Cyanobacterial blooms in the Baltic Sea

SMHI

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Key Message

Cyanobacterial blooms in the Baltic Sea during the summer 2006 had the third greatest extent during the period 1997-2006. The duration of the bloom was equal to the bloom 2005 but the intensity of the bloom was the greatest during the period 1997-2006.

Nutrient conditions in the southern Baltic Proper during 2006 show increased phosphate level in the surface layer, while phosphate concentrations were back to normal in the northern and central Baltic Proper.

Sunny, warm and calm weather during early July 2006, with water surface temperatures well over 20 degree C., in combination with available phosphate, resulted in a widespread bloom. Affected areas stretched from the Bothnian Sea, the Gulf of Finland, the Gulf of Riga, the Baltic Proper, the Gulf of Gdansk, the Belt Sea and Kattegat.

Results and Assessment

Relevance of the indicator for describing developments in the environment

The cyanobacterial blooms are depended on the available amounts of phosphate in the surface water and favorable weather conditions during the summer. After the inflow to the Baltic Sea in 2002/2003 phosphate rich deep water was transported to the surface water and caused elevated phosphate concentrations (double normal values) both during 2004 and 2005. However, summer 2004 was both cold and windy and when the warmth came in August only minor blooms were detected. The phosphate concentrations in the surface water during winter and early spring 2005 remained elevated and together with warm, calm and sunny weather contributed to the intense and widespread bloom during July 2005.

High concentrations of phosphorus (normal winter values, 0.5-0.6 µmol/l) were also available in the Arkona and the Bornholm Deep, during the whole summer but no bloom was detected. This was confirmed by ship measurements in the area. Why only minor cyanobacterial bloom appeared in this area is unclear. (SMHI, R/V Argos cruise report, 8-13 August, 2005)

The phosphorus concentrations in the northern Baltic Proper during 2006 were back to normal during the spring period, while in the southern parts of the Baltic Proper, the Sound, Hanö Bight, Arkona and Bornholm Basin concentrations remained elevated (0.7-0.8 µmol/l). As a result of warm and calm weather (surface temperature well over 20 degrees C., see R/V Argos, cruise report 10-15 July) during July and August the most intense bloom during the analyzed period (1997-2006) occurred.

To be able to compare the blooms between different years definitions of bloom normalized **duration (T)**, **extent (A)** and **intensity (I)** has been developed. Based on the yearly summaries (see example in figure 1) where the area (a_i) is equal to the extent that is covered by surface accumulations of blooms during (i) number of days, the normalized duration and extent is given. Where (i) ranges from 1 to the maximum number of days with bloom observations during the current year. The intensity is given in “extent days” or km^2days. (Hansson, 2006)

Duration, T =	$\frac{\sum a_i * i}{\sum a_i}$ $[days]$
Area, A =	$\frac{\sum a_i * i}{\sum i}$ $[km^2]$
Intensity,	I = A * T [km^2 *days*]

Assessment 2006

The first cyanobacterial blooms was detected on the 2nd of July north west of Bornholm and around Öland and Gotland, though uncertain blooms had been observed since the 30th of June. Water samples taken by R/V Argos (See SMHI, AlgAware, No 6, 13-16 June) in mid June indicated high numbers of cyanobacterial filaments (cf. *Nodularia* spp.) at BY2 and BY5 in the southern Baltic Proper.

Development of surface accumulations was quick and dense blooms covered almost all areas in the southern Baltic Proper and the eastern and western Gotland Basins within a week. Scattered blooms were also observed in the Gulf of Finland and the Gulf of Riga. Water samples taken from R/V Argos in mid July (See SMHI, R/V Argos, cruise report 10-15 July) confirmed that the toxic *Nodularia* sp. was present in the southern parts, while non-toxic *Aphanizomenon* sp. and *Anabena* sp. dominated around Gotland.

The bloom reached its maximum extent during 16th of August (~140 000 km^2). In late July blooms were also observed between Öland and Gotland, in the Kiel Bight and in the Sound. The first surface accumulations in the Bothnian Sea were observed on 26th of July and the blooms were mainly concentrated to the central parts.

