



r/v Gunnar Thorson

# Monitoring Cruise Report

**Cruise no.: 197**

**Time: 7 - 18 August 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 August 2000. Cruise no. 197.

**Report:** Gunni Ærtebjerg

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

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## Summary

Low saline water was spread out on the surface in the Skagerrak and eastern North Sea. In the North Sea a pycnocline was present only at the westernmost and northernmost stations. At these stations the minimum oxygen concentration was 4-5 ml/l. Generally, nutrients in the surface water were only observed in the German Bight. However, traces of nitrate, nitrite and silicate were also present along the Danish North Sea coast. Blooms of *Noctiluca miliaris* were observed in the German Bight as deep orange coloured stripes on the surface.

In the Kattegat, Sound and Belt Sea the stratification was strong, except in shallow areas. An upwelling was indicated in the western Kattegat, where traces of nitrate were observed in the surface water. Cold and unusually salty bottom water (34.1-34.5 psu) was present in the eastern Kattegat. In the surface water ammonium was observed in the Sound and Great Belt. Phosphate and silicate were present in the western Kattegat, Sound, Belt Sea and Arkona Sea. The chlorophyll was relatively homogeneously distributed in the uppermost 15 m of the water column, and no pronounced subsurface maximum was observed.

The lowest oxygen concentration of 0.6 ml/l (9%) was observed in the Fehmarn Belt, increasing to 1.6 ml/l (23%) at Gedser Rev and 1.8 ml/l (25%) in the deeper part of the Arkona Sea. In the Sound 1.7 ml/l (25-27%) was observed in the whole water column from 30 m depth to the bottom in 51 m depth. In the southern Kattegat the minimum concentrations varied between 2.5 and 3.3 ml/l (39-49%), lowest at the entrances to the Sound and Belt Sea. In the Great Belt the minimum oxygen concentration decreased from 2.5 ml/l (39%) in the north to 2.3 (36%) in Langelands Belt.

Compared to August last year and to mean for August in the 1980's the minimum oxygen concentrations this year are lower in the Sound, Great Belt, Fehmarn Belt, western Kattegat and east of Anholt. The minimum oxygen concentrations in the Arkona Sea were lower than in the 1980's. Thus, low oxygen concentrations occur this year earlier than usual.

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 in the Fehmarn Belt, and oxygen depletion occurred in the south-western Kattegat, the Sound, Great Belt, Mecklenburg Bight, Gedser Rev area and Arkona Sea. 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*.

## 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 unusually warm, while the summer (June-August) was colder than average. Only March was wet, April to June about normal, July and August relatively dry. The mean wind was rather low in April, May, July and August.

*Table 1.* Deviations in monthly mean temperature and precipitation in March to August 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
March	+1.7	+30	5.9	SW-W-NW
April	+2.5	0	4.2	E-SE—SW
May	+1.7	+6	4.3	E-SE—SW-W
June	-0.6	-4	5.1	SW-W
July	-0.7	-36	4.1	W-NW
August	-0.5	-28	4.3	SW-W

## North Sea and Skagerrak

### Hydrography

Low saline water was spread out in the surface of the eastern North Sea from 30.7 psu in the German Bight increasing to the west and north. In the surface above 34 psu was only observed at the westernmost stations 1046 and 1074 (*figure 2*). Along the Danish North Sea coast the salinity increased to 33 at Limfjorden. Also Skagerrak was covered by low saline water (29.4-31.5), lowest in the central Skagerrak, probably originating from the Baltic via the Kattegat. The surface temperature ranged from 14.5°C in the central Skagerrak to 17.5°C at the coast-near stations in the German Bight (*figure 3*). A thermocline was present at the westernmost stations at all transects in the North Sea. At the two northern transects a pycnocline was present at all stations, except closest to the coast. In the central Skagerrak the pycnocline was situated in about 12 m depth.

## Nutrients

In the surface of the Skagerrak and North Sea traces of nitrate (up to 0.15  $\mu\text{mol/l}$ ) were only observed along the Danish North Sea coast (*figure 4*), while low concentrations of nitrite up to 0.08  $\mu\text{mol/l}$  were also found in the German Bight (*figure 5*). Ammonium was only observed in the German Bight with up to 1.2  $\mu\text{mol/l}$  at the south-easternmost station (*figure 6*). Rather high phosphate concentrations (0.05-0.3  $\mu\text{mol/l}$ ) were found along the coast in the German Bight (*figure 7*). Rather high silicate concentrations (6.3  $\mu\text{mol/l}$ ) were observed in parts of the German Bight (*figure 8*), while practically no silicate was present in the surface at the western and northern stations in the North Sea nor in the Skagerrak. 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 surface layer (0-10 m) are shown in *table 2*.

*Table 2.* Linear regression analyses of salinity and concentrations of total-N and total-P in the surface (0-10 m) at the 36 stations in the North Sea 10-12 August 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 =  $\mu\text{mol/l}$ .

Nutrient	Slope	Intercept	34.5 psu	N	R <sup>2</sup>
Total-N	-4.67	174	12.6	106	0.44
Total-P	-0.18	6.70	0.35	106	0.44

## Chlorophyll-a

The mean chlorophyll concentration in the uppermost 10 m was in the Skagerrak 1-2  $\mu\text{g/l}$ , highest at the coast. A significant subsurface peak of 10.6  $\mu\text{g/l}$  was seen in the central Skagerrak (St. 1006) at 24 m depth. In the North Sea the concentration was below 1  $\mu\text{g/l}$  at the north-westernmost stations, increasing towards the coast up to 5.8  $\mu\text{g/l}$  at the two northern transects and 7.2  $\mu\text{g/l}$  outside the Danish Wadden sea (*figure 11*). At two stations in the German Bight 6.4-10.3  $\mu\text{g/l}$  was observed, probably due to blooms of *Noctiluca miliaris*, which was observed as deep orange coloured stripes on the surface several places in the German Bight (*figure 12*), but not at the sampling stations.

## Oxygen

The minimum oxygen concentrations were between 4.0 and 5.0 ml/l (67-85%) at the stratified westernmost and northernmost stations in the North Sea (*figure 13*). In the Skagerrak the lowest concentrations were 5.0 ml/l (76%) in 60 m depth at station 1133 and 5.2 ml/l (76-81%) in 70 m depth at the stations 1104 and 1106.

## Kattegat, Sound, Belt Sea and Arkona Sea

### Hydrography

The stratification was strong in all areas, except the shallow western Kattegat (Aalborg Bight), with the pycnocline generally situated around 15 m depth. The surface temperature (1 m depth) varied from 15.2°C in the western Kattegat (St. 409) to 17.1-17.7°C in many areas (*figure 3*). The bottom water temperature ranged from 6.8°C east of Anholt (St. 413) to 15.3°C in the north-eastern Kattegat (St. 1007) with the bottom water 1.3-10.2°C colder than the surface water (*figure 14*).

The surface salinity ranged from 7.9-8.2 in the Arkona Sea (St. 441, 444, 449) to 30.3 in the north-western Kattegat (St. 1008, 1009) (*figure 2*). The bottom water salinity ranged from 11.6-15.0 in the Arkona Sea (St. 441, 444, 449) to 34.1-34.5 in the north-eastern Kattegat (St. 413, 905, 1001) (*figure 15*). The salinity stratification was strongest (10.3-18.4 psu) in the Sound, eastern and southern Kattegat and the Belt Sea.

Compared to long term monthly means (Lightship observations 1931-1960) for August the surface temperature was 0.3-1.7°C lower than normal, except for 0.4-0.7°C higher temperatures in the Fehmarn Belt (St. 952, 954). The bottom water temperature was generally 0.2-0.6°C higher than normal, except for 1.0-2.8°C lower temperatures in the western Kattegat (St. 403, 409) and east of Anholt (St. 413). The salinity during the present cruise was generally lower than normal, both at the surface and in the bottom water, except for higher salinity in the western Kattegat and central Great Belt and in the bottom water of the eastern Kattegat. Both temperature and salinity indicate upwelling in the western Kattegat.

### **Nutrients**

In the surface traces of nitrate (0.25 µmol/l) were observed only in the western Kattegat (St. 409) due to upwelling (*figure 4*). In the bottom water high nitrate concentrations (10.9-11.2 µmol/l) were observed east of Anholt (St. 413) and in the Sound (St. 431) (*figure 16*). Contrary, nearly no nitrate was present at the bottom in the northern Great Belt (St. 925, 935, 939).

Nitrite concentrations in the surface were very low (*figure 5*), but somewhat higher at the bottom, especially in the north-eastern Kattegat, the Sound and Great Belt (*figure 17a*). Ammonium was present in the surface in the Sound and Great Belt (*figure 6*), and in high concentrations (1.5-2.9 µmol/l) in the bottom water in the Great Belt, Gedser Rev area and Arkona Sea (*figure 17b*).

Phosphate and silicate were present in the surface water in the western Kattegat, the Sound, Belt Sea and Arkona Sea (*figures 7 and 8*). High phosphate (0.7-1.3 µmol/l) and silicate (25-50 µmol/l) concentrations were observed at the bottom in the eastern Kattegat, the Sound, Belt Sea and Arkona Sea (*figures 18a and 18b*).

### **Chlorophyll-a**

The mean chlorophyll concentration in the uppermost 10 m varied between 1.4 µg/l in the Arkona Sea to 4.3 µg/l in the northern Great Belt and 4.7 µg/l in the north-eastern Kattegat (*figure 12*). The chlorophyll was relatively homogeneously distributed in the uppermost 15 m of the water column, and no pronounced subsurface maximum was observed (*figure 19*).

### **Oxygen**

Below 3 ml/l was observed in the southern Kattegat, the Sound, Belt Sea and Arkona sea (*figure 13*). The lowest oxygen concentration of 0.6 ml/l (9% saturation) was observed in the Fehmarn Belt (St. 952), increasing to 1.6 ml/l (23%) at Gedser Rev and 1.8 ml/l (25%) in the deeper part of the Arkona Sea (*figure 20*). In the Sound 1.7 ml/l (25-27%) was observed in the whole water column from 30 m depth to the bottom in 51 m depth. In the southern Kattegat the minimum concentrations varied between 2.5 and 3.3 ml/l (39-49%), lowest at the entrances to the Sound and Belt Sea. In the Great Belt the minimum oxygen concentration

decreased from 2.5 ml/l (39%) in the north to 2.3 (36%) in Langelands Belt, but increased to 2.8 ml/l (45%) at the southern tip of Langeland.

Compared to August last year and to mean for August in the 1980's the minimum oxygen concentrations this year are lower in the Sound, Great Belt, Fehmarn Belt, western Kattegat and east of Anholt. The minimum oxygen concentrations in the Arkona Sea were lower than in the 1980's. Thus, low oxygen concentrations occur this year earlier than usual.

