



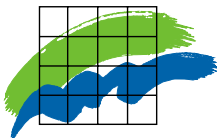
r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: 203

Time: 6 - 17 August 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, 6-17 August 2001. Cruise no. 203.

Report: Gunni Ærtebjerg

Cruise leader: Gunni Ærtebjerg/Dorete Jensen.

Participants: 6-14/8: Gunni Ærtebjerg, Lars Renvald, Kjeld Sauerberg, Martin Larsen, Jeanette Blidorf. 6-17/8: Dorete Jensen, Peter Kofoed.

6-9/8: Bo Nielsen (Danish Fishery Research Institute).

14-17/8: Hanne Ferdinand, Gitte Jacobsen, Tine Juul (student), Sanne Kjellerup (student).

6/8 + 15-17/8: TV-crew from Danmarks Natur og Miljø TV.

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

Summary

North Sea – Skagerrak. Low saline water (29-33 psu) was spread out over the eastern North Sea and southern Skagerrak. In the surface 34 psu was only observed at the westernmost station 1064. The surface temperature ranged from 15.8°C to 18.4°C, and varied inversely to the salinity. A pycnocline was present in certain areas. Nitrate, nitrite and ammonium were observed in the surface, especially west of the Limfjord and in the German Bight. Also phosphate and silicate was present, especially in the German Bight. The chlorophyll-a concentration was unusually high for the season, up to 11 µg/l at the north-western station 1025, and 8.6-8.8 µg/l in the German Bight and north of Horns Rev. The lowest oxygen concentration of 4.2-4.4 ml/l (73-75%) was observed at the stratified north-western stations.

Kattegat, Belt Sea, Arkona Sea. Compared to long term monthly mean for August the bottom water temperature in the southern Kattegat and Belt Sea was 0.4-1.0°C lower than normal, while the surface temperature generally was 0.4-2.0°C higher. The salinity was generally higher than normal, both at the surface and in the bottom water.

In the surface water nitrate and nitrite was very low, while ammonium was generally present. Also phosphate and silicate were present, except in mid and southern Kattegat. At the bottom high phosphate and silicate concentrations were observed in Fehmarn Belt and Arkona Sea, highest at Gedser Rev, that is in the areas with low oxygen concentrations.

The mean chlorophyll concentration in the uppermost 10 m varied from 0.9-1.0 µg/l in the northern Great Belt to 3.0-5.1 µg/l in the north-western Kattegat. Pronounced subsurface maximum was observed in the Sound and at Gedser Rev.

Oxygen Below 3 ml/l was observed in the southern Belt Sea and western Arkona Sea with the lowest oxygen concentration of 1.05 ml/l observed at Gedser Rev.

Compared to August last year and to mean for August in the 1980's the minimum oxygen concentrations this year are higher in all areas, except at Gedser Rev.

According to Danish definitions serious oxygen depletion (<2 mg/l) occurred at Gedser Rev, and oxygen depletion (<4 mg/l) occurred in the Fehmarn Belt, Mecklenburg Bight, and south of Møn. In *figure 20* is shown the stations where oxygen depletion and serious oxygen depletion was observed by Danish counties and NERI within the first 3 weeks of August 2000.

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 oxygen situation, but also the hydrography and the concentrations of nutrients and chlorophyll-*a*. The stations of the cruise are shown in *figure 1*. Yellow substance samples were collected for calibration of fluorescence profiles.

Meteorology

Characteristics of the weather conditions since the last cruise in February are given in *table 1*. As the winter also the spring (March-May) was generally warm, June was colder than average, while the rest of the summer (July-August) was warm. April, June and August were wet, March, May and July dry. The mean wind was rather low, especially in July.

Table 1. Deviations in monthly mean temperature and precipitation in March to August 2001 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
March	+1.0	-13	4.9	E-SE-S-SW
April	-0.1	+49	4.6	SE-S-SW-W
May	+0.6	-33	4.7	SW-W-NW
June	-1.5	+13	4.7	SW-W-NW
July	+1.9	-29	3.9	SW-W-NW
August	+1.3	+36	4.5	E-SE---SW-W

North Sea and Skagerrak

Hydrography

Low saline water was spread out over the eastern North Sea from 29.7 psu in the German Bight increasing to the west and north. In the surface above 34 psu was only observed at the westernmost station 1064 (*figure 2*). Along the Danish North Sea coast the salinity increased to only 31.1 at the Limfjord and Hanstholm. Also the southern Skagerrak was covered by low saline water (31.1-33.16). The surface temperature ranged from 15.8°C at the north-western stations 1024 and 1025 to 18.2-18.4°C at the coast-near stations in the German Bight (*figure 3*). The temperature varied inversely to the salinity. A pycnocline was present at the north-western stations in the North Sea (St. 1025, 1073, 1045) and in a belt 2-3 stations away from the coast (St. 1035, 1071, 1043, 1053, 1054, 1061, 1062). In the south-western Skagerrak the pycnocline was situated in about 15 m depth.

Nutrients

Inorganic nitrogen nutrients were observed in the surface of the North Sea and south-western Skagerrak. Especially west of the Limfjord and in the German Bight nitrate concentrations up to 1.3 and 1.1 $\mu\text{mol/l}$ were observed (*figure 4*). Nitrite up to 0.2 $\mu\text{mol/l}$ and ammonium up to 4.2-4.8 $\mu\text{mol/l}$ were found in the same two areas (*figure 5 and 6*). Rather high phosphate concentrations (0.3-0.7 $\mu\text{mol/l}$) were found in the German Bight (*figure 7*). Also high silicate concentrations were present in the North Sea, especially west of the Limfjord (4.6 $\mu\text{mol/l}$) and in the German Bight (7.2 $\mu\text{mol/l}$) (*figure 8*). The highest concentrations of both total-N and total-P were observed in the eastern German Bight, decreasing to the west and north (*figures 9 and 10*). The total-N and total-P concentrations varied inversely to the salinity. The results of linear regression on measurements from the North Sea are shown in *table 2*.

Table 2. Linear regression analyses of salinity and concentrations of total-N and total-P at the 32 stations in the North Sea 10-12 August 2001. 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 = $\mu\text{mol/l}$.

Nutrient	Slope	Intercept	34.5 psu	R ²
Total-N	-2.57	101	12.2	0.44
Total-P	-0.20	7.00	0.21	0.53

Chlorophyll-a

The mean chlorophyll concentration in the uppermost 10 m was unusually high for the season, up to 11 $\mu\text{g/l}$ at the north-western station 1025, and 8.6-8.8 $\mu\text{g/l}$ in the German Bight and north of Horns Rev (St. 1060, 1040) (*figure 11*).

Oxygen

The lowest oxygen concentrations of 4.2-4.4 ml/l (73-75%) were observed at the stratified north-western stations (St. 1025, 1073) in the North Sea, and 4.5 ml/l (79%) at station 1053 in the German Bight (*figure 12*).

Kattegat, Sound, Belt Sea and Arkona Sea

Hydrography

The surface temperature (1 m depth) varied from 15.4°C in the south-western Kattegat (St. 415) to 18.5-18.9°C in the southern Kattegat (St. 418, 921, 922, 925) (*figure 3*). The bottom water temperature ranged from 6.0°C east of Anholt (St. 413) to 14.2-15.2°C in the north-western Kattegat (St. 1008, 403, 1009) with the bottom water 2.2-12.2°C colder than the surface water (*figure 13*).

The surface salinity ranged from 7.6-8.2 in the Arkona Sea (St. 441, 444, 449) to 26.5-29.1 in the northern Kattegat (St. 1001, 1007, 1008, 1009) (*figure 2*). The bottom water salinity ranged from 15.4 in the Arkona Sea (St. 444) to 34.5 in the north-eastern Kattegat (St. 1001) (*figure 14*). The salinity stratification was about normal, strongest (16.4 psu) in the Sound, and weakest (3.8 psu) in the north-western Kattegat (St 1009).

Compared to long term monthly means (Lightship observations 1931-1960) for August the temperature was generally 0.4-2.0°C higher than normal, except for 0.4-1.0°C lower bottom water temperatures in the southern Kattegat and Belt Sea (St. 952, 954). The salinity during the present cruise was generally higher than normal, both at the surface and in the bottom water, except for lower salinity in the western Kattegat.

Nutrients

In the surface traces of nitrate (0.1 µmol/l) were observed only in the south-western Kattegat (St. 415), central Sound (St. 431) and central Great Belt (St. 939). In the bottom water nitrate concentrations above 4 µmol/l were observed east of Anholt (St. 413), in the Sound (St. 431) and in Fehmarn Belt (St. 952) (*figure 15*). Contrary, very little nitrate was present at the bottom in the Great Belt (St. 925, 935, 939, 443, 450).

Nitrite concentrations in the surface were very low (*figure 5*), but somewhat higher at the bottom, especially in the Sound, southern Belt Sea and Arkona Sea (*figure 16a*). Ammonium was present in the surface, except in the Arkona Sea (*figure 6*), and in high concentrations (>2 µmol/l) in the bottom water in the northern Kattegat, Fehmarn Belt and Arkona Sea (*figure 16b*).

Phosphate (>0.05 µmol/l) and silicate (>1 µmol/l) were present in the surface water in the northern Kattegat, the Sound, Belt Sea and Arkona Sea (*figures 7 and 8*). High phosphate (0.8-1.9 µmol/l) and silicate (25-52 µmol/l) concentrations were observed at the bottom in the Fehmarn Belt and Arkona Sea, highest at Gedser Rev (St. 954) (*figures 17a and 17b*).

Chlorophyll-a

The mean chlorophyll concentration in the uppermost 10 m varied from 0.9-1.0 µg/l in the northern Great Belt to 2.0-2.6 µg/l in the southern Belt Sea and western Arkona Sea, and 3.0-5.1 µg/l in the north-western Kattegat (*figure 12*). The chlorophyll was relatively homogeneously distributed in the uppermost 15 m of the water column, except for pronounced subsurface maximum observed in the Sound and at Gedser Rev (*figure 18*).

Oxygen

Below 3 ml/l was observed in the southern Belt Sea and western Arkona sea (St. 952, M2, 954, 449) (*figure 12*). The lowest oxygen concentration of 1.05 ml/l was observed at Gedser Rev (St. 954) (*figure 19*).

Compared to August last year and to mean for August in the 1980's the minimum oxygen concentrations this year are higher in all areas, except at Gedser Rev.

In Denmark oxygen depletion is defined as minimum oxygen concentrations below 2.8 ml/l (4 mg/l), and serious oxygen depletion as below 1.4 ml/l (2 mg/l). From these definitions serious oxygen depletion occurred at Gedser Rev, and oxygen depletion occurred in the Fehmarn Belt, Mecklenburg Bight, and south of Møn. In *figure 20* is shown the stations where oxygen depletion and serious oxygen depletion was observed by Danish counties and NERI within the first 3 weeks of August 2000.