Outflow between 17th of July and the 6th of August from the Baltic Proper through the Sound transported large amount of surface accumulation of algae to the southern Kattegat. Strong surface accumulation could also be seen during the cruise with R/V Argos in late August (See SMHI, R/V Argos, cruise report 25 August - 1st September). Measurement showed that the accumulations were dominated by *Nodularia* sp..

Observations of the bloom in the Baltic Proper continued to the 10th of August, while it became increasingly patchier.

Cloud conditions during early July were suitable for detection of cyanobacteria blooms. From mid and late July cloudy weather prevailed, which made detection of blooms difficult. In August the cloud cover was frequent and the bloom observation in the Bothnian Sea and Kattegat are likely underestimated.

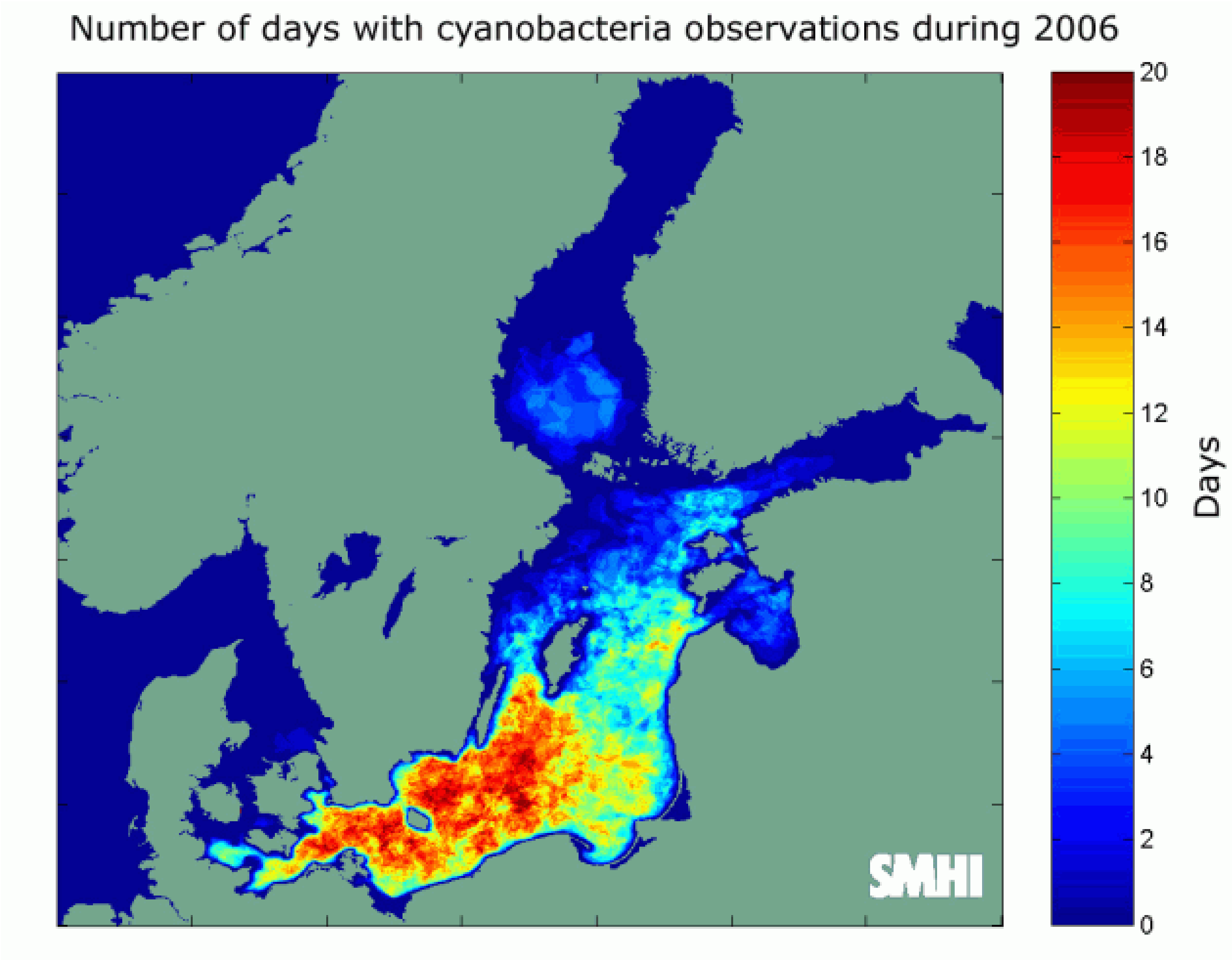

Figure 1. Number of days during 2006 with surface accumulations of cyanobacteria observed in each pixel based on NOAA-AVHRR satellite imagery. Note that five days of satellite data in August is missing due to technical problems at the receiving station.