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 in the Fehmarn Belt, and oxygen depletion occurred in the southwestern Kattegat, the Sound, Great Belt, Mecklenburg Bight, Gedser Rev area and Arkona Sea. In *figure 21* 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.



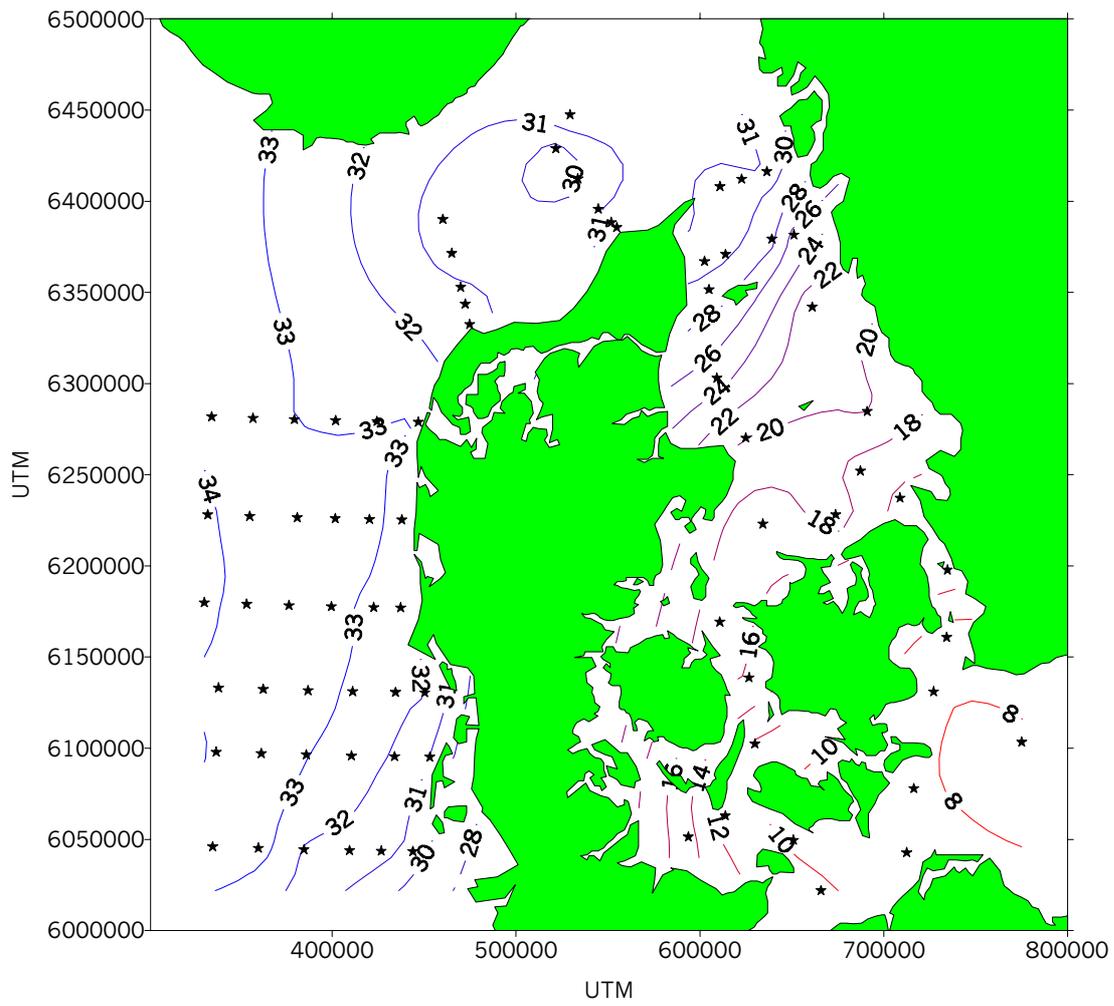


Figure 2. Interpolated distribution of surface salinity (mean 1, 5 and 10 m depth).

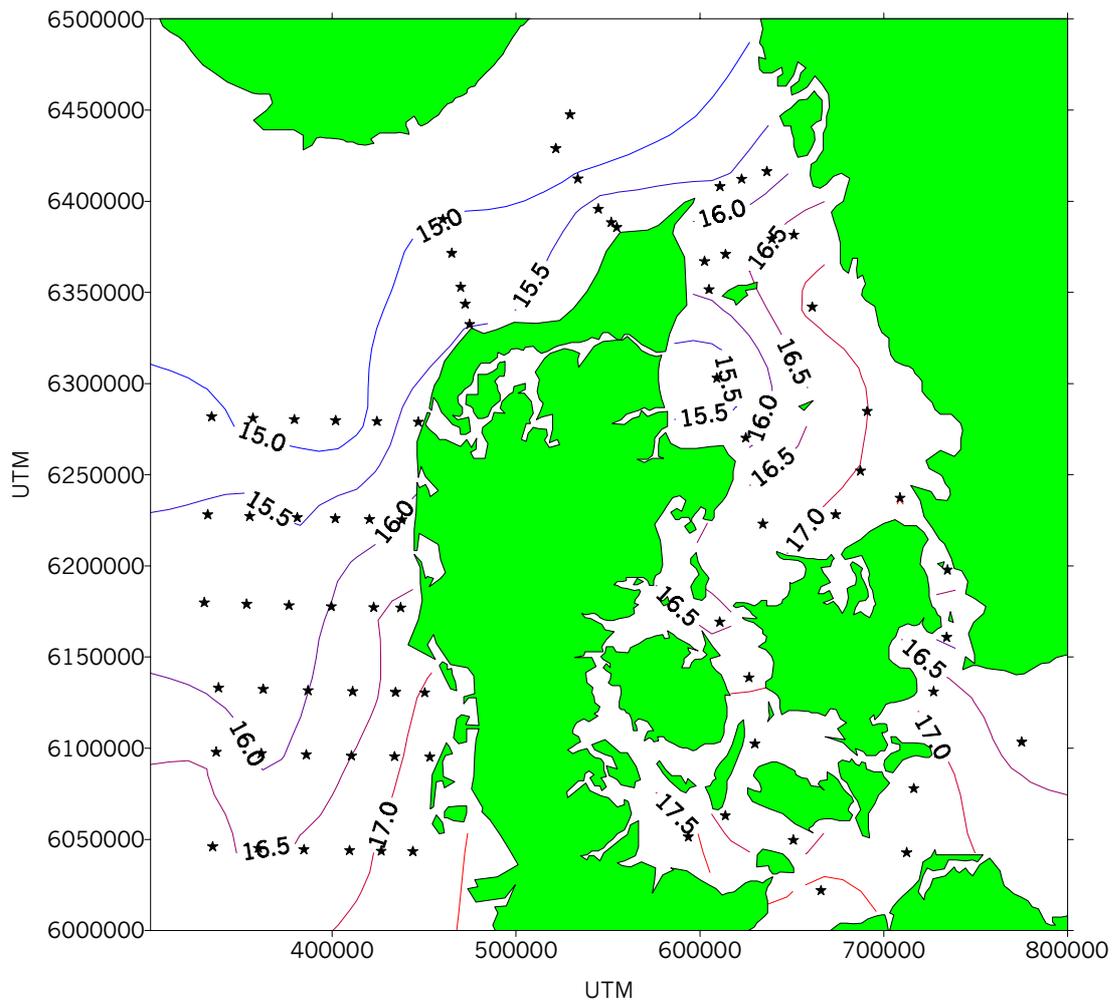


Figure 3. Interpolated distribution of surface temperature (mean 1, 5 and 10 m depth).

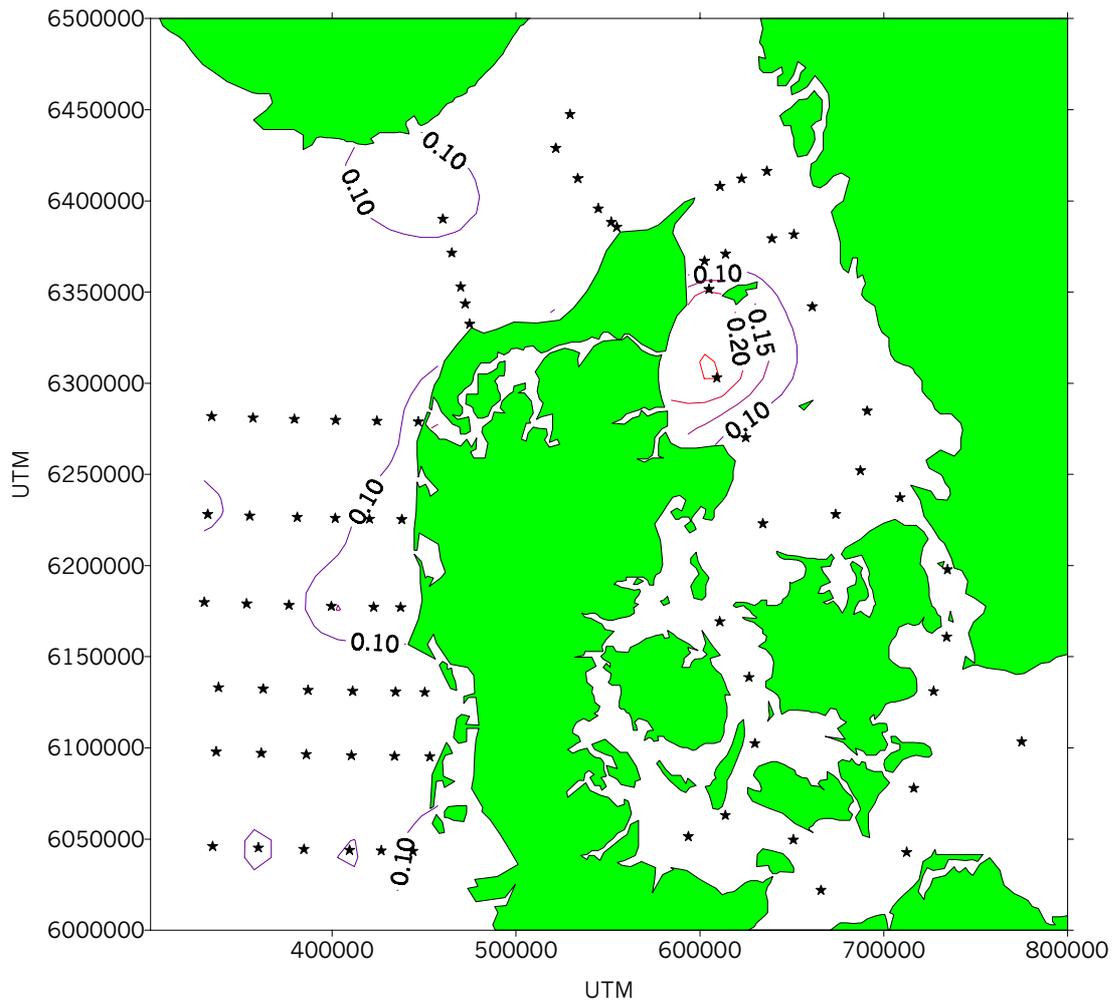


Figure 4. Interpolated distribution of surface nitrate concentrations (mean 1, 5 and 10 m depth).

