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## Extent of anoxia and hypoxia in the Baltic Sea, 1960-2009





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## Introduction

In recent years the extent of oxygen deficiency in the Baltic Sea deep water has increased and stabilised. In this report a time series of the extent of anoxic<sup>1</sup> and hypoxic<sup>2</sup> autumn conditions is presented for the period 1960 to 2009.

## Data and Method

For the period 1960 to 2007, the analysis is based on the HELCOM/COMBINE dataset available from the ICES data centre. During 2008 additional data from the SMHI (Swedish Meteorological and Hydrological Institute) autumn oxygen survey in the Baltic Sea has been added. The result for 2009 is based purely on SMHI data (SMHI, 2009). These data are preliminary, and has been subject to initial quality control only (quality assured laboratory procedures; timing and position checks; range checking). These time series will be updated when more data is reported to ICES in 2010. To process the dataset and perform calculations a few station profiles had to be filtered out: for example when data was missing in the deep water or when questionable data were found.

For the autumn period, August to October, each profile was examined for the occurrence of hypoxia and anoxia. To find the depth of the onset of hypoxia and anoxia, interpolation between discrete measurements in each profile was used, with linear extrapolation from the last two measurements in a profile if hypoxia/anoxia did not occur at that point. The depths for the onset of hypoxia and anoxia were then gridded with linear interpolation (Delaunay triangulation) between sampling stations. Where the interpolated hypoxic/anoxic depths were less than the water depth was mapped using the IOW bathymetry (Seifert, 2001) and the total affected area calculated.

## Results

The greatest extent of anoxic conditions in the Baltic Sea occurred in 2005 and 2007, when ~28% of the bottom area in the Western and Eastern Gotland basins and Northern Baltic Proper were completely oxygen free. The greatest extent of hypoxia was found in 1999 when over half (51%) of the area in the same basins was affected<sup>3</sup>. Our result show that since 2001 the extent of anoxia and hypoxia has increased and stabilised at a high level. (figure 1). The cause of this increase has not yet been completely explained.

The salt water inflows of 2003 had little effect on the oxygen conditions in the central and northern Baltic Proper. Before 1984 the frequency of inflows to the Baltic Sea was high with multiple inflows during some years. Only two major inflows (1993 and 2003) have occurred since 1983.

There are several likely contributory and concurrent causes to the recent development such as changes in wind speed and direction, increased loading of organic matter to the deep water, altered vertical mixing and stratification, changes in freshwater runoff and potentially some other phenomena. Additional work, including more observations, is needed to fully understand the present oxygen situation.

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<sup>1</sup> no dissolved oxygen; hydrogen sulphide (which is toxic) present

<sup>2</sup> <2ml/l dissolved oxygen, considered to be acute oxygen deficiency

<sup>3</sup> Based on the basin subdivisions according to Fonselius S. 1995.

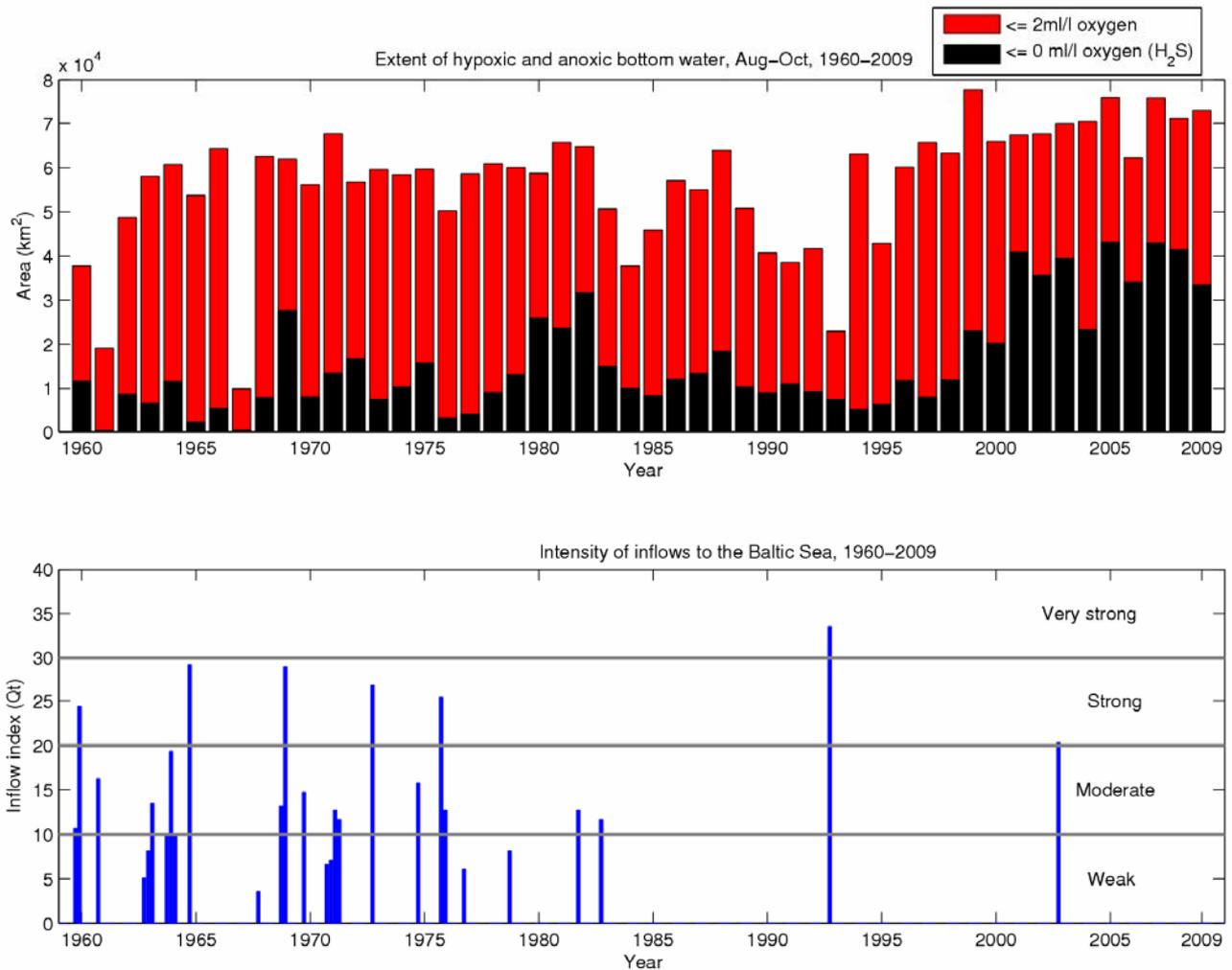


Figure 1. Top: Extent of anoxic and hypoxic conditions in the Baltic Sea during the period 1960-2009. Lower: Index diagram of saltwater inflows to the Baltic Sea, 1960-2009. From Fischer, H., Matthäus, W. 1996 & Matthäus, W., Franck, H. 1992. Revised and updated.

## Reference

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Fischer, H., Matthäus, W. 1996: The importance of the Drogden Sill in the Sound for major Baltic inflows. *J. Mar. Res.*, 9, 137 - 157.

Fonselius, S., 1995: *Västerhavets och Östersjöns Oceanografi*. ISBN 91-87996-07-3

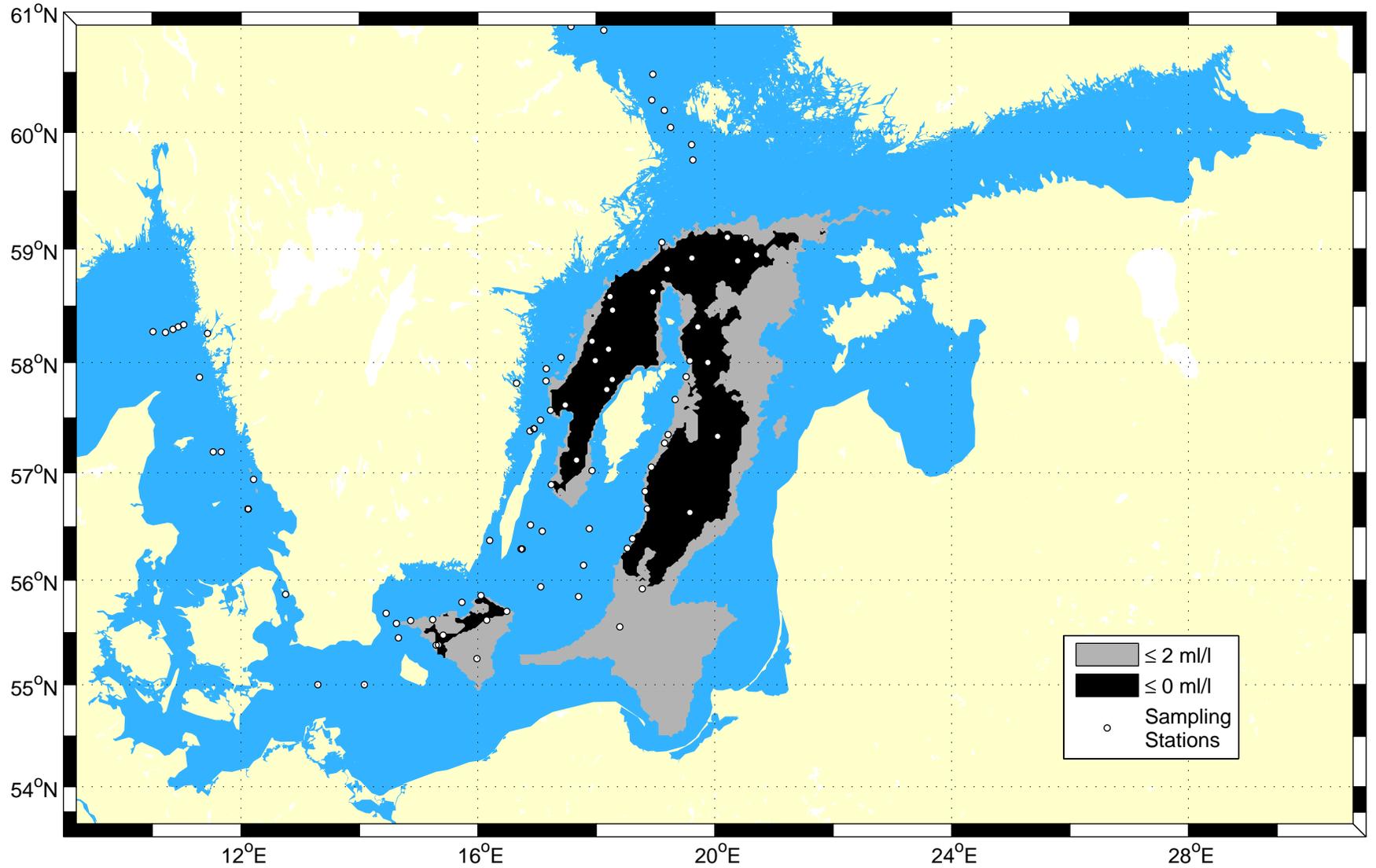
Matthäus, W., Franck, H. 1992: Characteristics of major Baltic inflows – a statistical analysis. *Cont. Shelf Syst.*, 12, 1375 – 1400.

T. Seifert, F. Tauber, B. Kayser: 2001: "A high resolution spherical grid topography of the Baltic Sea – 2nd edition", *Baltic Sea Science Congress, Stockholm 25-29. November 2001, Poster #147,*

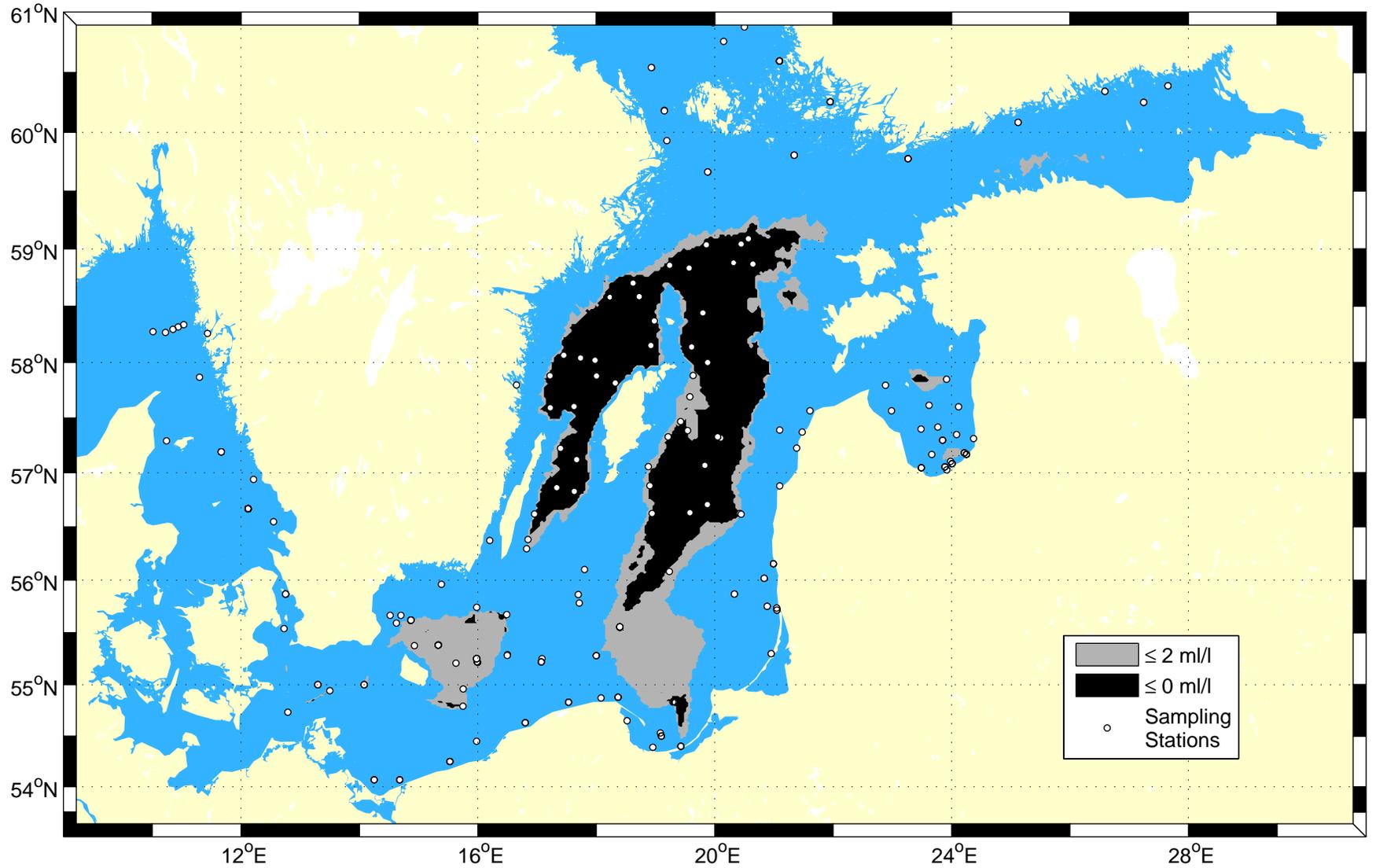
## **Appendix**

**Charts of annual anoxic and hypoxic areas during August to September in the Baltic Sea from the period 1960-2009.**

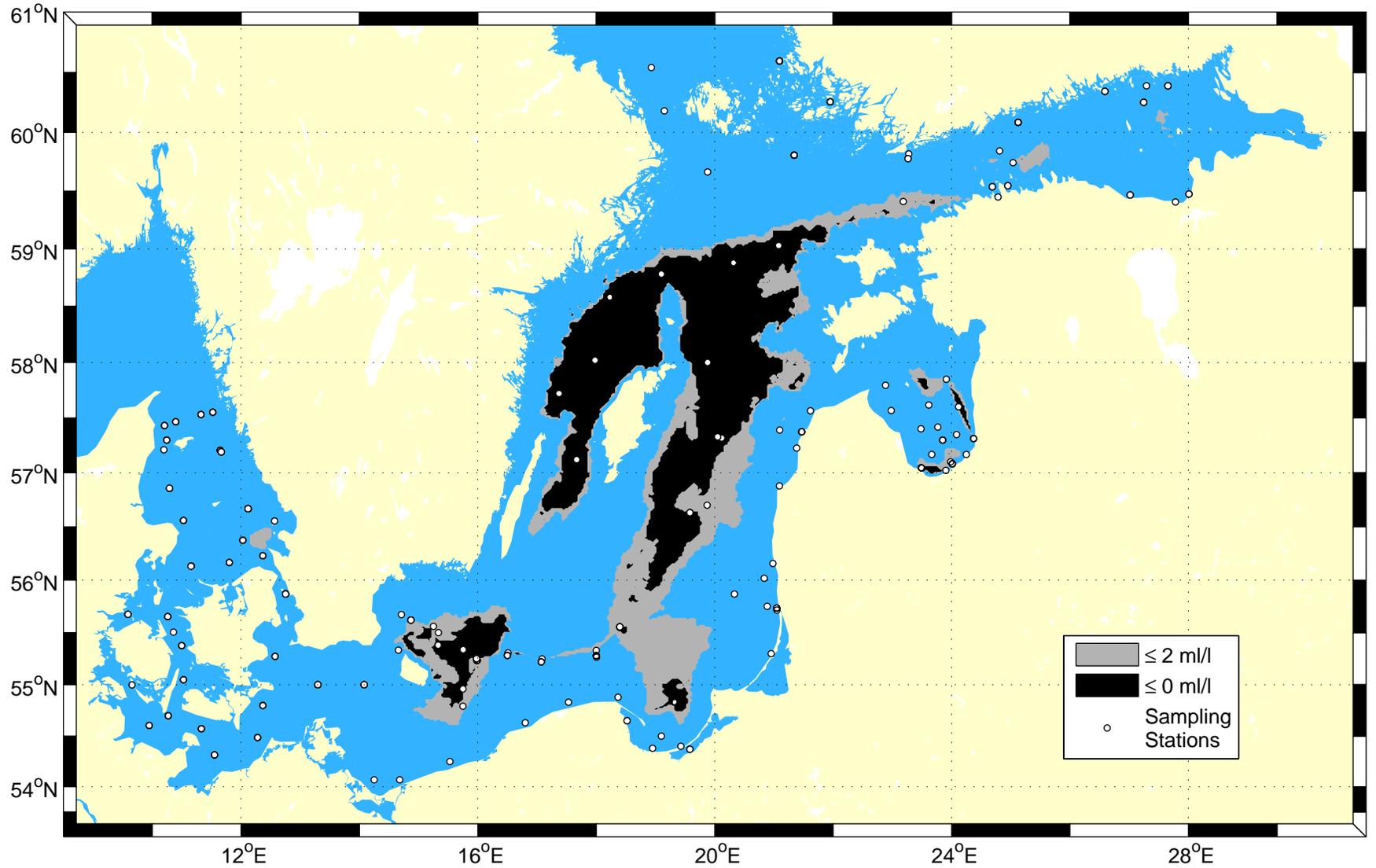
Extent of hypoxic & anoxic bottom water, Autumn 2009



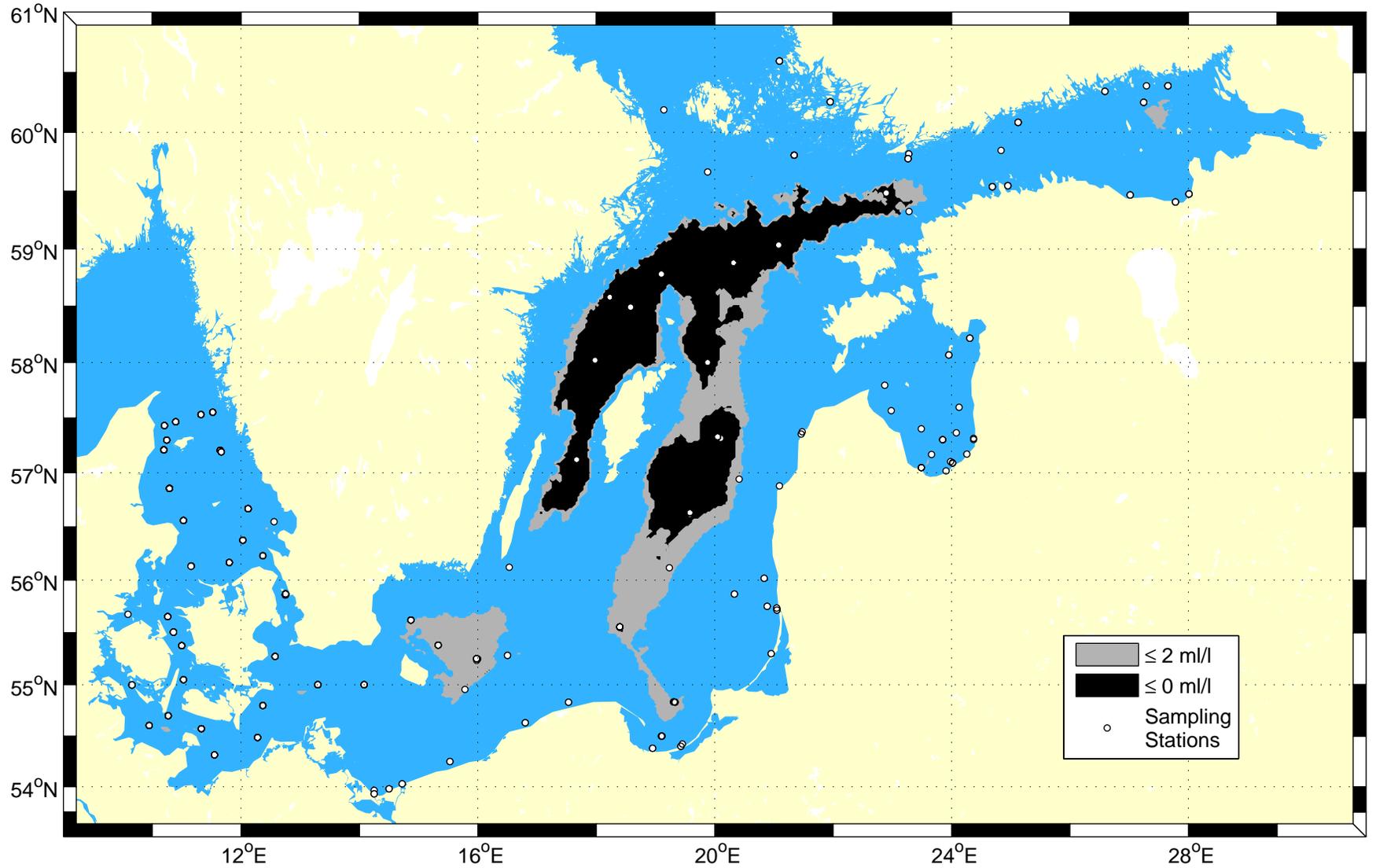
Extent of hypoxic & anoxic bottom water, Autumn 2008



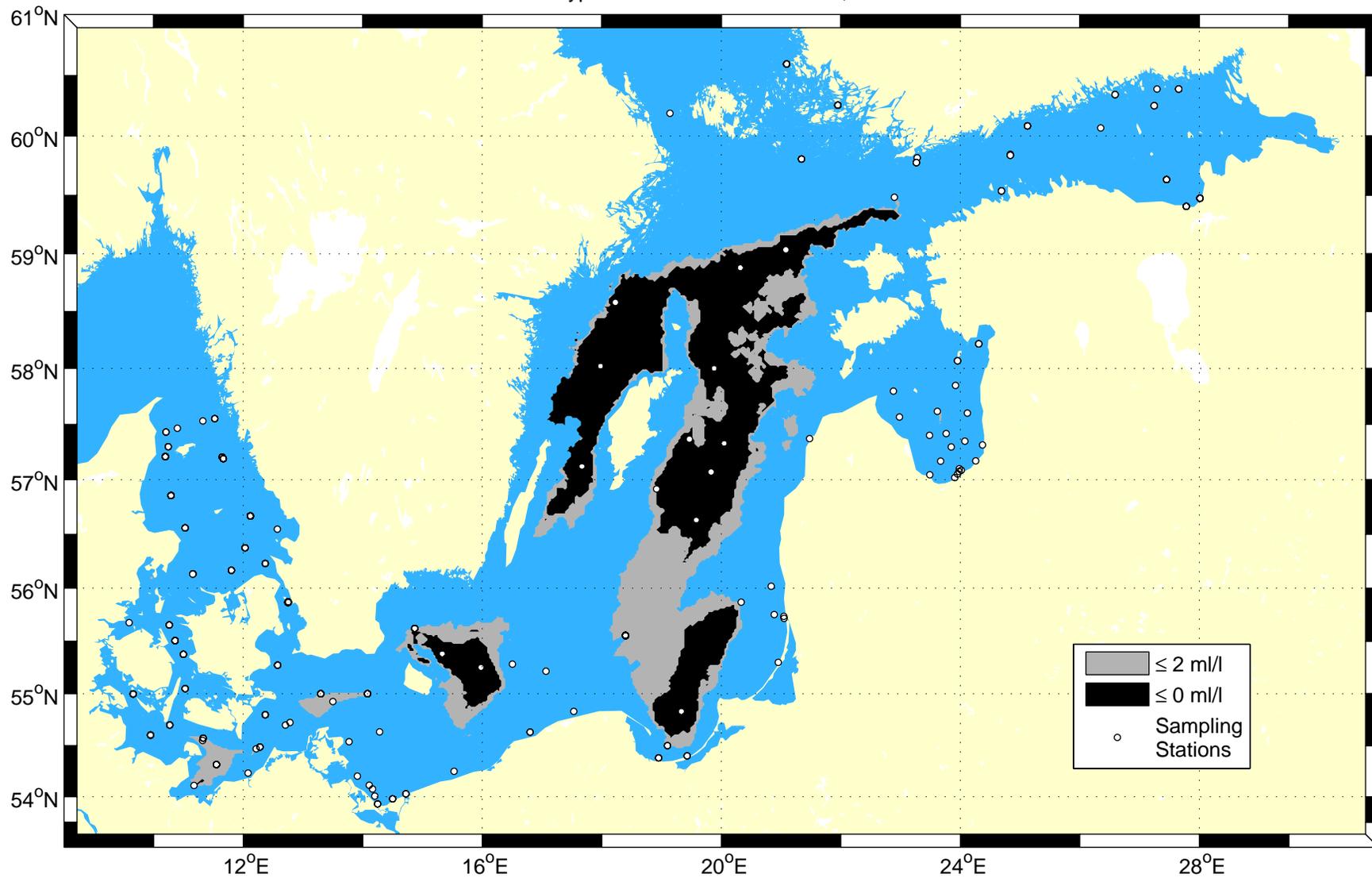
Extent of hypoxic & anoxic bottom water, Autumn 2007



