

r/v Gunnar Thorson

Monitoring Cruise Report

Cruise no.: GT 239

- Time: 16 20 October 2006
- Area: The Sound, the Arkona Sea, the Belt Sea and the Kattegat



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Monitoring cruise with r/v Gunnar Thorson in the Sound, the Arkona Sea, the Belt Sea and the Kattegat, 16-20 October 2006 Cruise no. GT 239

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.

Summary

The record warm September and October resulted in surface water temperatures 2.2-2.9° C warmer than average for October, and bottom water temperatures 1.2-2.9° C higher than average in all areas. The surface salinity was generally lower than average, and the bottom water salinity was in the Belt Sea 3.2-4.0 above normal, but about average in the Kattegat. Thus the stratification was stronger than average for the season in most areas.

Due to the persistent warm and calm weather the bottom oxygen concentration had decreased further since the cruise in September. The lowest oxygen concentrations of 1.9-2.5 ml/l (30-40% saturation) were observed in the Fehmarn Belt, Mecklenburg Bight and east of Falster, as well as in the Sound and south-eastern Kattegat. In the Great Belt the minimum oxygen concentration was 2.7-3.0 ml/l (44-49%). Oxygen depletion (<2.8 ml/l) was present in the Sound, southern Kattegat, southern Great Belt, Fehmarn Belt, Mecklenburg Bight and east of Falster.

In the bottom water extremely high ammonium concentrations of $4.7-7.5 \mu mol/l$ were still present in the southern Belt Sea, and $2.1-3.6 \mu mol/l$ in the Arkona Sea and southern Great Belt. Also phosphate and silicate were found in the highest concentrations in the southern Belt Sea at the lowest oxygen concentrations.

In the surface layer the nitrate concentration was still low, <0.1 μ mol/l, except in Læsø Rende, Central Sound and central Great Belt. But generally ammonium was present in the surface water in all areas, most often in concentrations of 0.3-0.9 μ mol/l, but ranging from 0.1 μ mol/l in Ålborg Bight to 1.3 μ mol/l in Kiel Bight and Fehmarn Belt. Phosphate concentrations of 0.2-0.4 μ mol/l were present in the surface water, except in the northern and eastern Kattegat. Surface silicate concentrations <1 μ mol/l were only found in the eastern Kattegat, >10 μ mol/l silicate were present in the Sound and southern Belt Sea. Thus nutrient limitation was probably no longer significant, except in parts of Kattegat.

In accordance with this, relatively high concentrations, 5.0-5.8 μ g/l, of chlorophyll were observed in Kiel Bight and Fehmarn Belt, and 3.6-4.7 μ g/l were found in the Great Belt and western Kattegat. The lowest concentrations of 0.9-2.0 μ g/l were observed in the northern and eastern Kattegat.

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 NOVANA, the HELCOM monitoring programme (COMBINE) for the Baltic Sea area (the Arkona Sea, the Sound, the Belt Sea, the Kattegat), and the OSPARCOM monitoring programme (JAMP) for the Greater North Sea (the Kattegat). 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 monitoring stations of the cruise are shown in *figure 1*. Besides the monitoring measurements, special investigations were performed on DOM and respiration in the bottom water.



Figure 1 Stations of the monitoring cruise with r/v Gunnar Thorson 16-20 October 2006 in the Sound, the Arkona Sea, the Belt Sea and the Kattegat. Gunnar Thorson cruise no. GT 239.

Meteorology

Characteristics of the weather conditions in October 2006 are given in *table 1*. As July and September, October was record warm, but the precipitation was relatively high. Except for strong winds in the beginning of October (week 40, *figure 2*), the calm weather generally still prevailed. The dominating wind directions were from south to west.

Table 1Deviations in monthly mean temperature and precipitation in October 2006 in Denmark compared to long-termmonthly means 1961-90, monthly mean wind force and dominating wind directions (based on data from the Danish Meteorological Institute).

	Temperature	Precipitation	Mean wind force	Dominating
Month	deviation °C	% deviation	m/s	wind direction
October	+3,1	+61	4.5	S-SW-W



Figure 2 Frequency per week of observations of wind forces above 10.8 m/s (above gale force) in 2006 (connected points) compared to 3-weeks running mean for the period 1994-2004 (thin line). Based on data from the Danish Meteorological Institute.

Hydrography

The surface temperature (1 m's depth) varied from 13.7° C in the Sound (St. 431) to 14.7° C in the Great Belt and southern Belt Sea (St. 935, 939, 443, 450, N3, 952). The bottom near temperature ranged from 9.3-10.9° C in the eastern Kattegat and the Sound (St. 1001, 905, 413, 418, 922, 921, 431) to 15.1-15.4° C in the north-western Kattegat (St. 403, 1009, 1008). The temperature stratification was very weak, except in the Sound and eastern Kattegat (*figure 3*).

The surface salinity ranged from 7.6-8.1 in the Arkona Sea (St. 441, 444, 449) to 23.7-24.1 in the north-western Kattegat (St. 1008, 1009). The bottom water salinity ranged from 15.3-18.3 in the Arkona Sea (St. 441, 444) to 34.0-35.0 in the north-eastern Kattegat (St. 905, 1001, 1007) (*figure 3*). The salinity stratification was stronger than average for the season in most areas.

Compared to long-term monthly means (Lightship observations 1931-1960) for October the surface temperature was 2.2-2.9° C higher than average, and the bottom water temperature 1.2-2.9° C above average in all areas. The surface salinity was lower than average, except in the south-western Kattegat. The bottom water salinity was 3.2-4.0 above normal in the Belt Sea, but about average in the Kattegat.

