# Distribution of cyanobacteria blooms in the Baltic Sea

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# Distribution of cyanobacteria blooms in the Baltic Sea

Bengt Karlson*, Kari Eilola, Johannes Johansson, Johanna Linders, Malin Mohlin, Anna Willstrand Wranne and Irene Wåhlström
Swedish Meteorological and Hydrological Institute, Oceanography, Sven Källfelts gata 15, 426 71 Västra Frölunda, Sweden, *bengt.karlson@smhi.se

## Abstract

Blooms of diazotrophic cyanobacteria in the Baltic Sea are common mainly in summer months. The dominant genera are *Aphanizomenon*, *Dolichospermum* (syn. *Anabaena*) and *Nodularia* of which the latter produces the hepatotoxin nodularin. Surface accumulations of cyanobacteria are observed offshore, along coasts and in archipelagos. The blooms are of concern to society in several ways, e.g. they affect tourism, ecosystem services and provide input of atmospheric nitrogen that may increase primary production leading to hypoxia in deep water. In this study, cyanobacteria distribution was examined by water sampling and microscope analysis and by automated measurements of fluorescence of the pigment phycocyanin using a Ferrybox-system as instrument platform. The *in situ* data were combined with ocean colour data from satellite remote sensing (Aqua-MODIS) to describe bloom distribution and spatial and temporal variability. Satellite observations showed a large inter-annual variability in the distribution of near surface cyanobacteria accumulations compared to other data. The *in situ* observations showed a different pattern in cyanobacterial bloom distribution with regular blooms most years. Dissimilar cloud cover in different years may bias the satellite-based results.

*Keywords:* Cyanobacteria, nitrogen fixation, Baltic Sea, *Nodularia*, Ferrybox, remote sensing

## Introduction

The Baltic Sea is a brackish water area in northern Europe and may be considered as a large sill fjord. The area is strongly influenced by riverine input. In the northernmost part, the Bothnian Bay, the surface salinity is approximately 3 and in the middle part, the Bothnian Sea, it is around 5. Further south, in the Baltic Proper, the surface salinity varies between approximately 6 and 10.
Water exchange with the North Sea – Skagerrak - Kattegat is through the Sound (Öresund) and the Belt Sea between Sweden and Denmark. Replenishment of the deep water occurs intermittently, often with several years in between. The Baltic Sea is considered to be eutrophic. Algal blooms are recurrent phenomena and a large part of the sea floor has low oxygen or anoxic conditions. Cyanobacteria blooms were observed already in the mid 19th century. During the second part of the 20th century, the frequency of cyanobacteria blooms may have increased. Surface accumulations consisting mainly of the diazotrophic (nitrogen fixing) genera *Aphanizomenon*, *Dolichospermum* (syn. *Anabaena*) and *Nodularia,* are a nuisance to tourism and also a health problem. *Nodularia spumigena* Mertens ex Bornet & Flahault produces the hepatoxin nodularin. Mortalities of dogs are regularly reported and small children should avoid surface scums. Picoplanktonic *Synechococcus*-like cyanobacteria are numerically dominant in summer in the Baltic Sea and are sometimes dominant in biomass. Dinoflagellates, diatoms and large cyanobacteria most often dominate the biomass. During summer nitrate and ammonium is often depleted in near surface water and the diazotrophic species have a competitive advantage compared to other phytoplankton. Nitrogen fixation adds nitrogen to the system and may increase eutrophication.
The aim of this article is to address the distribution of cyanobacteria blooms using a multi method approach. Satellite remote sensing, i.e. ocean colour measurements, is used to give a large horizontal coverage of surface accumulations detected, and an automated observation system on a merchant vessel, i.e. a Ferrybox system, provides data on the fluorescence of chlorophyll and phycocyanin, as proxies for total phytoplankton biomass and the biomass of certain cyanobacteria. Water sampling from research vessels and subsequent microscope

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analysis of phytoplankton gives detailed taxonomic information and biomass based on cell volume measurements. By combining the different data sources a broad view of the cyanobacteria bloom distribution can be constructed.