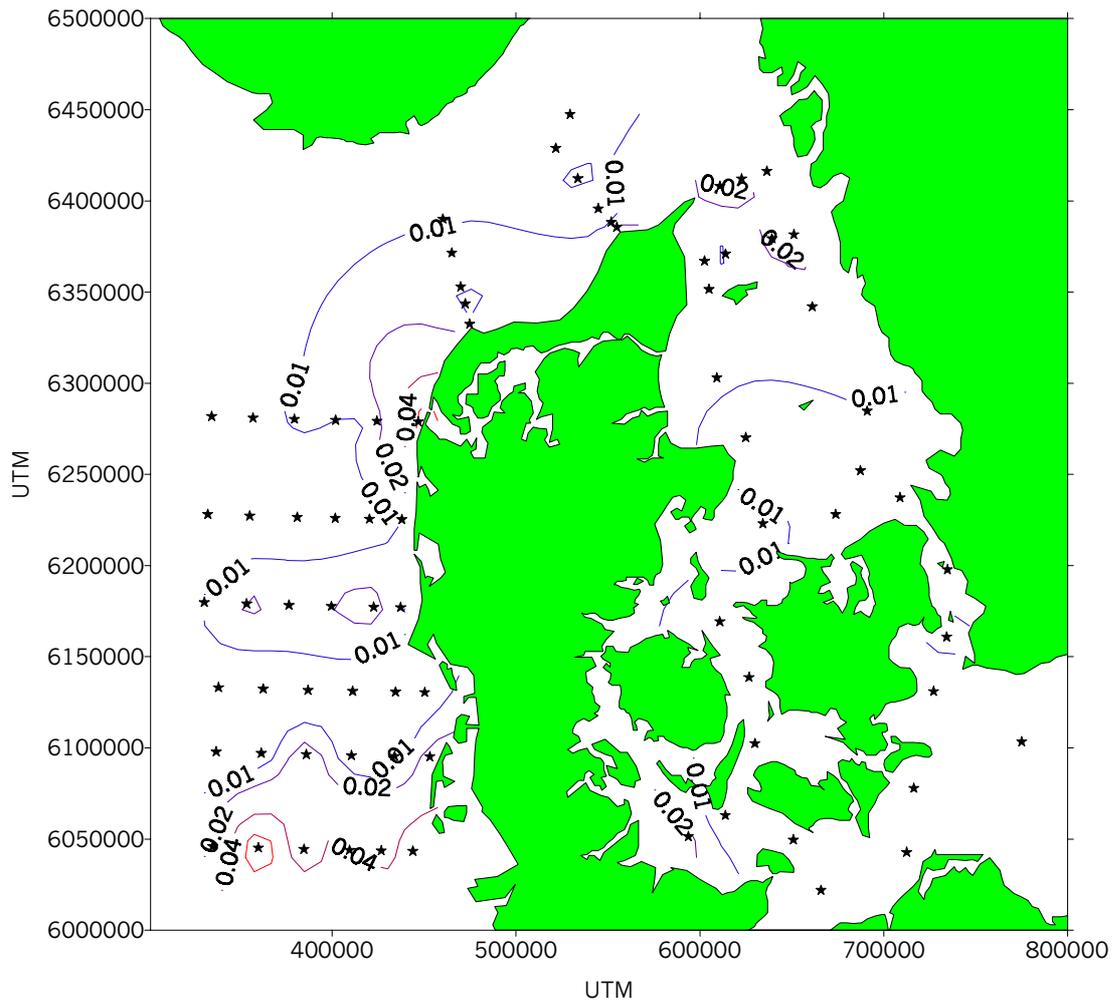


Figure 5. Interpolated distribution of surface nitrite concentrations (mean 1, 5 and 10 m depth).

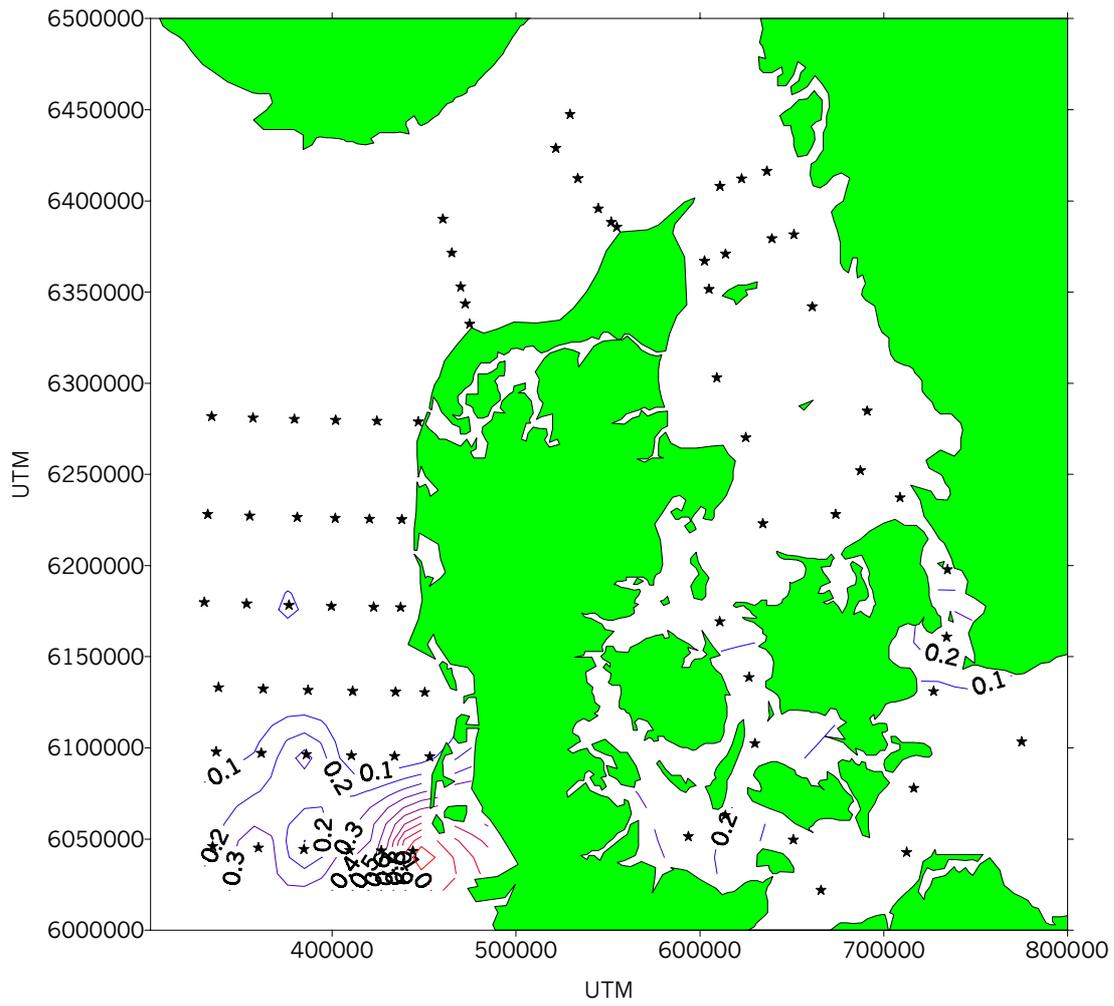


Figure 6. Interpolated distribution of surface ammonium concentrations (mean 1, 5 and 10 m depth).

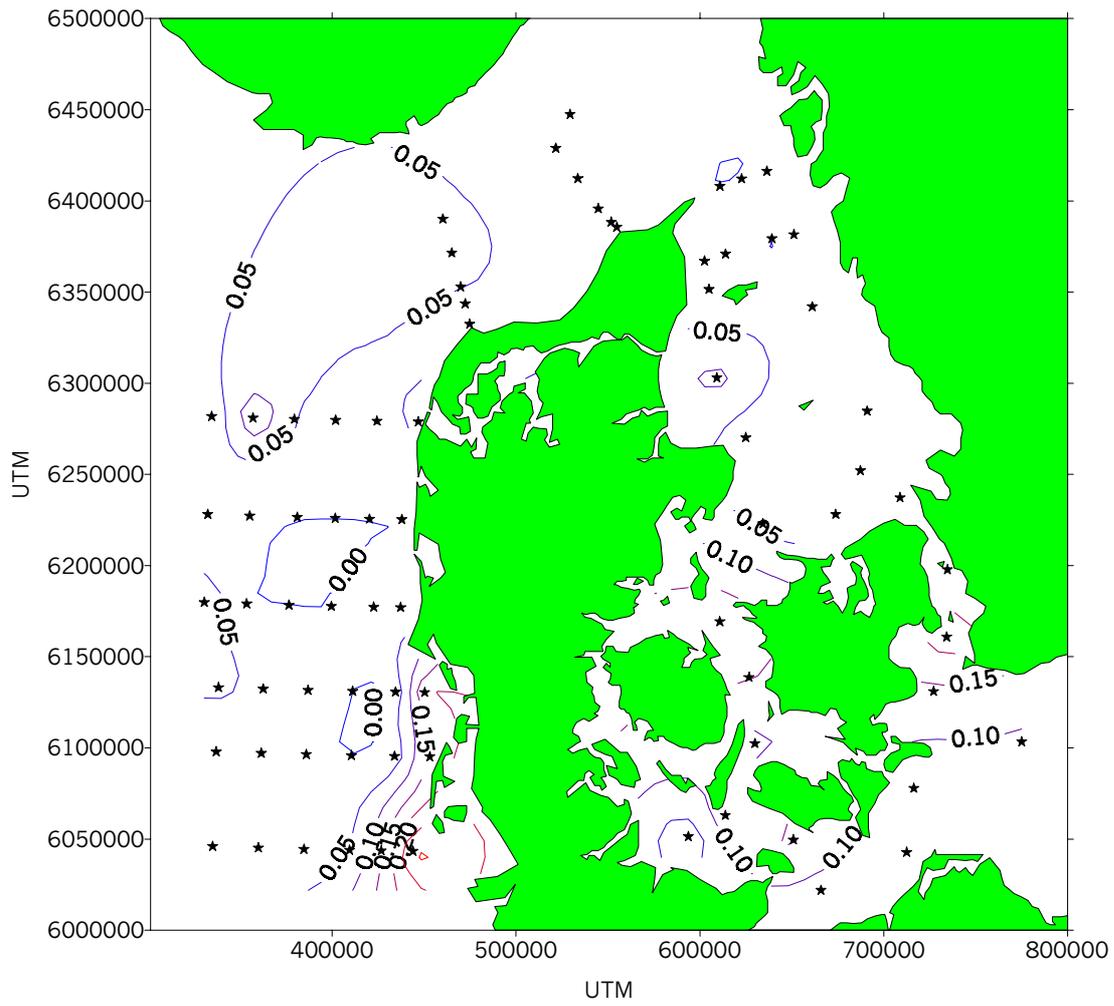


Figure 7. Interpolated distribution of surface phosphate concentrations (mean 1, 5 and 10 m depth).