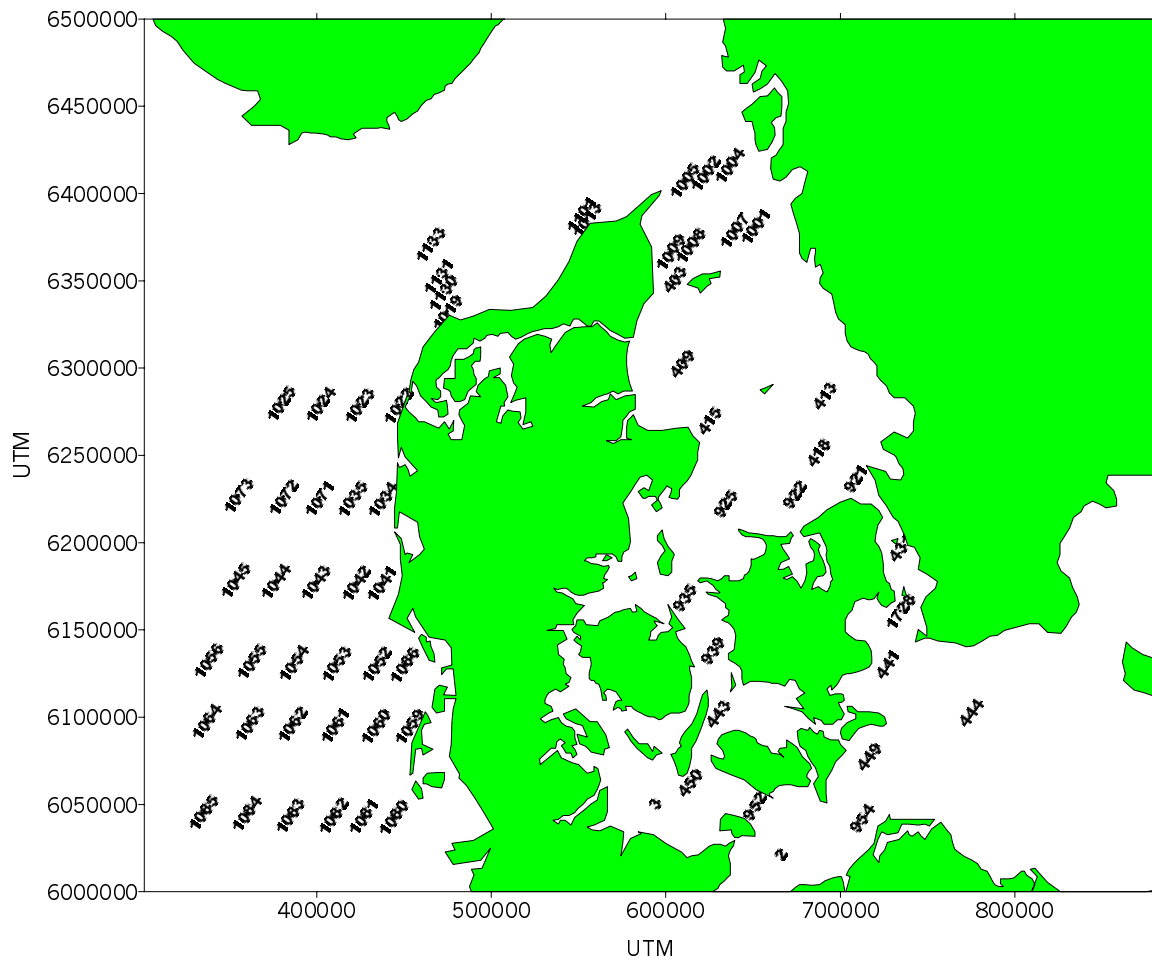


Figure 1. Stations of the monitoring cruise with r/v Gunnar Thorson 6-17 August 2001 in the Sound, Kattegat, Skagerrak, North Sea, Belt Sea and Arkona Sea. Gunnar Thorson cruise no. 203.

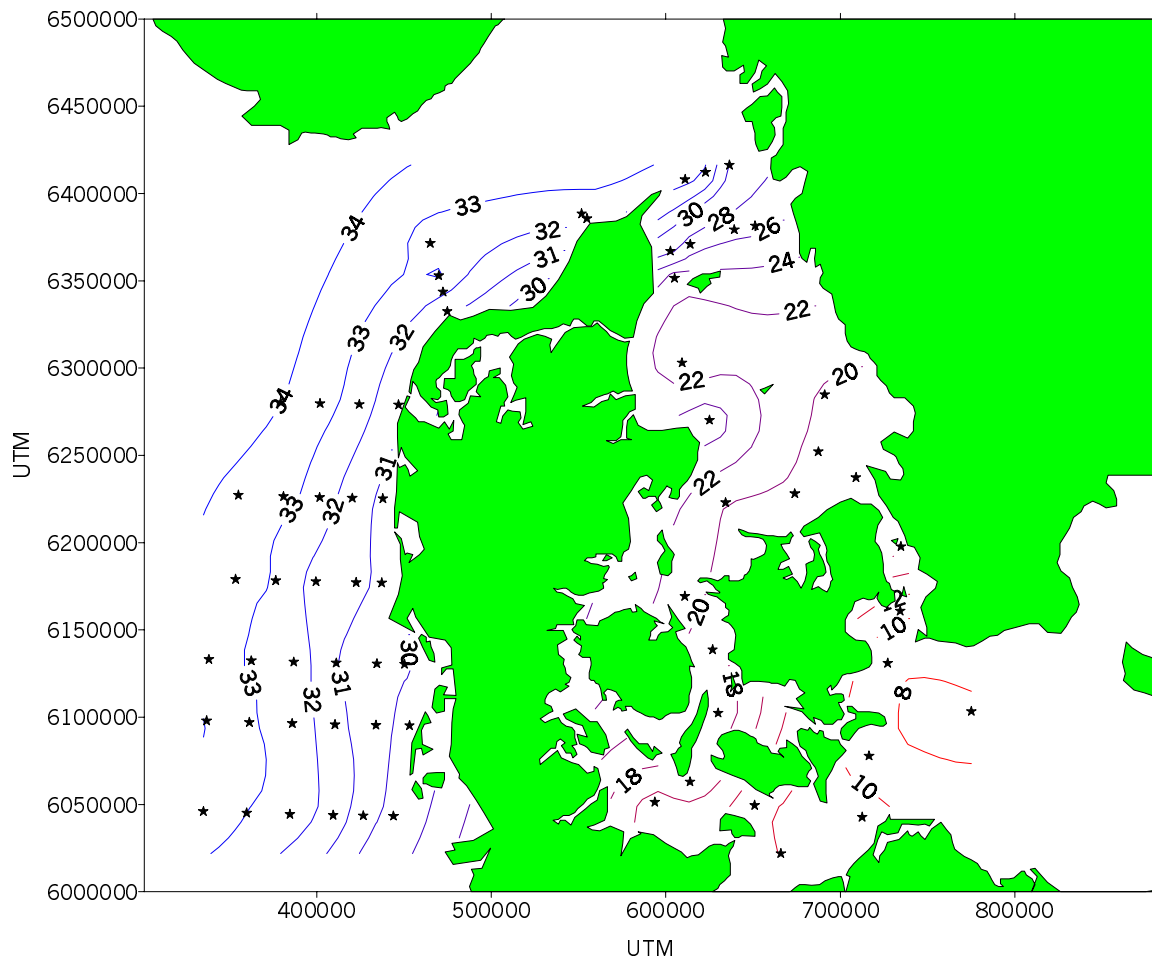


Figure 2. Interpolated distribution of surface salinity (mean 1, 5 and 10 m depth).

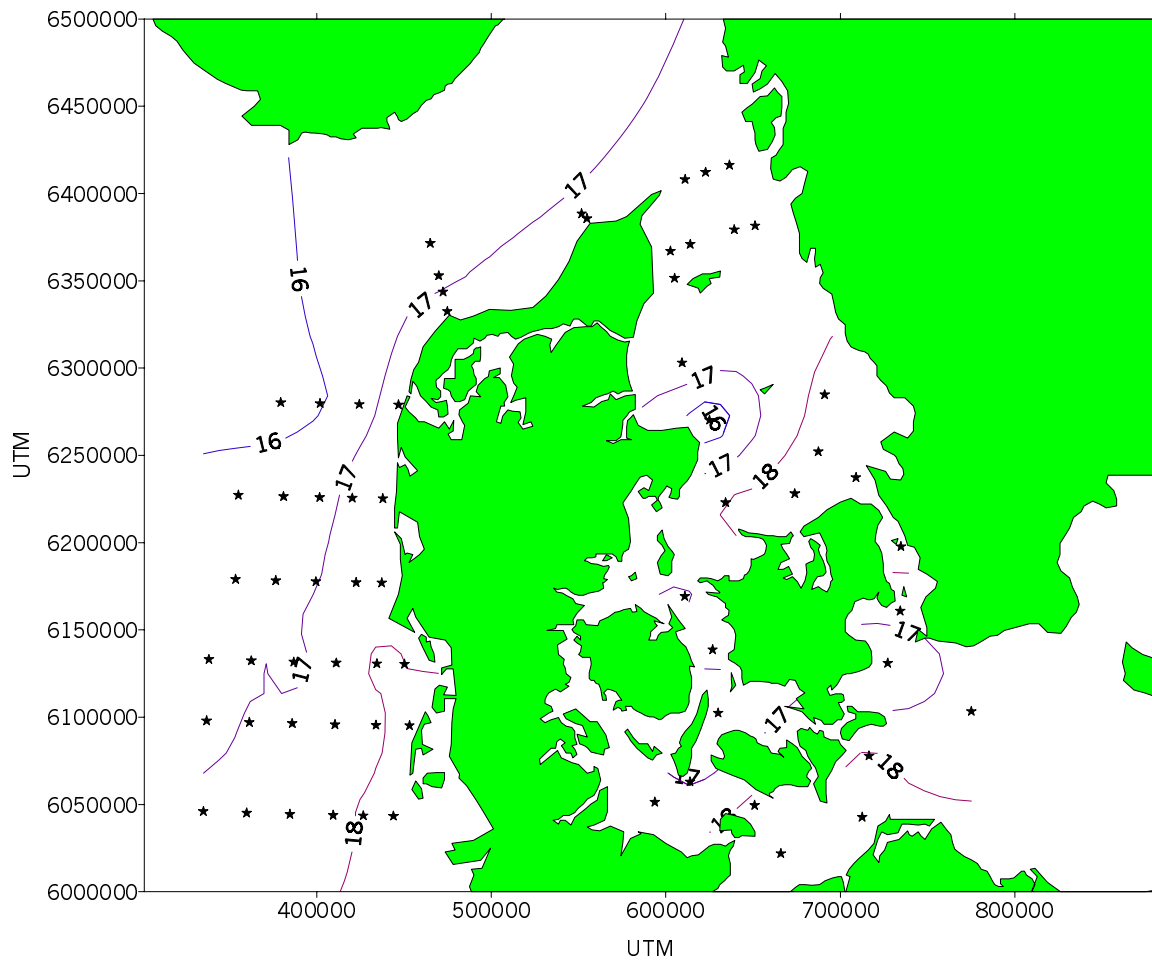


Figure 3. Interpolated distribution of surface temperature (mean 1, 5 and 10 m depth).