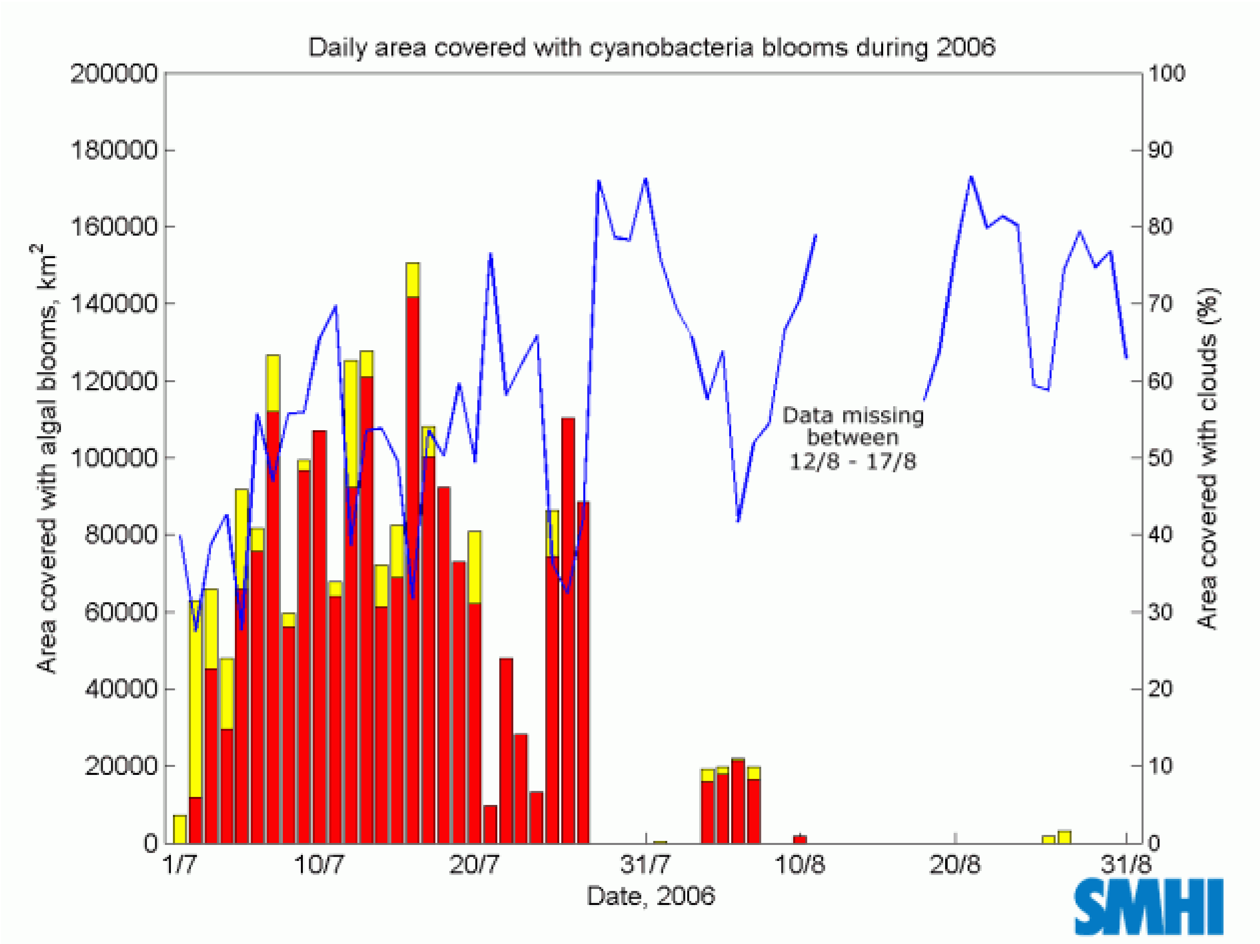

Figure 2. Daily extent of surface accumulations of cyanobacteria in the Baltic Sea during 2006, observed by NOAA-AVHRR satellite imagery. Red bars correspond to definite bloom observations and yellow bars indicate uncertain bloom observations. The blue line represents the integrated cloud cover (in percent of the total area) over the whole