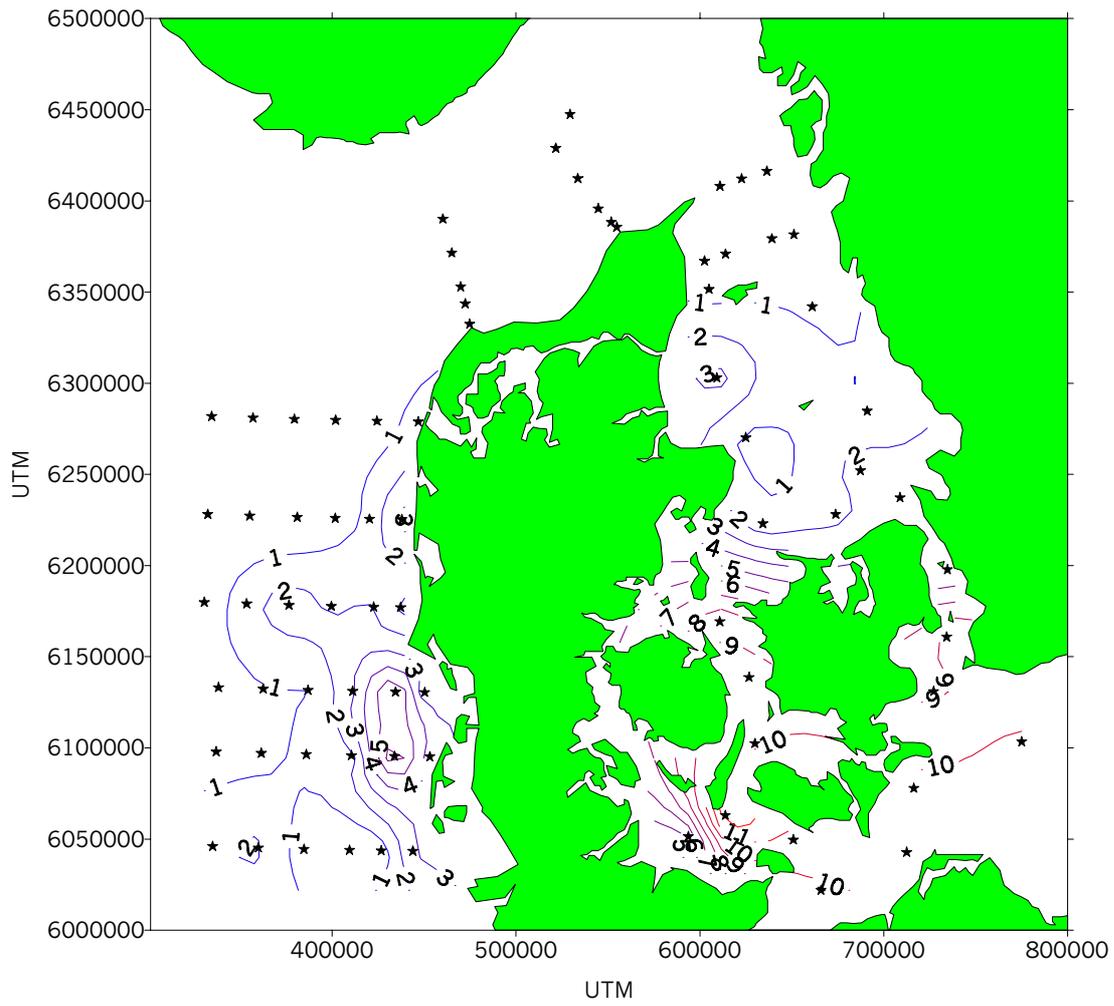


Figure 8. Interpolated distribution of surface silicate concentrations (mean 1, 5 and 10 m depth).

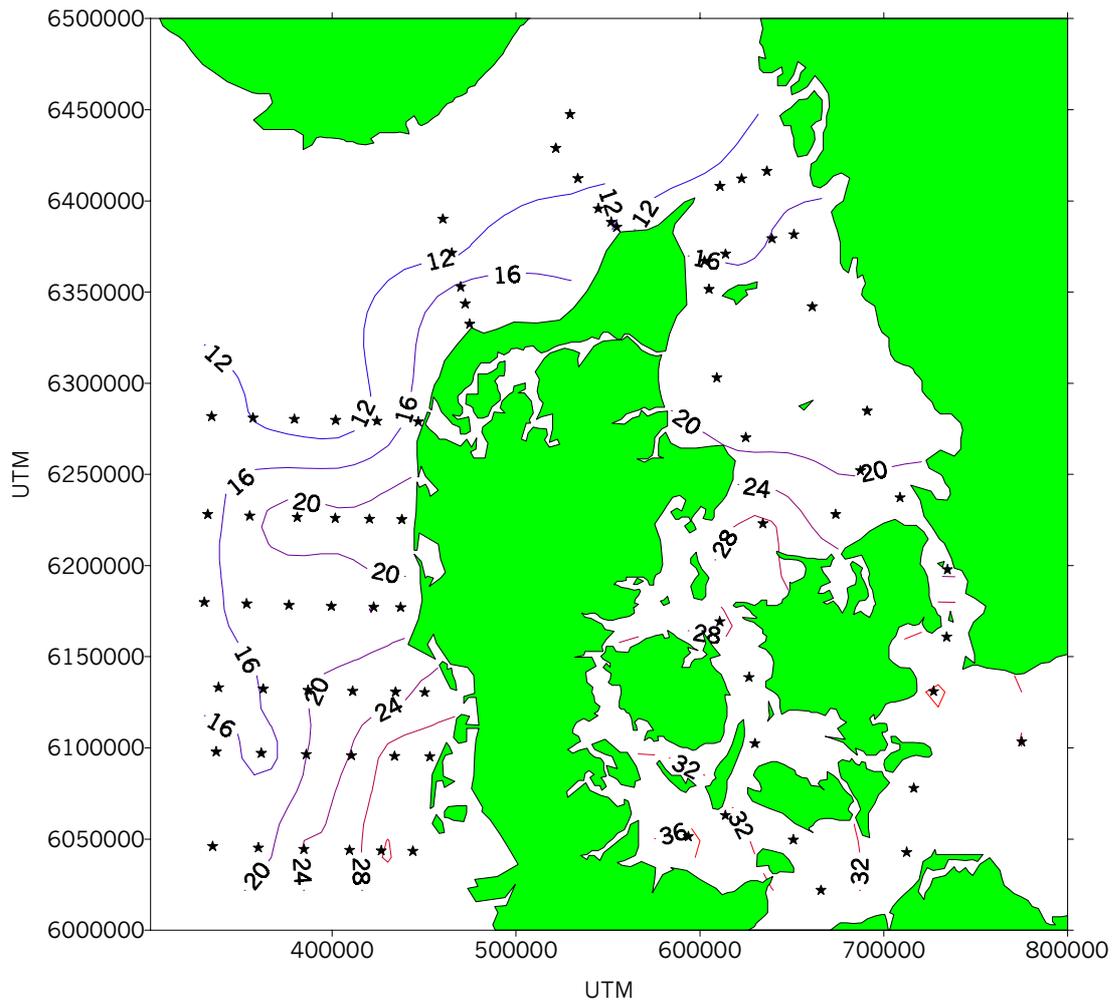


Figure 9. Interpolated distribution of surface total-N concentrations (mean 1, 5 and 10 m depth).

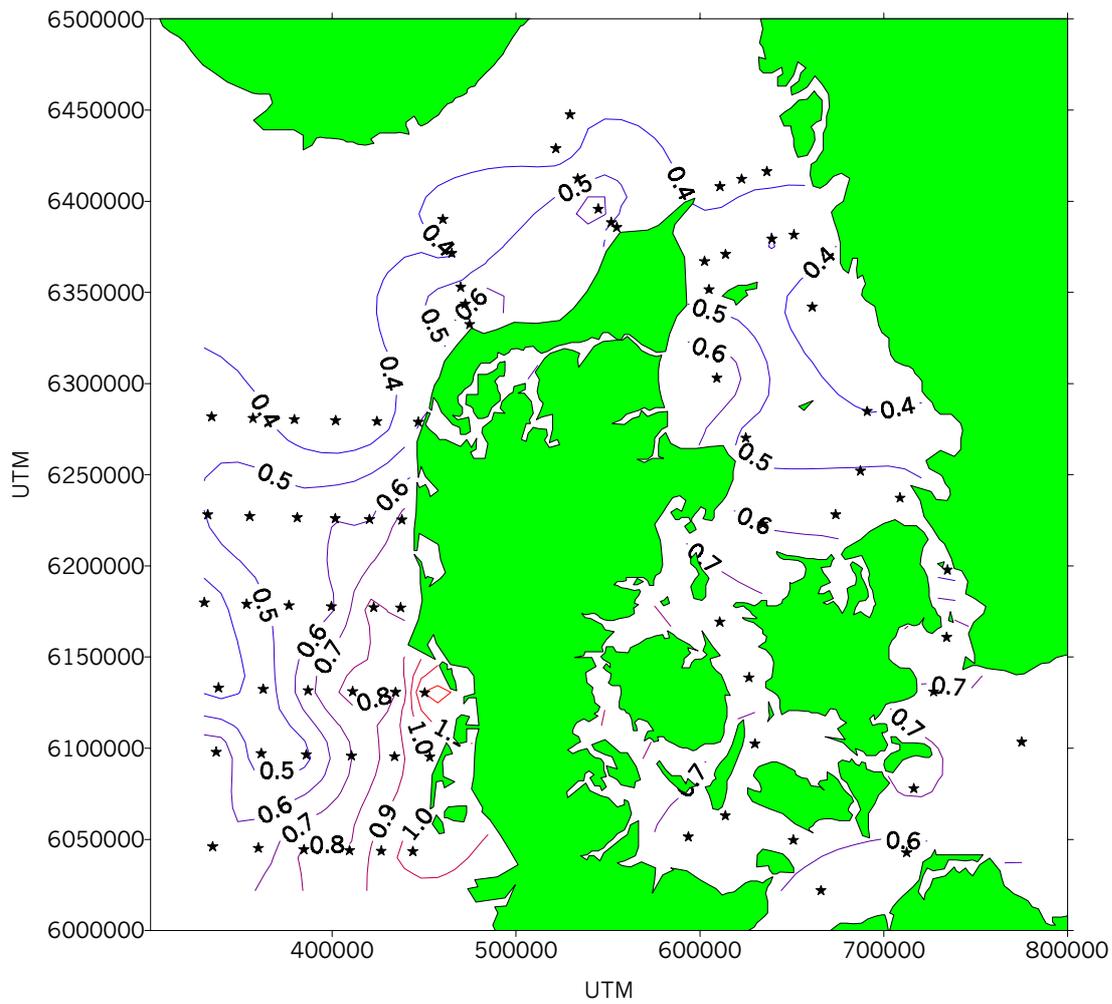


Figure 10. Interpolated distribution of surface total-P concentrations (mean 1, 5 and 10 m depth).

