

## Cyanobacterial blooms in the Baltic Sea



**Author:** Martin Hansson (Martin.Hansson@smhi.se), SMHI

### Key Message

Already on the 28<sup>th</sup> of June surface accumulations of cyanobacteria were observed north of Gotska Sandön and the following day blooms were detected around Bornholm. But bloom observations during the summer were sparse and mostly weak. The normalized index for bloom intensity, duration and extent were the lowest recorded during the time period 1997-2007. However, blooms were detected in most parts of the Baltic region, with the exception of the Bay of Bothnia.

### Results and Assessment

#### Relevance of the indicator for describing developments in the environment

The amount of available phosphate in the surface water and weather conditions during the summer are important factors regulating the intensity of cyanobacterial blooms in the Baltic Sea. During 2007 phosphate concentrations were back to normal in the Baltic Proper with the exception of elevated concentrations in the Arkona and Bornholm Basin. (SMHI, R/V Argos cruise report, 6-11 August, 2007)

Weather conditions during the summer 2007 were not favorable for cyanobacterial blooms. Cold, windy and rainy weather conditions prevailed and prevented formations of surface accumulations of cyanobacteria.

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  $\text{km}^2\text{days}$ . (Hansson, 2006)

$$\text{Duration, } T = \frac{\sum a_i * i}{\sum a_i} \quad [\text{days}]$$

$$\text{Area, } A = \frac{\sum a_i * i}{\sum i} \quad [\text{km}^2]$$

$$\text{Intensity, } I = A * T \quad [\text{km}^2 \text{ days}]$$

#### Assessment 2007

A week after the first observation on 28<sup>th</sup> June blooms were established in the Gulf of Finland and prevailed there until the end of August. Most observations of cyanobacteria were registered in this region during 2007.

On the 19<sup>th</sup> of July weak blooms were detected in almost all the southern Baltic Proper, but it were not until the first week of August when all the Baltic regions could be observed from a cloud free sky.

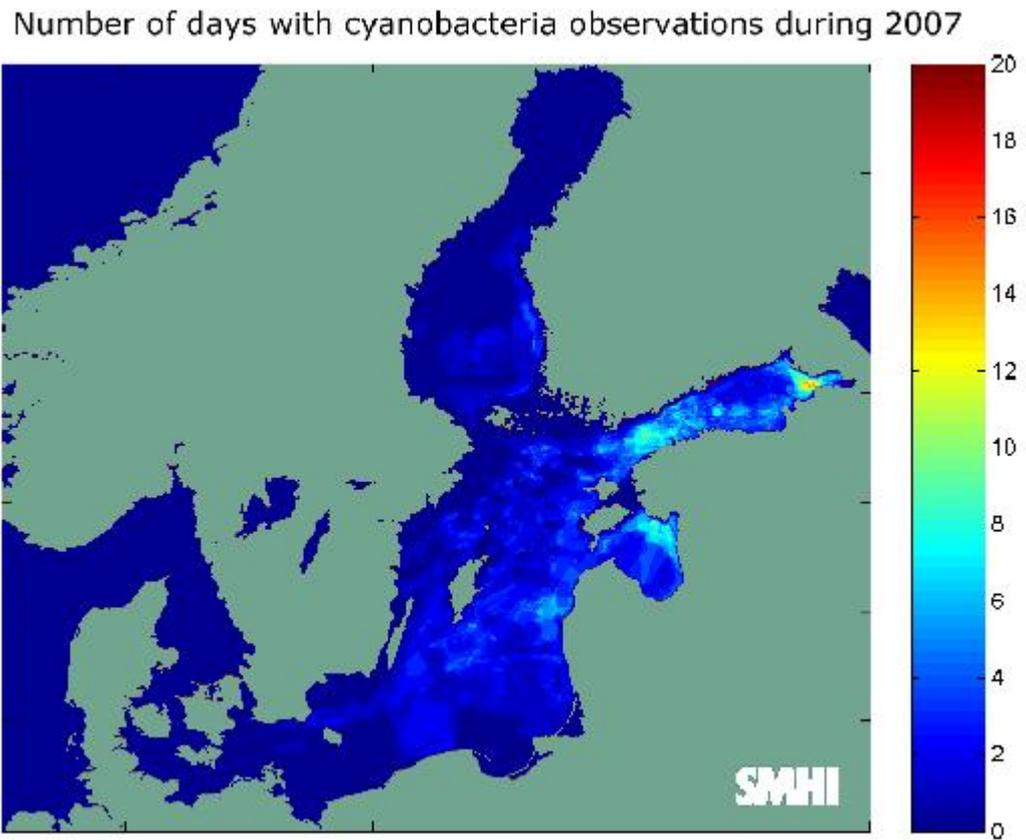
During the first half of July clouds made detection of blooms difficult over large parts of the Baltic Sea, but from the 15<sup>th</sup> August weak blooms were present in the Baltic Sea. Water samples from the U/F Argos cruise during this month showed that the non-toxic *Aphanizomenon* sp. and *Anabaena* sp. were found in the south-west Baltic while the toxic *Nodularia* sp. dominated in south-east. (SMHI, R/V Argos cruise report & Algaware, 9-14 July, 2007)