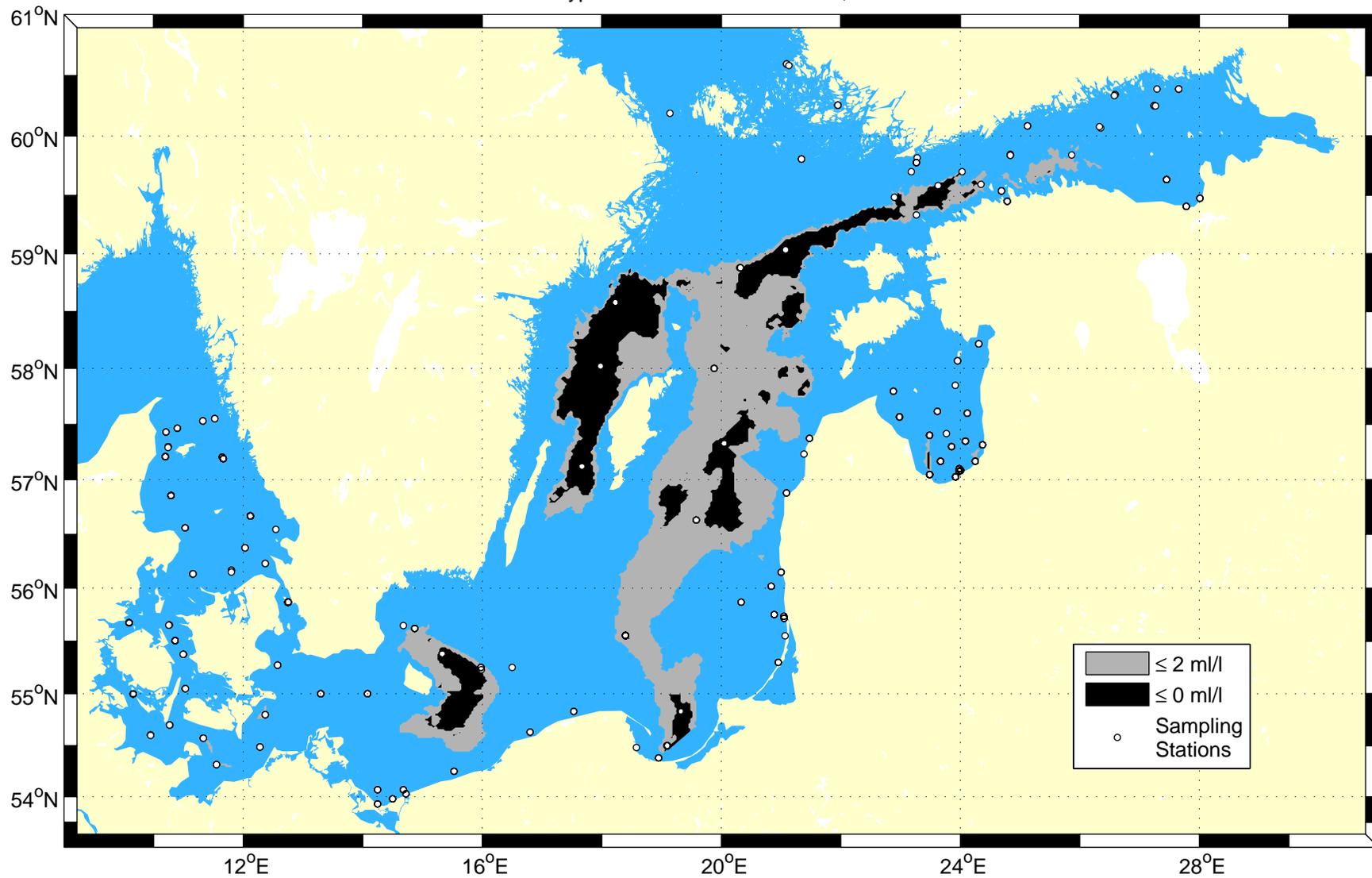
Extent of hypoxic & anoxic bottom water, Autumn 2006



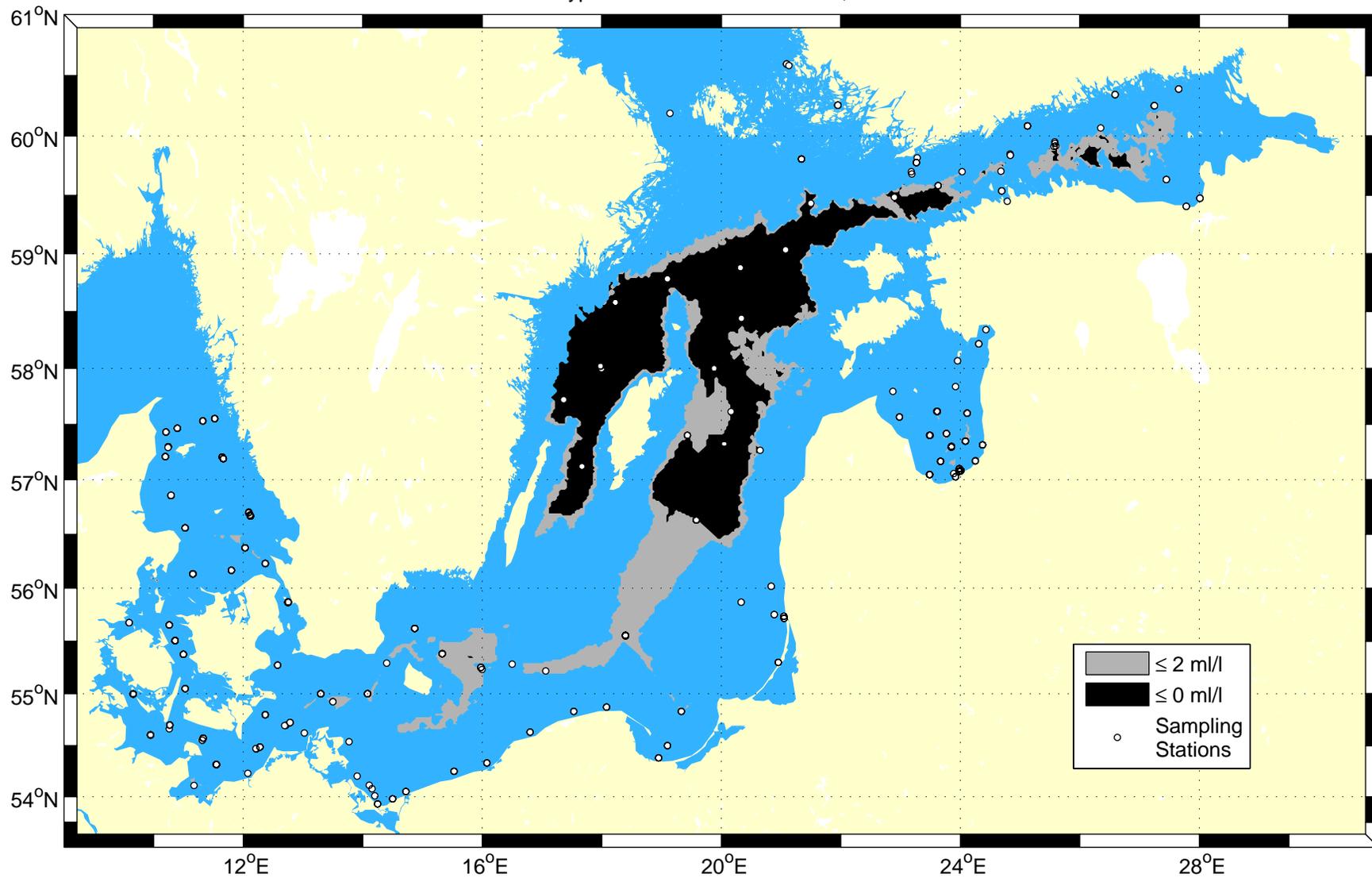
Extent of hypoxic & anoxic bottom water, Autumn 2005



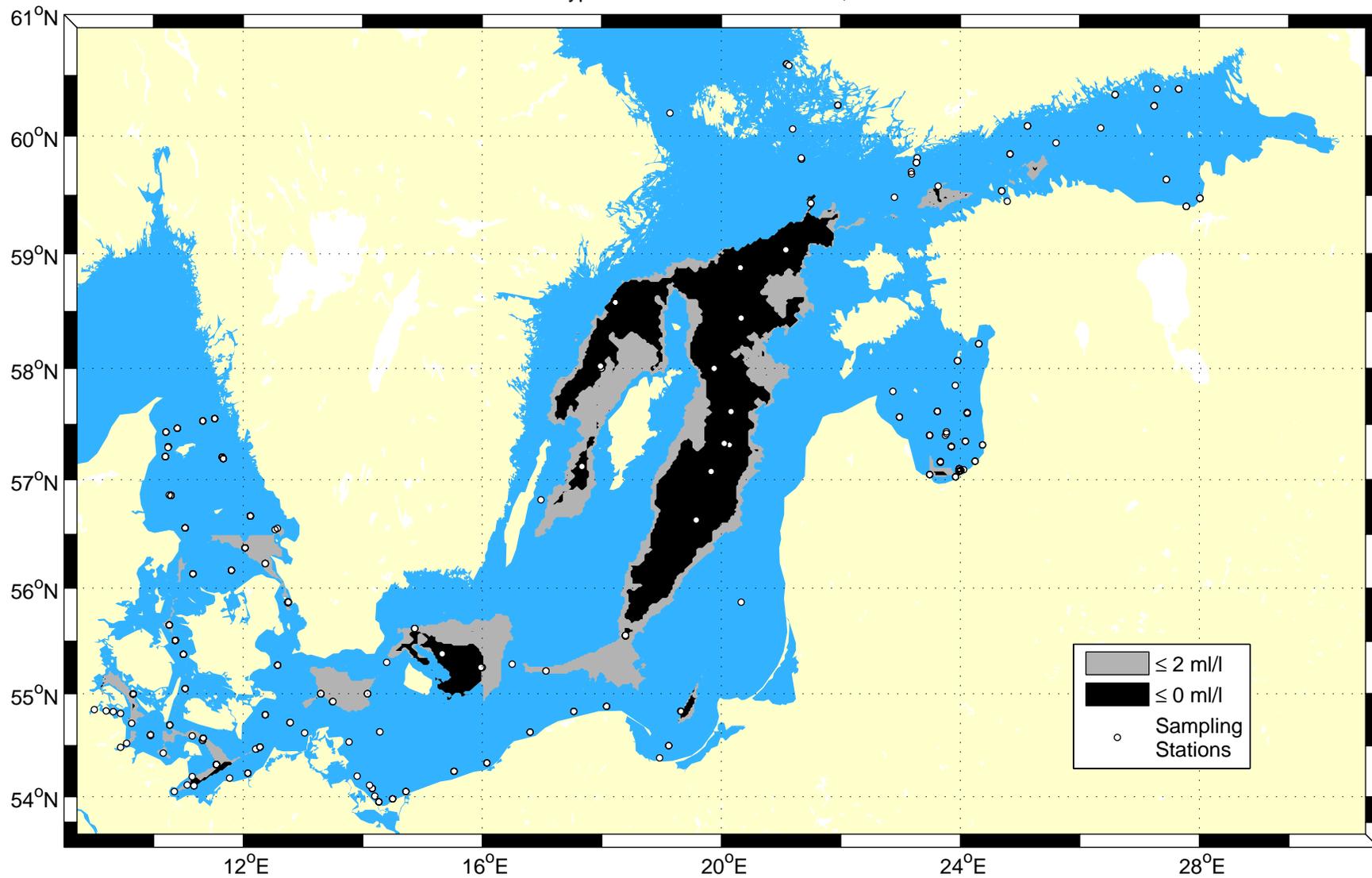
Extent of hypoxic & anoxic bottom water, Autumn 2004



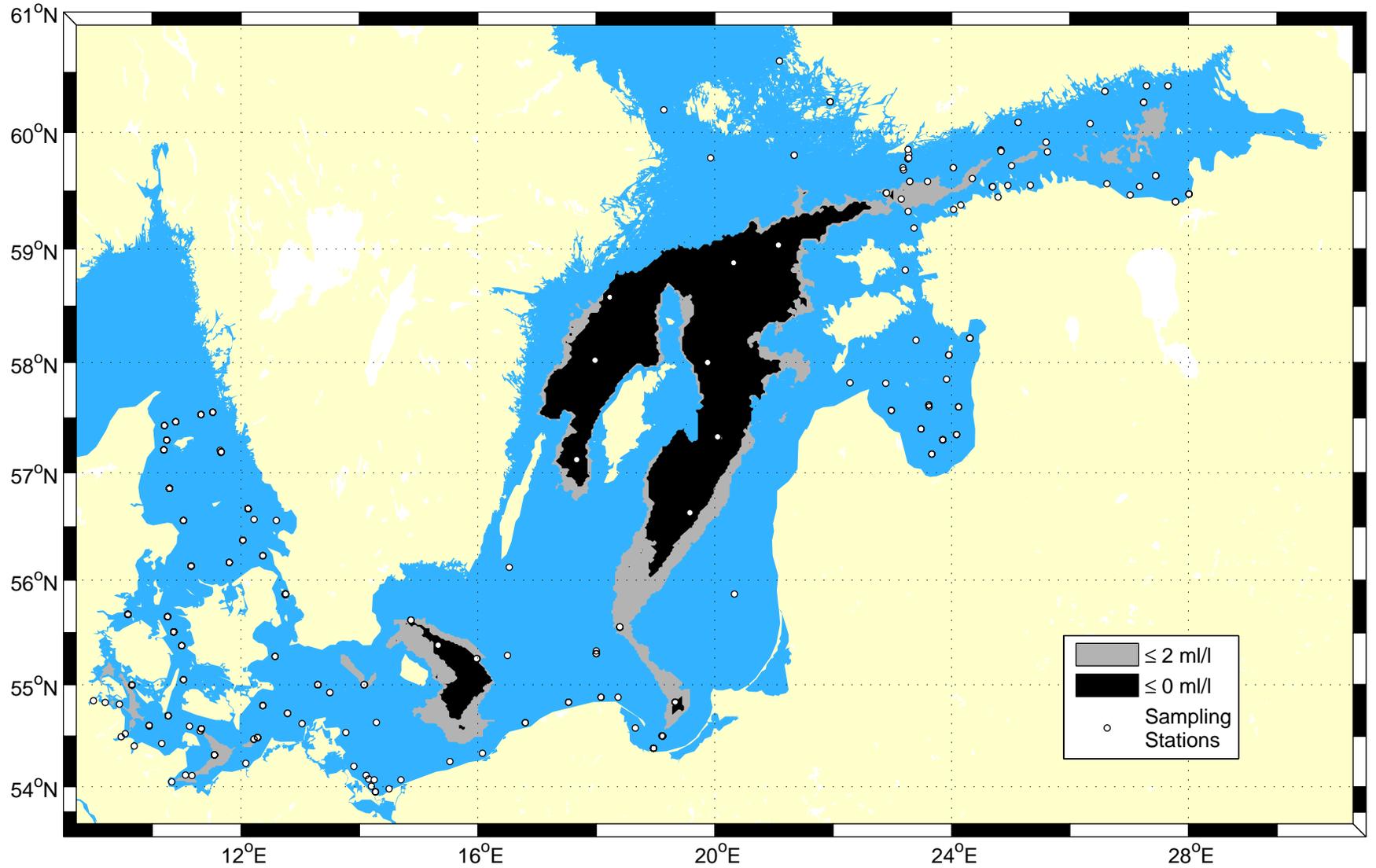
Extent of hypoxic & anoxic bottom water, Autumn 2003



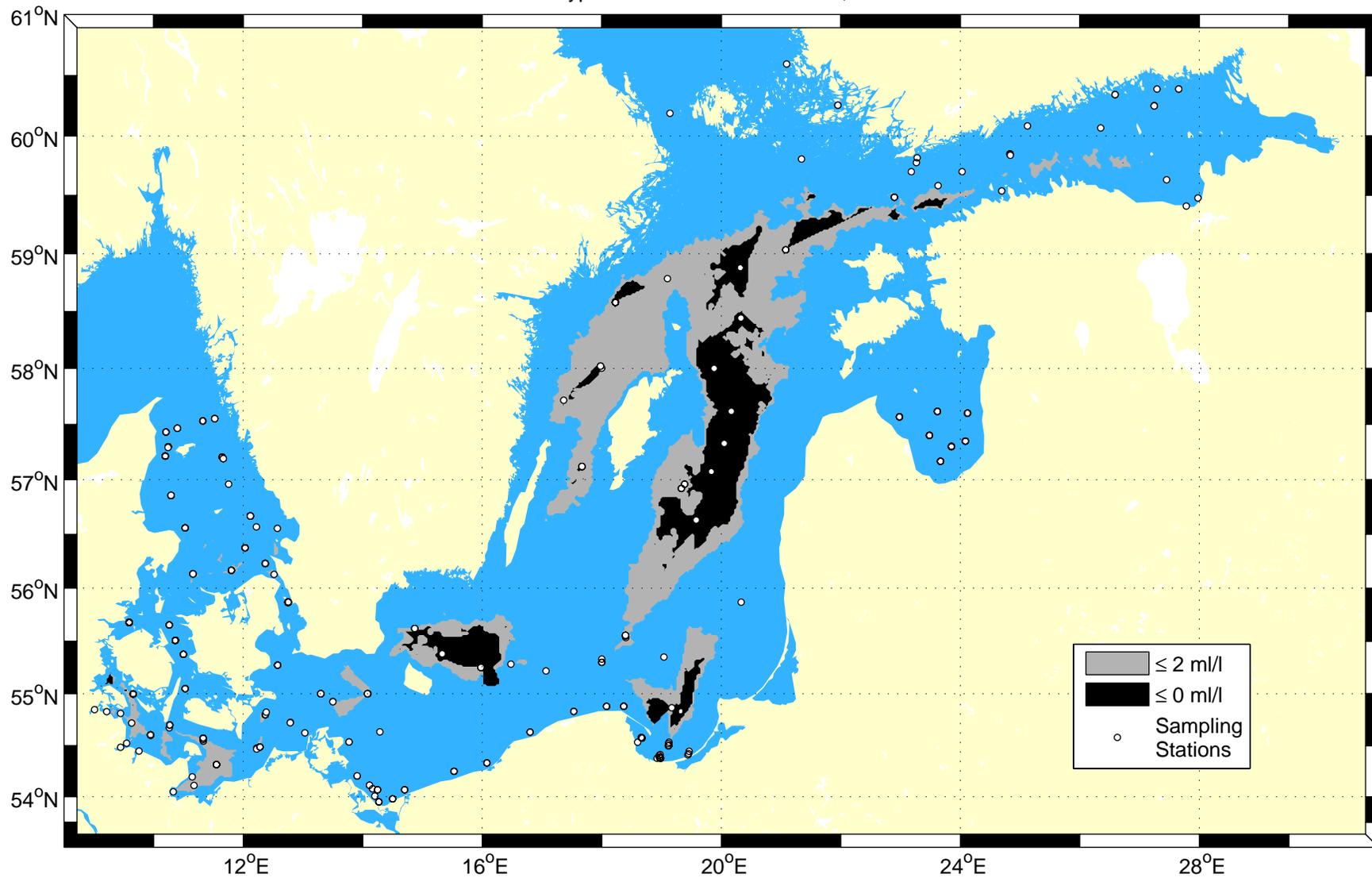
Extent of hypoxic & anoxic bottom water, Autumn 2002



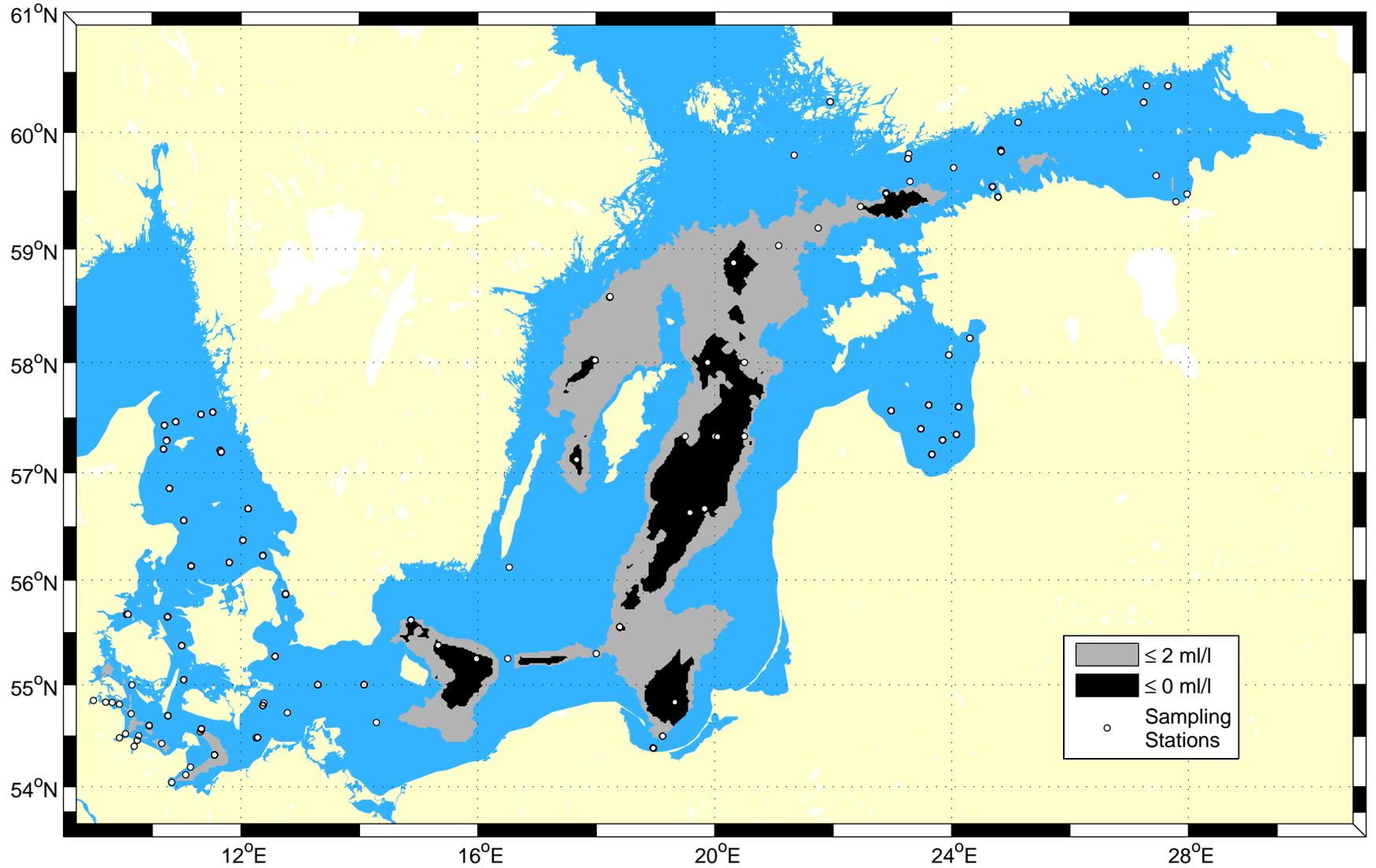
Extent of hypoxic & anoxic bottom water, Autumn 2001



