-*a* concentrations in 1 m, 5 m, 10 m and 15 m depths along transect I.