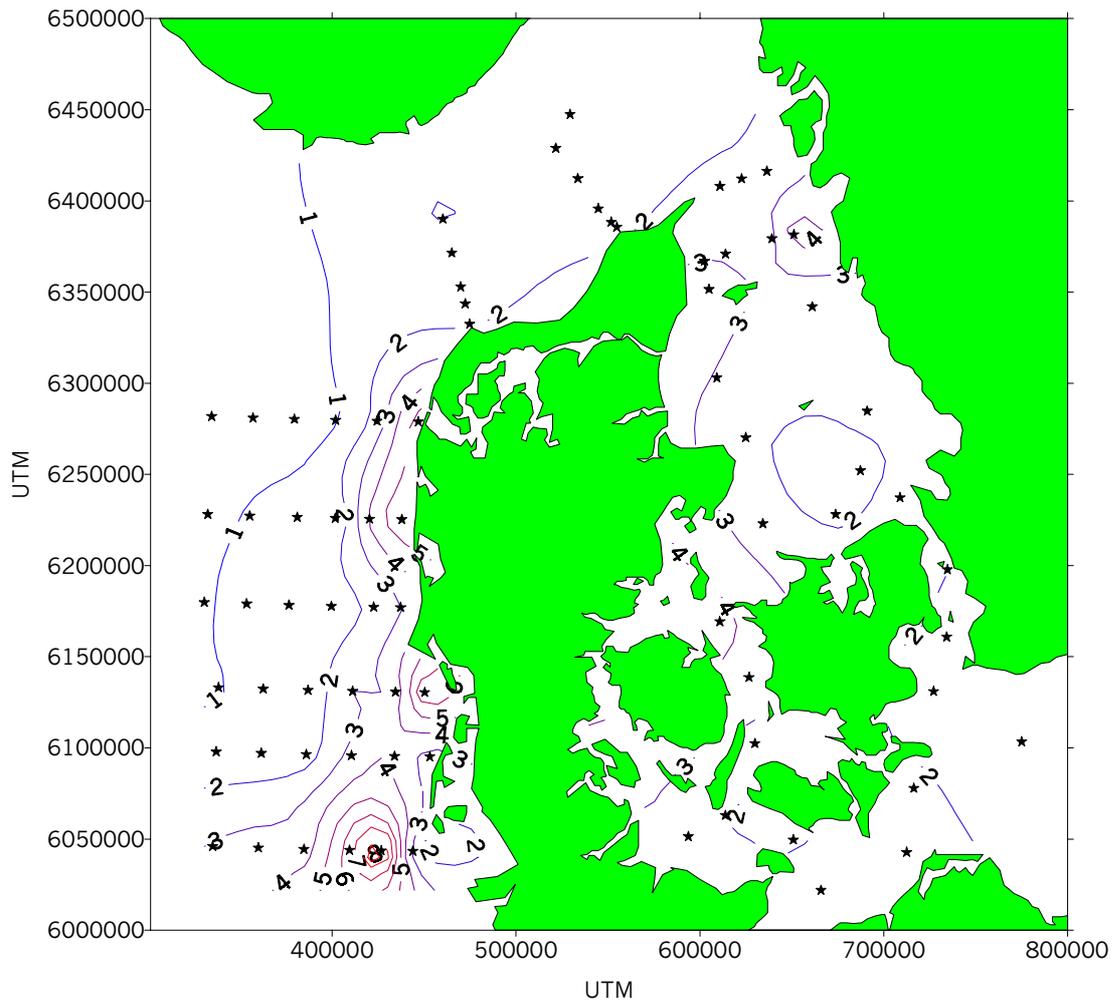


Figure 11. Interpolated distribution of surface chlorophyll-*a* concentrations (mean 1, 5 and 10 m depth).



Figure 12. Blooms of *Noctiluca miliaris* in the German Bight 13 August 2000.

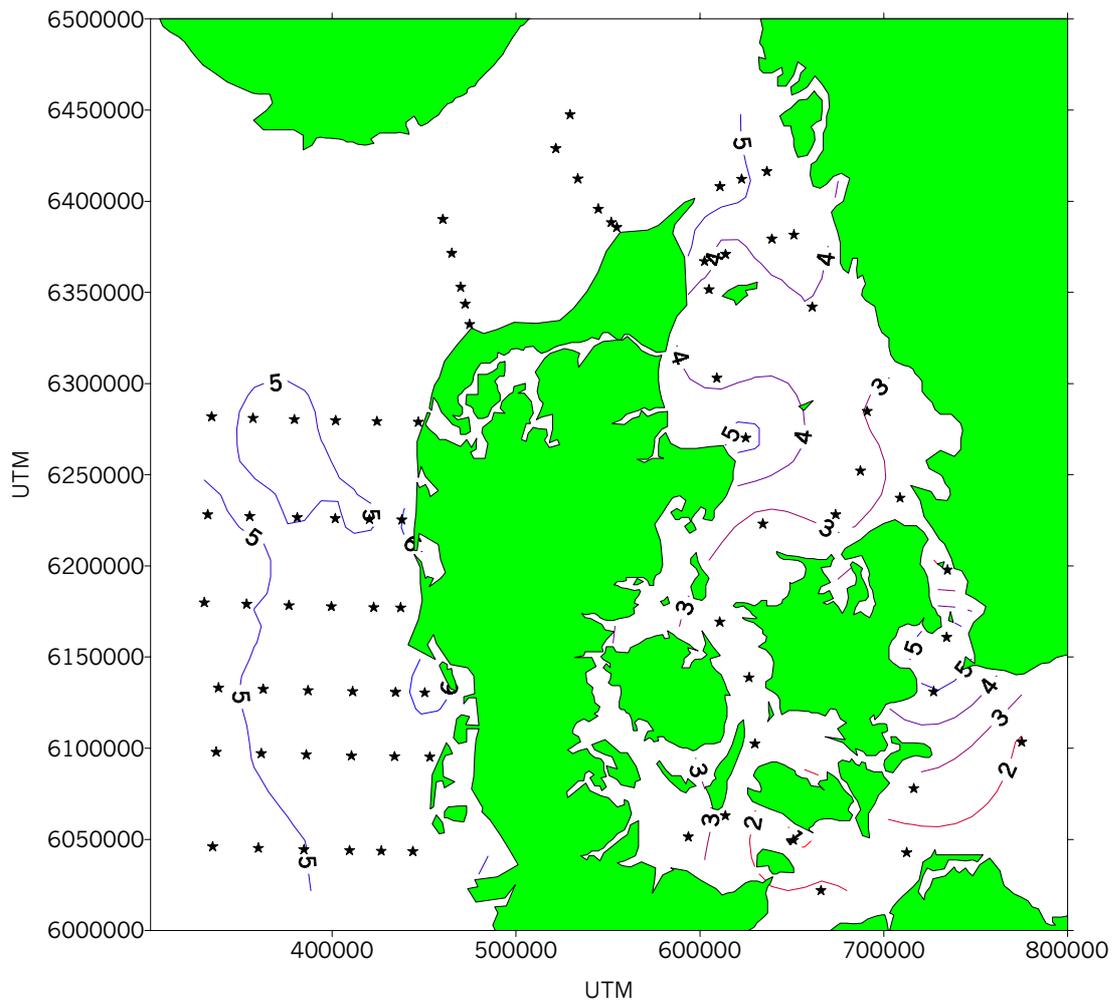


Figure 13. Interpolated distribution of minimum oxygen concentrations, independent on water depth and observation depth.