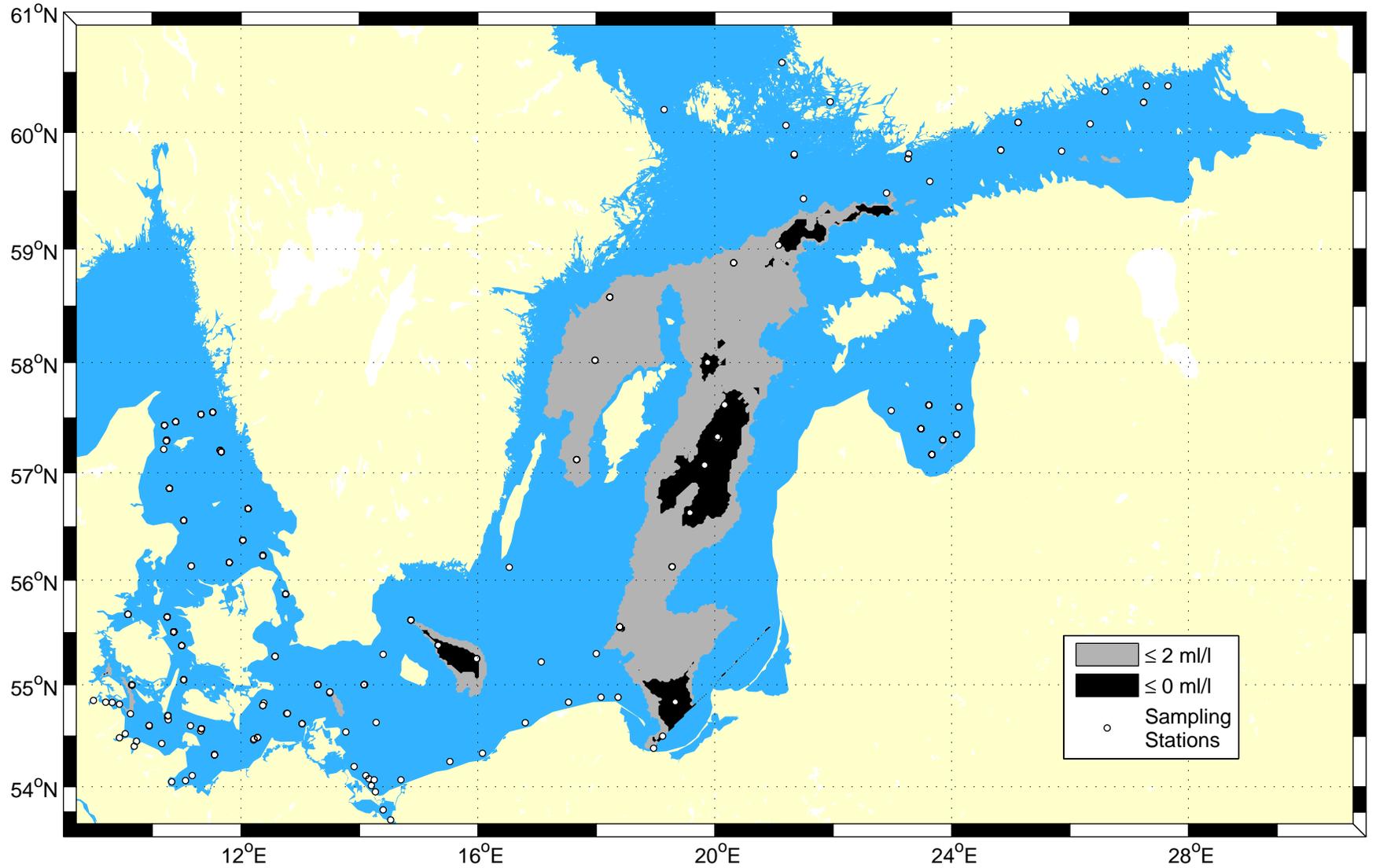
Extent of hypoxic & anoxic bottom water, Autumn 2000



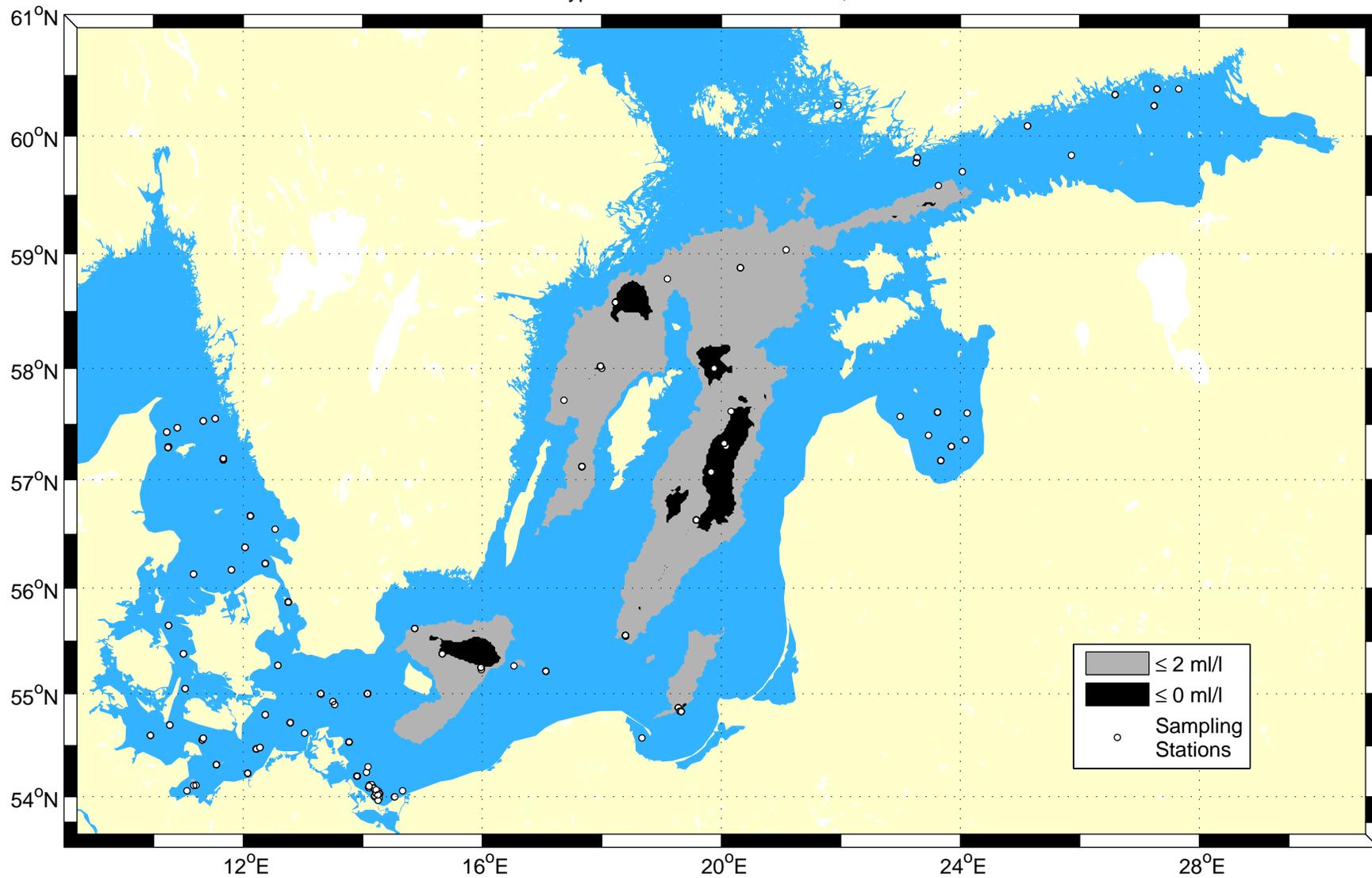
Extent of hypoxic & anoxic bottom water, Autumn 1999



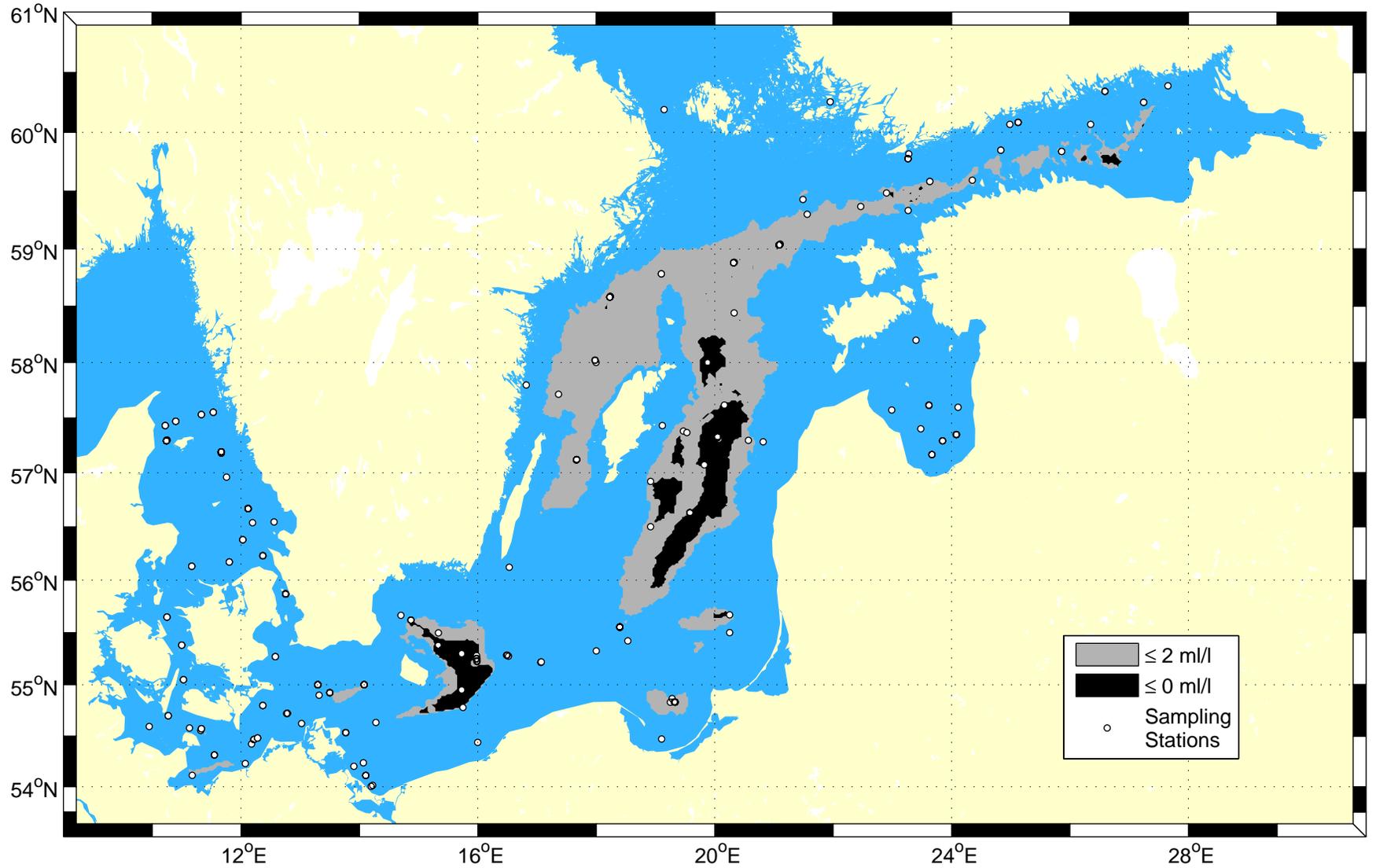
Extent of hypoxic & anoxic bottom water, Autumn 1998



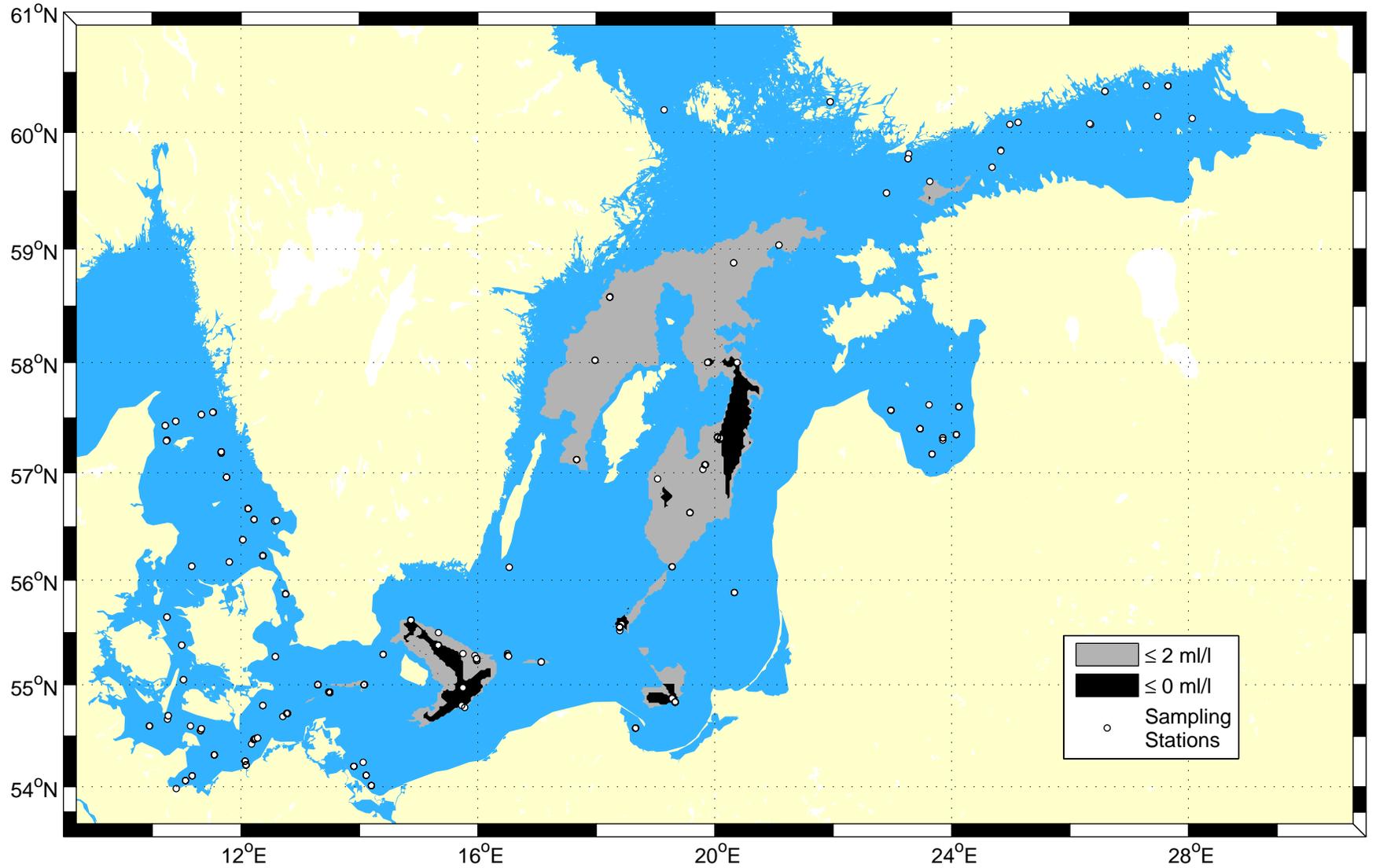
Extent of hypoxic & anoxic bottom water, Autumn 1997



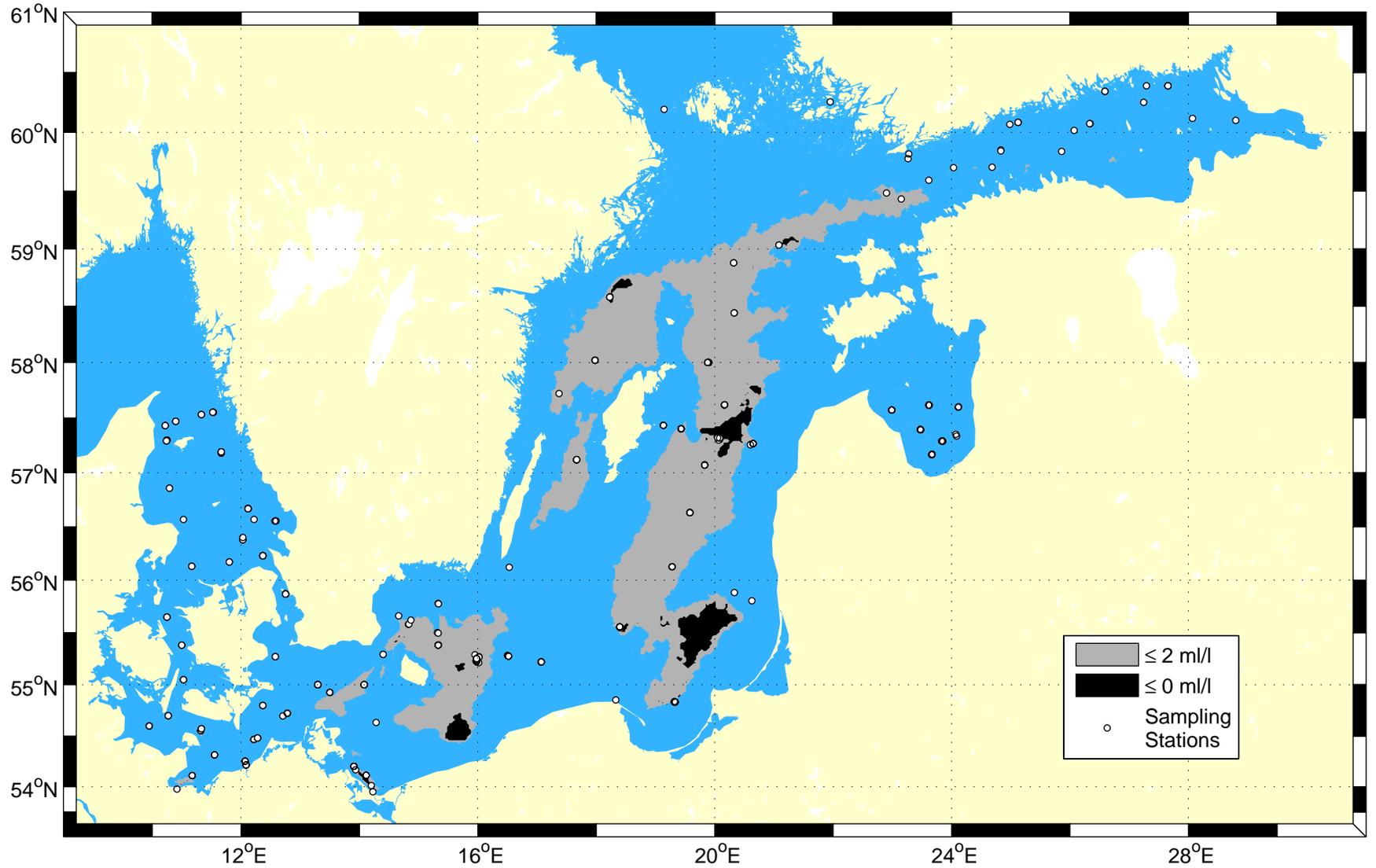
Extent of hypoxic & anoxic bottom water, Autumn 1996



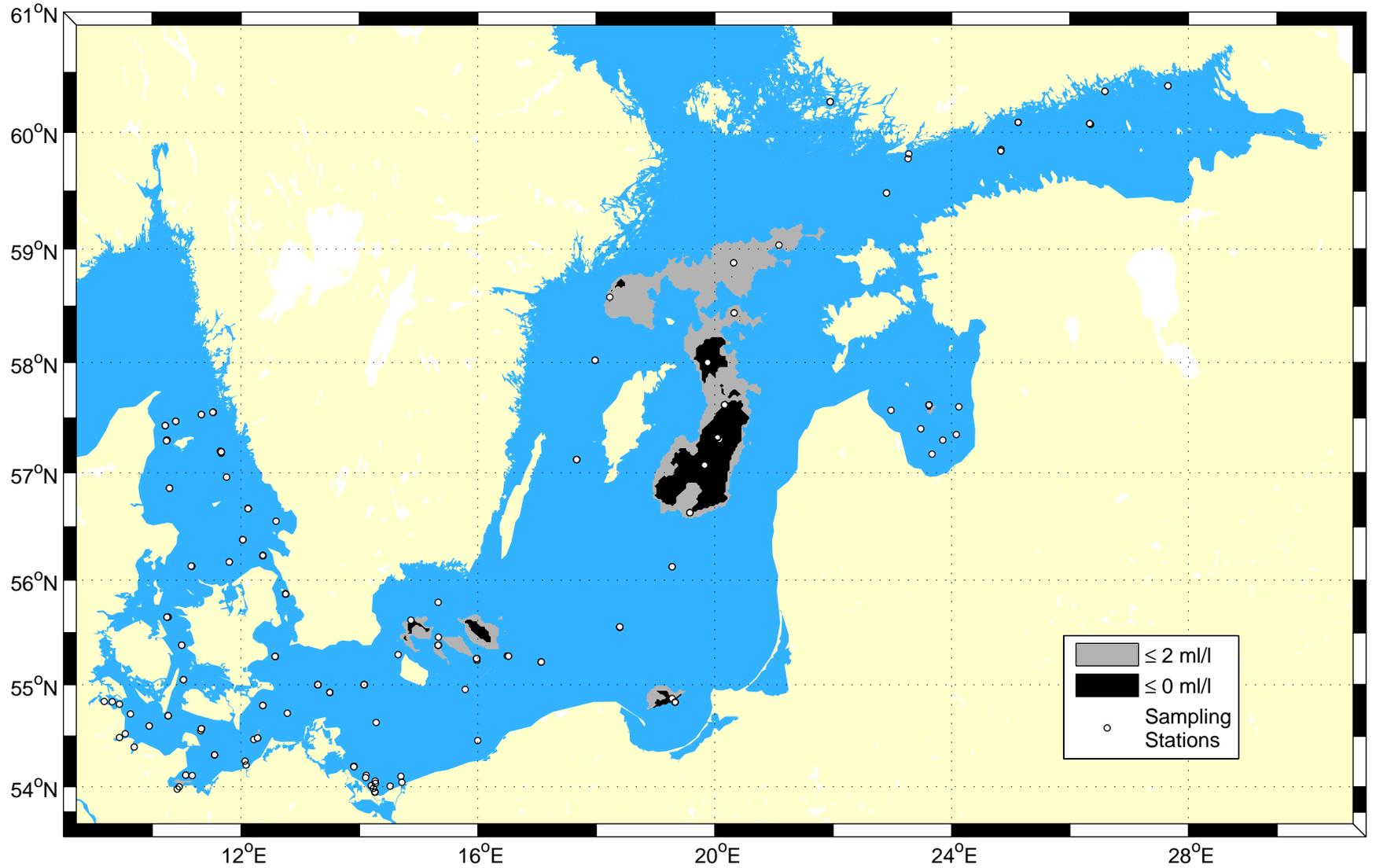
Extent of hypoxic & anoxic bottom water, Autumn 1995



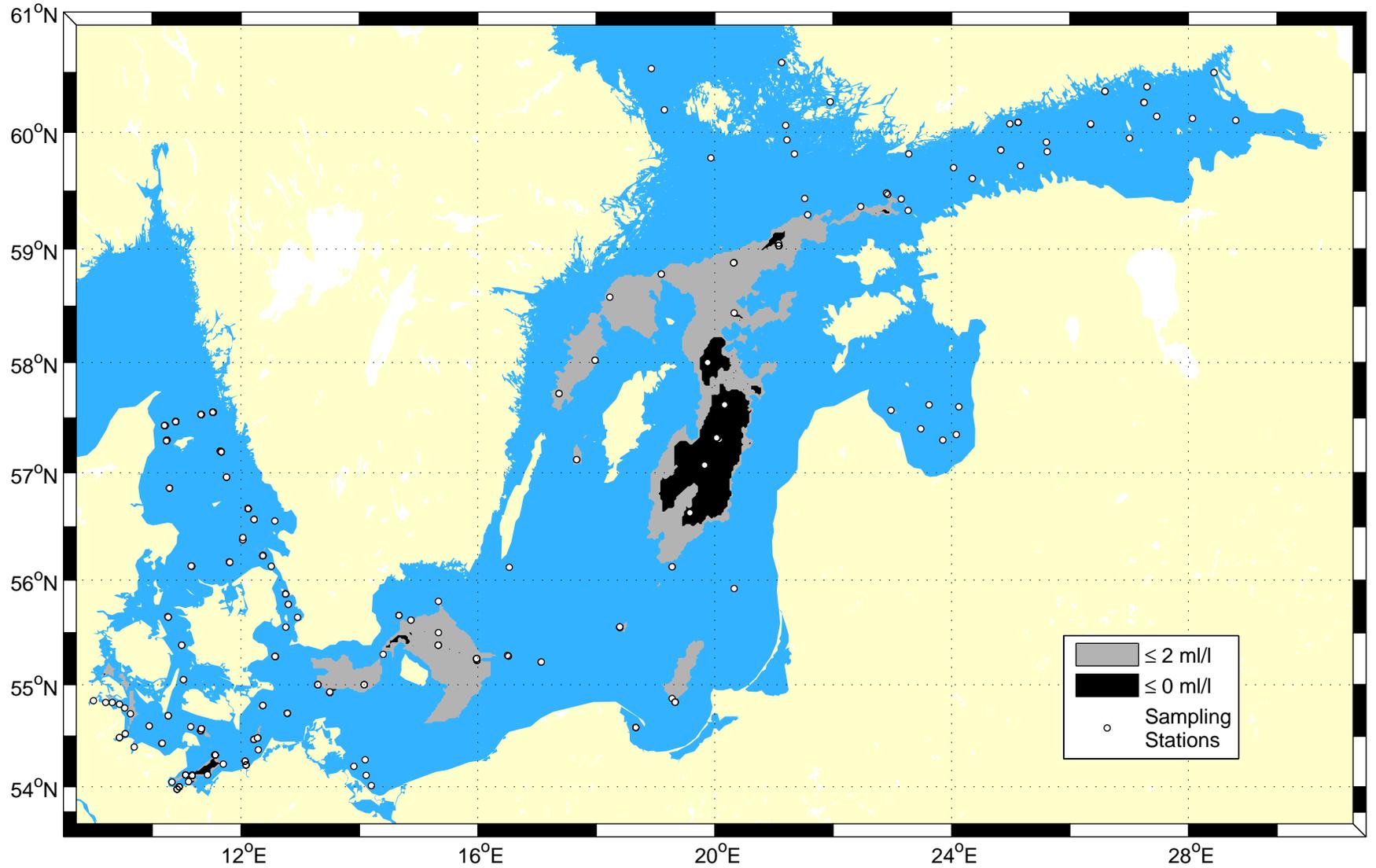
Extent of hypoxic & anoxic bottom water, Autumn 1994