## Material and Methods

*Water sampling and microscopy*

Water samples were collected monthly between 1999-2015 as part of the Swedish National Marine Monitoring programme by SMHI and the University of Umeå. A tube was used to collect water from 0-10 m depth. Samples were preserved using Lugol's iodine and the whole phytoplankton community except for autotrophic picoplankton was analysed using the Utermöhl method. Cells were measured and cell volumes were estimated according to Olenina et al. (2006). Data was downloaded from the Swedish National Oceanographic data Centre at SMHI and processed using the Plankton Toolbox software (Karslon et al. 2014). Data were plotted using the R software and the ggplot2 library for box and whisker plots, details are available at http://www.r-project.org and http://ggplot2.org/.

*Ferrybox – phycocyanin flurescence*

The merchant vessel TransPaper was used as an instrument platform for a Ferrybox system described by Karlson et al. (2016). The fluorescence of phycocyanin was used as a proxy of cyanobacteria biomass (Seppälä et al. 2007). The ship covers a large part of the Baltic Sea twice a week (Fig. 1).

*Satellite remote sensing*

Ocean colour data was used to detect surface accumulations of cyanobacteria during cloud free condtions in the months June, July and August during the period 2002-2015. Data from the MODIS sensor on satellites Aqua and Terra were downloaded from NASA and processed by SMHI according to Öberg and Karlson (2014) using a method originally described by Kahru (2007). Areas shallower than 10 m were excluded in the analysis due to problems with artefacts related to the sea floor. In the Gulf of Finland and the Gulf of Riga, the data from areas shallower than 30 m were excluded due to high sediment content.

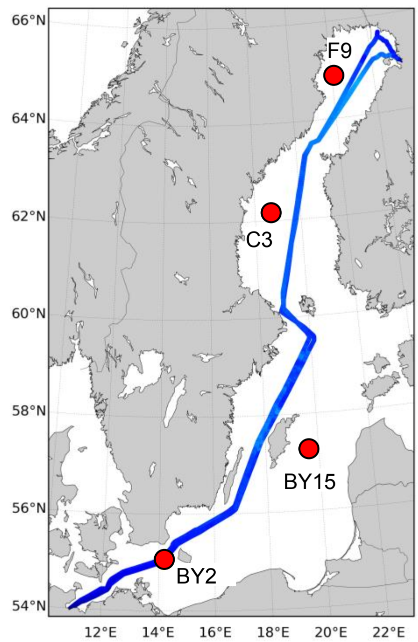


Fig. 1. Red symbols represent sampling locations for phytoplankton data presented in Figs. 4 and 5. The blue line indicate the route of ship TransPaper in 2015. Data from latitude 54-64° N are presented in Fig. 3.

## Results and Discussion

The satellite remote sensing data are summarized in Fig. 2. The number of days with observed surface accumulations in summers (Jun. - Aug.) for years 2002-2015 is illustrated. The highest number of surface accumulations were observed in the Baltic proper, only a few observations were made in the Bothnian Sea and none in the Bothnian Bay. Blooms in the south-western Baltic Proper were in general few except for year 2006. An example of Ferrybox data on phycocyanin fluorescence is presented in Fig. 3. When comparing results between phycocyanin fluorescence and satellite observations of surface accumulations of cyanobacteria from year to year (data not shown) there was no consistent pattern found. This may be due to that the water intake of the Ferrybox system is at 3 m depth while satellites mainly detect near surface accumulations of cyanobacteria. During windy conditions cyanobacteria are mixed down in the water column and do not form surface scums. During cloudy conditions detection of ocean colour from satellites is not possible. Thus satellite observations may underestimate the frequency of observed cyanobacteria blooms.

