Hydrography and oxygen in the deep basins

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Key message

The surface waters (0 – 10 metres) of the Baltic Sea basins have become less saline since 1990, at an average rate of 0.04 psu (‰) per year. Deepwater (below a depth of 80 meters) salinities have in contrary increased in all basins except for the Southern Baltic Proper and the Gulf of Bothnia.

Oxygen levels have declined from a peak in 1992-1994. Oxygen conditions are worst in the East Gotland Basin, where almost 40% of the basin volume is affected by lowered oxygen levels or total lack of oxygen. Hydrogen sulphide is present in all basins of the Baltic Proper, and its amount has increased strongly in 2001. The areas with oxygen deficiency in the Kattegat and Belt Sea have increased since 1997 and 1998, respectively, exceeding oxygen levels where fish is dying escaping the area.

Relevance of the indicator for describing developments in the environment

Indicators based on salinity, temperature and oxygen are presented in this report. The Indicators represent the average conditions of the Baltic Sea sub-regions, while single stations might show even worse conditions although not shown here.

Salinity, temperature and oxygen are physical background parameters, constraining bio-diversity, fish recruitment and water quality in a semi-enclosed water body as the Baltic Sea. For example, the Cod larvae are dependent on water with salinity and oxygen levels above 11 psu and 1.5 mg/l, respectively. Currently, such water masses only exist in the western part of the Baltic Proper.

Baltic surface waters are strongly influenced by land run-off of freshwater. Changes in run-off alter the surface salinity while inflows through Öresund and the Belt Sea control the salinity of the deeper waters. Stratification between the upper and lower layers inhibits surface and deep waters mixing together, and thus preventing the oxygenated surface water penetrating to depth, as well as hindering the transfer of phosphorous (which is abundant in the deep water) to the surface waters. In some basins this limits the algal productivity. The strength of the stratification is indicated by the salinity difference between the surface and deepwater and by the depth of the pycnocline (Figure 1) i.e. the volume of the deepwater.

Oxygen depletion is widely used as an indicator for the indirect effects of nutrient enrichment. While oxygen levels above 6 mg/l are considered to cause no problems for macroscopic animals, levels below cause increasing stress to most organisms.

Lowest oxygen levels are experienced at the end of summer, between August and October, when detritus from biological activity in the surface waters has sank, and is decomposed by bacteria. This process consumes the oxygen. When oxygen concentrations fall below about 1.5 mg/l, hydrogen sulphide may be produced by anaerobic processes. Hydrogen sulphide is toxic, and its concentration is described in terms of negative oxygen.

Results and assessment

Assessment

The pycnocline depth is an indicator of the deepwater volumes in different basins of the Baltic Sea. Between 1990 and 2001, the pycnocline depth decreases in the eastern and northern Baltic Proper, whereas in the southern and western Baltic Proper, Gulf of Finland and the Gulf of Bothnia the pycnocline depth either increases or shows no clear trends (Figure 1).

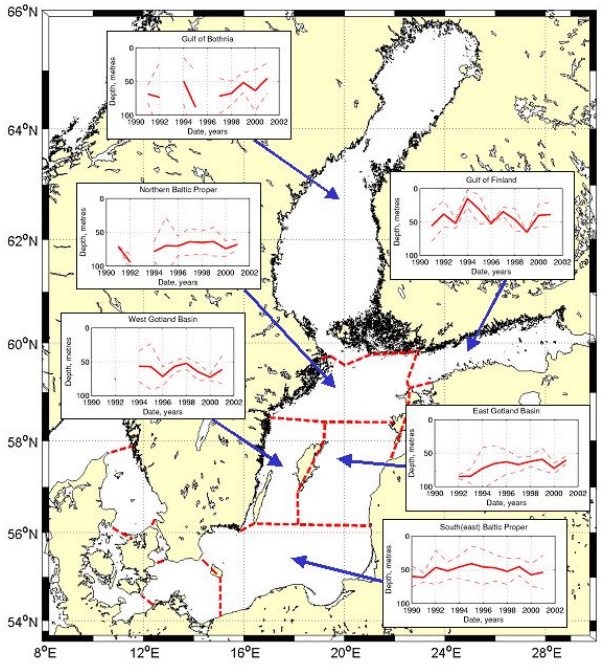

Figure 1: Changes in the pycnocline depth (maximum winter buoyancy frequency).