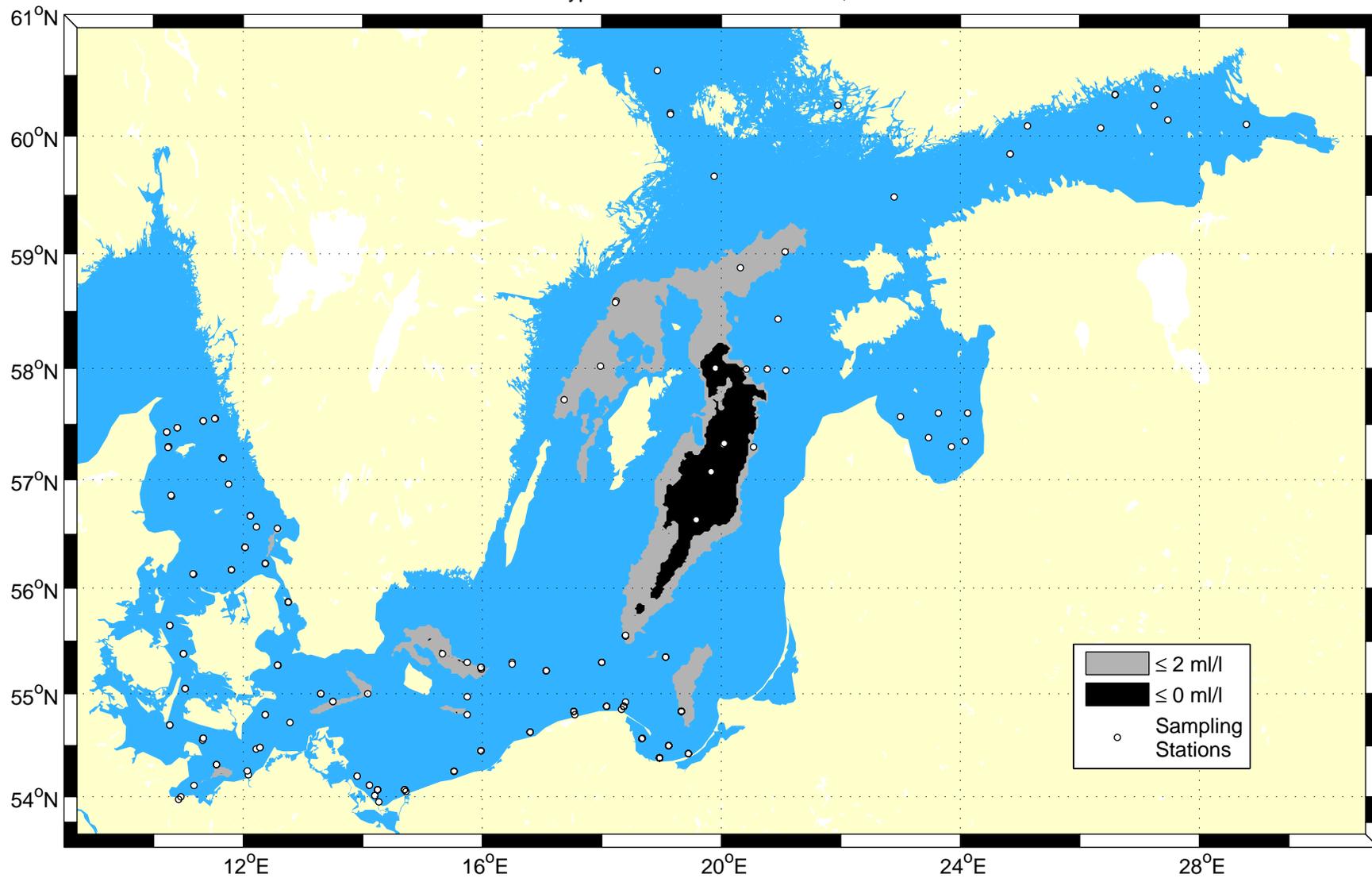
Extent of hypoxic & anoxic bottom water, Autumn 1993



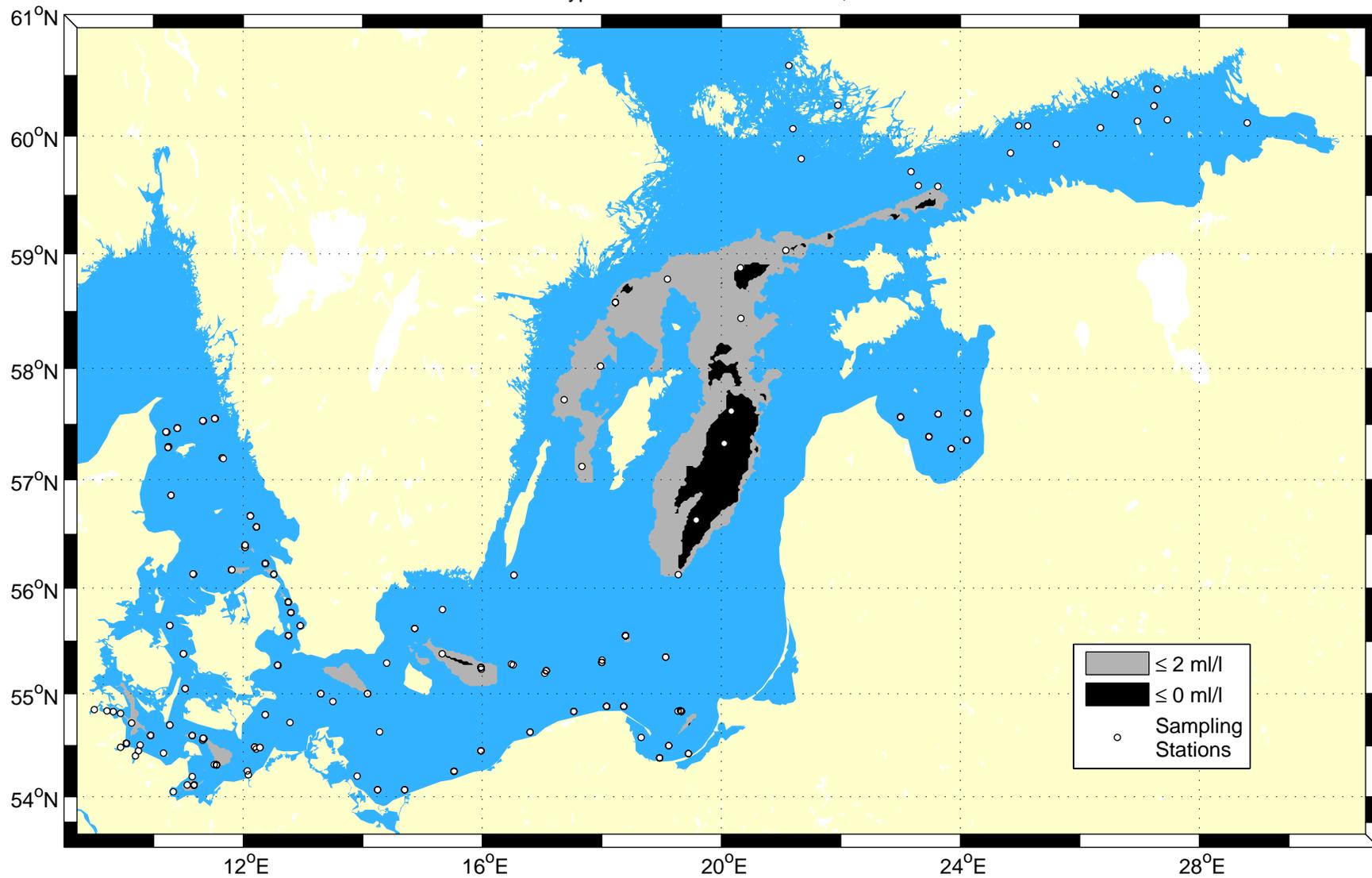
Extent of hypoxic & anoxic bottom water, Autumn 1992



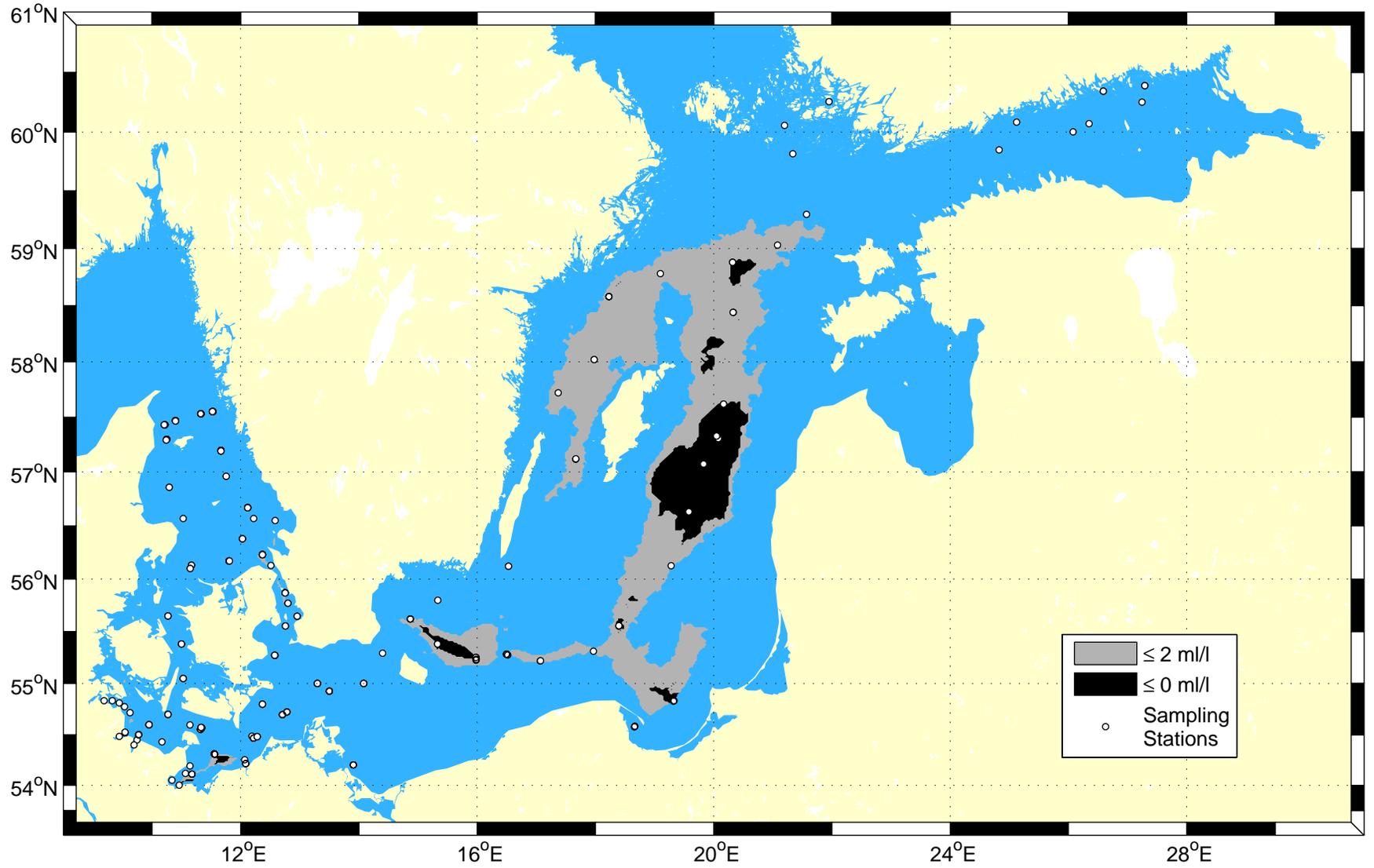
Extent of hypoxic & anoxic bottom water, Autumn 1991



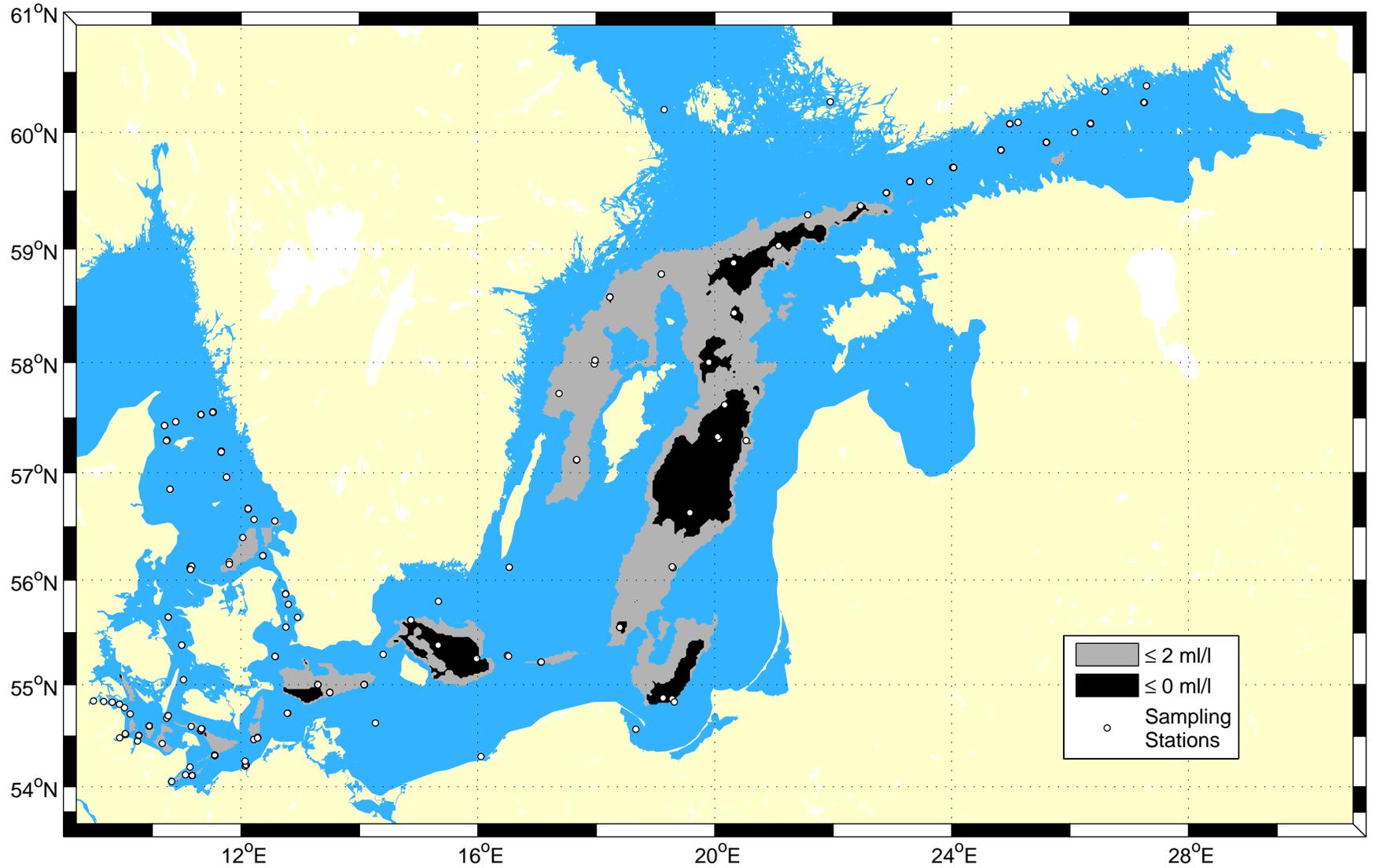
Extent of hypoxic & anoxic bottom water, Autumn 1990



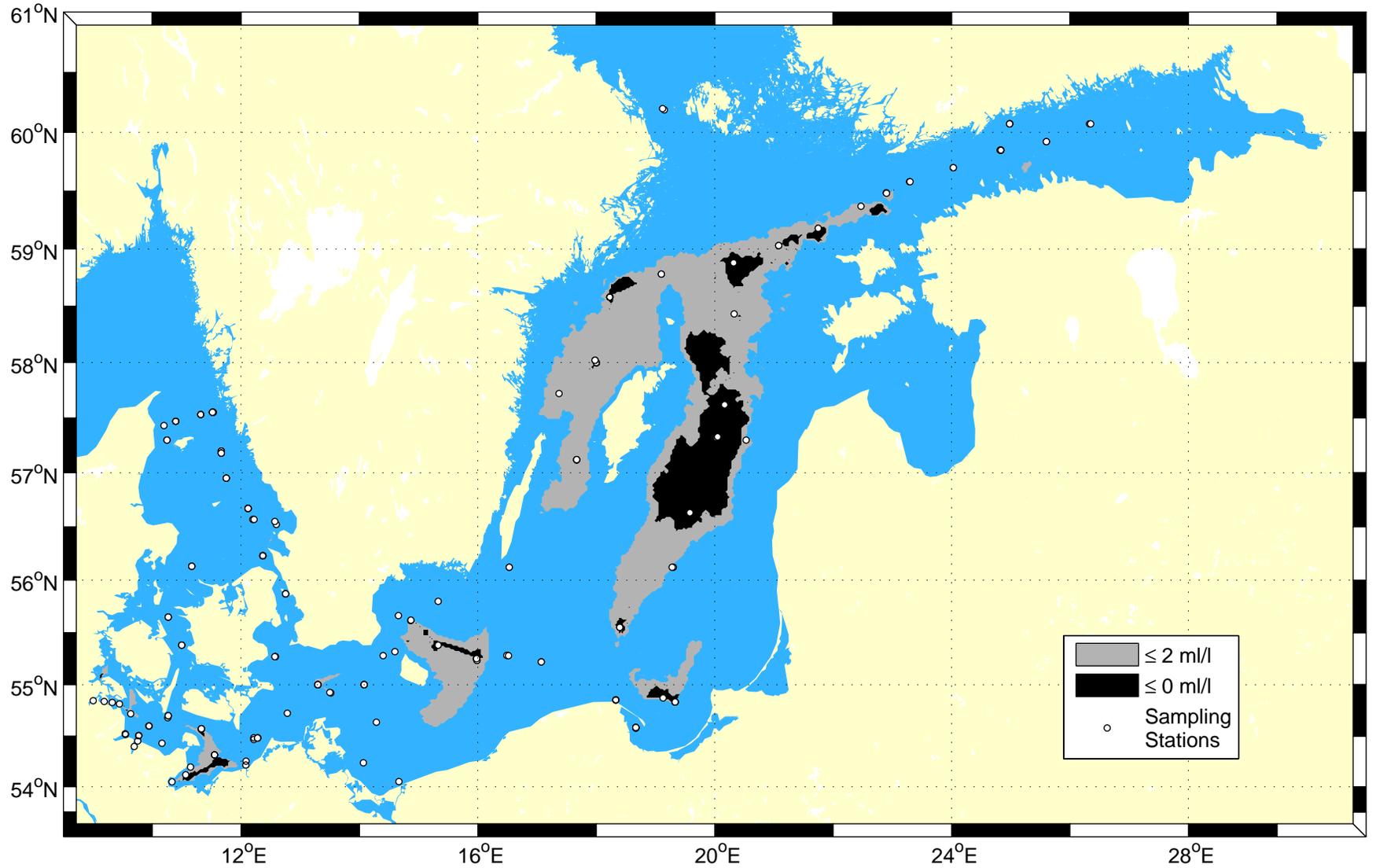
Extent of hypoxic & anoxic bottom water, Autumn 1989



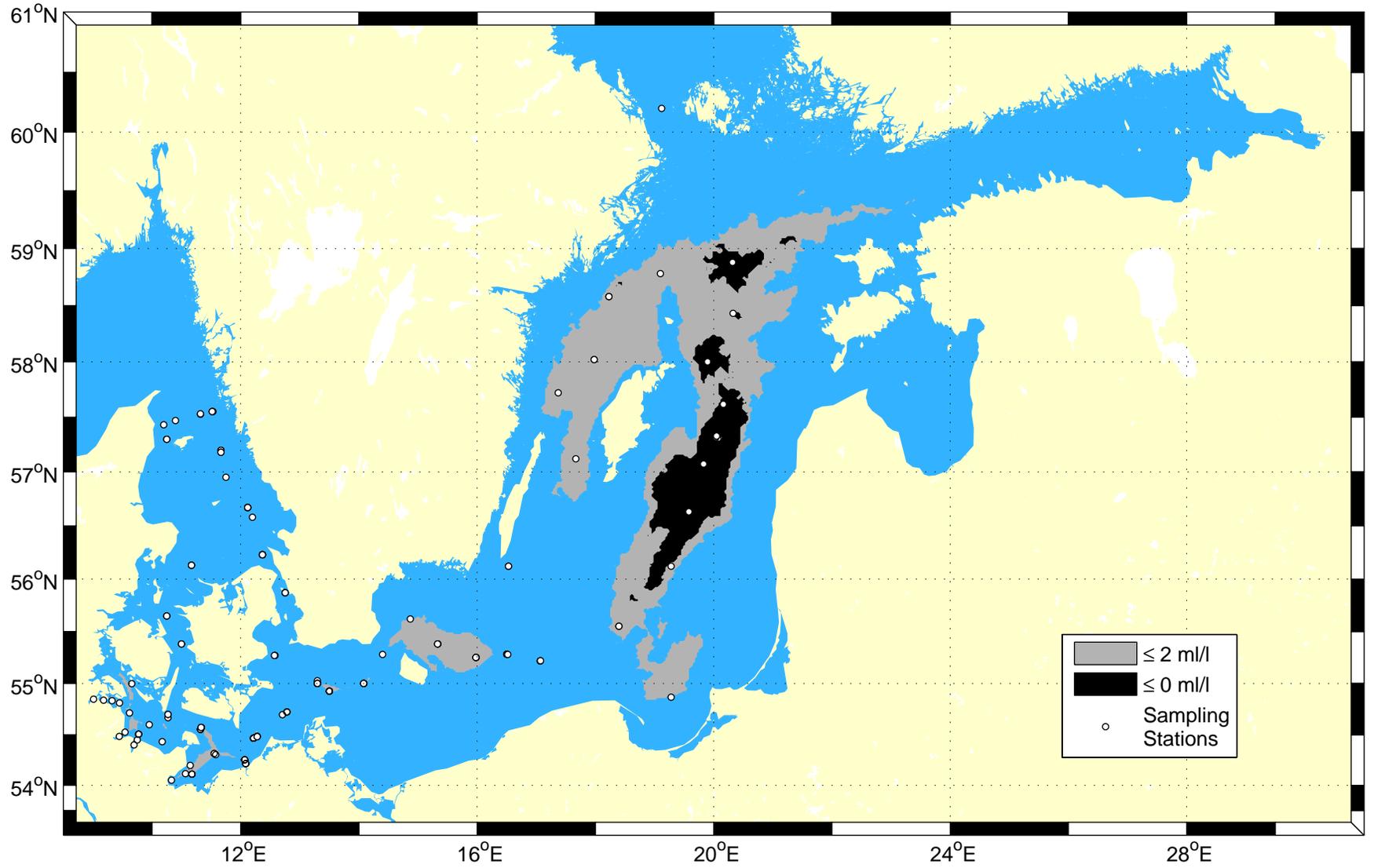
Extent of hypoxic & anoxic bottom water, Autumn 1988