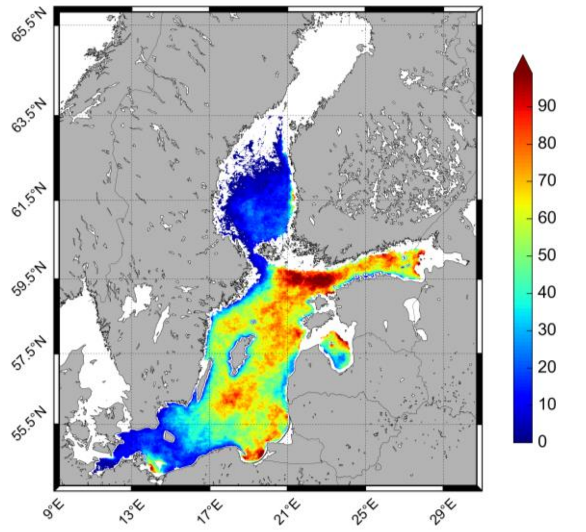


Fig. 2. The number of days of detected surface accumulations of cyanobacteria in June-August using satellite remote sensing in years 2002-2015, NASA Aqua-MODIS processed by SMHI.

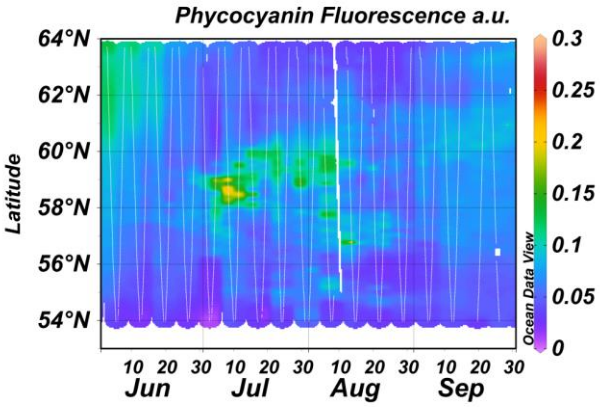


Fig. 3. Phycocyanin fluorescence detected using sensor on Ferrybox-system. See Fig 1. for route of ship.

Data on the distribution of selected cyanobacteria from water sampling and subsequent microscope analysis are summarised in Fig. 4 and 5. The genus *Nodularia* was mainly observed in June-August in the Baltic Proper and only occassionally in the Bothnian Sea. It was almost absent in the Bothnian Bay. *Aphanizomen* sp. was common both in the Baltic Proper and in the Bothnian Sea and absent in the Bothnian Bay. Salinity is likely to be a structuring factor for the distibution of cyanobacteria in the Baltic Sea. Experiments using cultures of *Nodularia spumigena* and *Aphanizomenon* sp. support this (Rakko and Seppälä 2014).