Time series of surface salinity between 1990 and 2001 (**Figure 2**) show a steady freshening of the top surface 10 metres of the Danish Straits, Baltic Proper and Gulf of Finland. This trend is most clear in the Baltic Proper where surface salinity decreases at an average rate of 0.04 practical salinity units (psu) per year. During the same period, deepwater salinity shows the opposite trend: Below 80 metres, salinity is increasing at a rate of 0.09 psu per year in the Eastern, Northern and Western Gotland basins of the Baltic Proper. In the Gulf of Bothnia and in the Southern Baltic Proper there are annual variations but no clear trend.

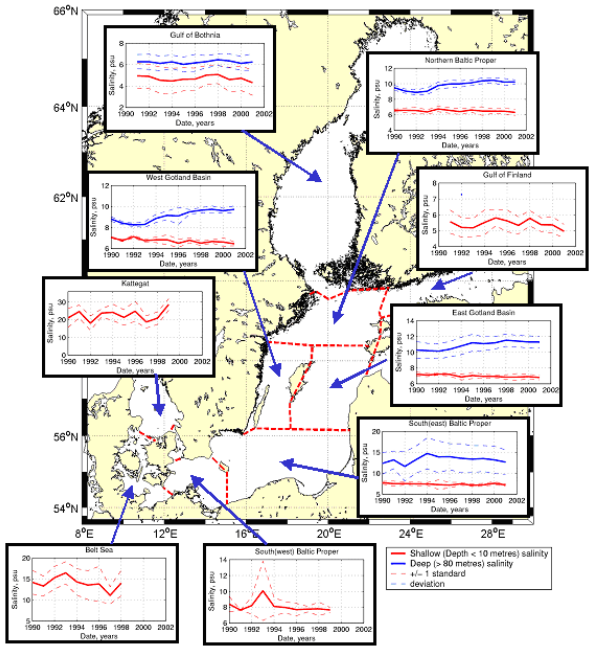

Figure 2: Salinity changes in deep (>80 metres) and shallow (<10 metres) water.

The surface salinity changes are reasonable, given the increasing fresh water input – particularly since mid 1990s. The deepwater changes suggest the movement of saline water into the deep basins of the Baltic Proper, which is not replaced with 'new' salt water in the shallow Southern Baltic Proper. These changes are in accord with the large inflow events of high saline water taking place during 1993 and 1994. Hence, during the 1990s the salinity difference between surface and deepwater has increased and in some parts of the Baltic Proper the deepwater volumes has also increased.

For each of the basins, autumn (August, September and October) oxygen profiles have been examined. Depths at which the oxygen concentration fell below certain levels were calculated, and these data were interpreted in terms of the proportion of water in each basin affected by reduced oxygen levels. These results are presented as time series in **Figure 3**.

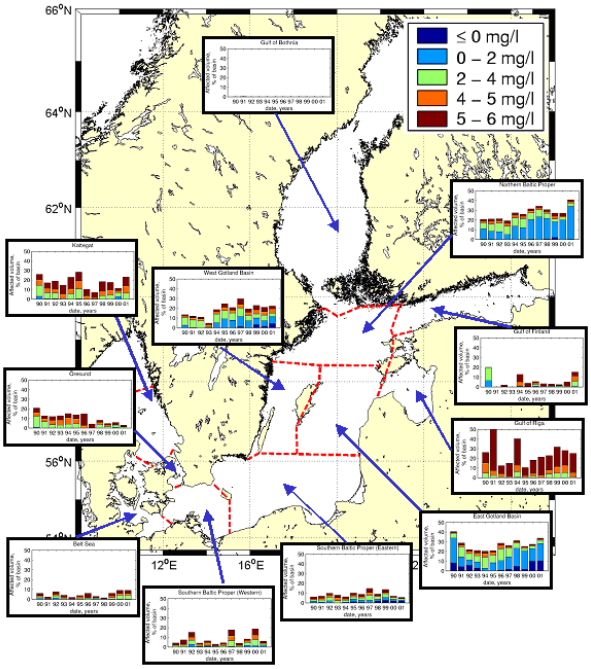

Figure 3: Histograms showing the proportion of basins affected by lowered oxygen levels.

All basins of the Baltic Sea show a minimum in oxygen shortage between 1992 and 1994. This may be correlated with the inflow of new, oxygenated saline water from the Kattegat, spreading out first through the Southern Baltic Proper, and then into the deep regions of the other basins.

The basin least affected by oxygen depletion is the Gulf of Bothnia, where there is weak stratification and relatively low biological activity.

In the western Baltic Proper, Danish Straits and Kattegat oxygen depletion is a seasonal phenomena which occur during autumns.

In the Southern Baltic Proper only the deepest 15% have been affected by reduced oxygen levels.