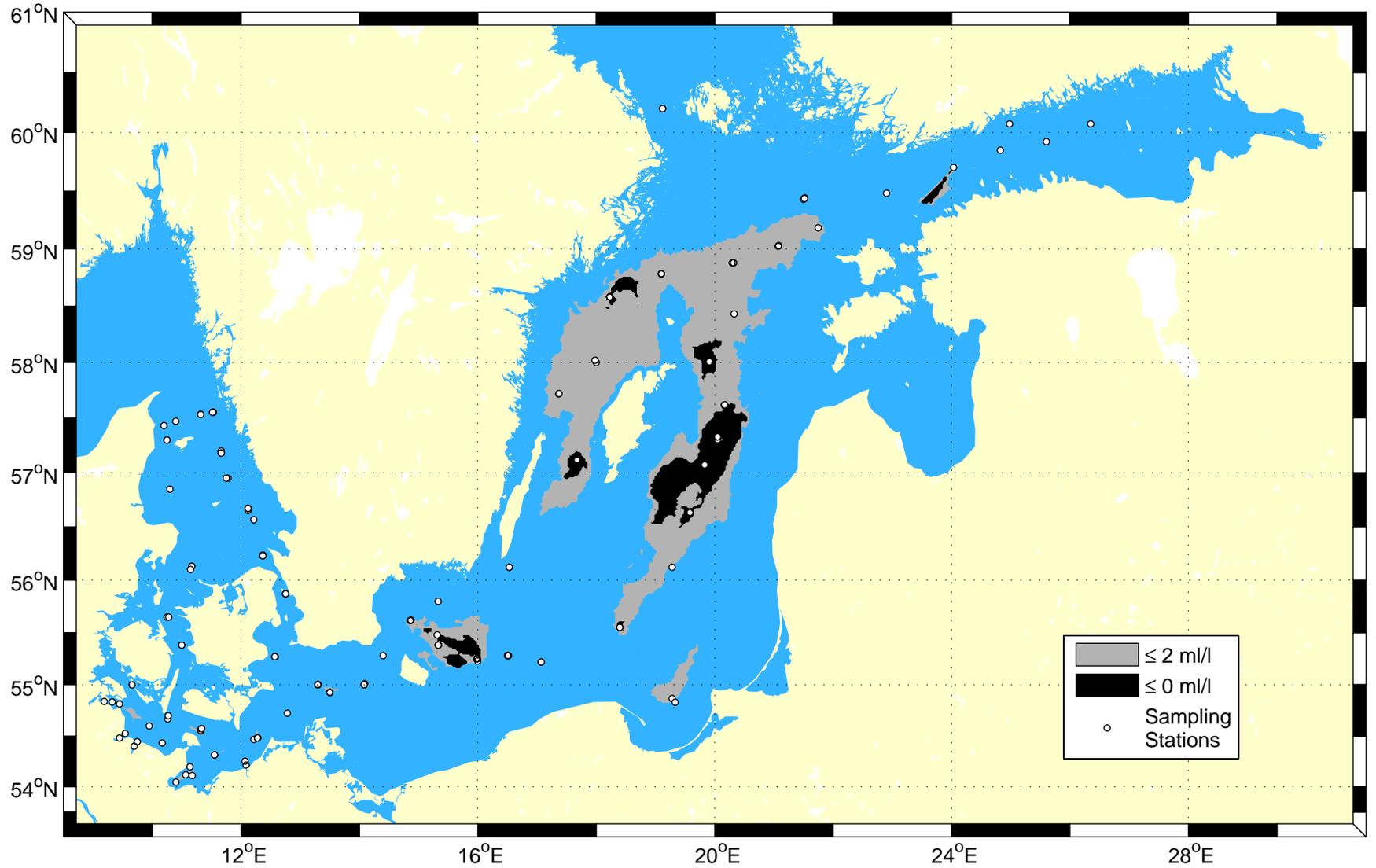
Extent of hypoxic & anoxic bottom water, Autumn 1987



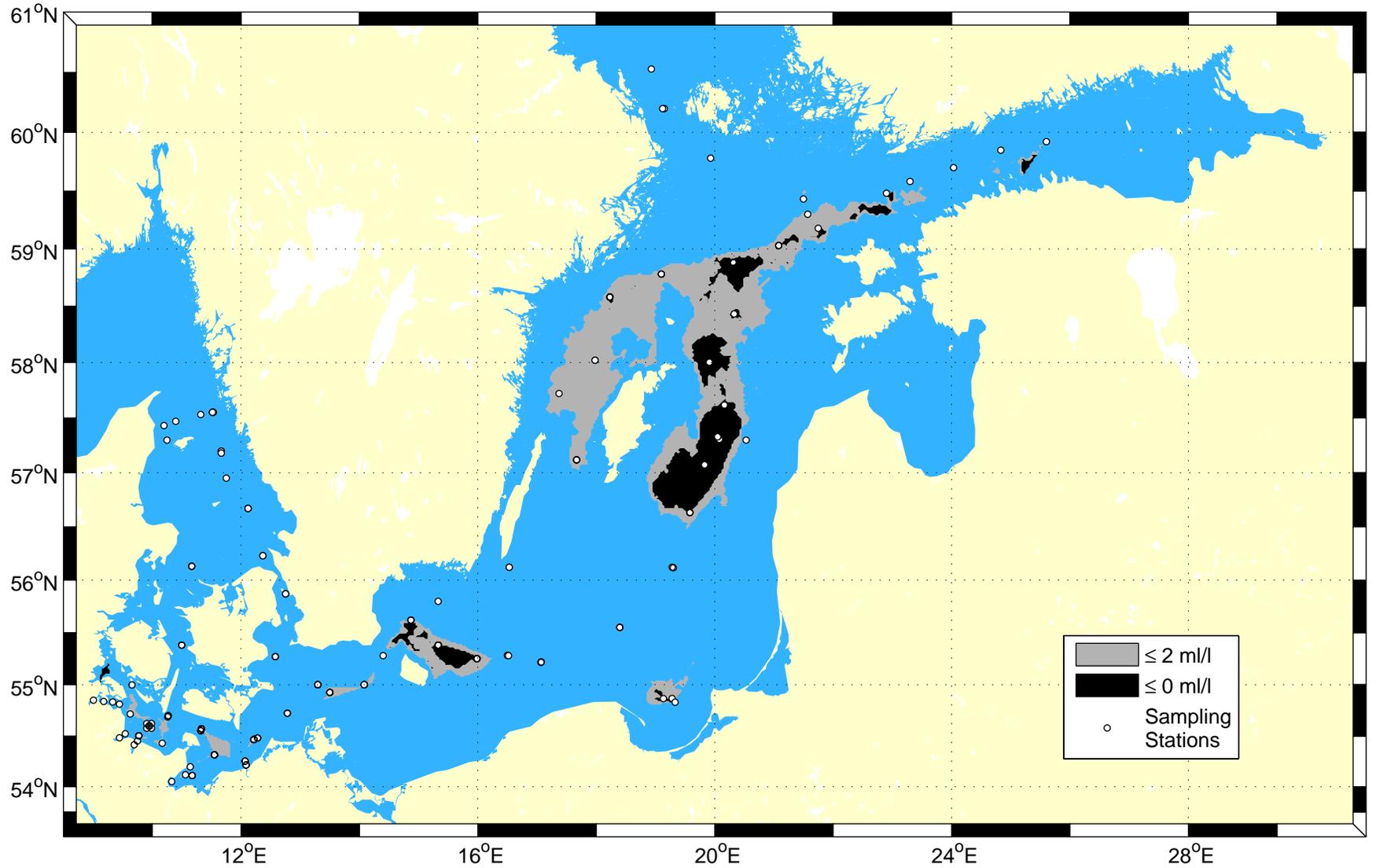
Extent of hypoxic & anoxic bottom water, Autumn 1986



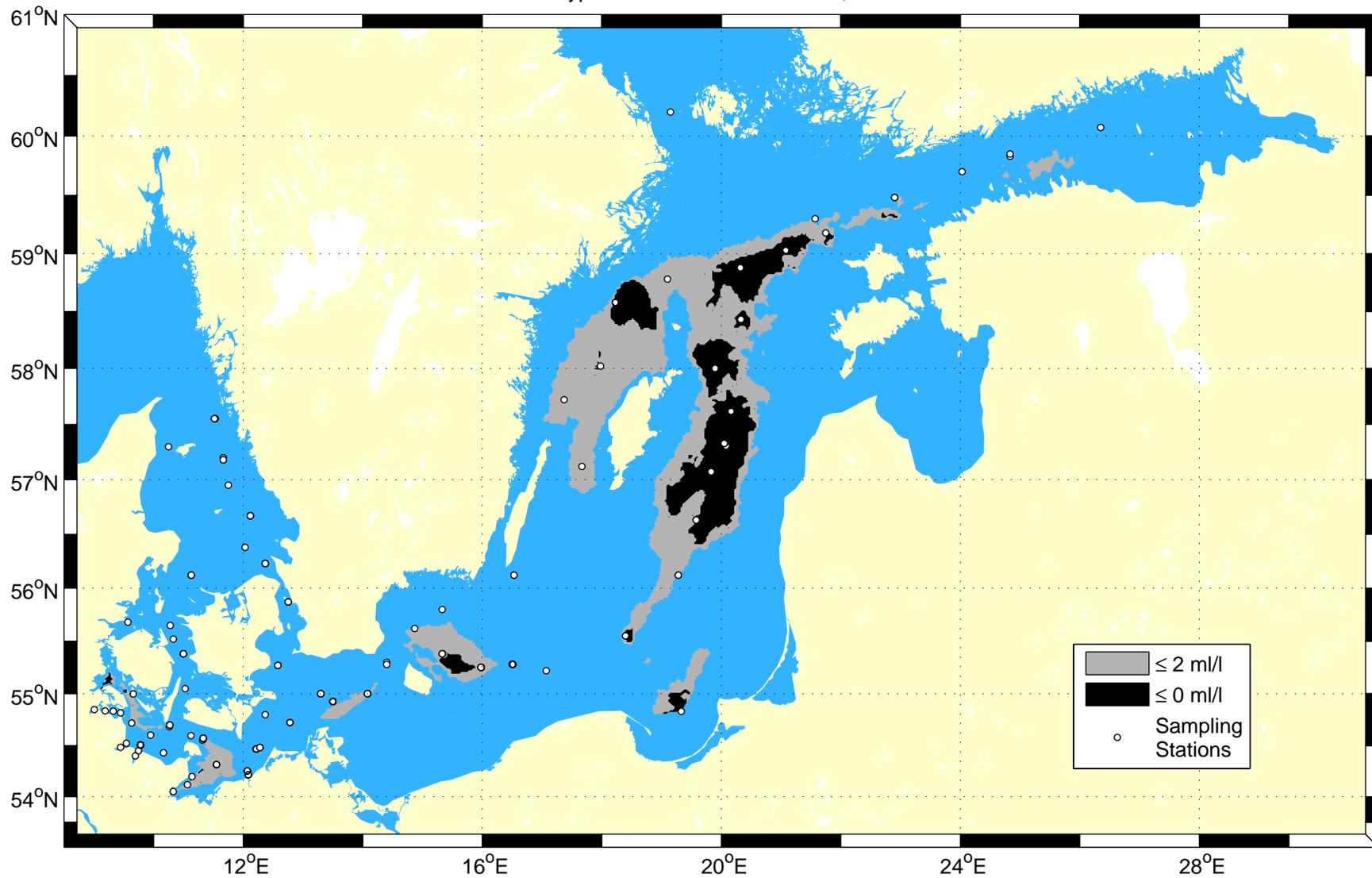
Extent of hypoxic & anoxic bottom water, Autumn 1985



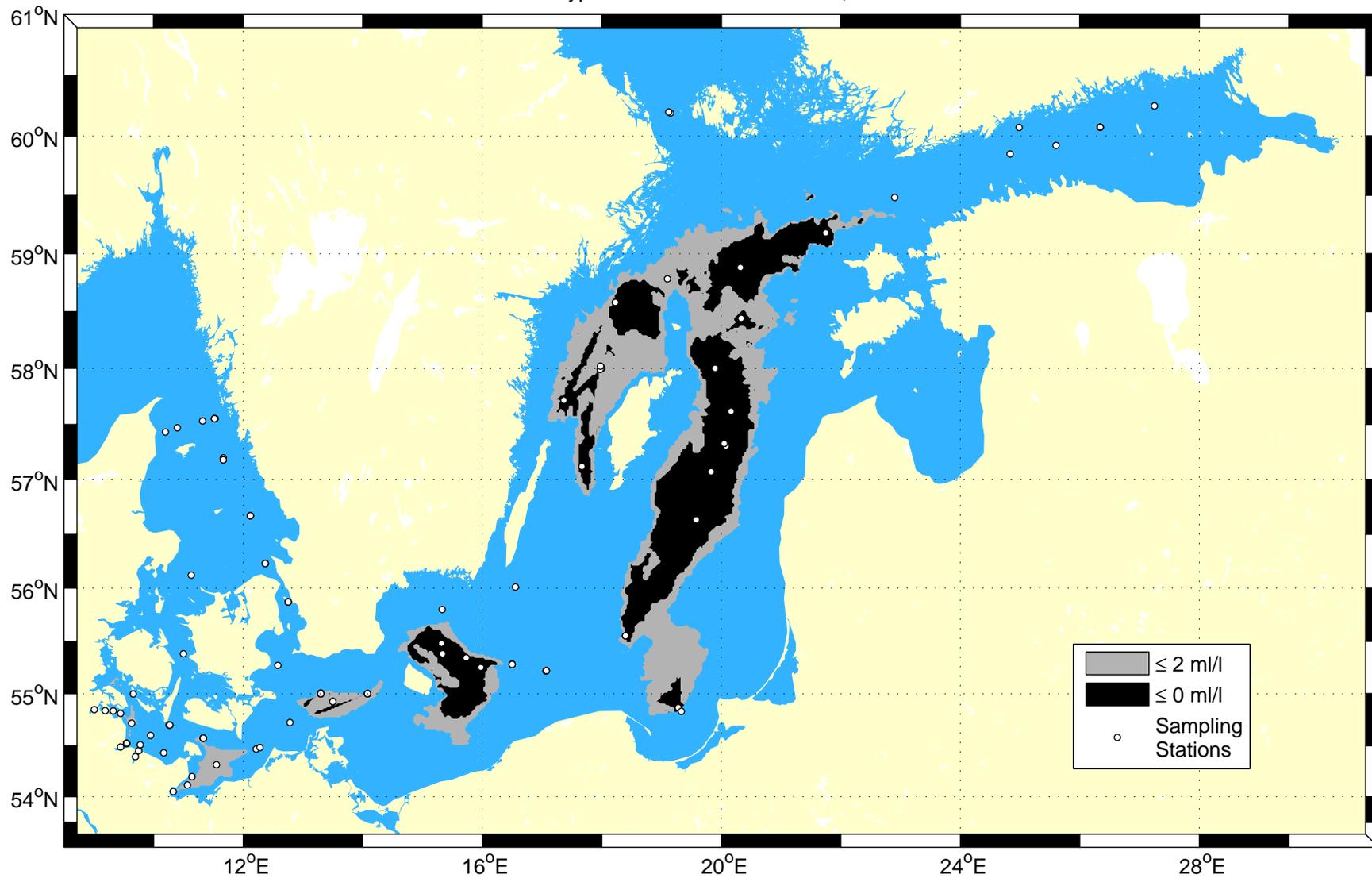
Extent of hypoxic & anoxic bottom water, Autumn 1984



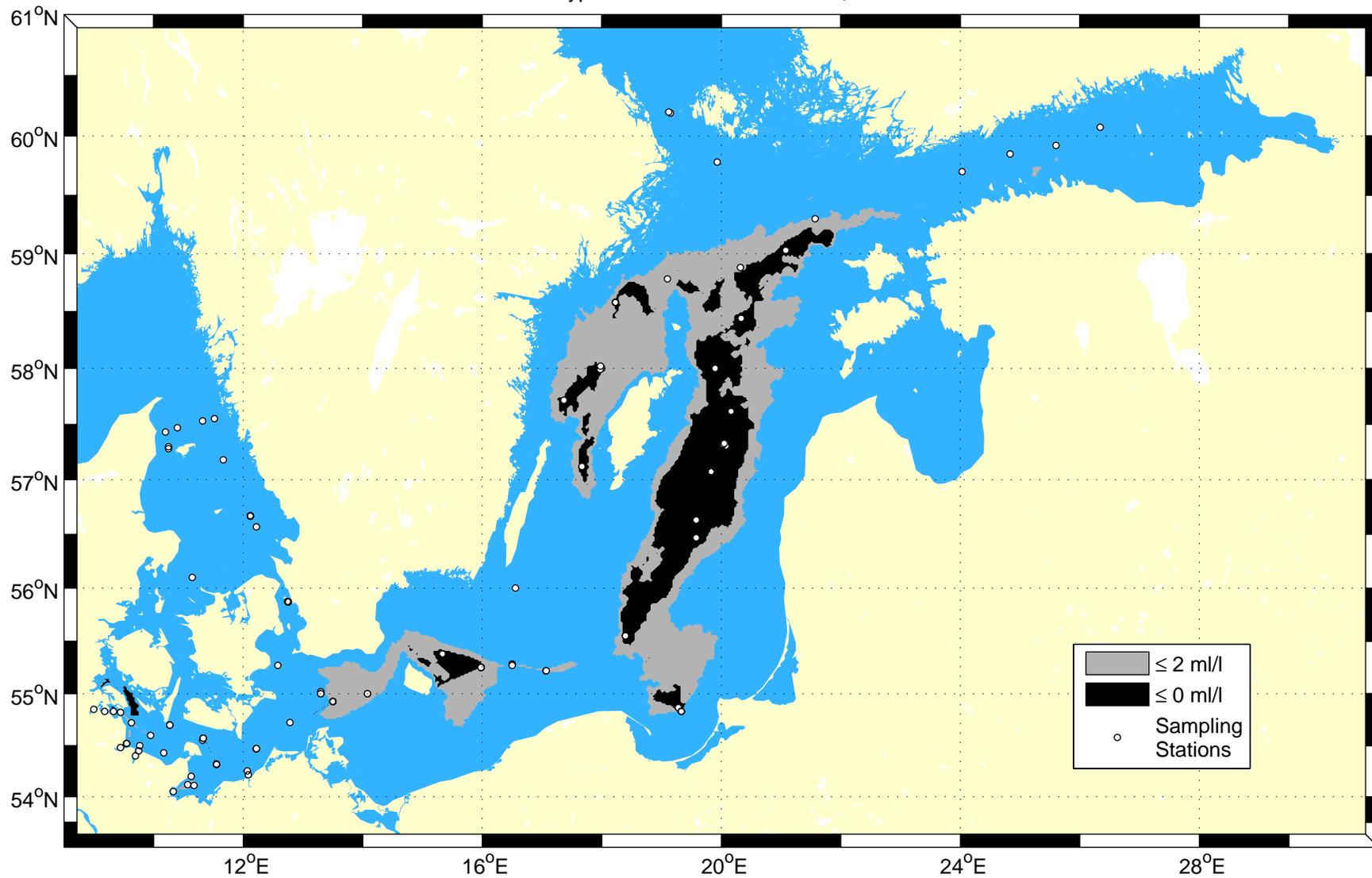
Extent of hypoxic & anoxic bottom water, Autumn 1983



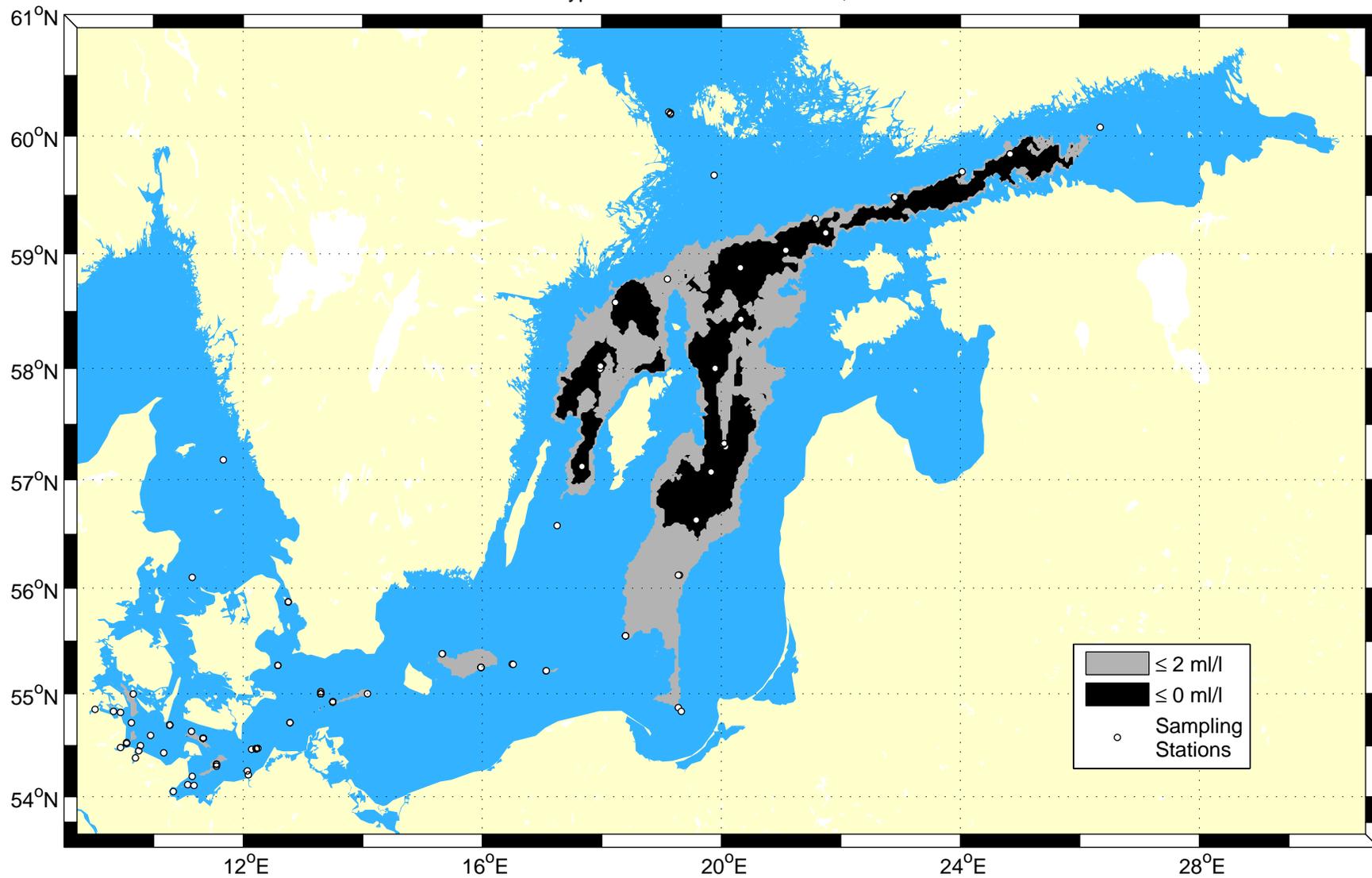
Extent of hypoxic & anoxic bottom water, Autumn 1982



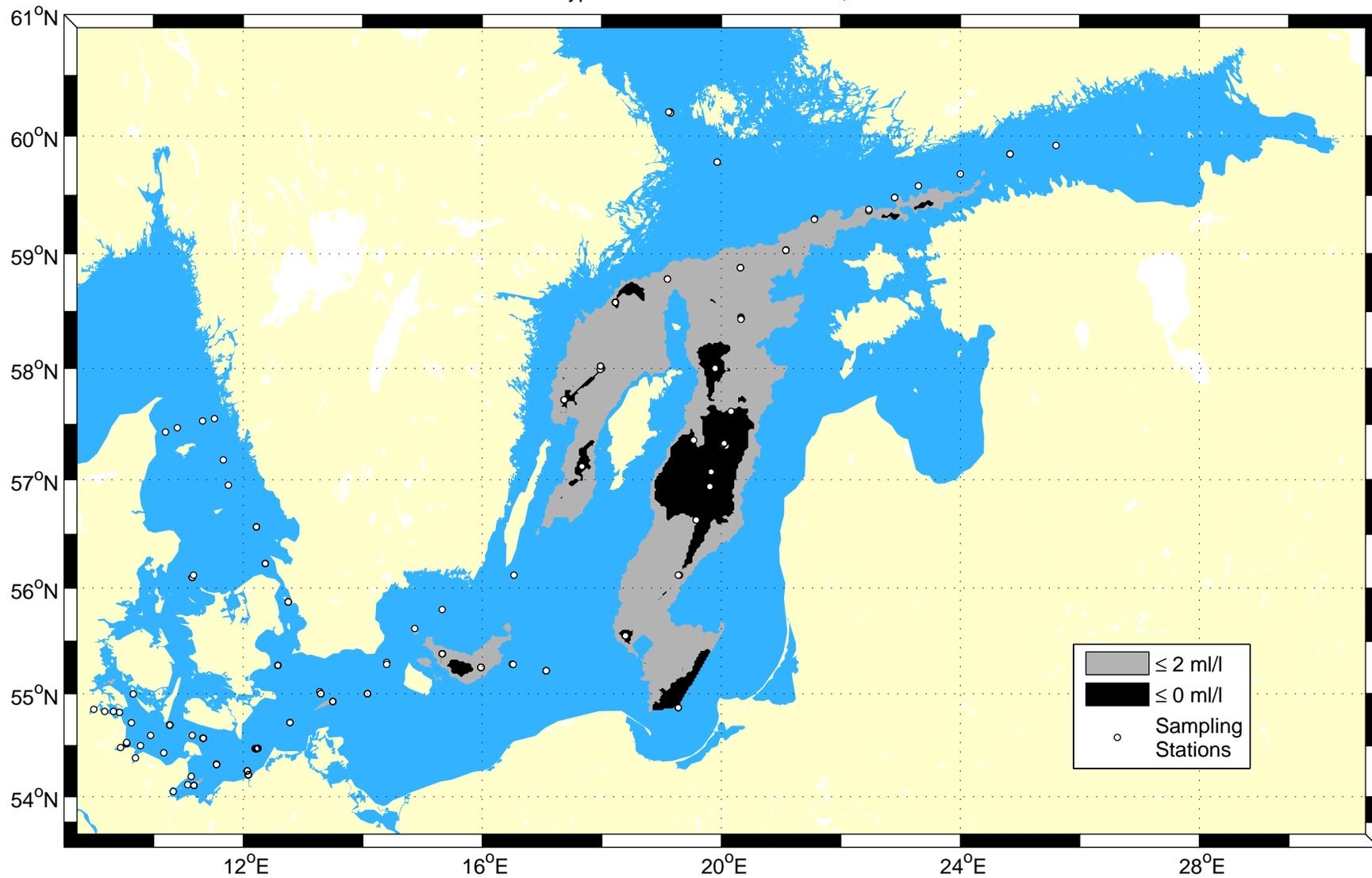
Extent of hypoxic & anoxic bottom water, Autumn 1981