### Transect I: Kattegat NE - Belt Sea - Arkona Sea

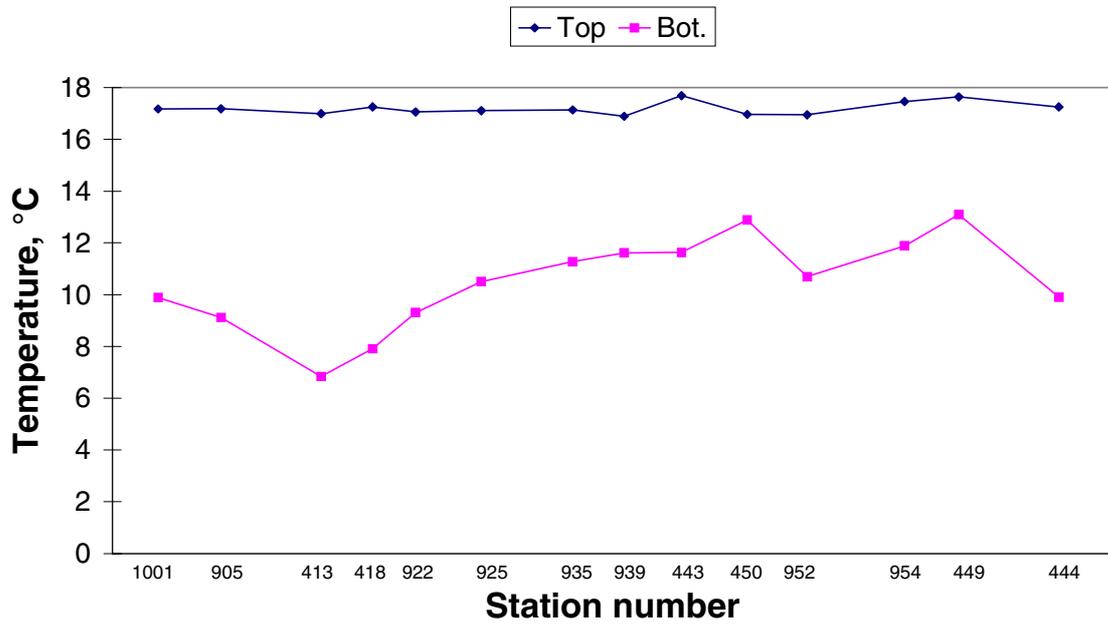
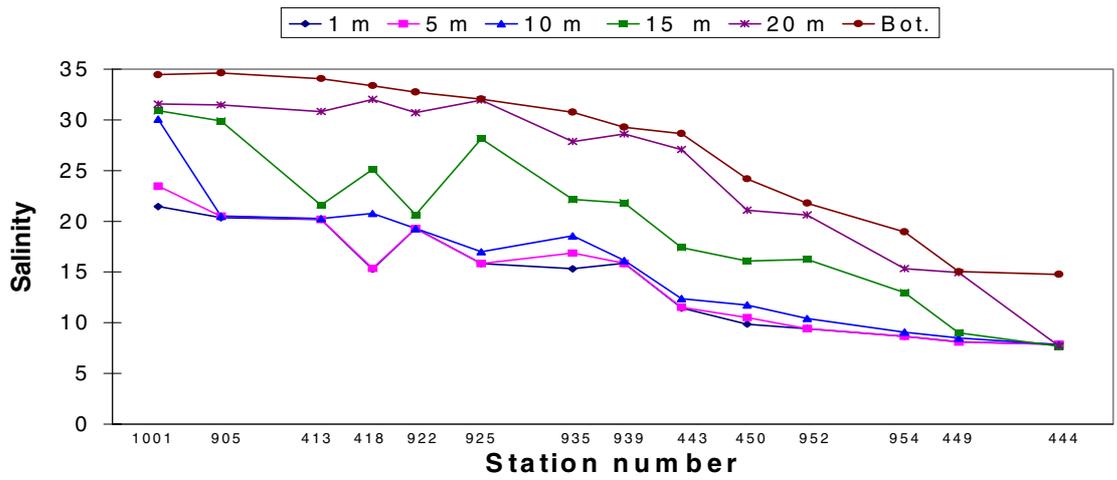
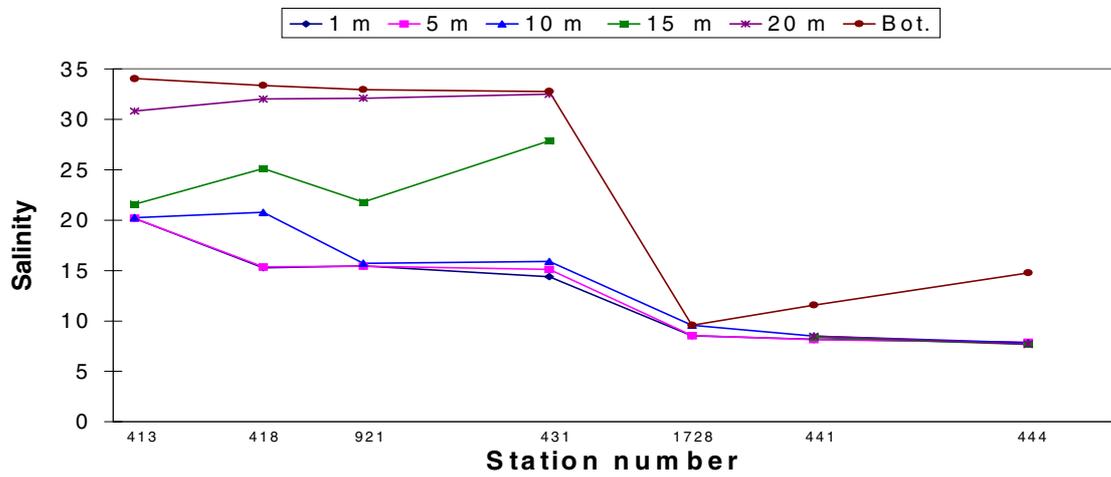


Figure 14. Surface and near bottom temperature along transect I from the north-eastern Kattegat through the Belt Sea to the Arkona Sea.

**Transect I: Kattegat NE - Belt Sea - Arkona Sea**



**Transect II: Kattegat SE - The Sound - Arkona Sea**



**Transect III: Kattegat W - Great Belt**

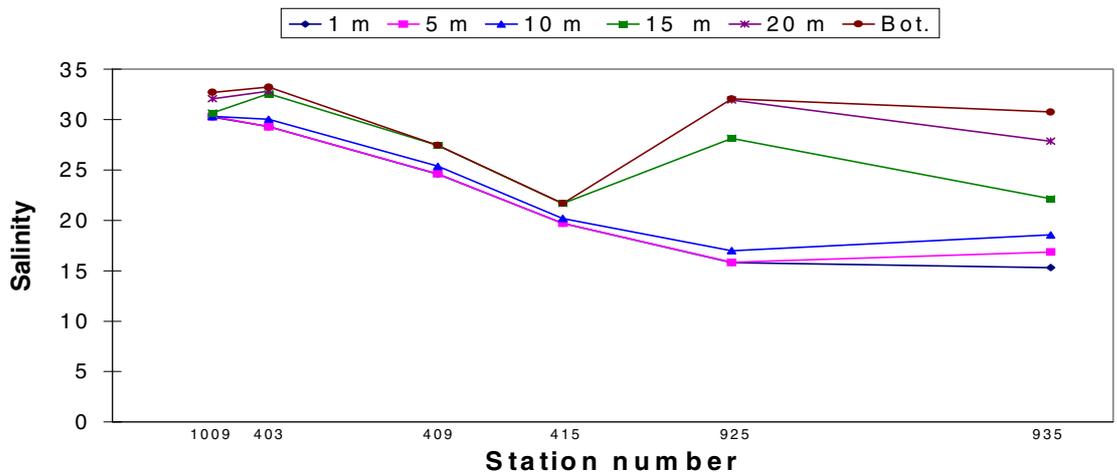
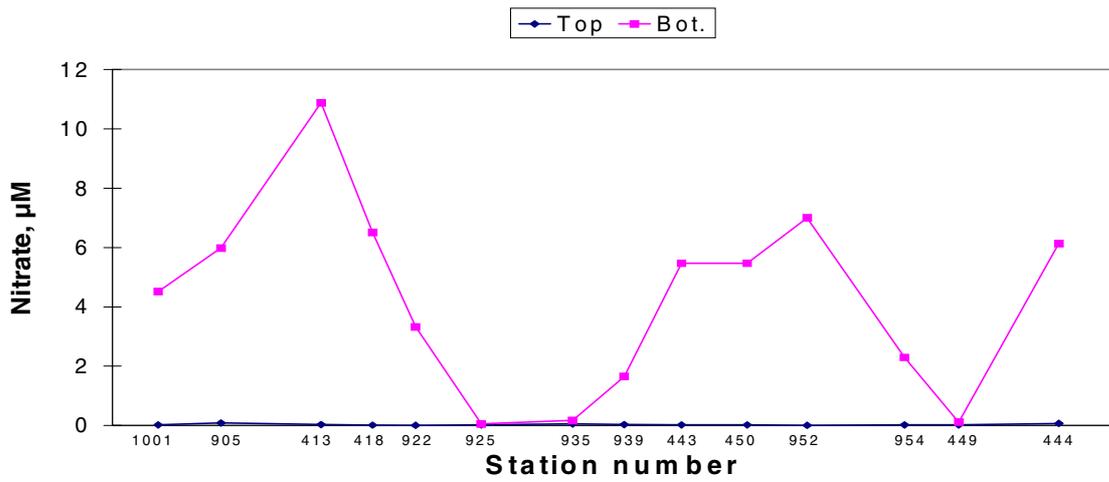
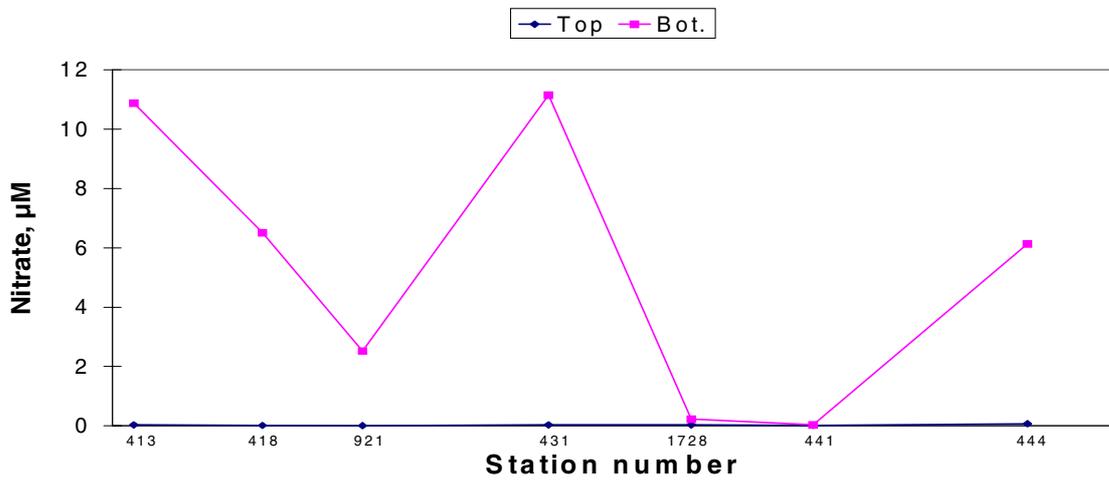


Figure 15. Salinity in 1 m, 5 m, 10 m, 15 m, 20 m depth and near bottom along transect I, II and III from the Kattegat through the Belt Sea and Sound to the Arkona Sea and in the western Kattegat to the Great Belt, respectively.

**Transect I: Kattegat NE - Belt Sea - Arkona Sea**



**Transect II: Kattegat SE - The Sound - Arkona Sea**



**Transect III: Kattegat W - Great Belt**

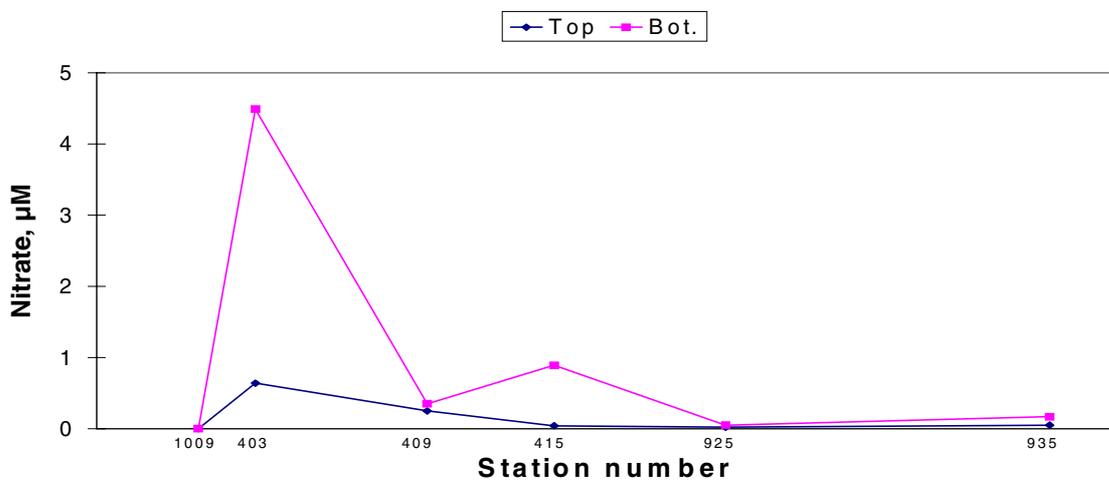
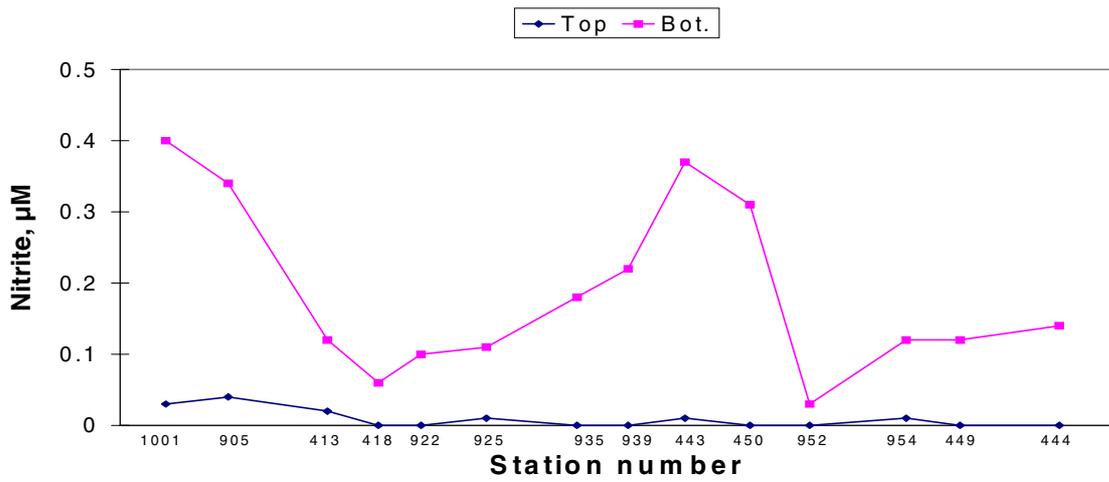