Nutrients

The nitrate concentration in the surface layer was still low (0.0-0.1 μ mol/l), except in the Læsø Rende with 0.2-1.5 μ mol/l (St. 403, 1008, 1009), the central Sound with 0.55 μ mol/l (St. 431) and the central Great Belt with 0.3-0.4 μ mol/l (St. 935, 939) (*figure 4a*). Generally ammonium was present in the surface layer in all areas in concentrations ranging from 0.1 μ mol/l in Ålborg Bight to 1.1-1.3 μ mol/l in Kiel Bight and Fehmarn Belt, but in most areas with concentrations of 0.3-0.9 μ mol/l (*figure 4c*). In the bottom water the highest nitrate concentration of 8.4-10.0 μ mol/l was observed in the eastern Kattegat (St.413, 418, 905, 922) and the Sound (St. 921, 431). The highest nitrite concentration of 1.0-1.1 μ mol/l was observed at the bottom in the central Great Belt (St. 443, 939) and north-western Kattegat (St. 1008, 1009) (*figure 4b*). The highest ammonium concen-

trations of 2.1-7.5 μ mol/l were observed at the bottom in the whole area from the Arkona Sea (St. 441, 444, 449) through the southern Belt Sea (St. 954, M2, 952, N3, 450) to the central Great Belt (St. 443, 939), with the unusually high concentrations of 4.7-7.5 μ mol/l in the southern Belt Sea (*figure 4c*). In the Sound (St. 431) 1.2 μ mol/l ammonium was observed at the bottom.

Phosphate concentrations of 0.2-0.4 μ mol/l were present in the surface layer, except in the northern and eastern Kattegat, where less than 0.1 μ mol/l was found (*figure 5a*). In the bottom water the highest phosphate concentrations of 1.4-1.6 μ mol/l were observed in the southern Belt Sea (St. 450, 952, 954, M2). Also high silicate concentrations of 33-46 μ mol/l were found at the bottom in the southern Belt Sea (St. 450, N3, 952, M2, 954) and east of Falster (St. 449) (*figure 5b*). High silicate concentrations of 28-41 μ mol/l were also observed in the bottom water in the south-eastern Kattegat and the Sound (St. 413, 418, 921, 922, 431). In the surface water silicate concentrations below 2 μ mol/l were only observed in the eastern Kattegat (St. 413, 418, 905, 922, 1001, 1007). Above 10 μ mol/l silicate were found in the surface in the Sound, (St. 431), central Great Belt (St. 939), southern Belt Sea (St. 450, N3, 952, M2, 954) and east of Falster (St. 449) (*figure 5b*).

Chlorophyll a

The highest mean chlorophyll concentration in the uppermost 10 m of 5.0-5.8 μ g/l was observed in Kiel Bight and Fehmarn Belt (St. 450, 952, N3). In the Great Belt (St. 443, 935, 939) and western Kattegat (St. 409, 415, 418, 925) the concentration was 3.6-4.7 μ g/l. In the Mecklenburg Bight (St. M2) and western Arkona Sea (St. 441, 449, 954) 3.0-3.6 μ g/l was found. The lowest mean concentrations of 0.9-2.0 μ g/l were observed in the northern Kattegat (St. 403, 905, 1001, 1007, 1008, 1009) (*figure 6*).

Oxygen

The lowest oxygen concentrations of 1.9-2.5 ml/l (30-40% saturation) were observed in the Sound and south-eastern Kattegat (St. 431, 413, 418, 921, 922) as well as in the Fehmarn Belt, Mecklenburg Bight and east of Falster (St. 952, M2, 954, 449). In the Great Belt the minimum oxygen concentration was 2.7-3.0 ml/l (44-49%). In all other areas the minimum concentrations were higher than 3.3 ml/l (58%) (*figure 7*).

Compared to mean for October last year, the minimum oxygen concentrations this year were generally higher, except in the south-eastern Kattegat (St. 413, 418, 921, 922), Læsø Rende (St. 403, 1008, 1009) and Kiel Bight (N3).

In Denmark oxygen depletion is defined as minimum oxygen concentrations below 2.8 ml/l (4 mg/l), and severe oxygen depletion as below 1.4 ml/l (2 mg/l). From these definitions severe oxygen depletion was not observed at the cruise. Oxygen depletion was present in the Sound, southern Kattegat, southern Great Belt, Fehmarn Belt, Mecklenburg Bight and east of Falster. *Figure 8* shows the stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of October 2006, and where oxygen depletion or severe oxygen depletion was observed.



Distance from Skagerrak Border, nm

Figure 3 Temperature (top) and salinity (below) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



Figure 4 Dissolved inorganic nitrogen, DIN (top), nitrite (middle) and ammonium (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



Figure 5 Phosphate (top) and silicate (bottom) distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



Transect: Kattegat NE - Belt Sea - Arkona Sea

Figure 6 Chlorophyll *a* at 1 m, 5 m, 10 m, 15 m and 20 m depth in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



Distance from Skagerrak Border, nm

Figure 7 Oxygen distribution in a transect from the north-eastern Kattegat through the Great Belt and Fehmarn Belt to the Arkona Sea.



Figure 8 Stations visited by the Danish counties, NERI, SMHI and Swedish coastal authorities within the first 3 weeks of October 2006, and where oxygen depletion (<4.0 mg/l) and severe oxygen depletion (<2.0 mg/l) was observed.