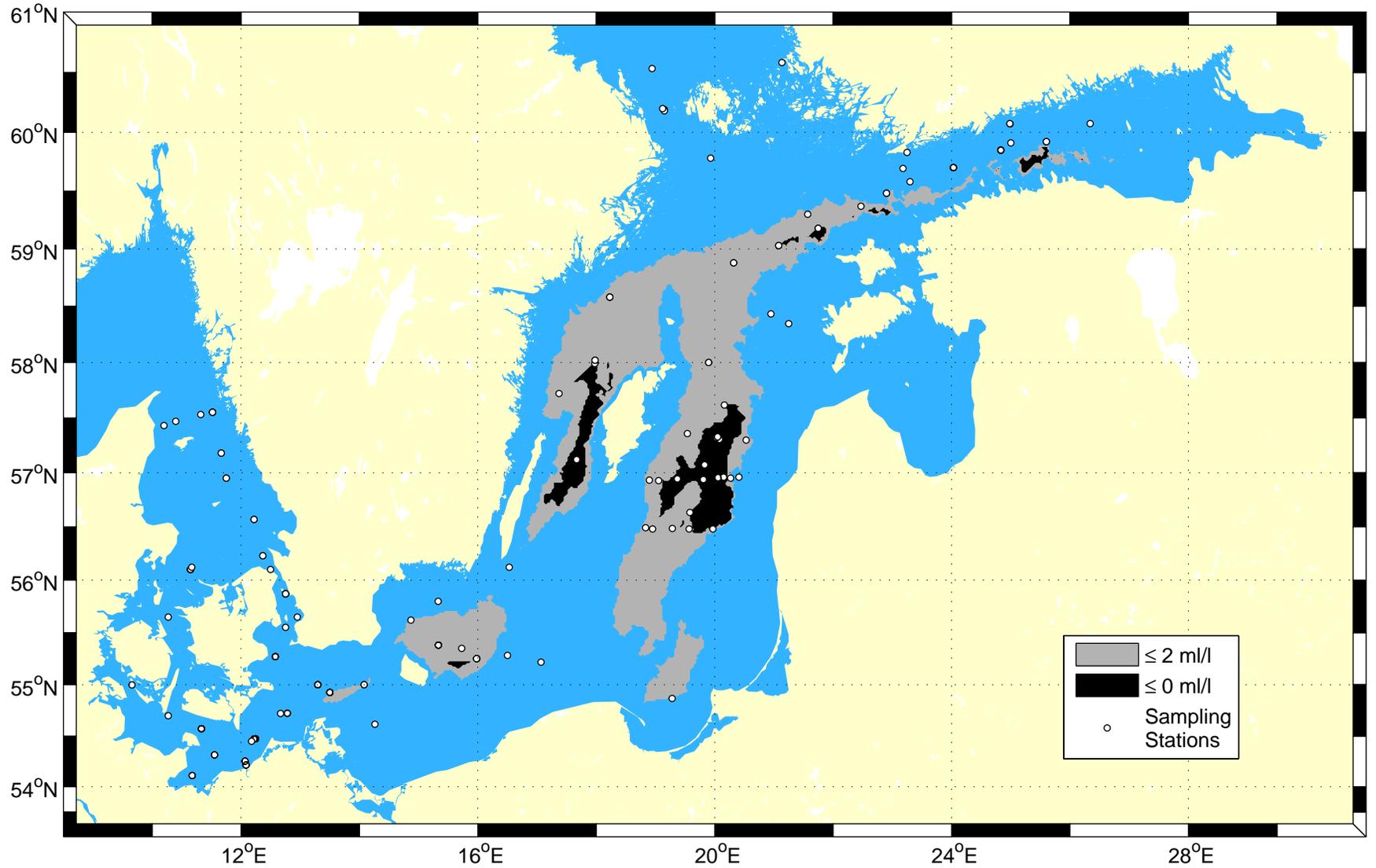
Extent of hypoxic & anoxic bottom water, Autumn 1980



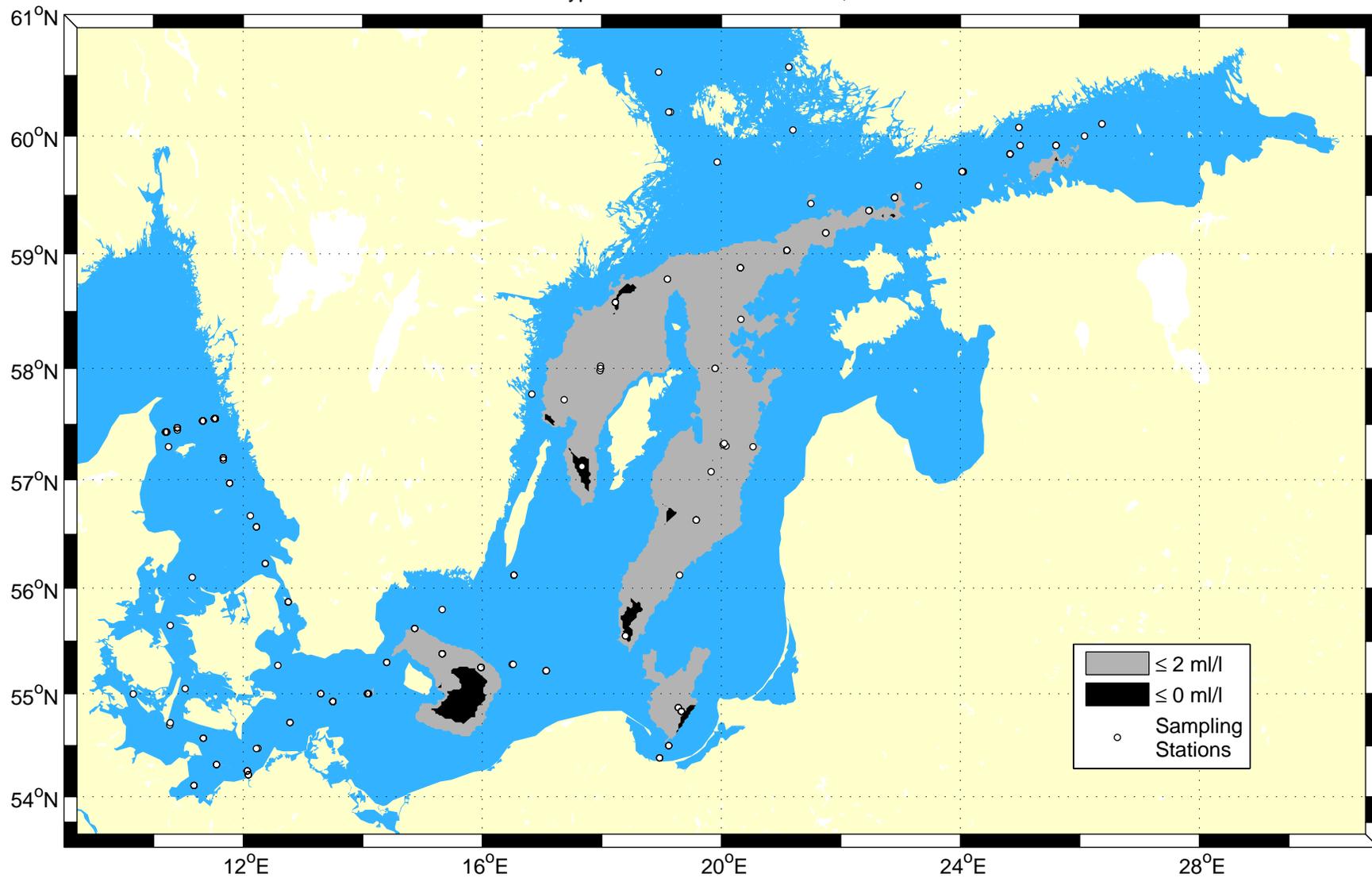
Extent of hypoxic & anoxic bottom water, Autumn 1979



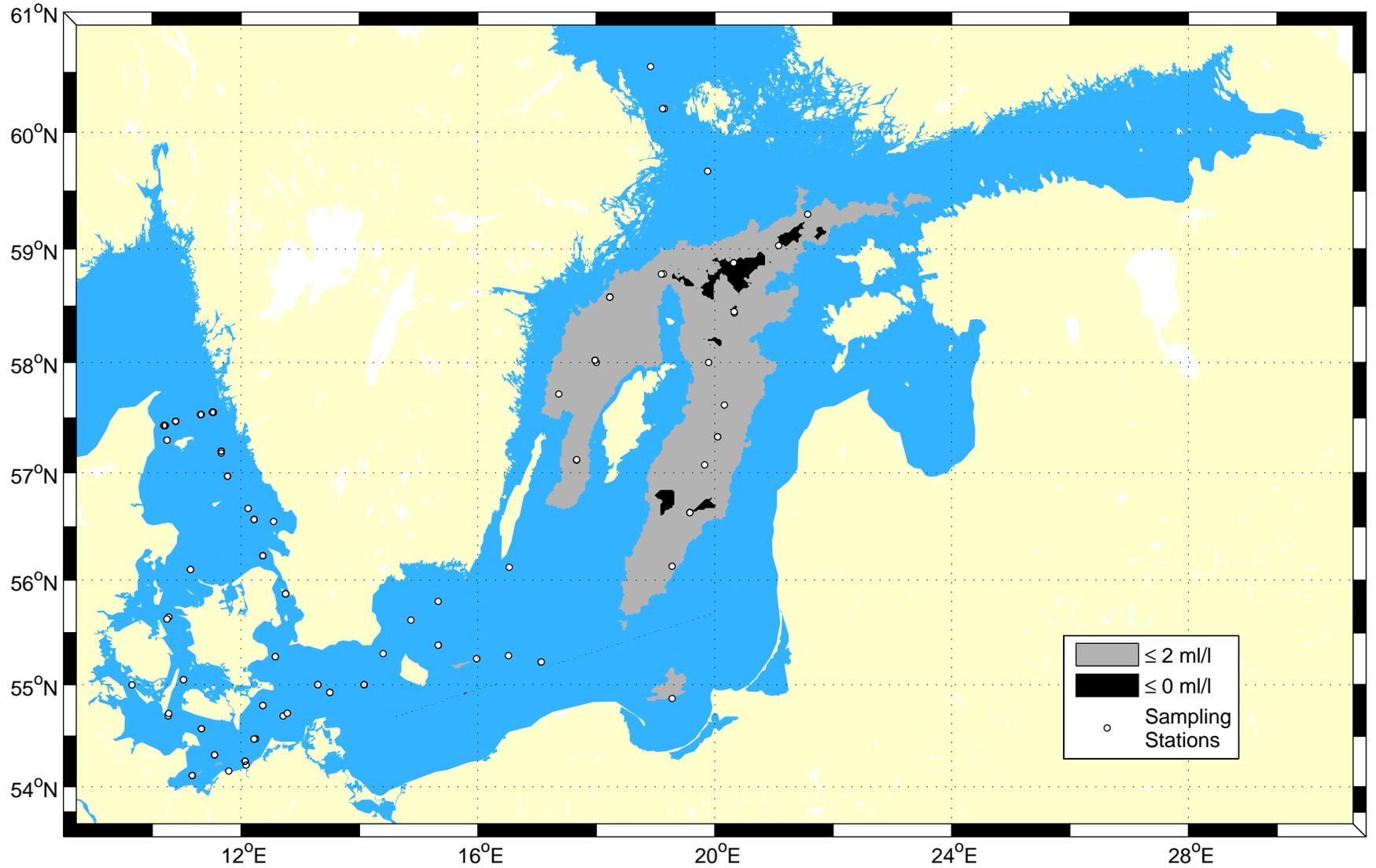
Extent of hypoxic & anoxic bottom water, Autumn 1978



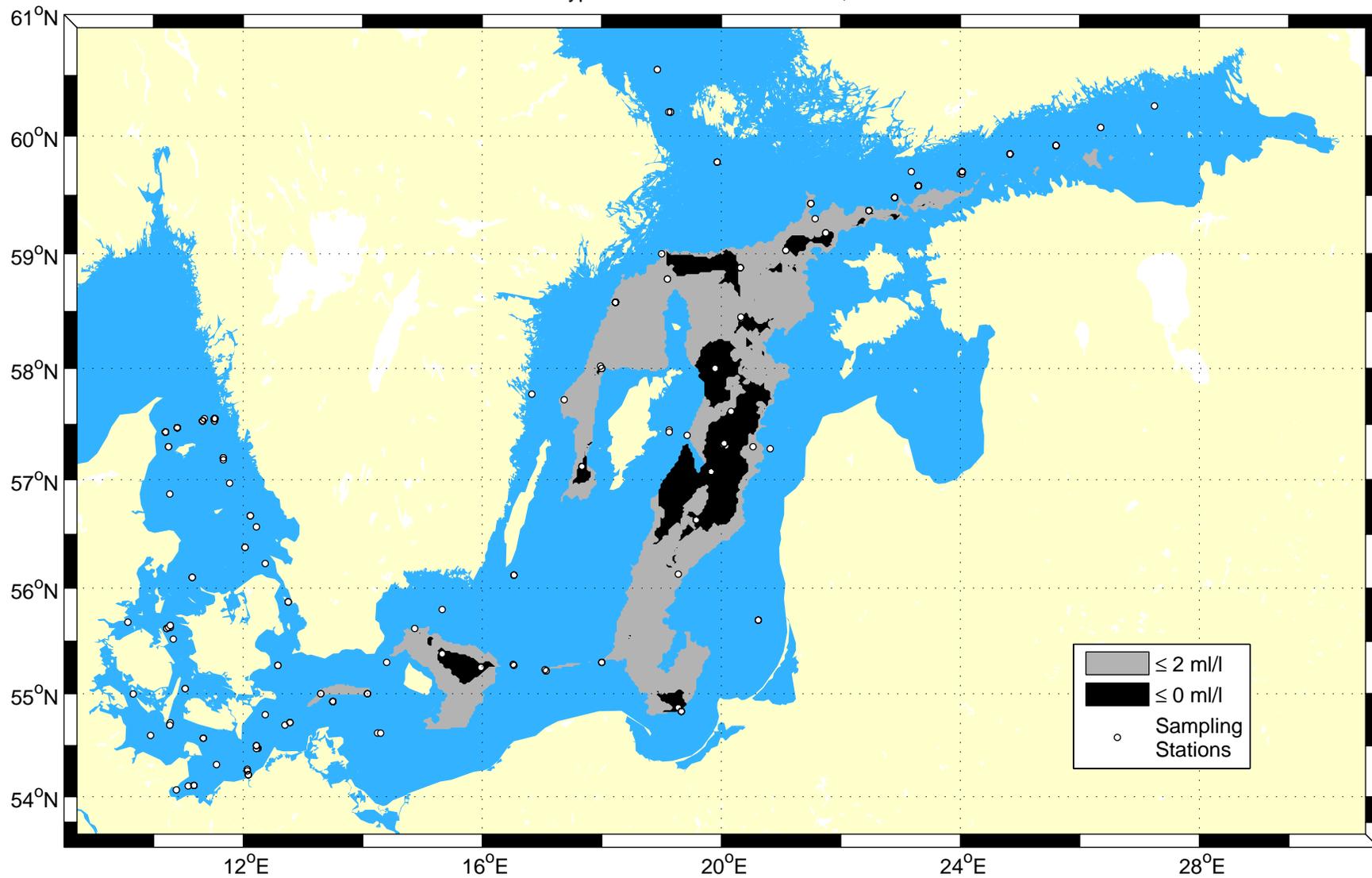
Extent of hypoxic & anoxic bottom water, Autumn 1977



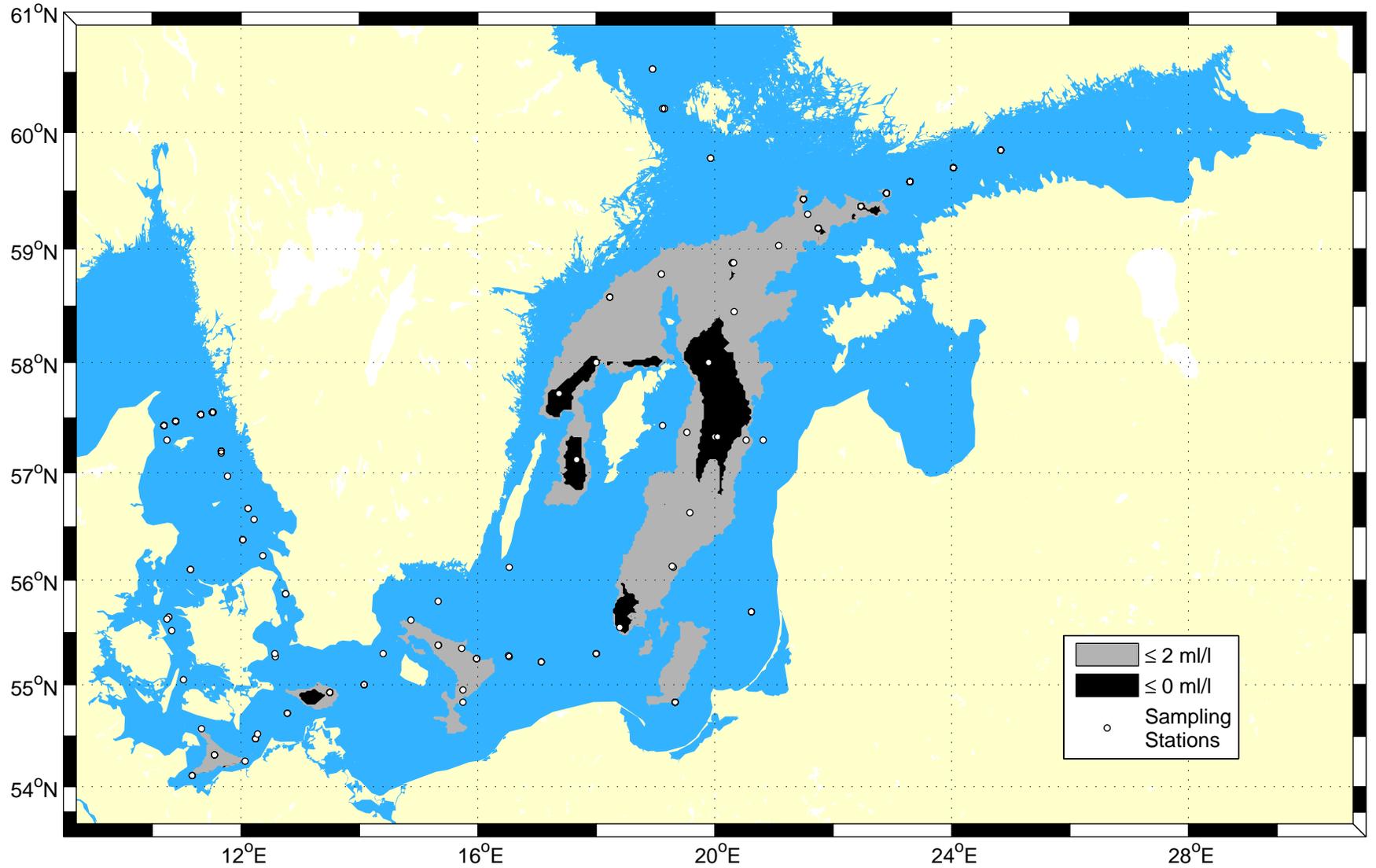
Extent of hypoxic & anoxic bottom water, Autumn 1976



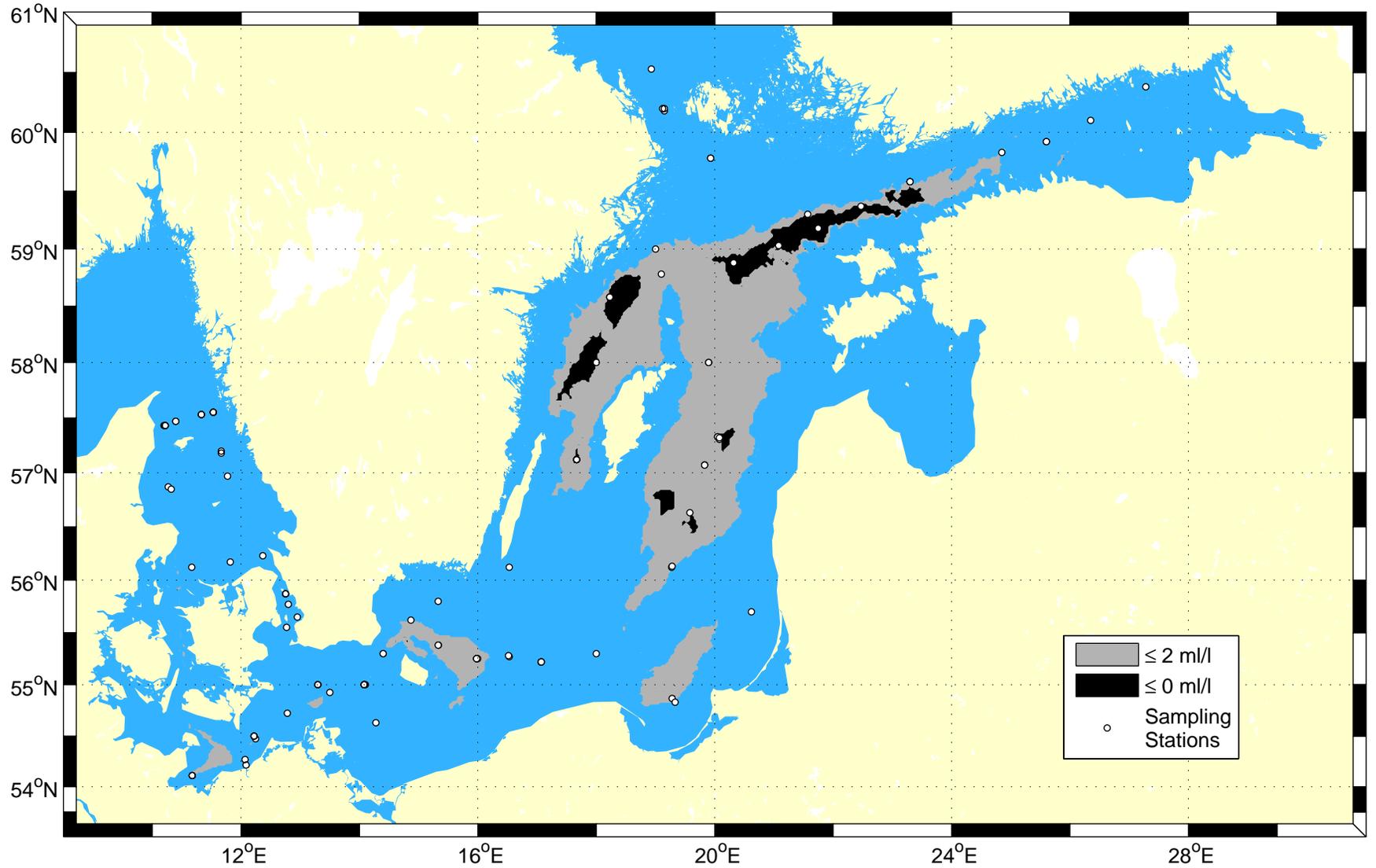
Extent of hypoxic & anoxic bottom water, Autumn 1975