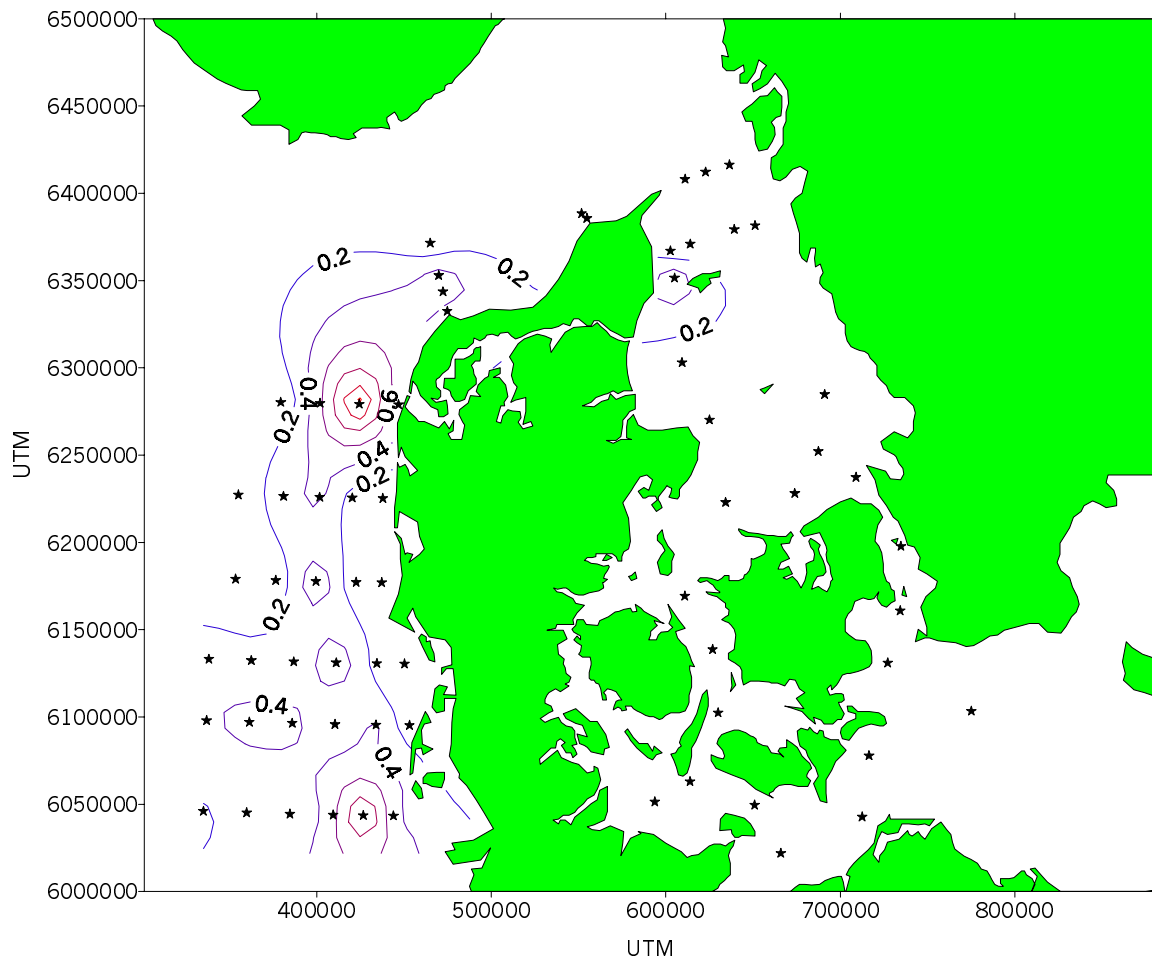


Figure 4. Interpolated distribution of surface nitrate concentrations (mean 1, 5 and 10 m depth).

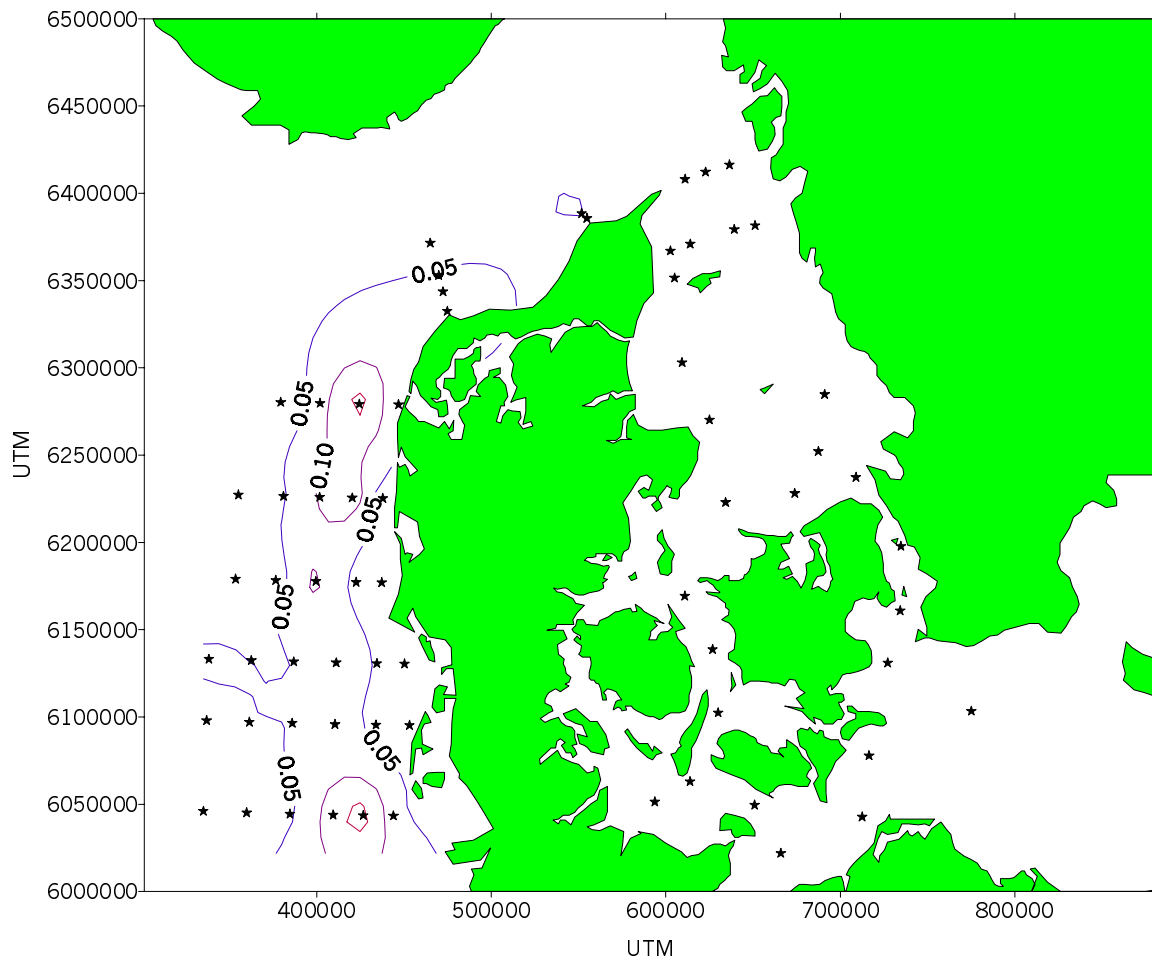


Figure 5. Interpolated distribution of surface nitrite concentrations (mean 1, 5 and 10 m depth).

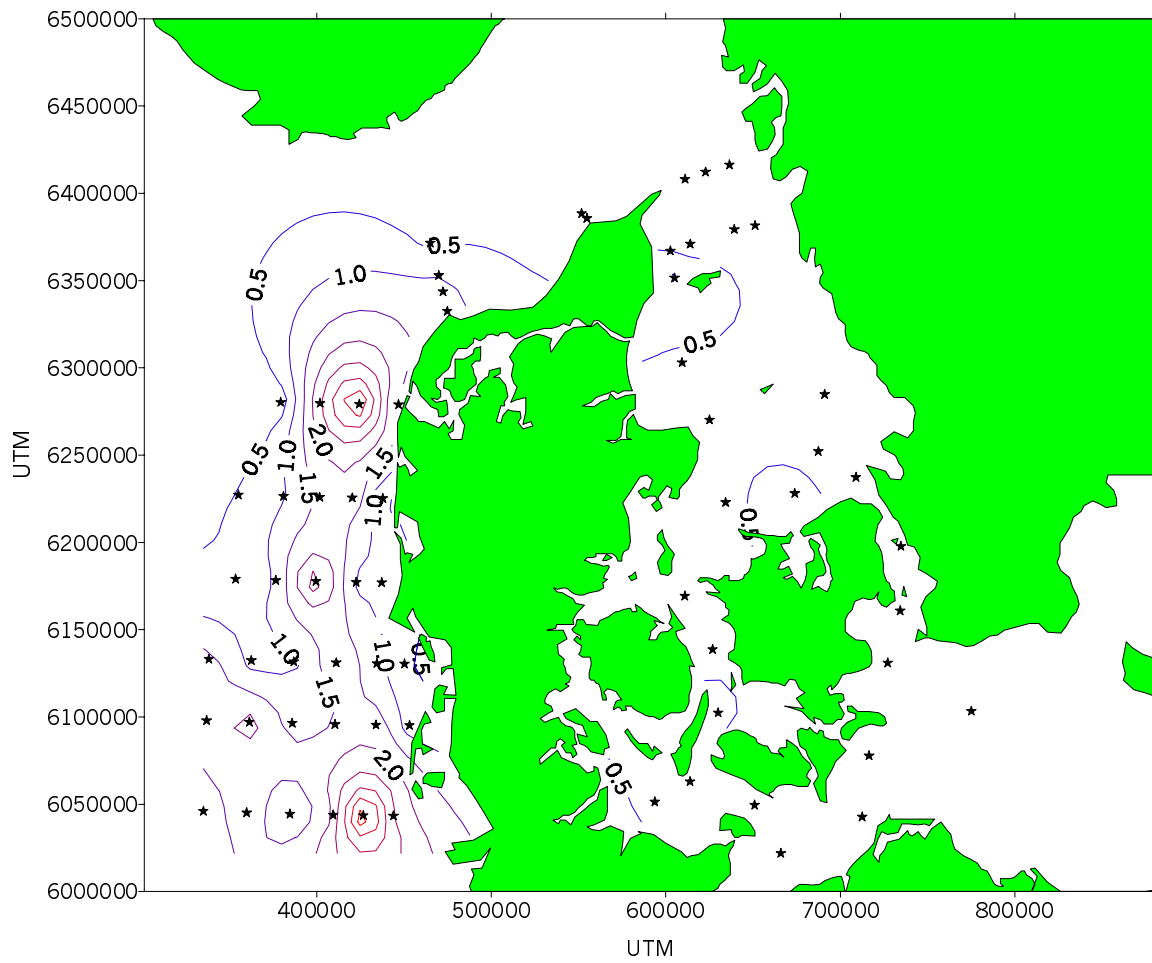


Figure 6. Interpolated distribution of surface ammonium concentrations (mean 1, 5 and 10 m depth).