Figure 16. Surface and near bottom concentrations of nitrate along transect I, II and III

**Transect I: Kattegat NE - Belt Sea - Arkona Sea**



**Transect I: Kattegat NE - Belt Sea - Arkona Sea**

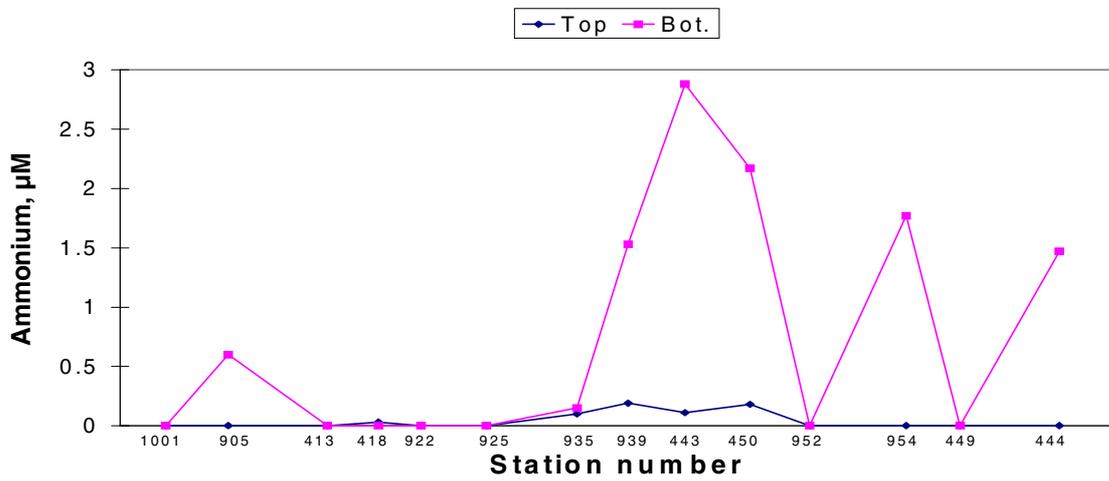
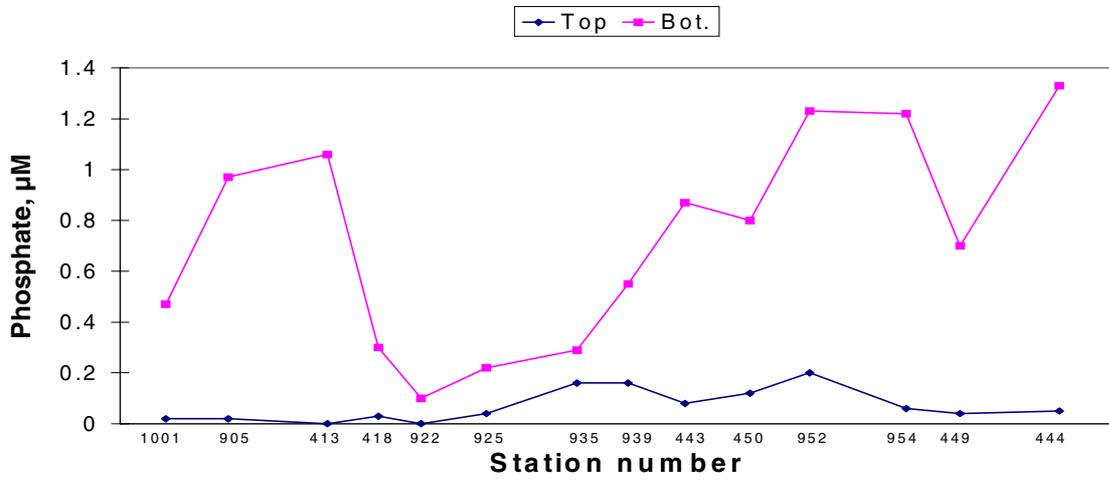


Figure 17. Surface and near bottom concentrations of nitrite and ammonium along transect I.

**Transect I: Kattegat NE - Belt Sea - Arkona Sea**



**Transect I: Kattegat NE - Belt Sea - Arkona Sea**

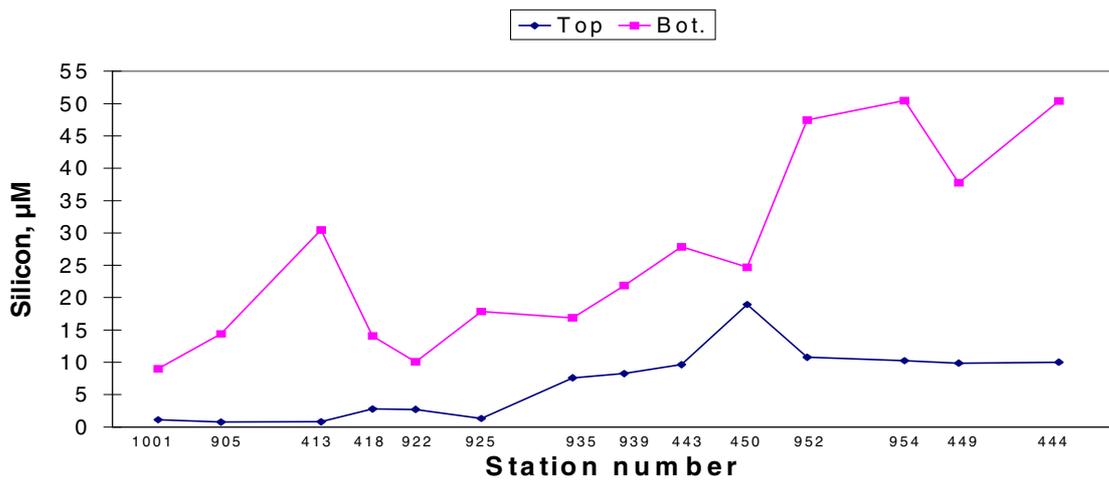
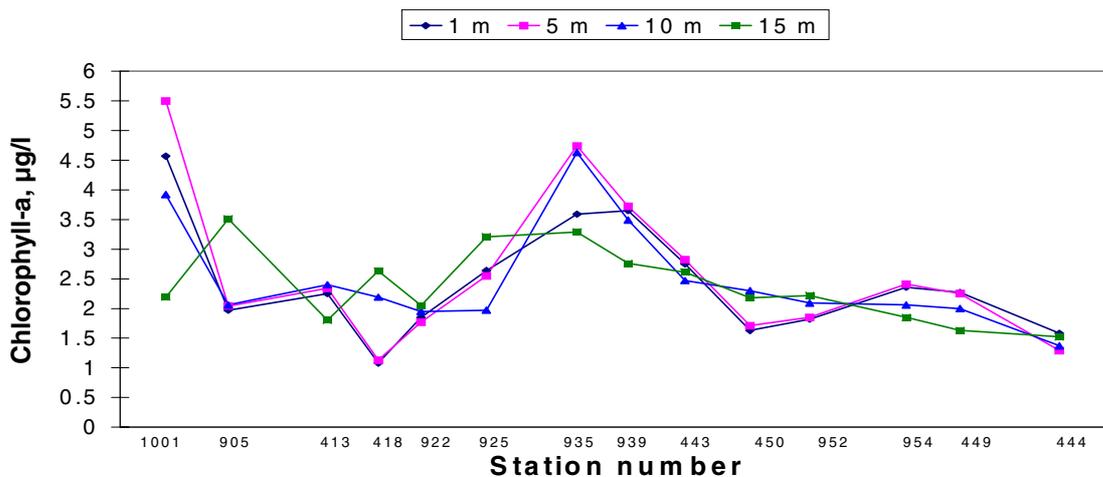
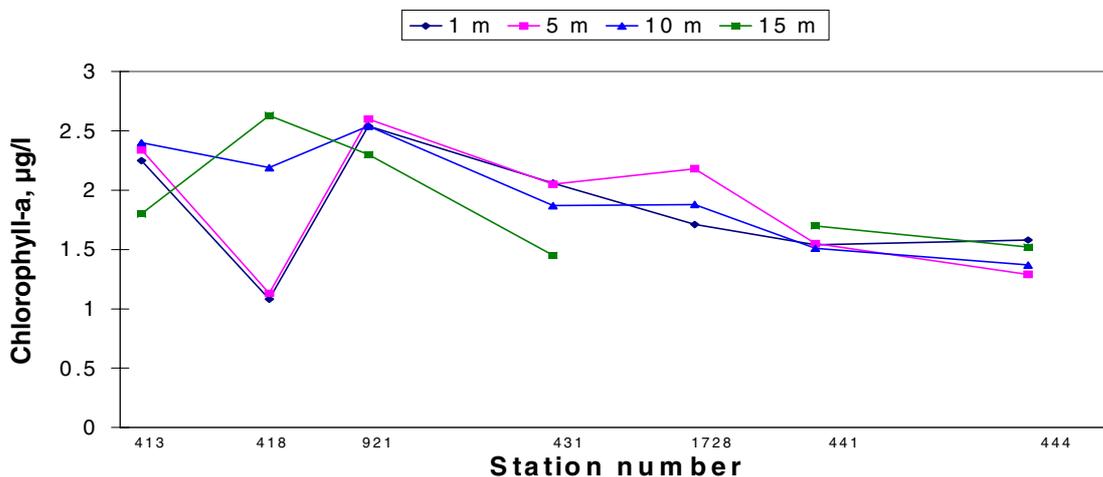


Figure 18. Surface and near bottom concentrations of phosphate and silicate along transect I.