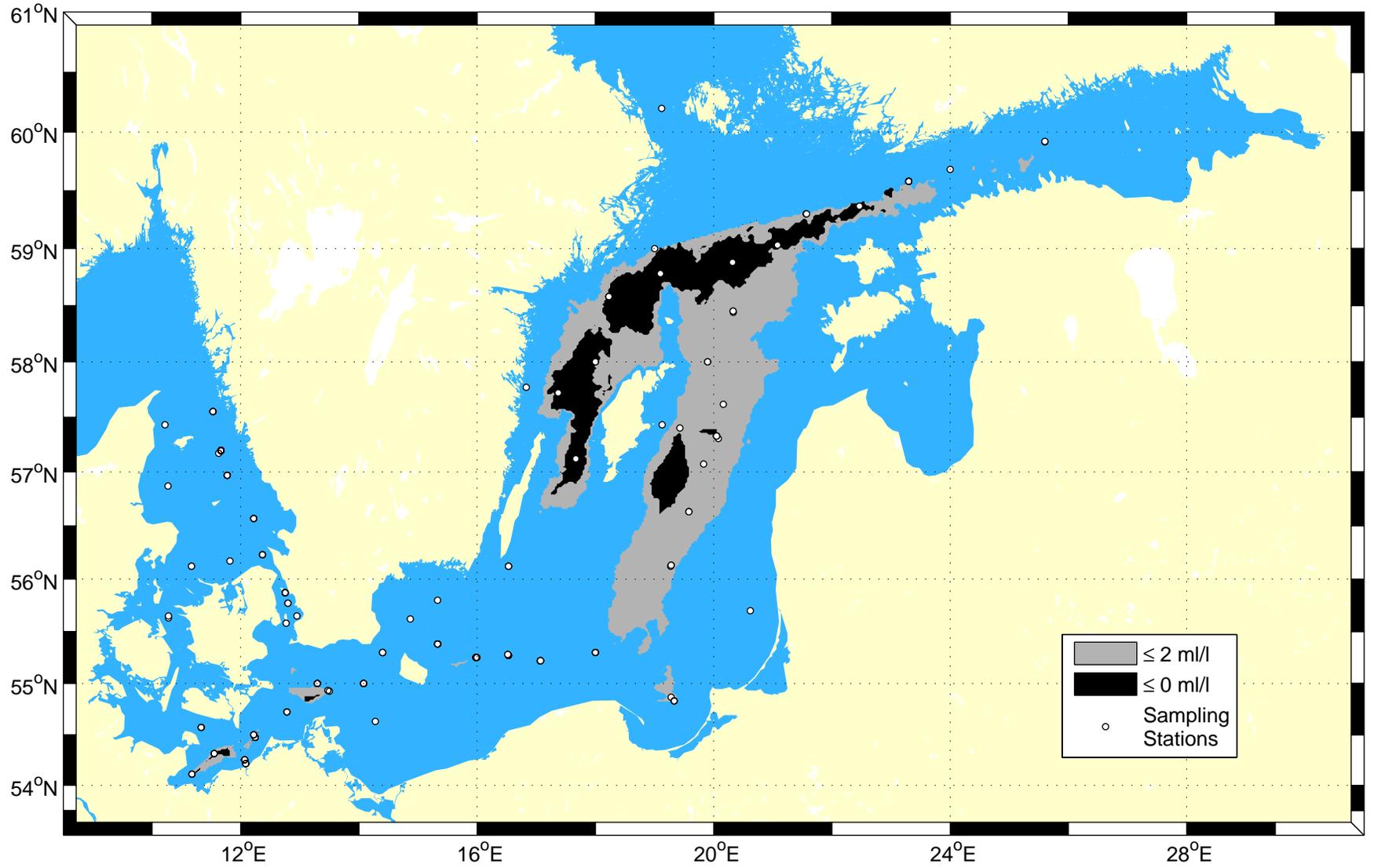
Extent of hypoxic & anoxic bottom water, Autumn 1974



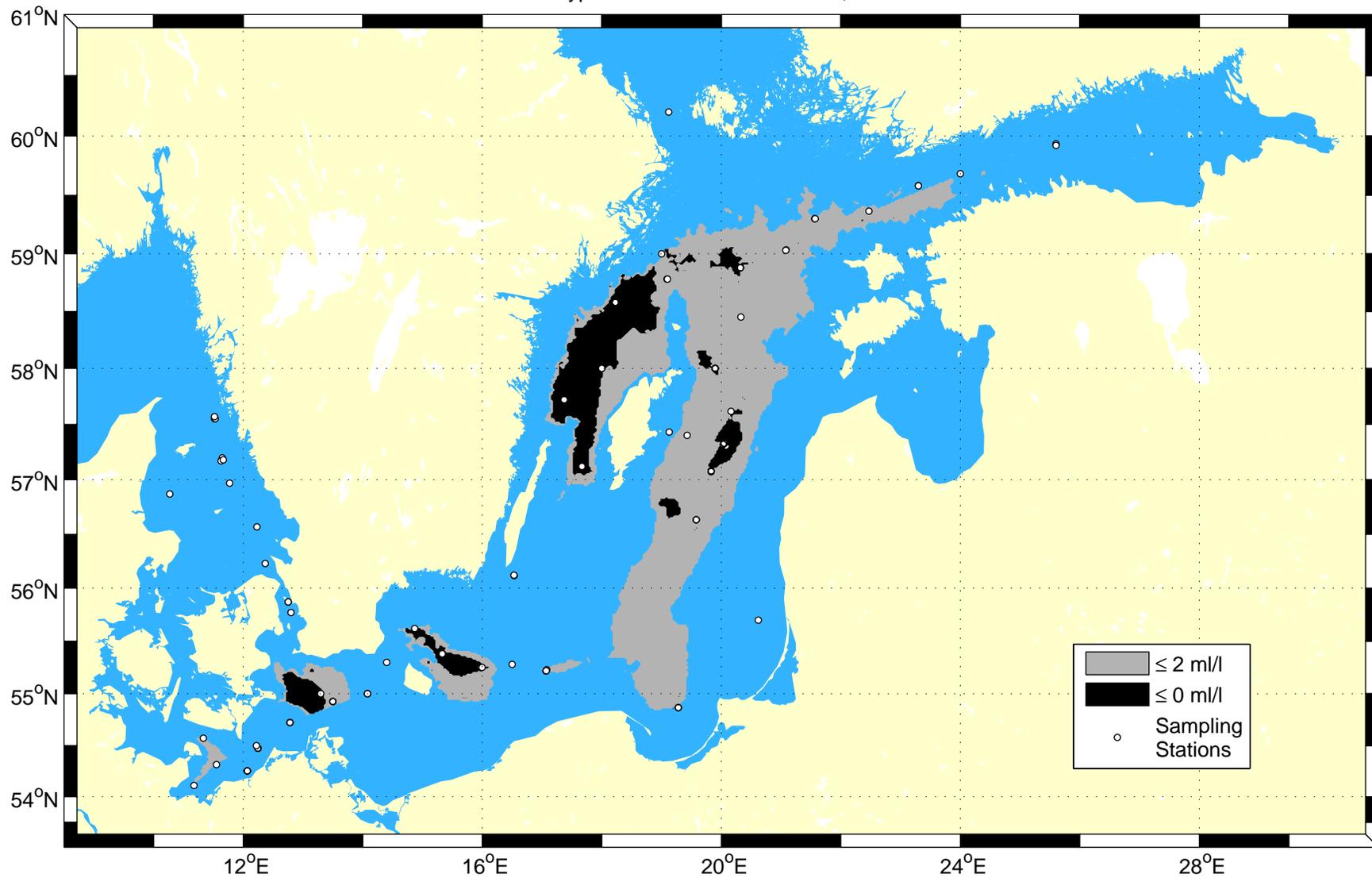
Extent of hypoxic & anoxic bottom water, Autumn 1973



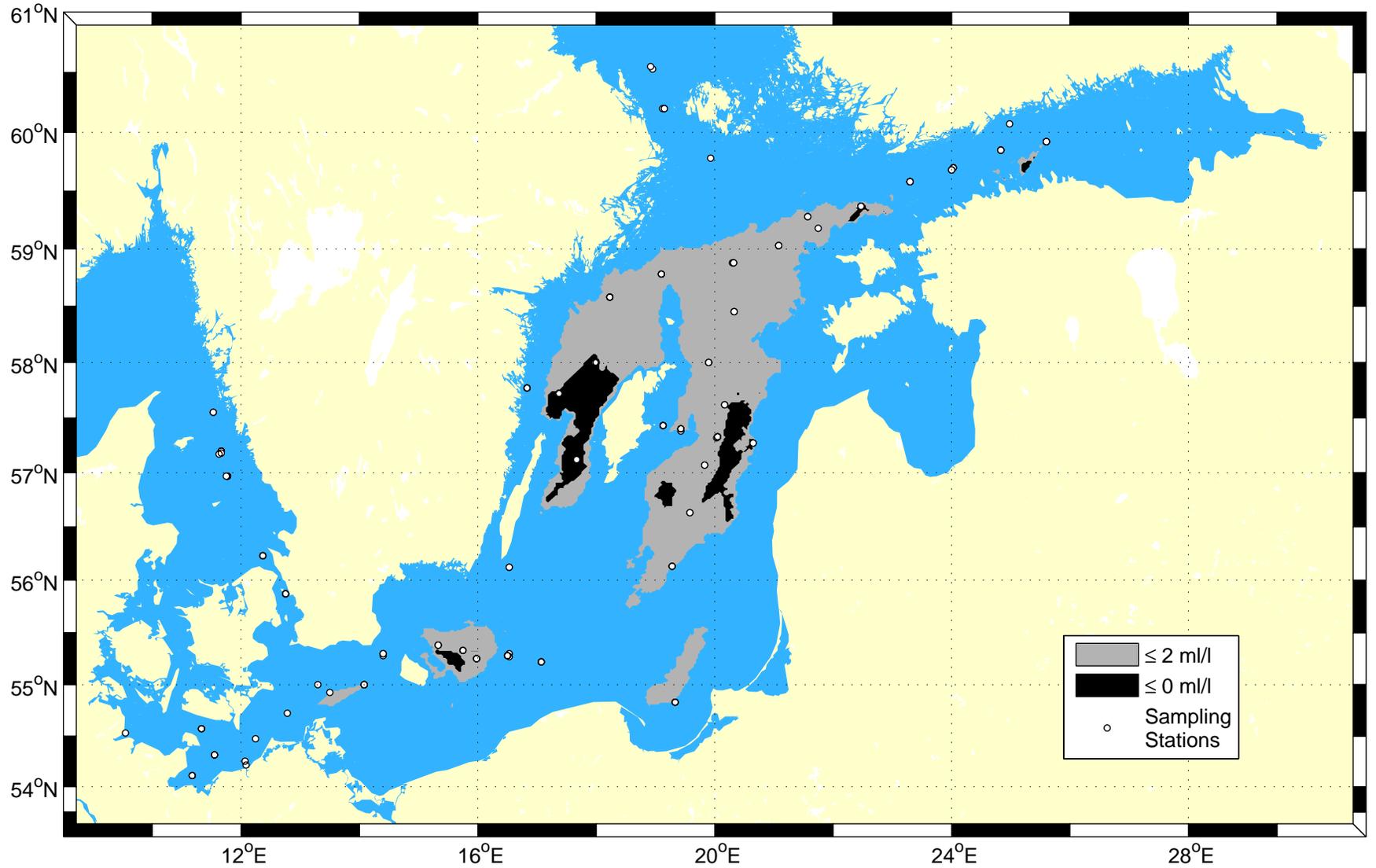
Extent of hypoxic & anoxic bottom water, Autumn 1972



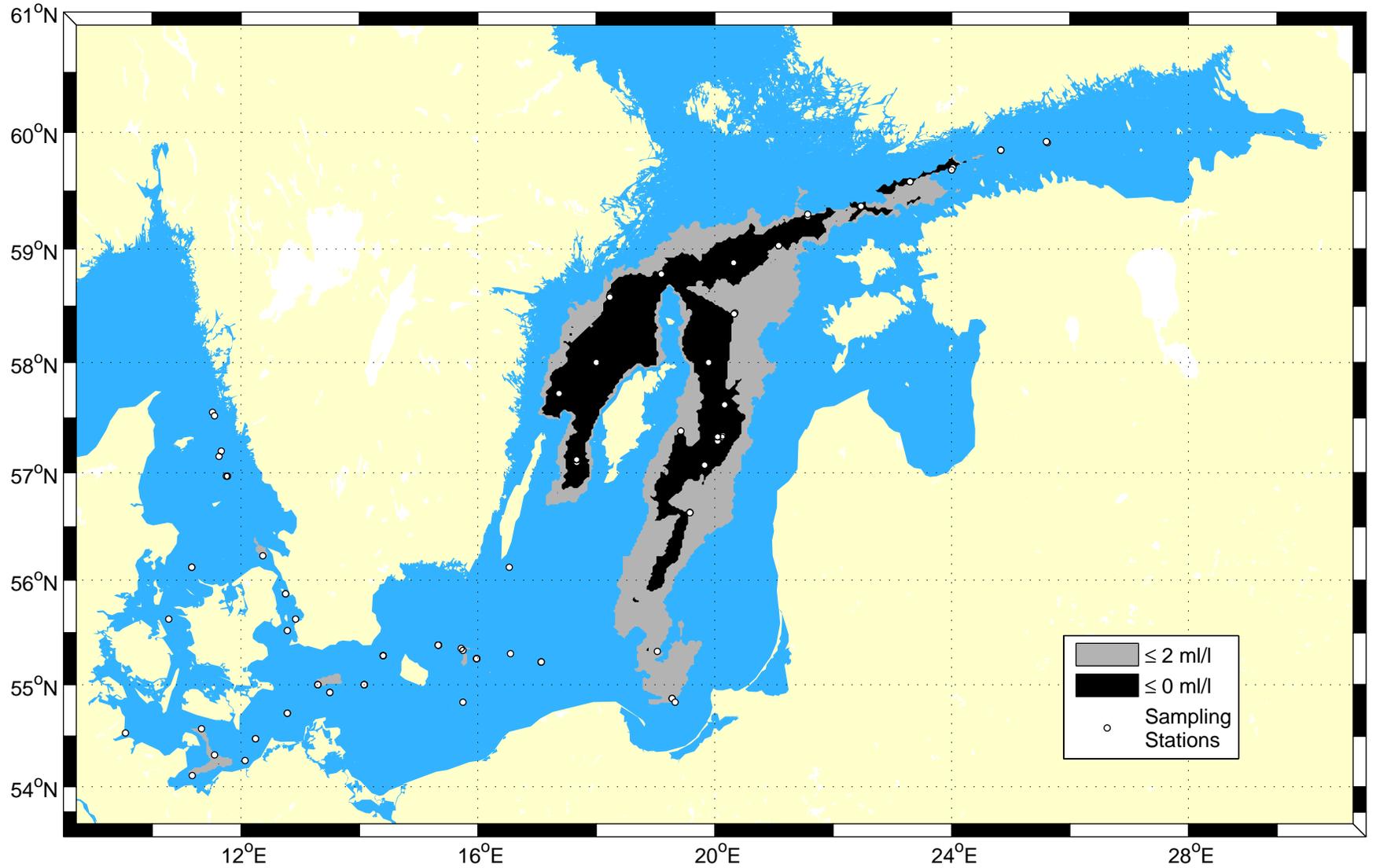
Extent of hypoxic & anoxic bottom water, Autumn 1971



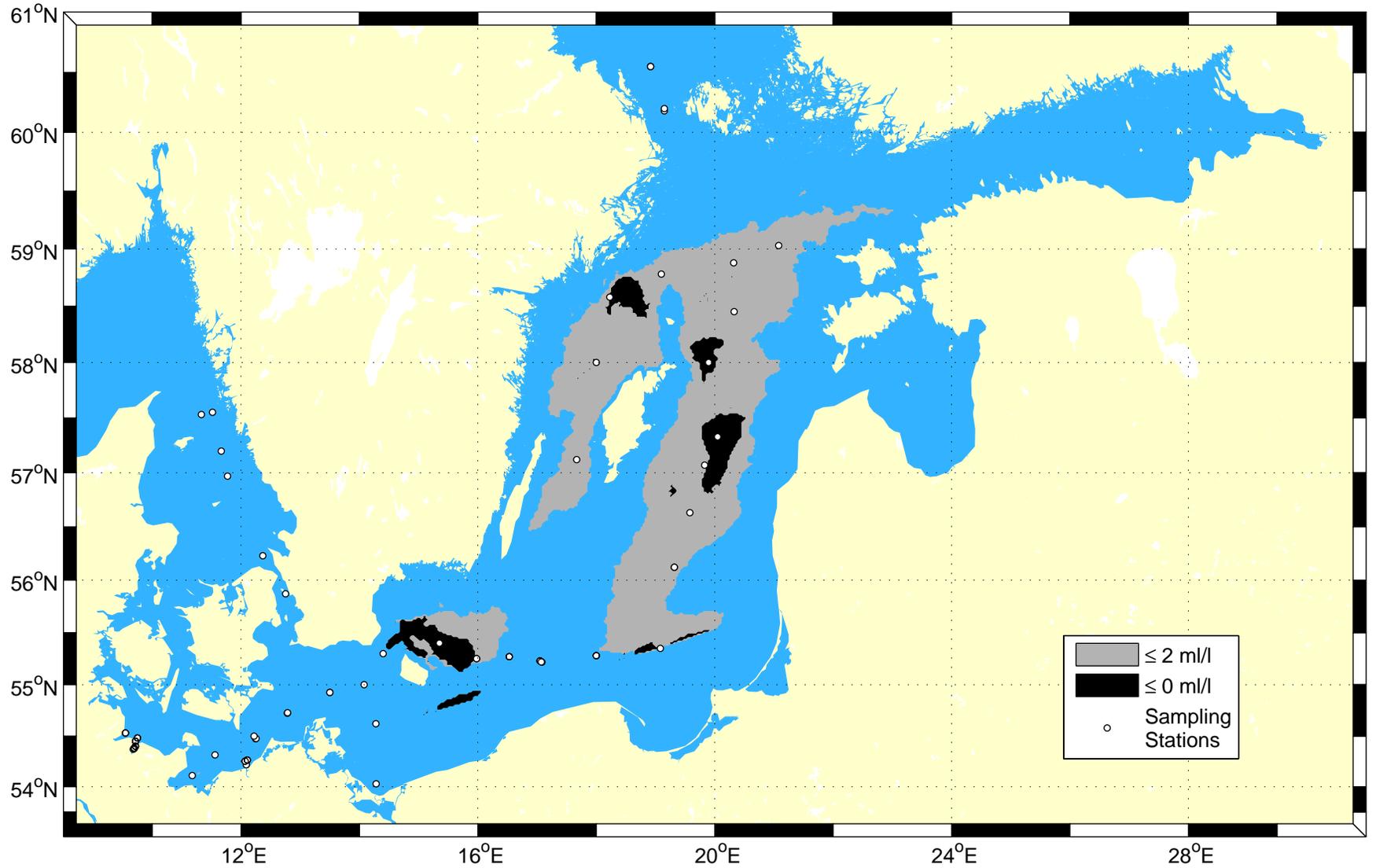
Extent of hypoxic & anoxic bottom water, Autumn 1970



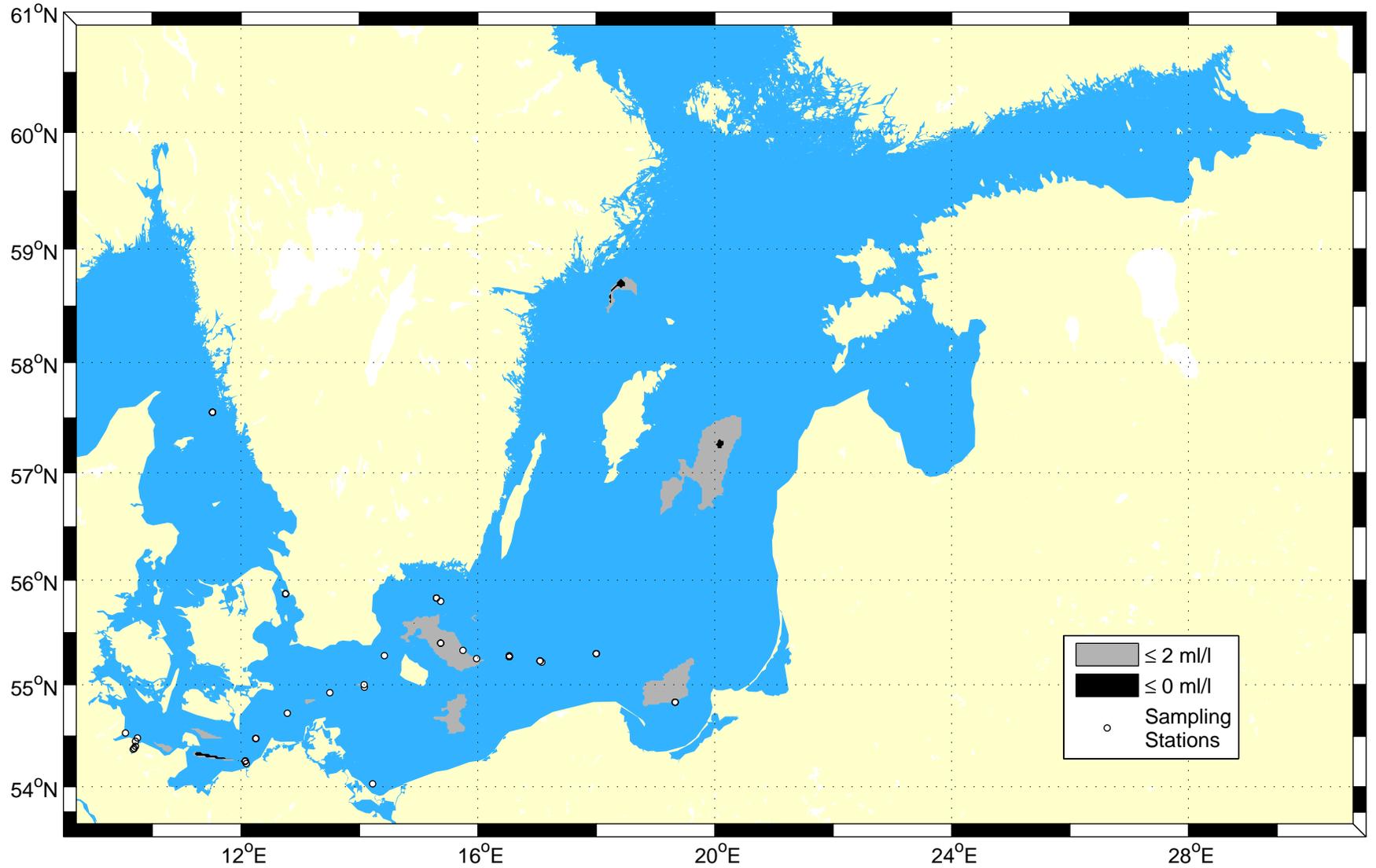
Extent of hypoxic & anoxic bottom water, Autumn 1969



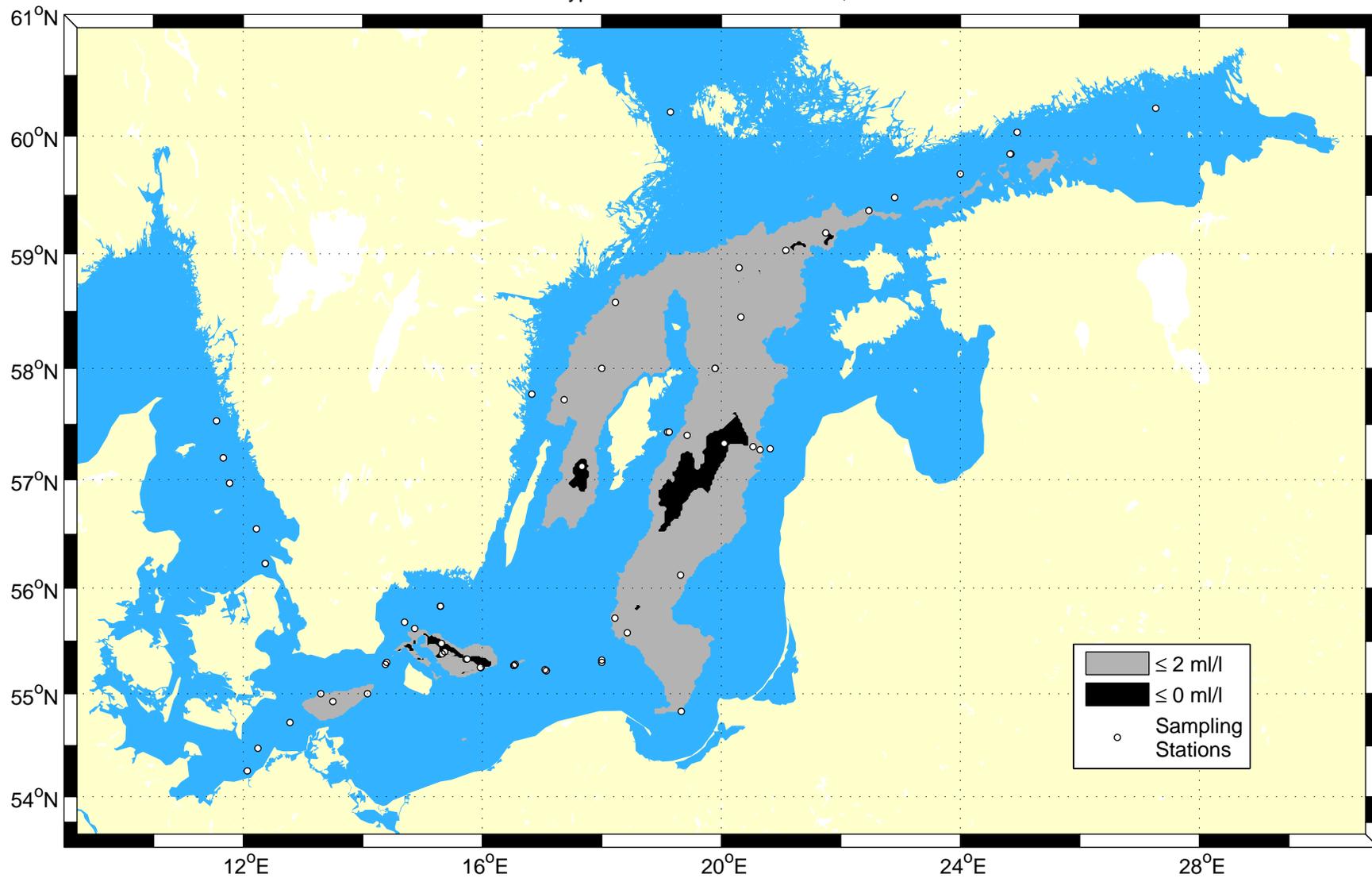
Extent of hypoxic & anoxic bottom water, Autumn 1968