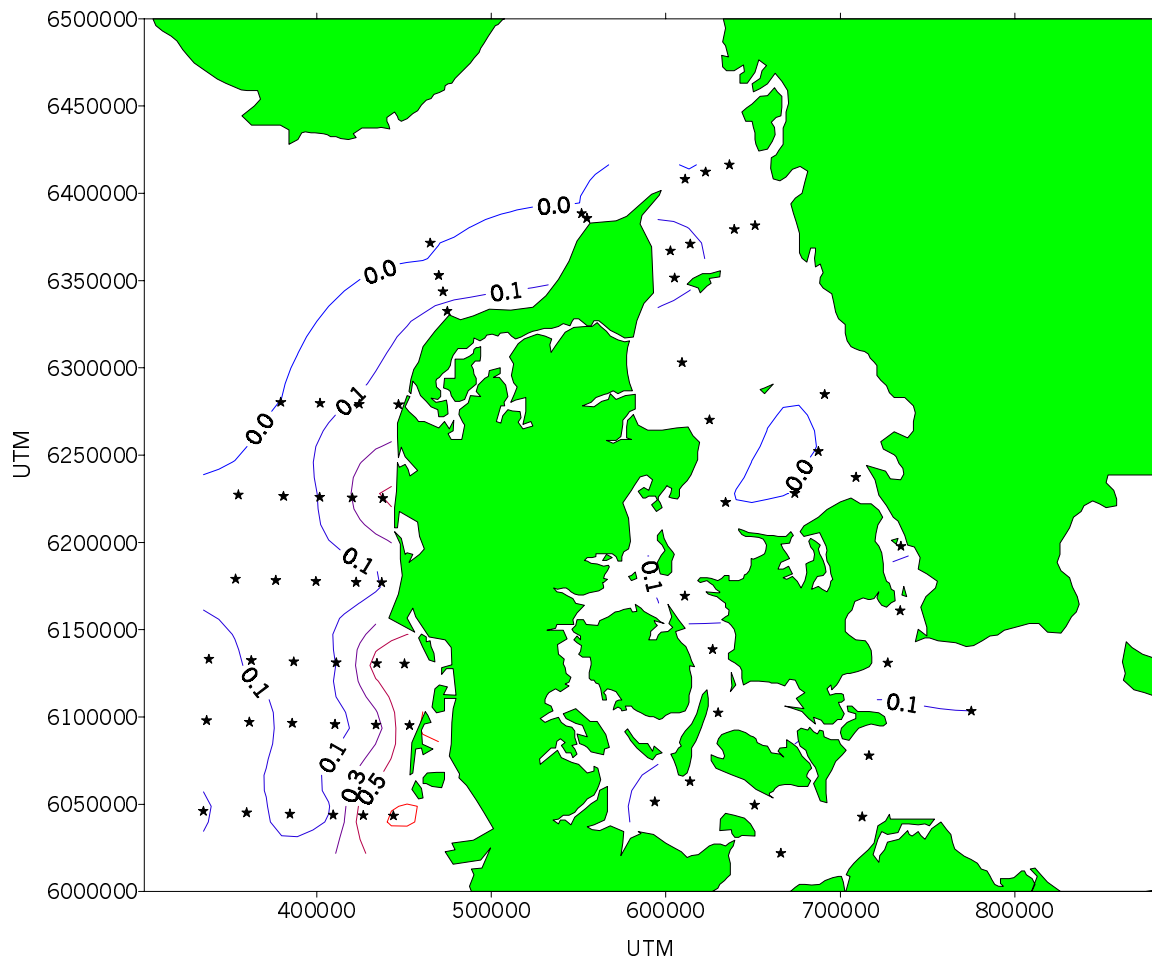


Figure 7. Interpolated distribution of surface phosphate concentrations (mean 1, 5 and 10 m depth).

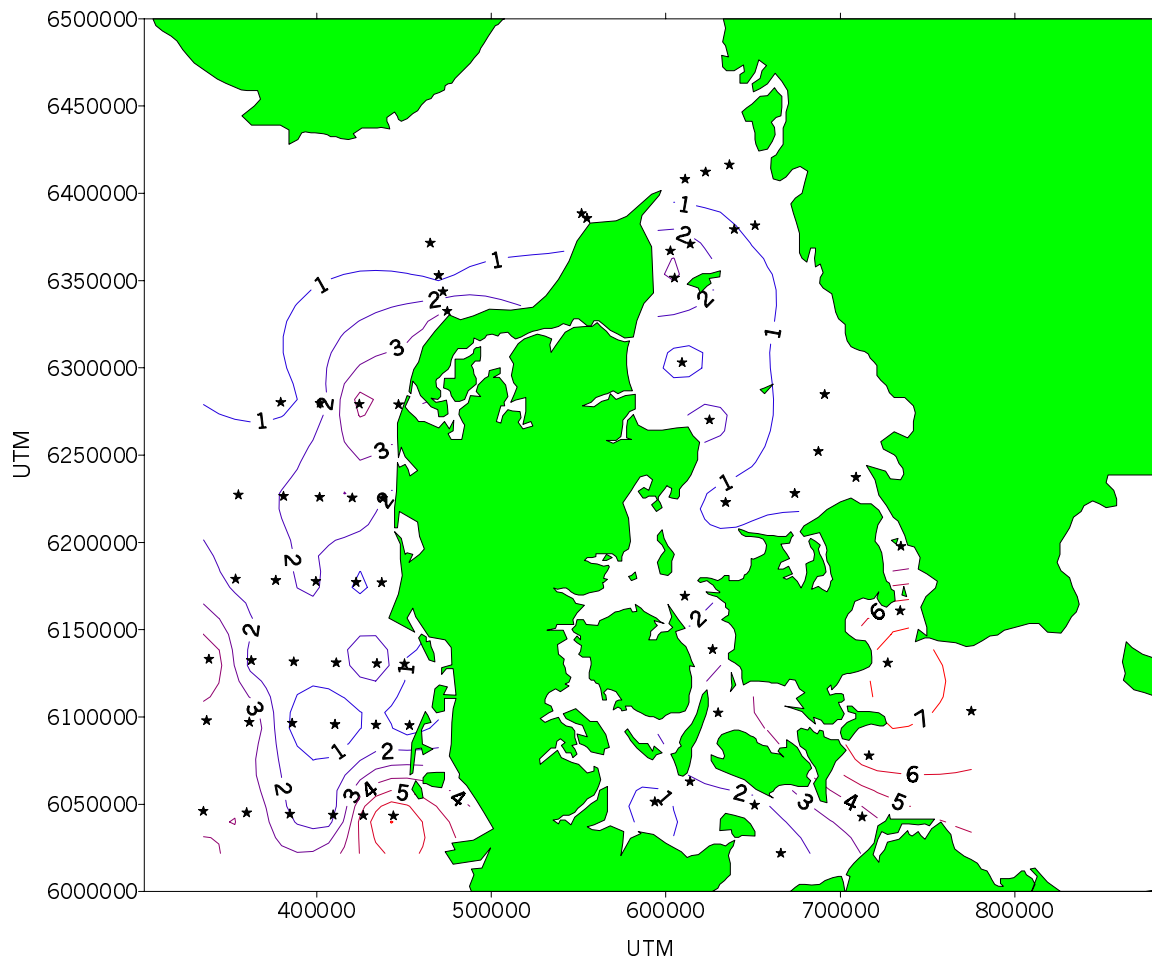


Figure 8. Interpolated distribution of surface silicate concentrations (mean 1, 5 and 10 m depth).

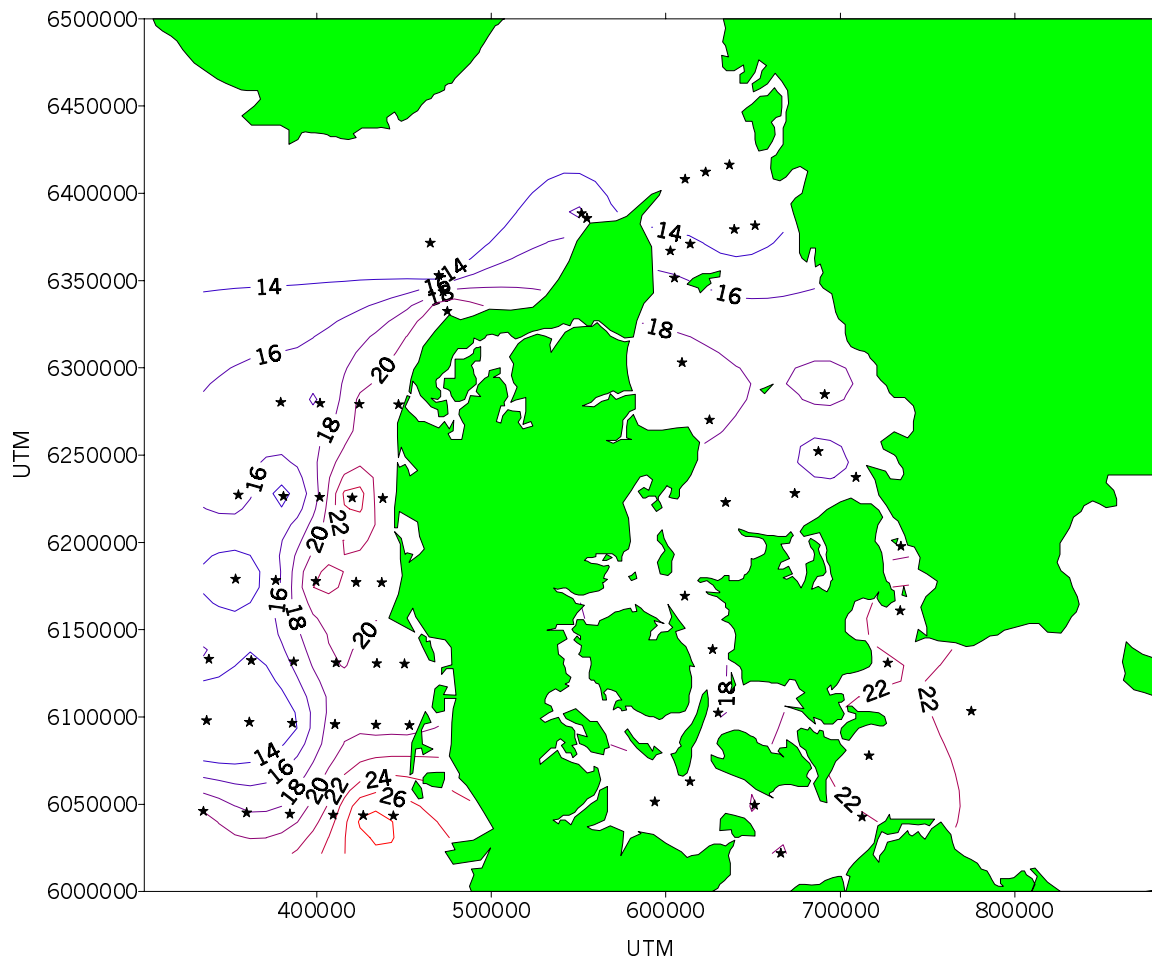


Figure 9. Interpolated distribution of surface total-N concentrations (mean 1, 5 and 10 m depth).