### Transect I: Kattegat NE - Belt Sea - Arkona Sea



### Transect II: Kattegat SE - The Sound - Arkona Sea



### Transect III: Kattegat W - Great Belt

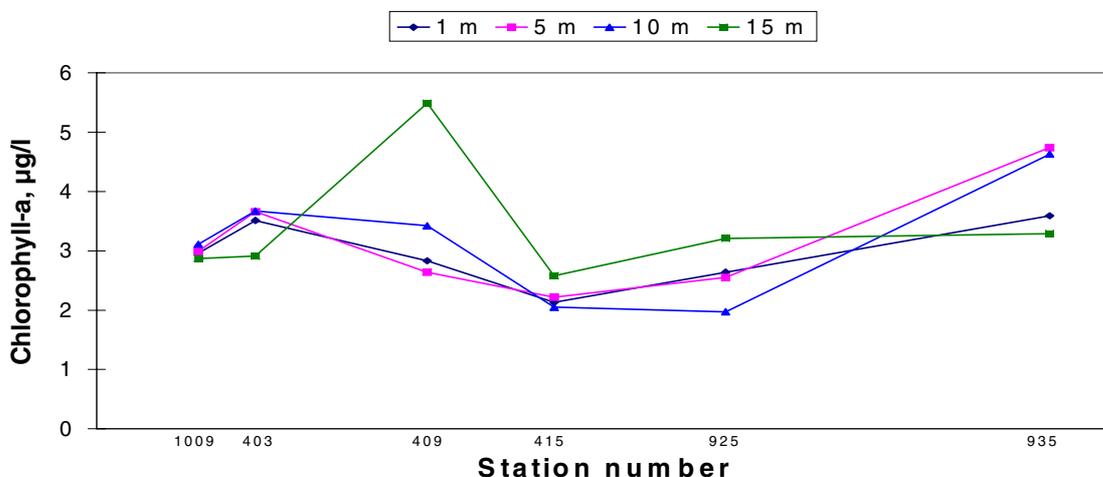
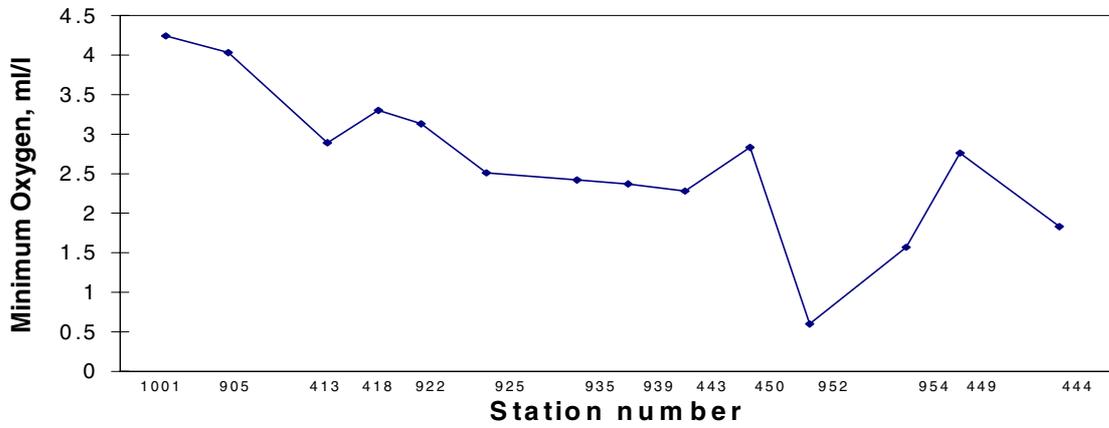
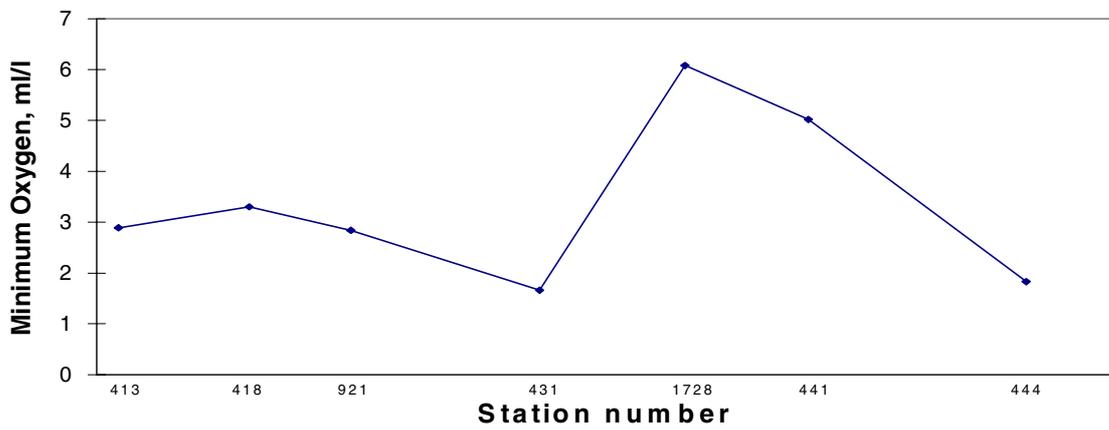


Figure 19. Chlorophyll-a concentrations in 1 m, 5 m, 10 m and 15 m depths along transect I, II and III.

**Transect I: Kattegat NE - Belt Sea - Arkona Sea**



**Transect II: Kattegat SE - The Sound - Arkona Sea**



**Transect III: Kattegat W - Great Belt**

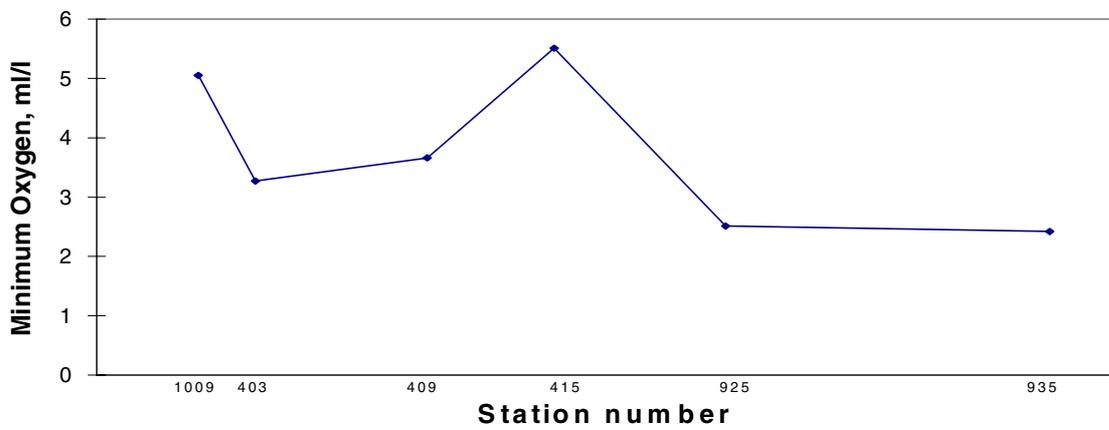


Figure 20. Minimum oxygen concentrations along transect I, II and III.

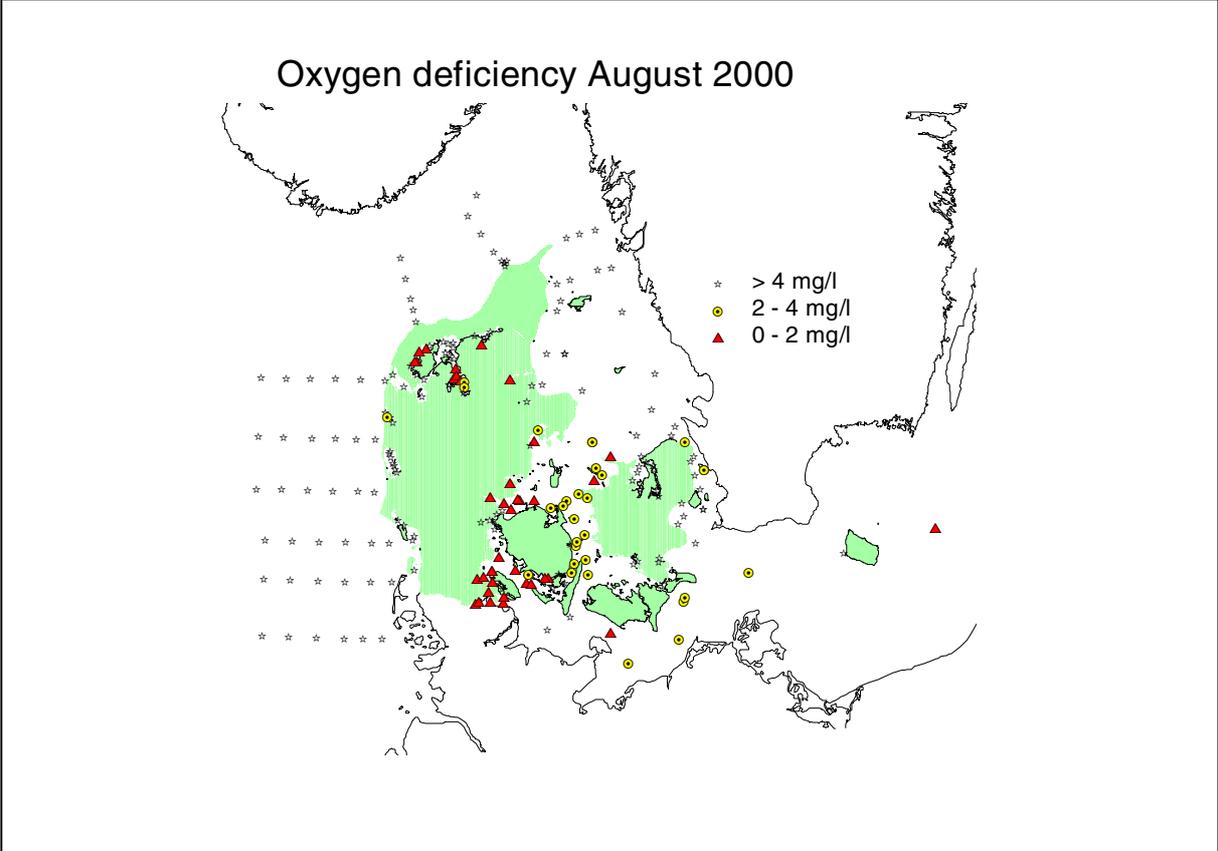


Figure 21. Stations visited by Danish counties or NERI within the first three weeks of August 2000, and where oxygen depletion (<4 mg/l) and serious oxygen depletion (<2 mg/l) were observed.