analyzed area. Note that five days of satellite data in August is missing due to technical problems at the receiving station.

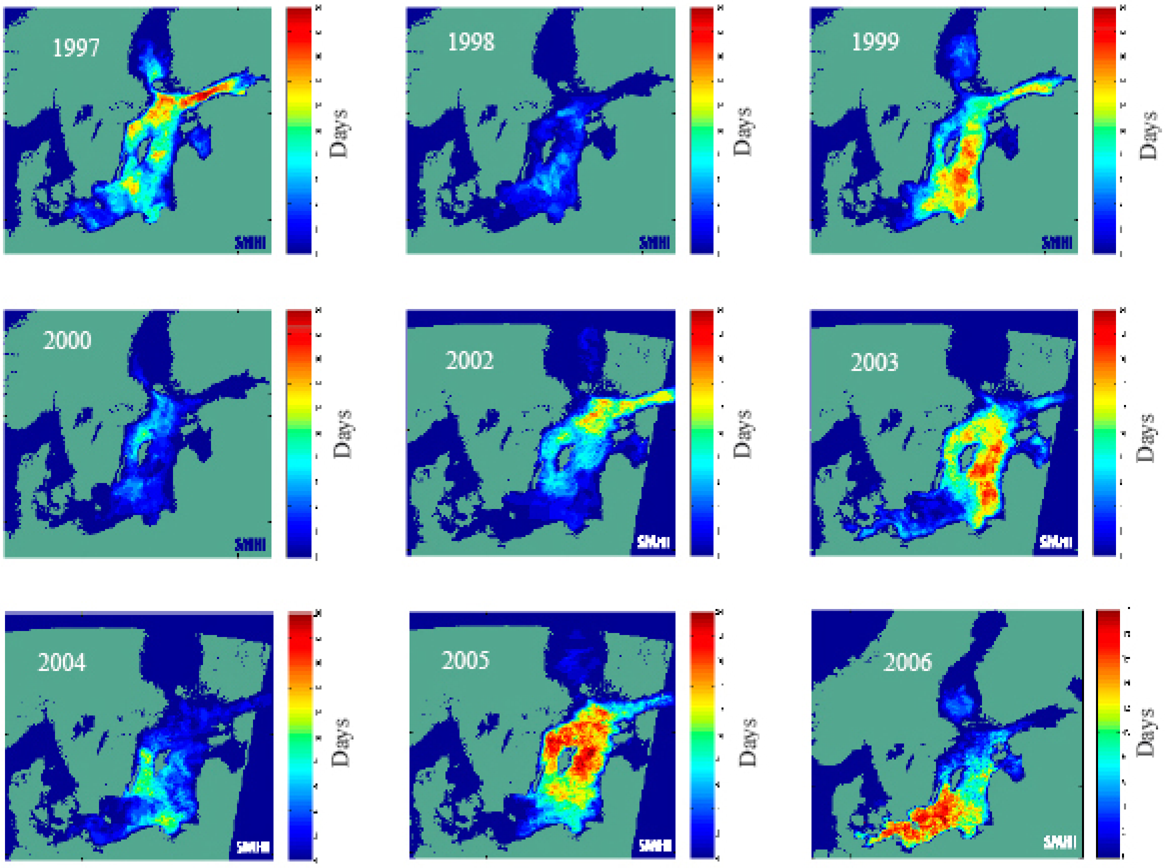

Figure 3. Summary of number of days with cyanobacterial observed in each pixel during the period 1997-2006, based on NOAA-AVHRR satellite imagery. Year 2001 is missing due to antenna malfunction at the receiving station.