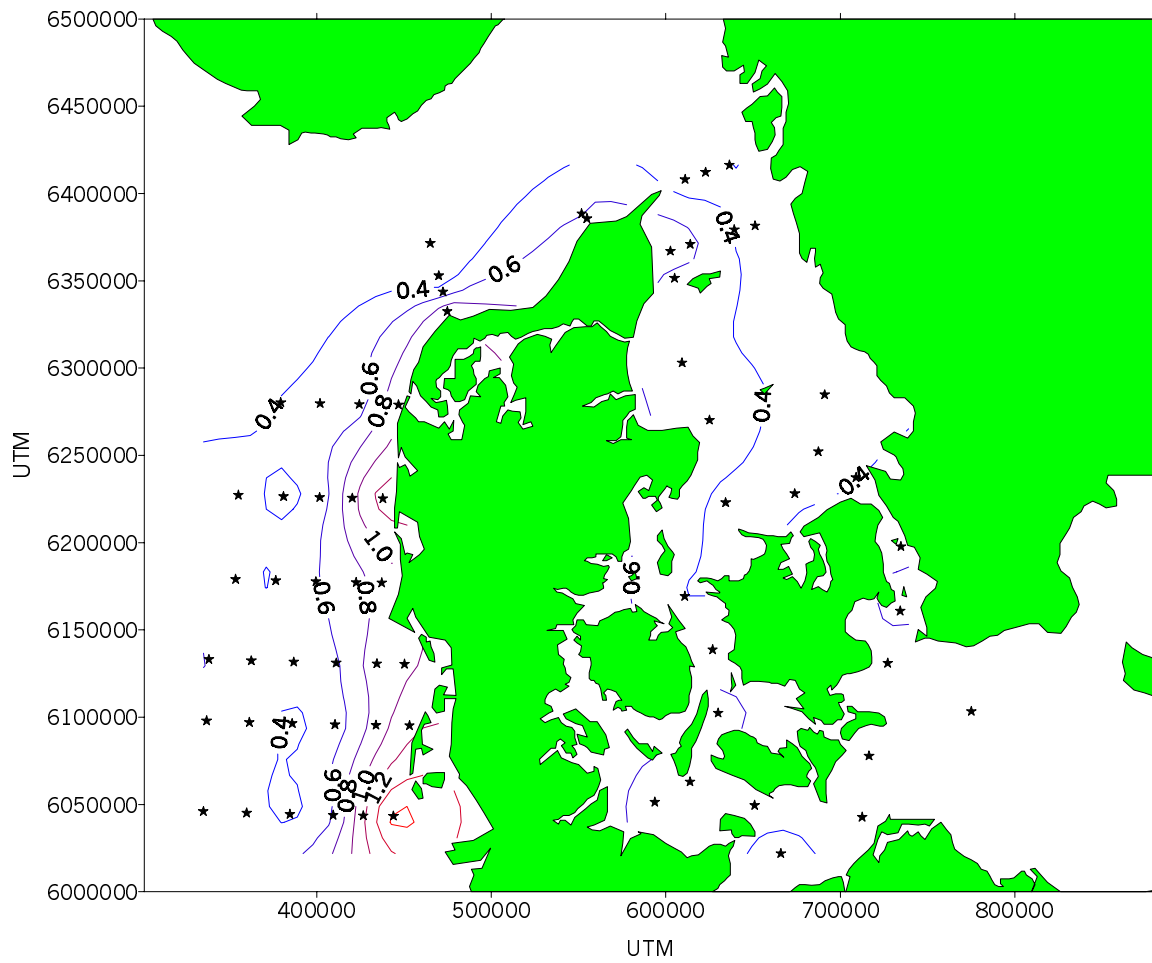


Figure 10. Interpolated distribution of surface total-P concentrations (mean 1, 5 and 10 m depth).

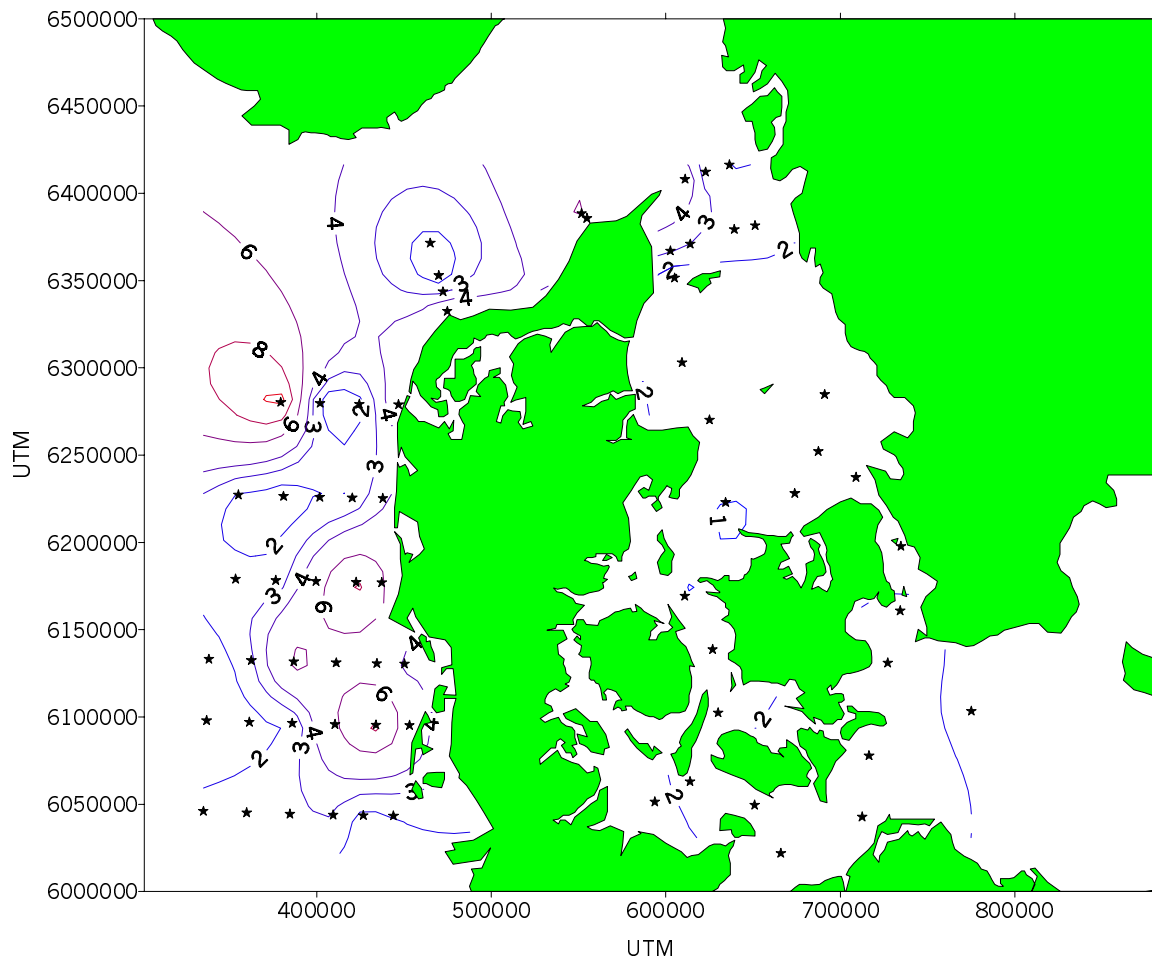


Figure 11. Interpolated distribution of surface chlorophyll-*a* concentrations (mean 1, 5 and 10 m depth).

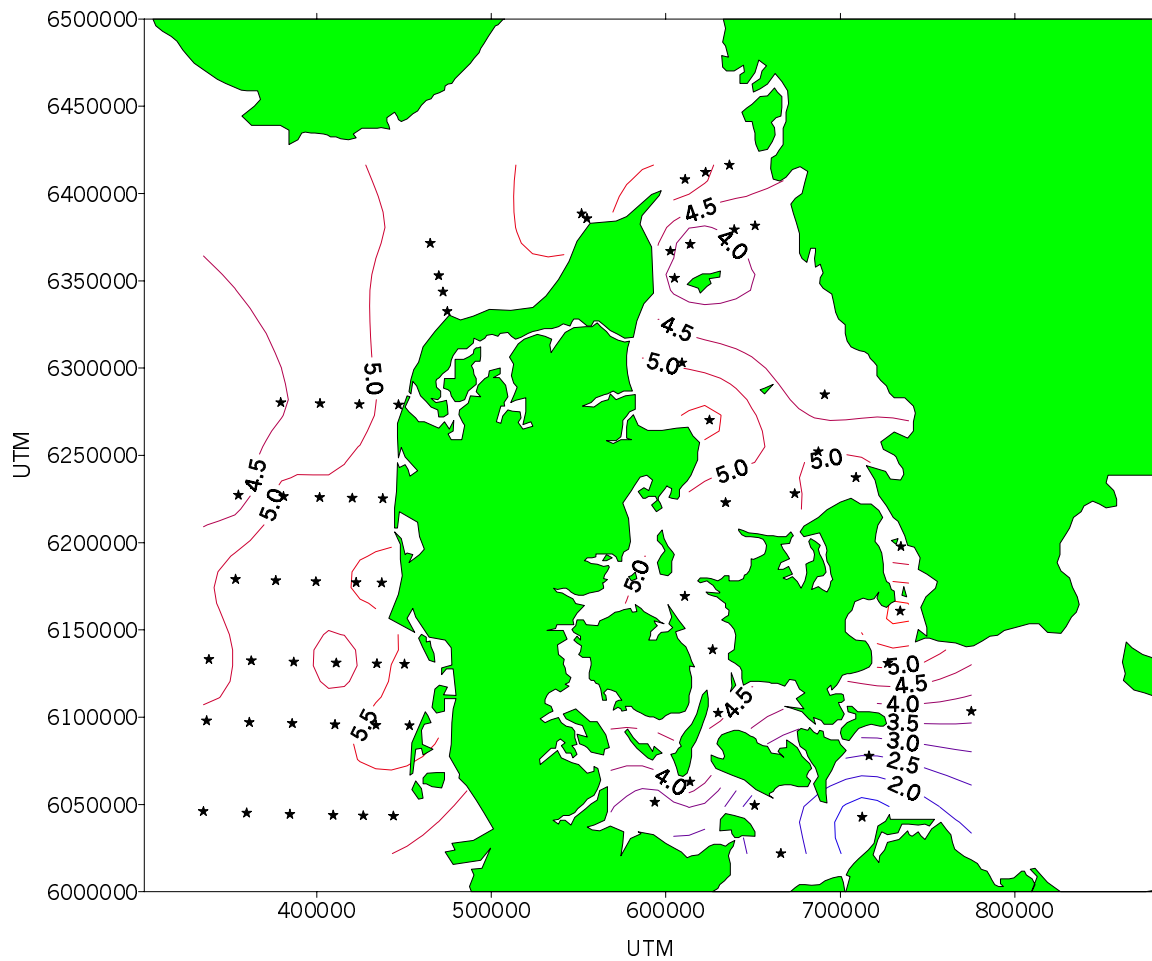


Figure 12. Interpolated distribution of minimum oxygen concentrations, independent on water depth and observation depth.