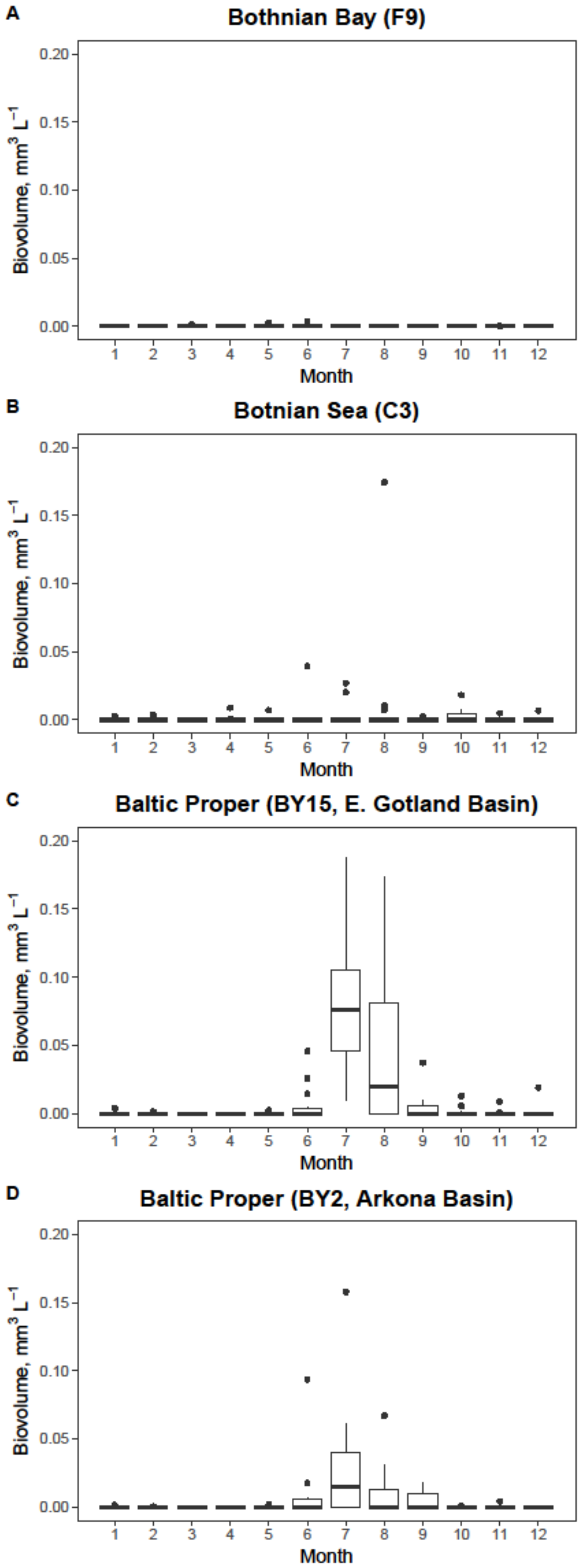


Fig. 4. Monthly distribution of *Nodularia* at four stations in the Baltic Sea. Data is based on a time series 1999-2015 with monthly sampling. Mid of box is median, lower hinge represents 25% quantile and higher 75% quantile. See Material & Methods for details.

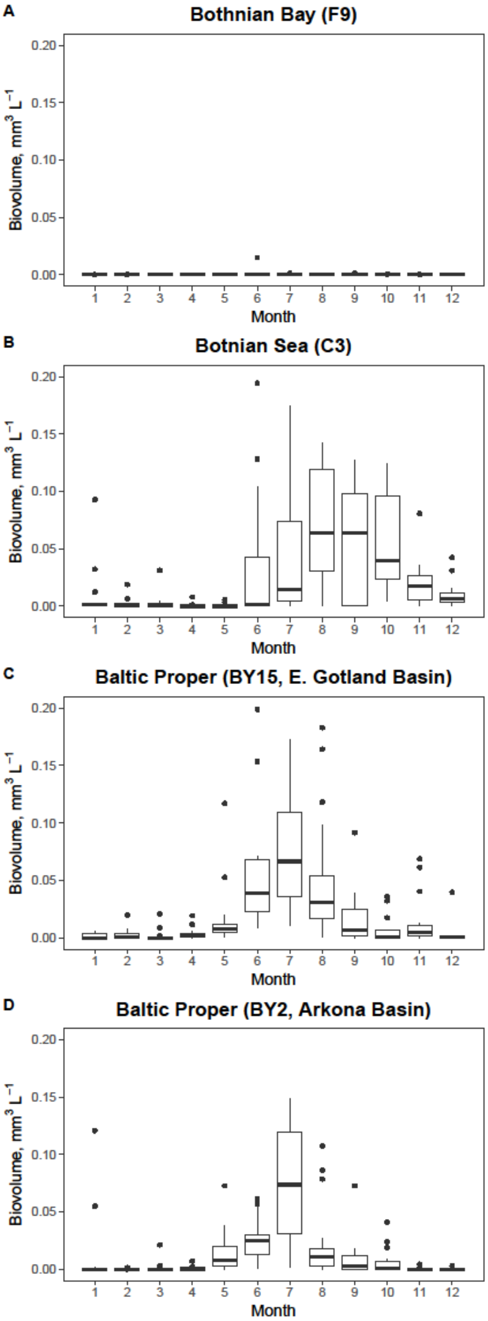


Fig. 5. Monthly distribution of *Aphanizomenon* spp. at four stations in the Baltic Sea. Data is based on a time series 1999-2015 with monthly sampling. Mid of box is median, lower hinge represents 25% quantile and higher 75% aquantile. See Material & Methods for details.

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