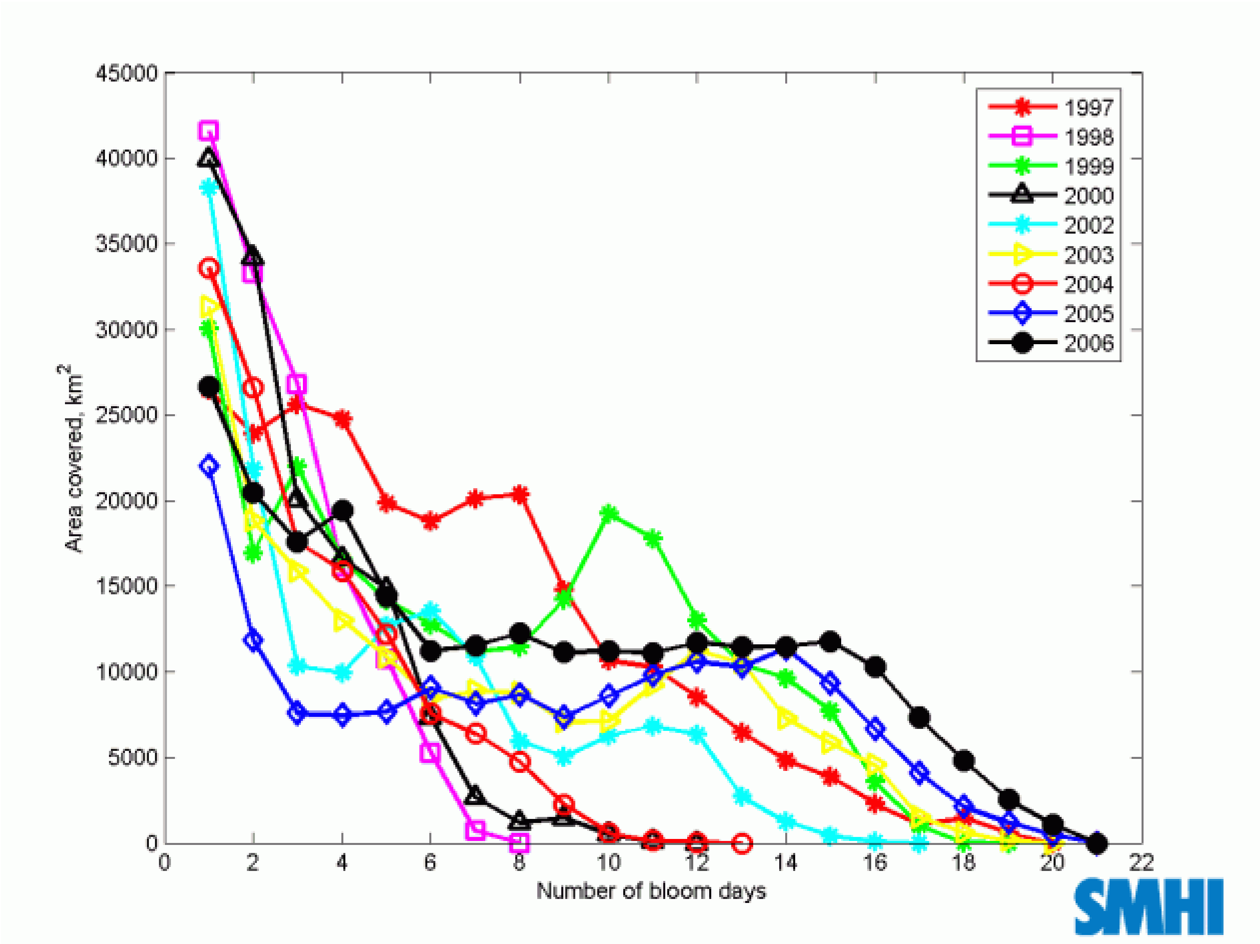

Figure 4. Plot over annual and temporal bloom coverage, 1997-2006. The graph shows the area covered by blooms versus the number of days with observed blooms. Year 2001 is missing due to antenna malfunction at the receiving station.