The East Gotland Basin was the worst affected basin, with between 30 and 40% of the total basin volume suffering reduced oxygen levels, and almost 30% having acute toxicity between 1998 and 2001. Hydrogen sulphide is present in 10% of the water, and affects an increasing proportion of the water column.

The deepwater basins in the Baltic Proper are severely suffering from permanent oxygen depletion. Between 1991 and 1993, oxygen levels were 'only' 50% depleted (equivalent to 4 – 5 mg/l). The level of depletion has increased steadily since, and from 1998, the oxygen concentration dropped to acutely toxic levels – with hydrogen sulphide (negative oxygen) observed in three of the four years. Despite this increase, the proportion of the basin affected has not increased greatly.

The proportions of affected water in the Northern Baltic Proper and West Gotland Basin are slightly lower than in the East Gotland Basin. This may be due to the basins having a higher proportion of shallow water than the East Gotland Basin but also could be due to an under-reporting of 'negative' oxygen – or Hydrogen Sulphide - data.

In 2000 and 2001, especially the East Gotland Basin showed a substantial increase in the proportion of water affected by hydrogen sulphide. This may be attributable to high levels of bacterial activity, breaking down carbon introduced either directly from land runoff, or from the surface layer, caused by higher levels of biological productivity. Analysis of the nutrient concentrations, dissolved organic carbon levels and bacterial populations should identify which of these mechanisms was responsible.

Figure 4 shows the regional distribution of the bottom areas where oxygen concentrations are below the critical level of 2 mg/l. The spatial change over time follows the changes discussed above. The large saltwater inflows during 1993 and 1994 oxygenated the bottom waters in the Baltic Proper. However, due to the lack of any further inflow events and the strong stratification built up by the inflows, the oxygen levels decrease again due to a too large sedimentation of organic material in comparison to the oxygen transported into the deep waters.

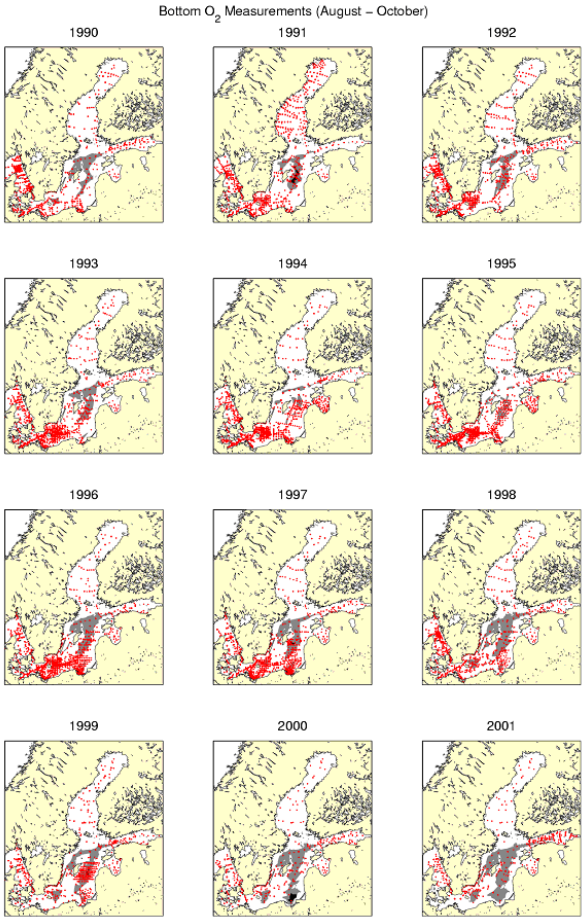

Figure 4: Oxygen concentrations (2 mg/l and 0 mg/l shaded) in bottom water, 1990-2001.

Data

This study has made use of data provided by the following institutes:

- Swedish Meteorological and Hydrological Institute (SMHI)
- Finnish Institute for Marine Research (FIMR)
- International Council for the Exploitation of the Sea (ICES)
- Danish Environmental Research Institute (DMU)

- Polish Maritime and Water Institute (IMGW)
- Institute of Aquatic Ecology (IAE)
- Estonia is Estonian Marine Institute (EMI)
- Estonian Meteorological and Hydrological Institute

Summary

Oxygen levels have declined from a peak between 1992-1994. Hydrogen sulphide is present in all basins of the Baltic Proper; and increased strongly in 2001.

The delicate relations between available nutrients, biomass, stratification, water exchange and oxygen levels is unfortunately not well balanced in many of the Baltic Sea sub-regions, leading to reduced bio-diversity, fish recruitment and water quality status.

For reference purposes, please cite this Baltic Sea environment fact sheet as follows:

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