Transect I: Kattegat NE - Belt Sea - Arkona Sea

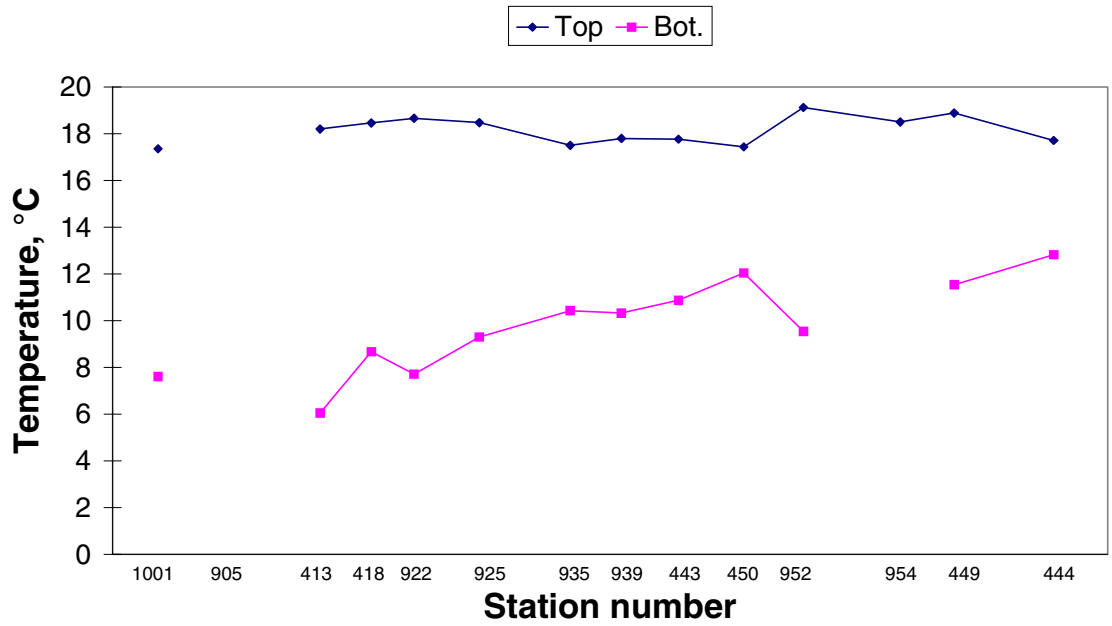
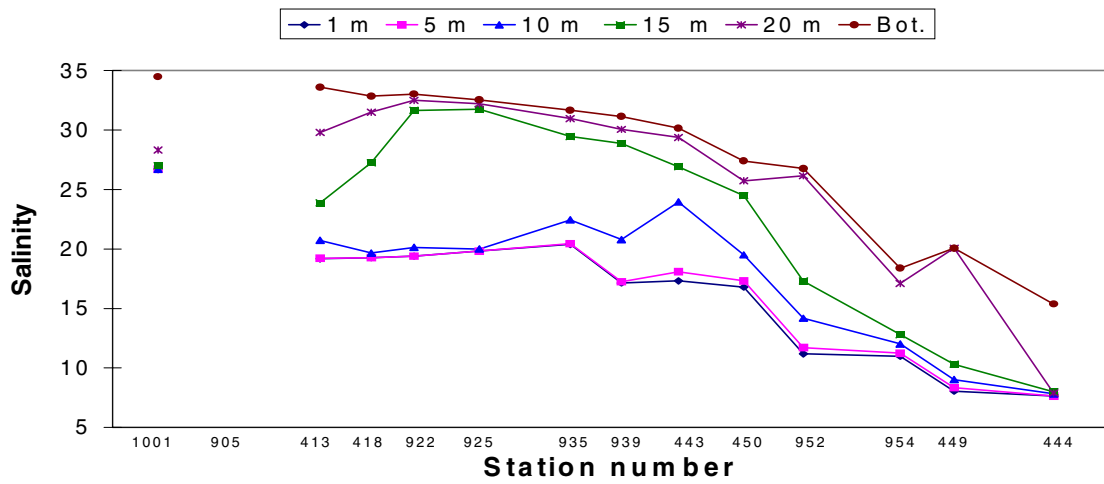
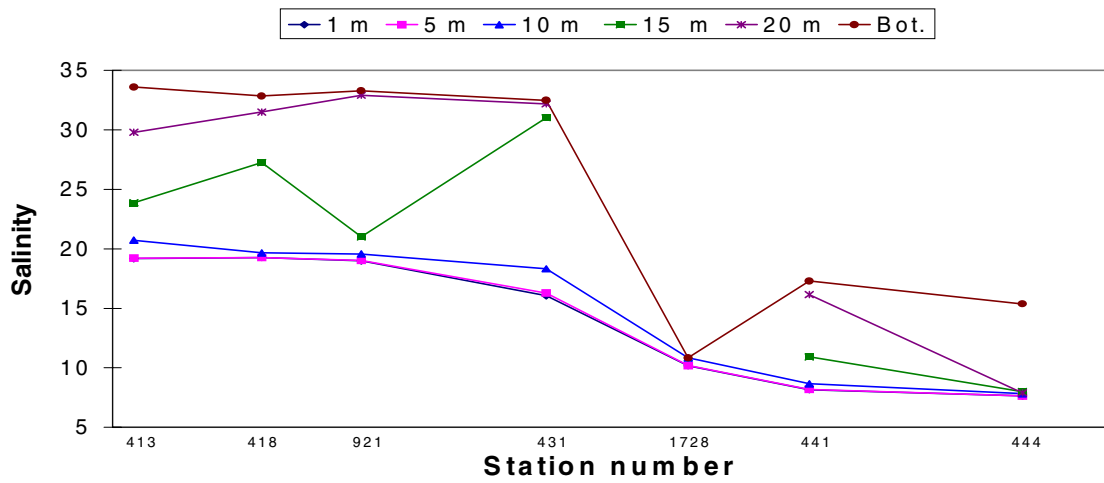


Figure 13. Surface and near bottom temperature along transect I from the north-eastern Kattegat through the Belt Sea to the Arkona Sea.

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect II: Kattegat SE - The Sound - Arkona Sea



Transect III: Kattegat W - Great Belt

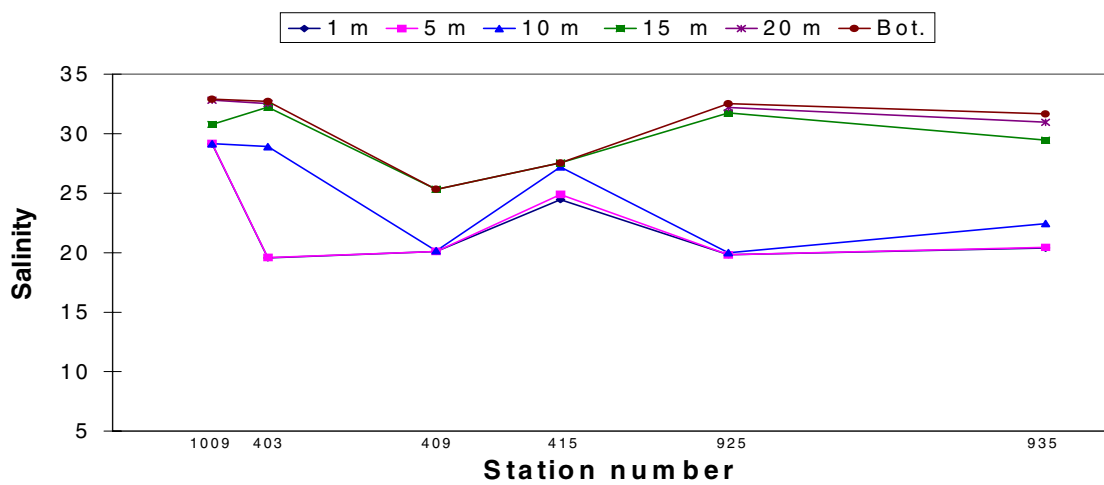
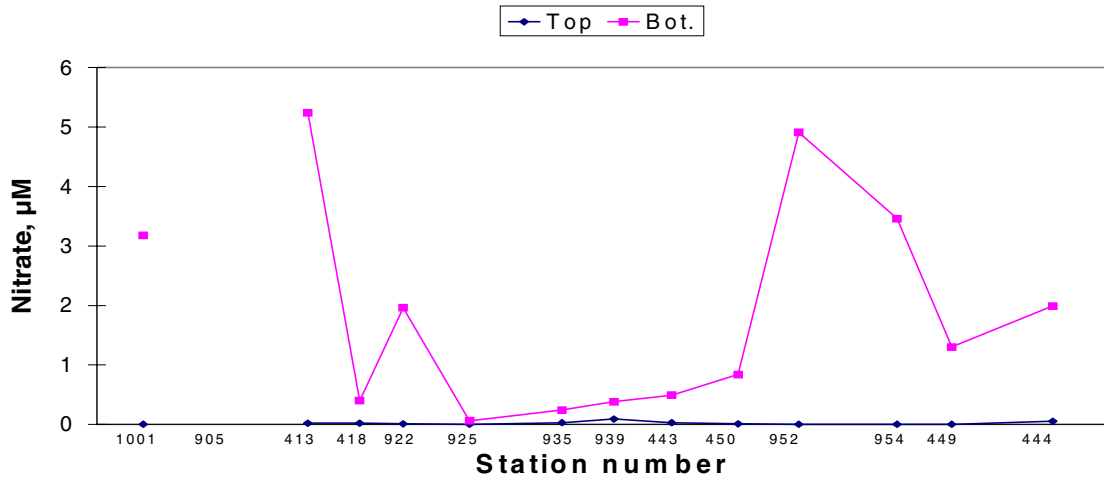
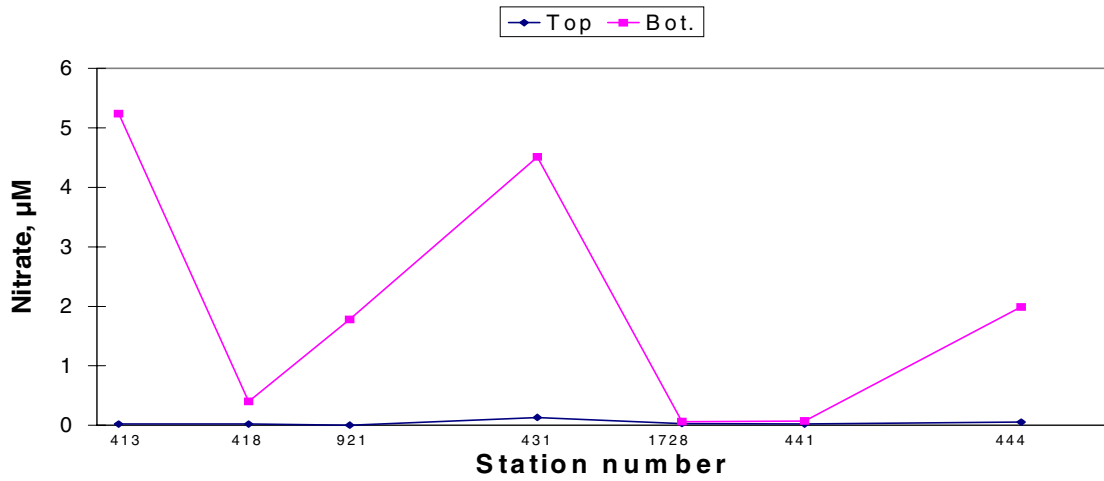


Figure 14. Salinity in 1 m, 5 m, 10 m, 15 m, 20 m depth and near bottom along transect I, II and III from the Kattegat through the Belt Sea and Sound to the Arkona Sea and in the western Kattegat to the Great Belt, respectively.