Table 1. Presents a comparison of normalized extent, duration and intensity of cyanobacterial blooms betweem the period 1997-2006. The results are based on the yearly summaries. See definition extent, duration and intensity above.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Extent (A) km^2	8009	12240	9621	6061	-	5448	6386	5384	6572	9149
Duration (T) Days	6	3	7	3	-	5	7	3	8	8
Intensity (I) km^2 days	49821	31214	68342	17461	-	26474	42841	17726	55319	73452

Reference

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Data

The SMHI satellite receiving station in Norrköping collected the NOAA-AVHRR data.

Interpreted satellite images showing the extent of surface accumulations of bloom in the Baltic Sea is presented at the following website. The images are updated on a daily basis during summer.
http://www.smhi.se/weather/baws_ext/balt/BAWSStartDag_en.htm

Metadata

Technical information

1. Data source: The AVHRR-data from NOAA-satellites was received with the antenna at SMHI headquarters, Norrköping.

2. Description of data: The AVHRR-sensor measures radiation in 5 broad wavelength bands ranging from visible to thermal infrared.

3. Geographical coverage: The satellite monitoring of cyanobacteria has many advantages compared to regular vessel based monitoring. The NOAA-AVHRR has a wide swath width (~2600km), hence the entire Baltic region are covered. An exception is near all land areas such as within archipelagos. These cannot be monitored due to the coarse pixel resolution (~1km). Since 2006 a new geographical coverage has been introduced covering the whole Baltic region.

4. Temporal coverage: Data from the NOAA-AVHRR sensor have been available since the late 1970s. Karhu et al. (1994;1997) has produced a compiled time series of satellite data for analysis of cyanobacterial blooms in the Baltic Sea from 1982 to 1994. In 2002, SMHI initiated Baltic Algal Watch System (BAWS) that performs daily interpretations of satellite imagery during the summer. AVHRR data have also been analyzed between 1997 and 2000 by SMHI in the EU-project HABES (Harmful Algal Blooms Expert System).

5. Methodology and frequency of data collection: Satellite imagery is analyzed using both automatic cloud masks (O&SI-SAF) and manual interpretations. NOAA satellites have a repeat cycle of ~0.5 days and since there are several NOAA satellites mounted with the AVHRR sensor there can be ~12 overpasses per day. Between 0-6 overpasses are unsuitable for further analysis due to low viewing angles, sun glint, clouds or haze. The best viewing conditions are usually encountered during the morning.

6. Methodology of data manipulation: Data were calibrated to albedo for visible and near infrared channels, and to brightness temperature for the thermal channels. Data were also geographically corrected to an equal area projection.

Quality information

1. Strength and weakness: Satellite data have high sampling frequency and allow a synoptic view. However, monitoring is limited to open sea areas due to the coarse pixel size, and is also limited by cloud cover.

2. Reliability, accuracy, robustness, and uncertainty: The AVHRR satellite can only be used for monitoring of meso-scale, surface accumulations of cyanobacteria. Algae can be found further down the water column. These are impossible to detect with satellite imagery. Therefore satellite data must be complemented by shipborne measurements, for example by data from SMHI:s offshore sampling program or Alg@line. Uncertain bloom observations are always noted and reanalyzed when more satellite scenes are available.

Satellite data from the high-resolution channels of MODIS (Moderate Resolution Imaging Spectroradiometer) flown on the TERRA and AQUA satellites and MERIS (MEdium Resolution Imaging Spectrometer Instrument) flown on ENVISAT were used when good imagery was available to re-analyse the algal maps derived from the NOAA-AVHRR data. Manual corrections were performed if needed.

3. Further work required: During 2007 SMHI will try to introduce MODIS and MERIS on a daily basis in the interpretation process to improve detection of algal blooms.

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

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