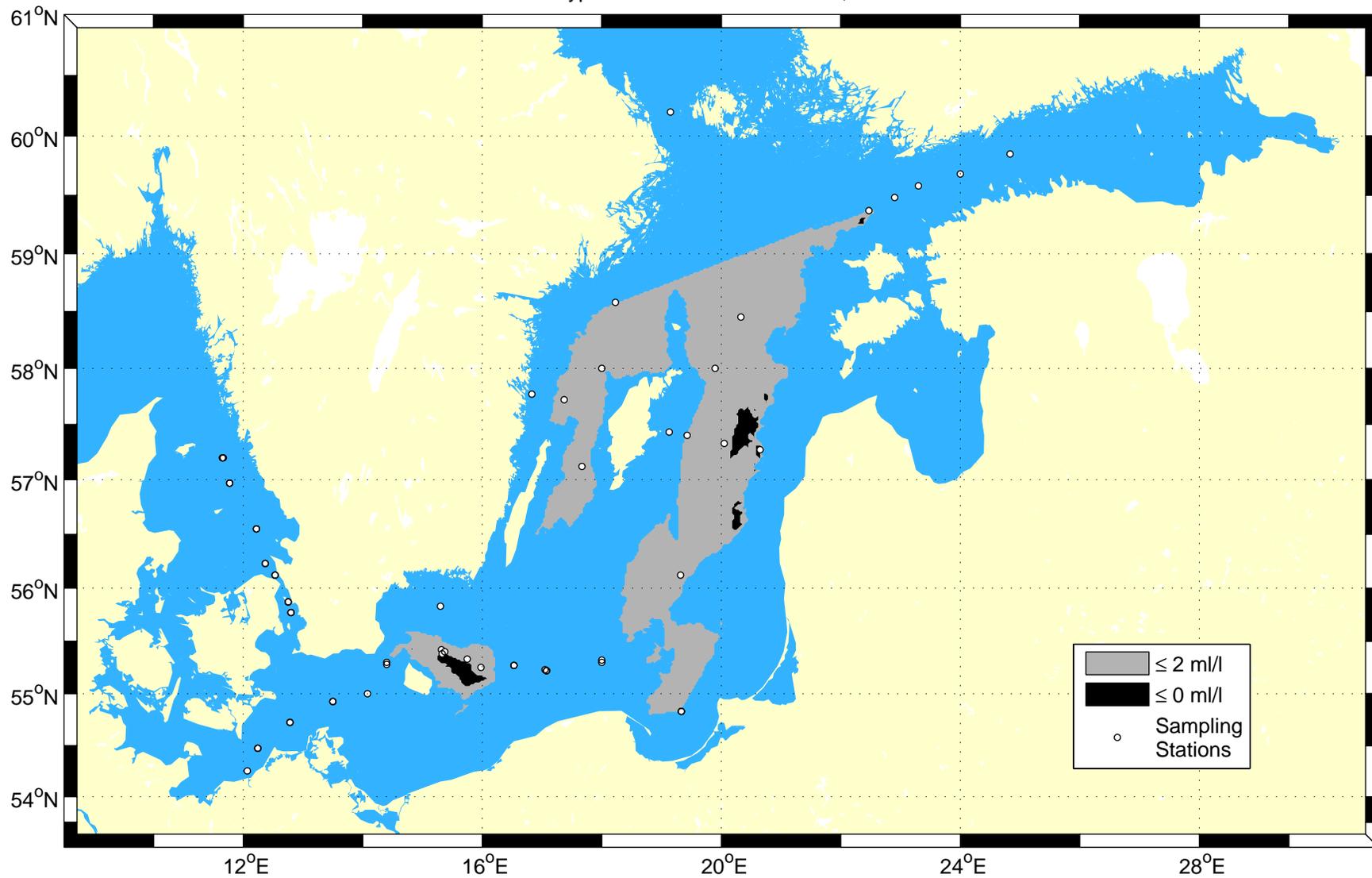
Extent of hypoxic & anoxic bottom water, Autumn 1967



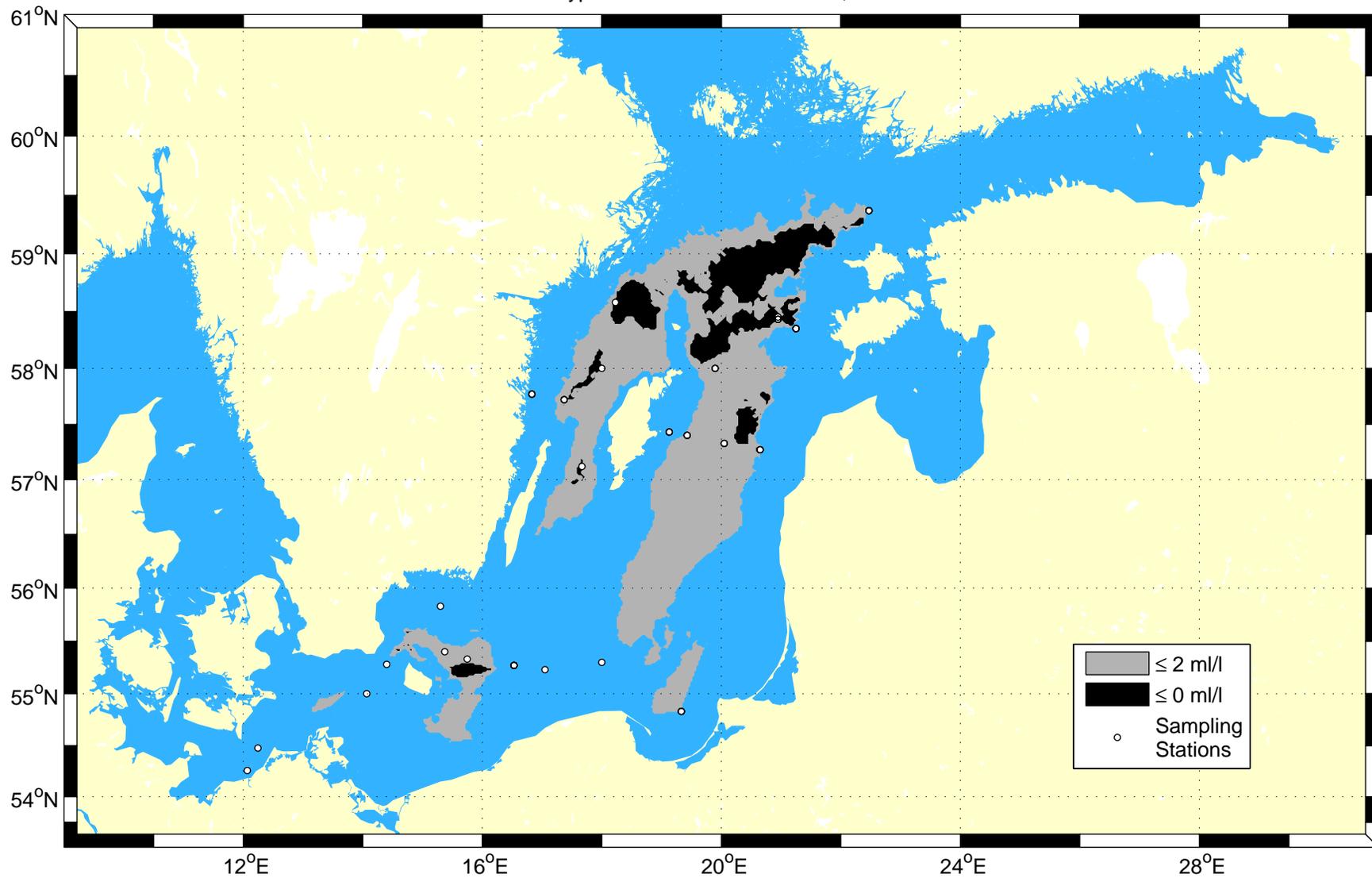
Extent of hypoxic & anoxic bottom water, Autumn 1966



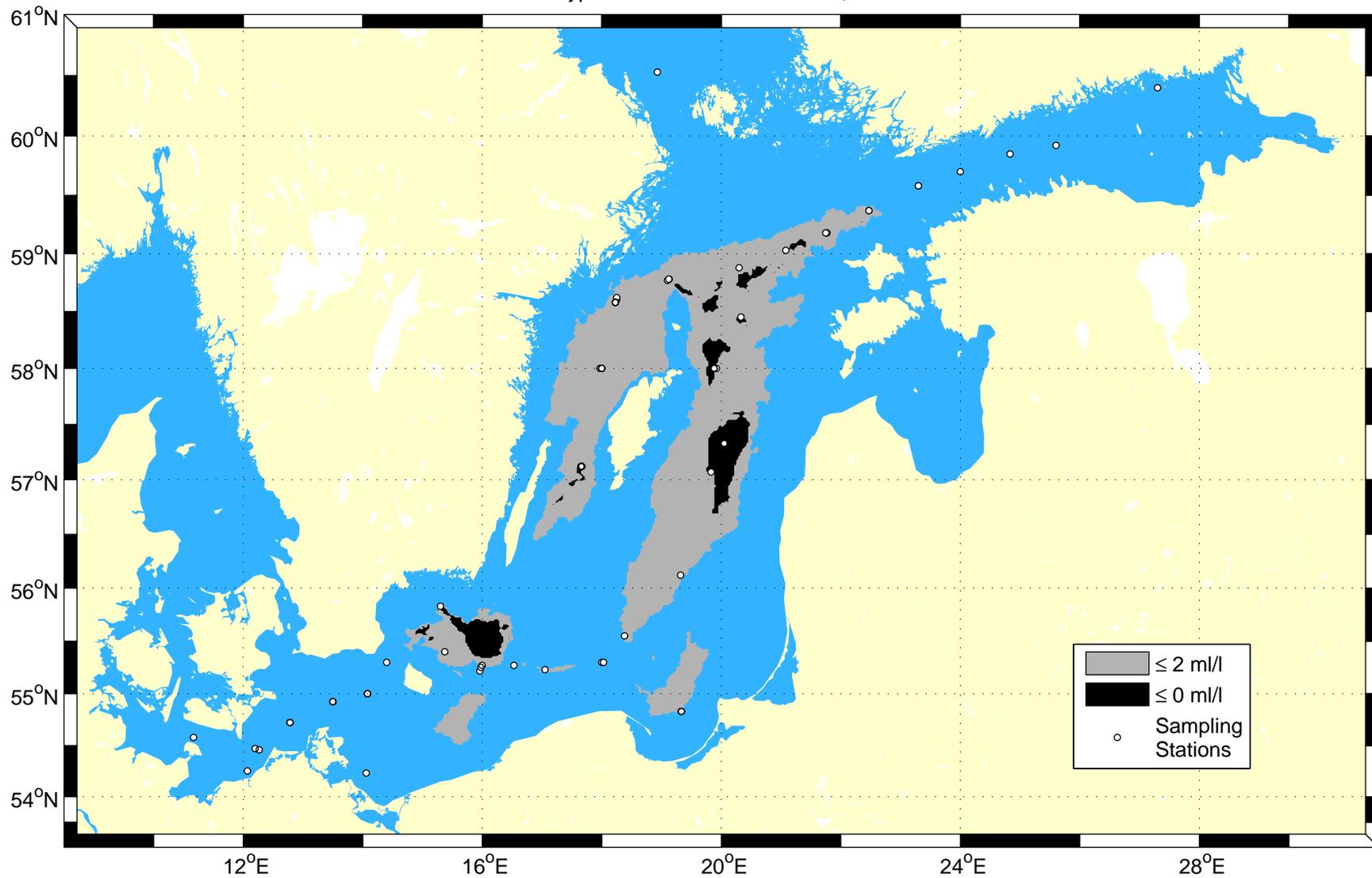
Extent of hypoxic & anoxic bottom water, Autumn 1965



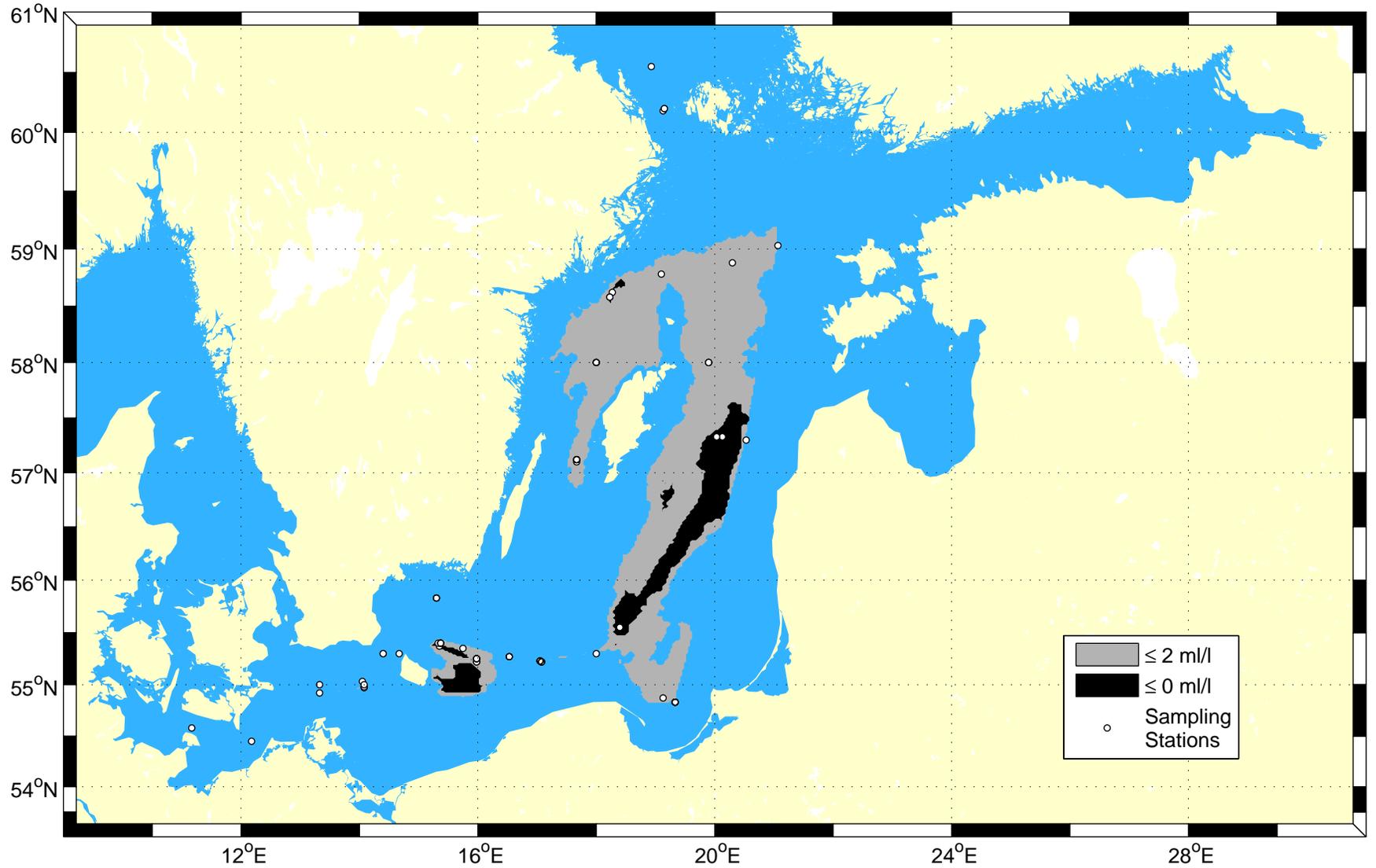
Extent of hypoxic & anoxic bottom water, Autumn 1964



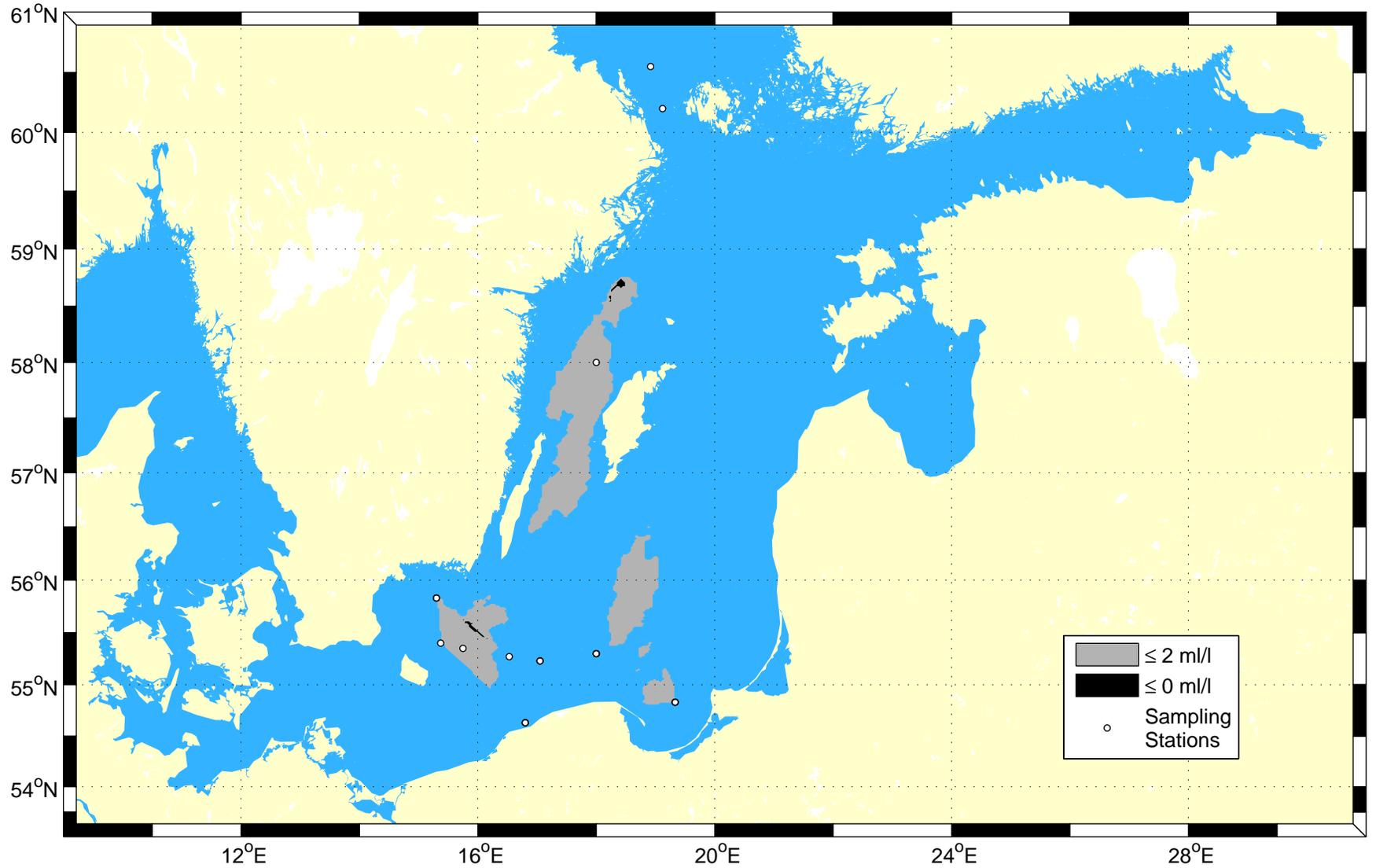
Extent of hypoxic & anoxic bottom water, Autumn 1963



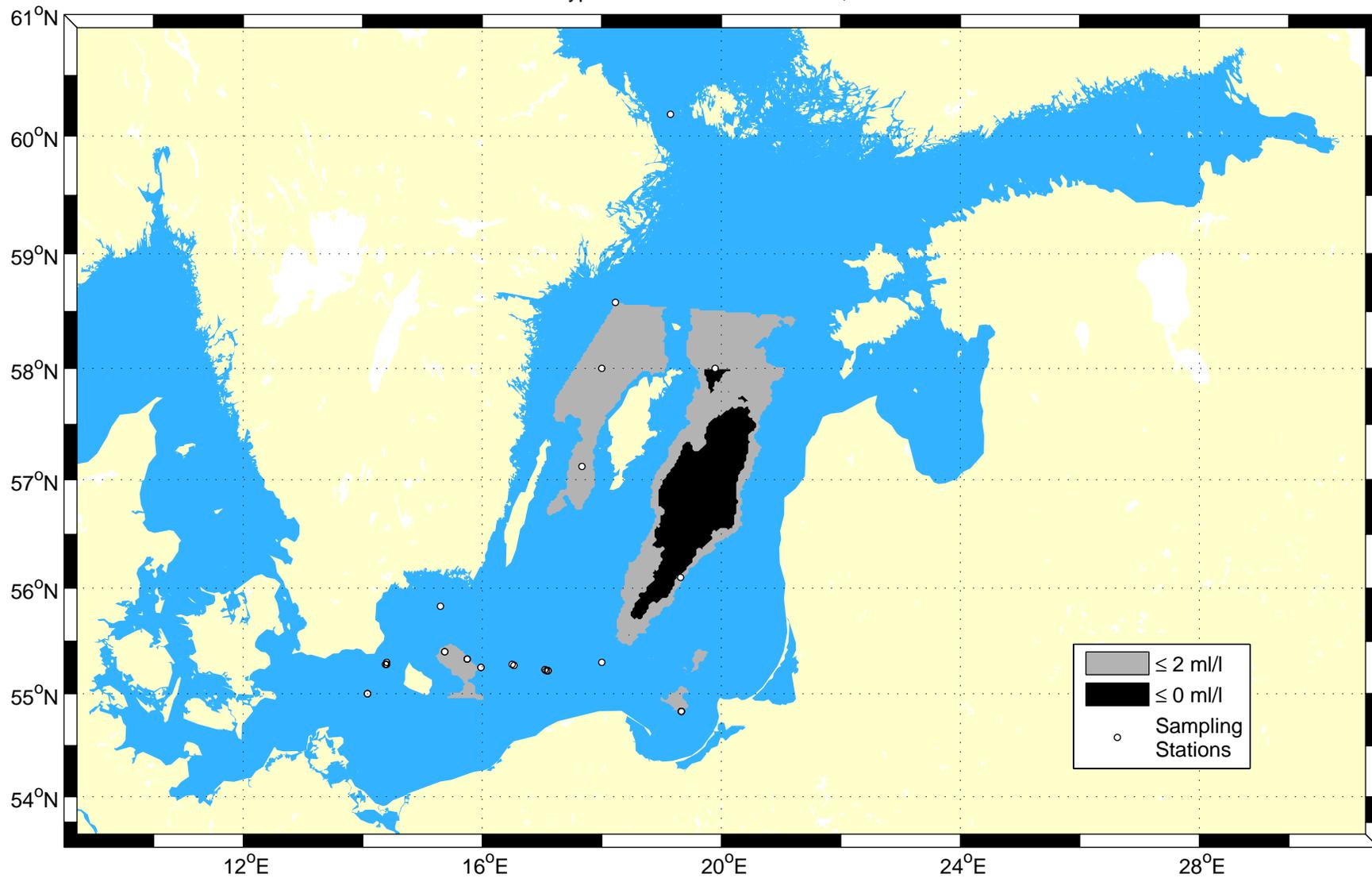
Extent of hypoxic & anoxic bottom water, Autumn 1962



Extent of hypoxic & anoxic bottom water, Autumn 1961



Extent of hypoxic & anoxic bottom water, Autumn 1960







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