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect II: Kattegat SE - The Sound - Arkona Sea



Transect III: Kattegat W - Great Belt

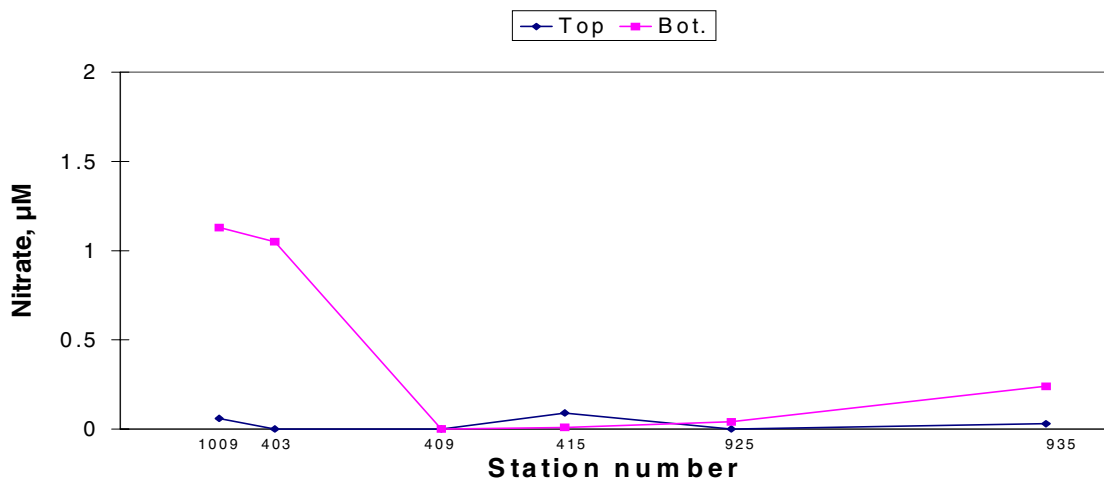
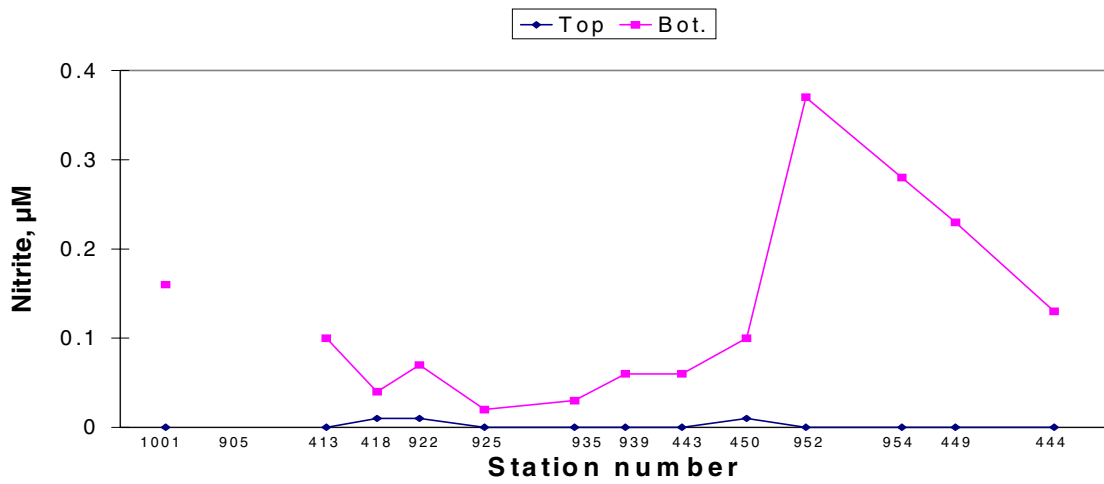


Figure 15. Surface and near bottom concentrations of nitrate along transect I, II and III

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect I: Kattegat NE - Belt Sea - Arkona Sea

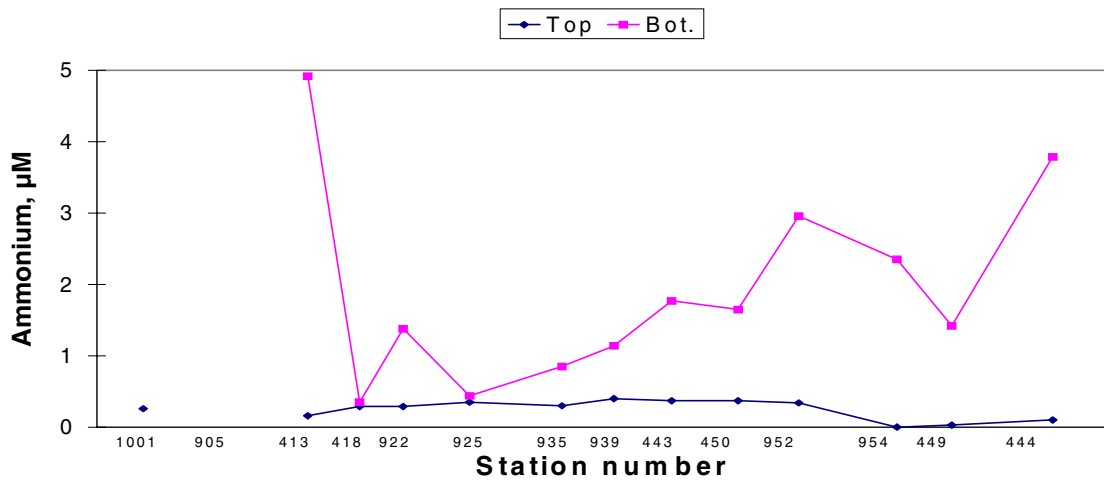
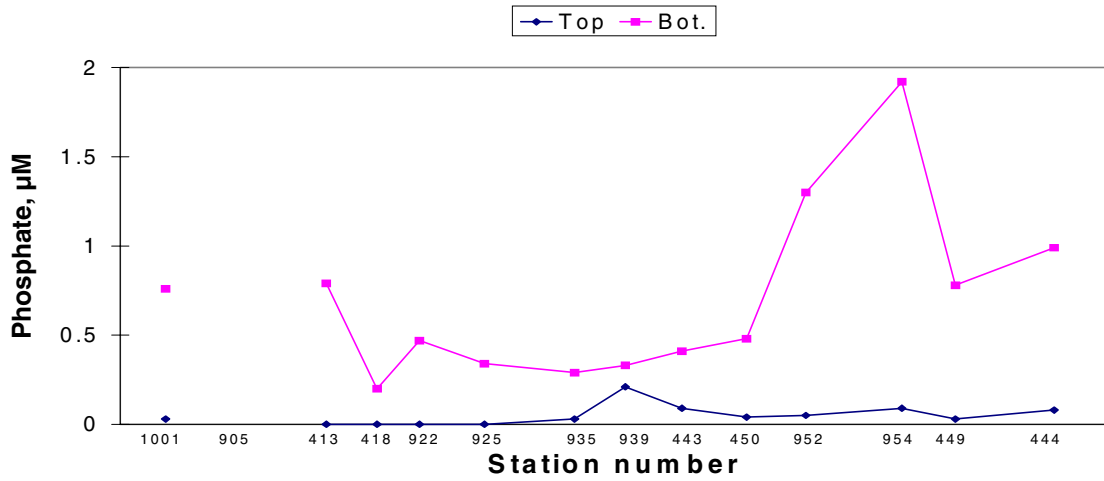


Figure 16. Surface and near bottom concentrations of nitrite and ammonium along transect I.

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect I: Kattegat NE - Belt Sea - Arkona Sea

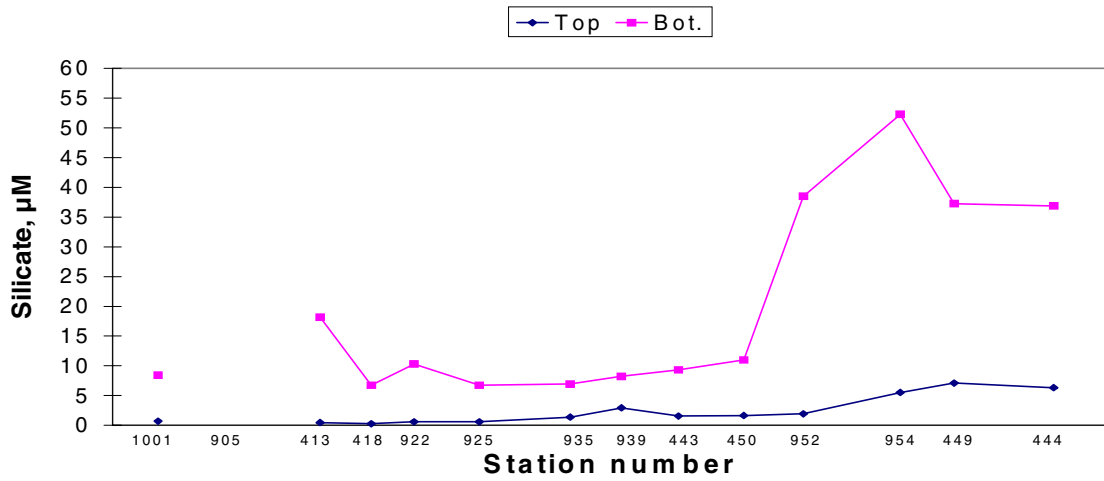
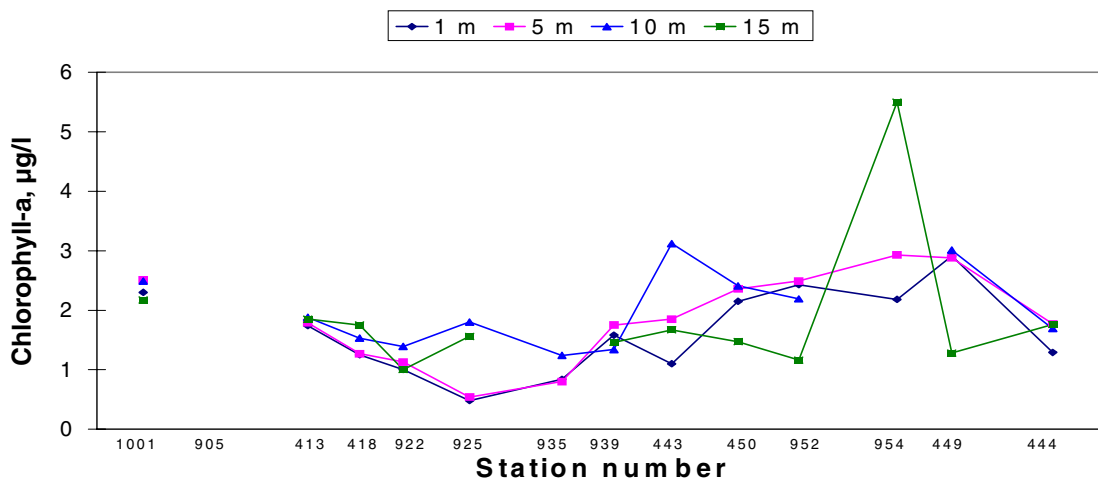
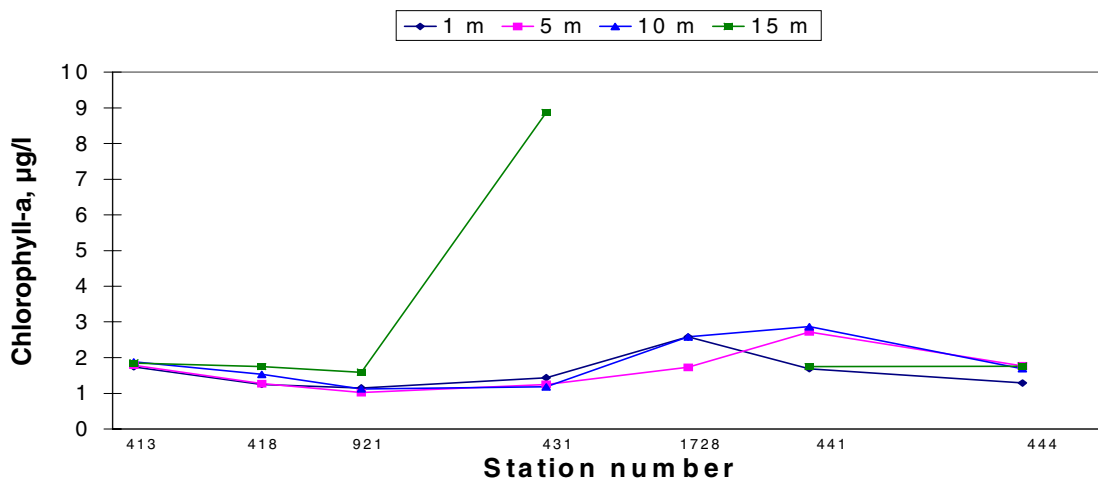


Figure 17. Surface and near bottom concentrations of phosphate and silicate along transect I.

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect II: Kattegat SE - The Sound - Arkona Sea



Transect III: Kattegat W - Great Belt

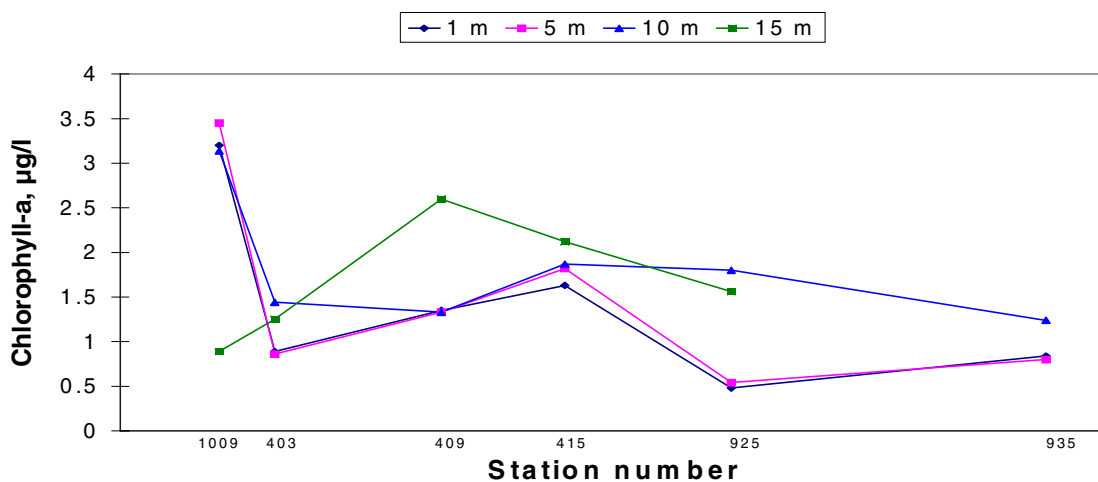
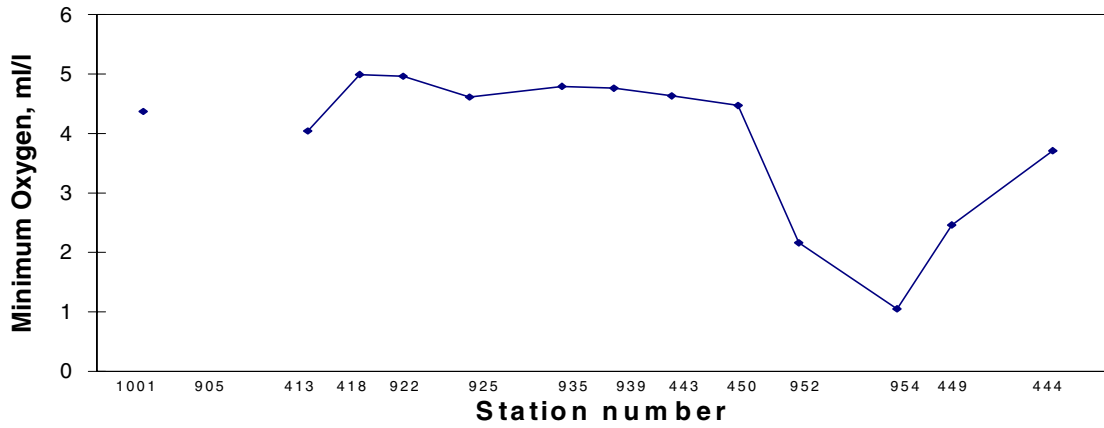
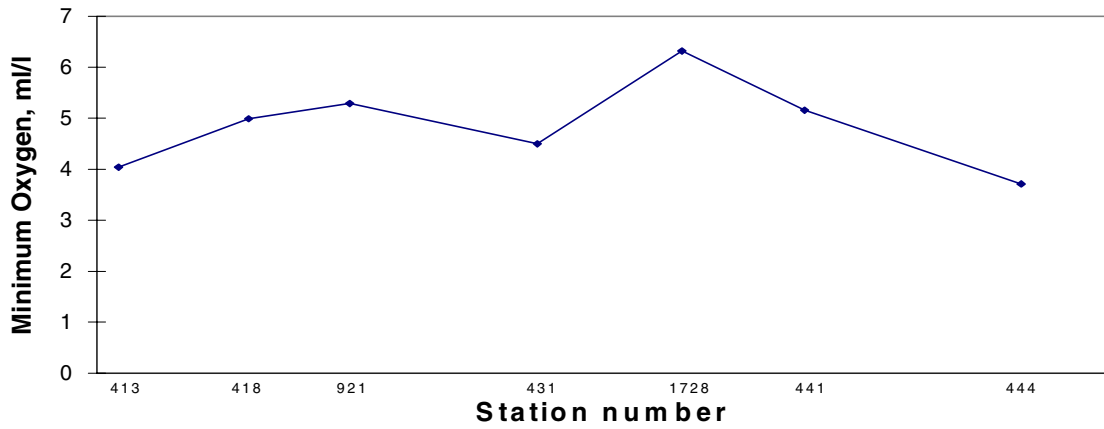


Figure 18. Chlorophyll-*a* concentrations in 1 m, 5 m, 10 m and 15 m depths along transect I, II and III.

Transect I: Kattegat NE - Belt Sea - Arkona Sea



Transect II: Kattegat SE - The Sound - Arkona Sea



Transect III: Kattegat W - Great Belt

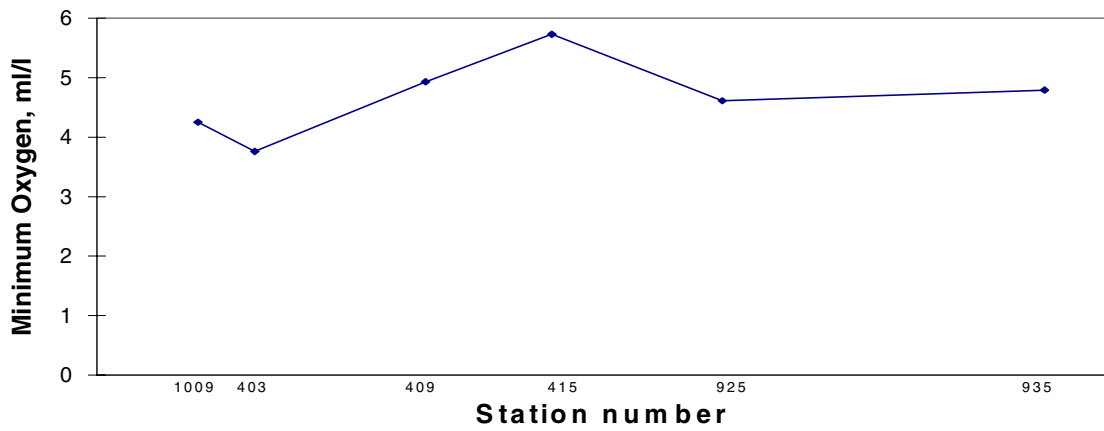


Figure 19. Minimum oxygen concentrations along transect I, II and III.

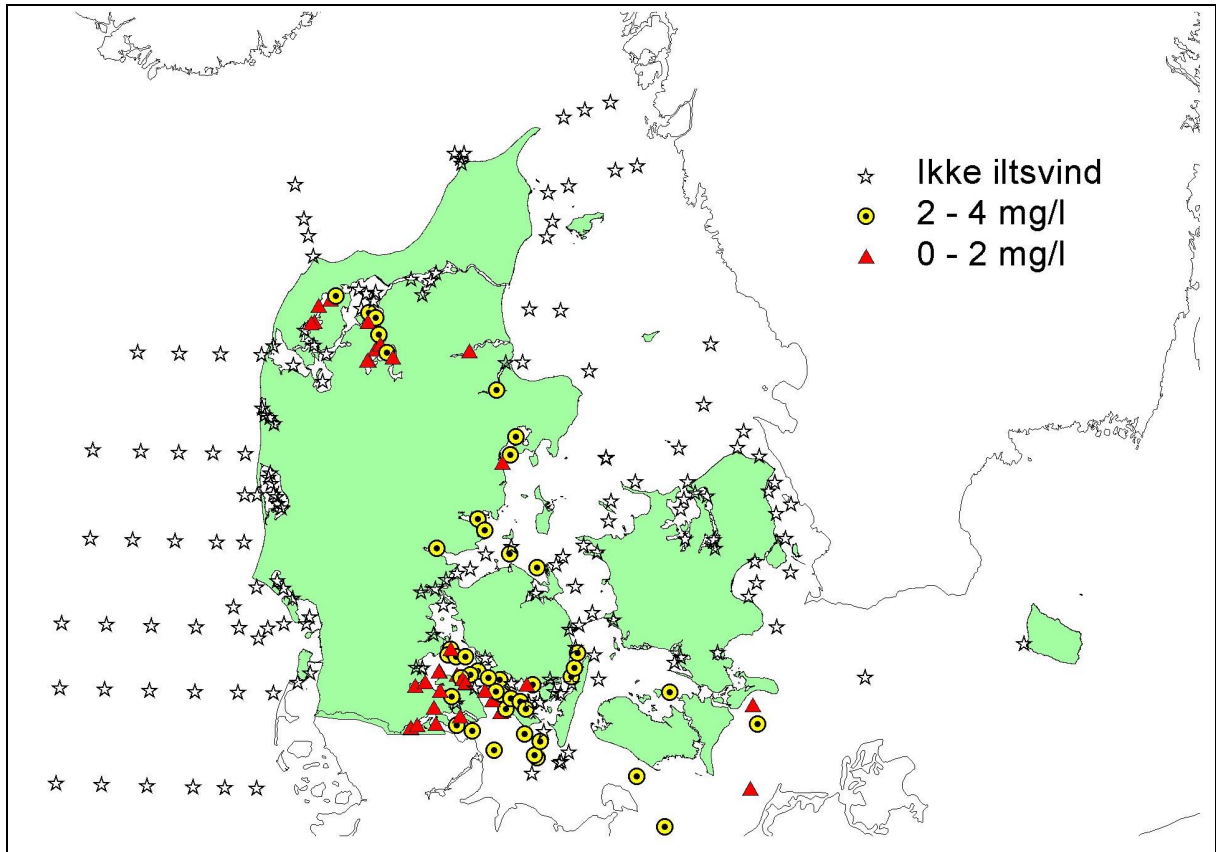


Figure 20. Stations visited by Danish counties or NERI within the first three weeks of August 2001, and where oxygen depletion (<4 mg/l) and serious oxygen depletion (<2 mg/l) were observed.