Satellite images from the 6<sup>th</sup> of August showed that major parts of the Baltic Proper, the Gulf of Finland and the north part of the Gulf of Riga were covered with weak surface accumulations of cyanobacteria. This situation could be expected due to the fragments of blooms which could be seen through the scattered clouds since the 19<sup>th</sup> of July. Water samples from the U/F Argos cruise in August now showed a clear dominance of *Nodularia*. During the later part of August the blooms where mostly visible in the central parts of the Bothnian Sea and along the Finnish coast, while the Baltic Proper mostly was covered by clouds during this time period. Though, water samples and visual observations from the cruise with U/F Argos in July and August clearly indicated that the surface accumulation of cyanobacteria were few and not as dense as the intense blooms during 2005 and 2006.

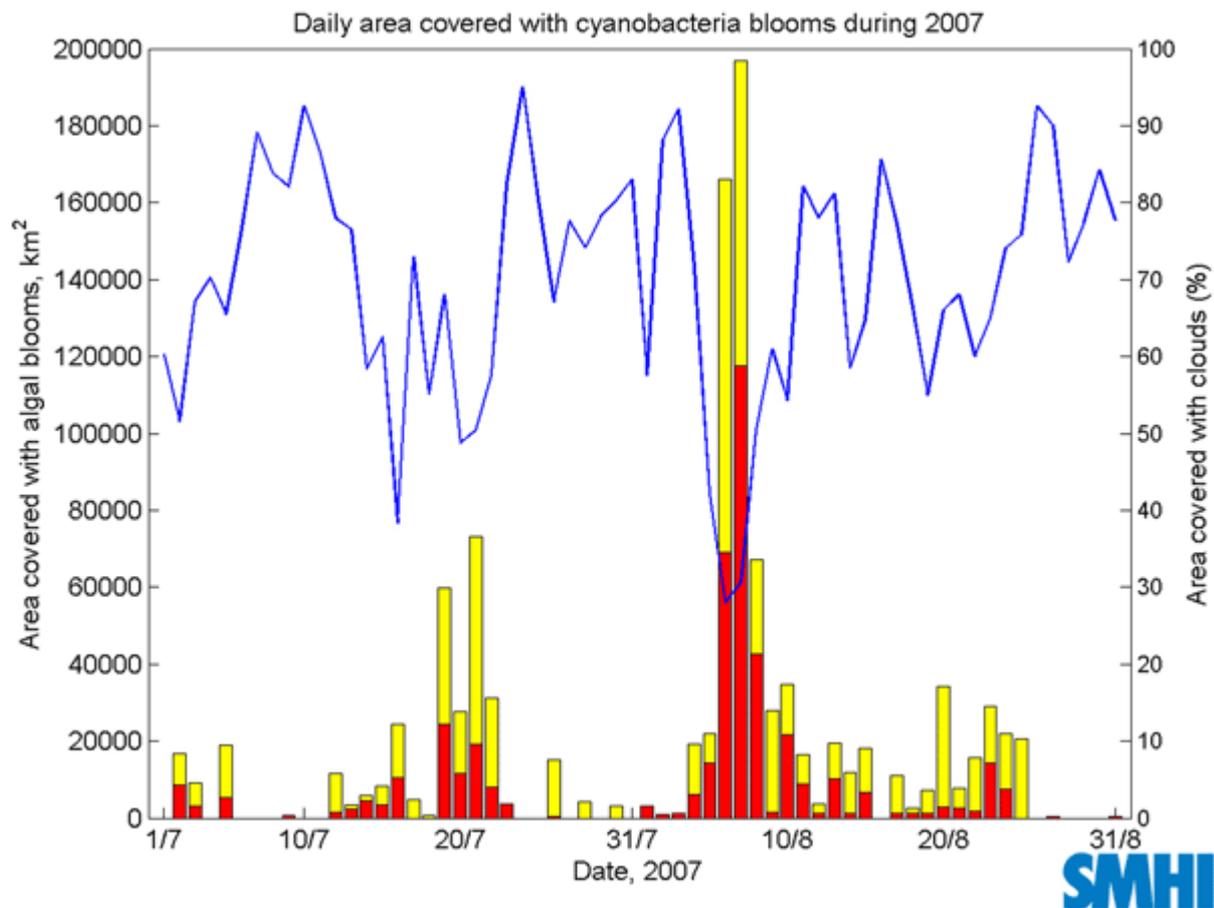
The maximal extent (~120 000 km<sup>2</sup>) was observed on the 7<sup>th</sup> of August and the bloom was detected in satellite imagery until the end of August. Suspicious discoloring of the sea surface could also be seen in the early September in the Bothnian Sea.

The cloud cover during July and August were frequent and the area covered with clouds was seldom below 50% of the monitored area.

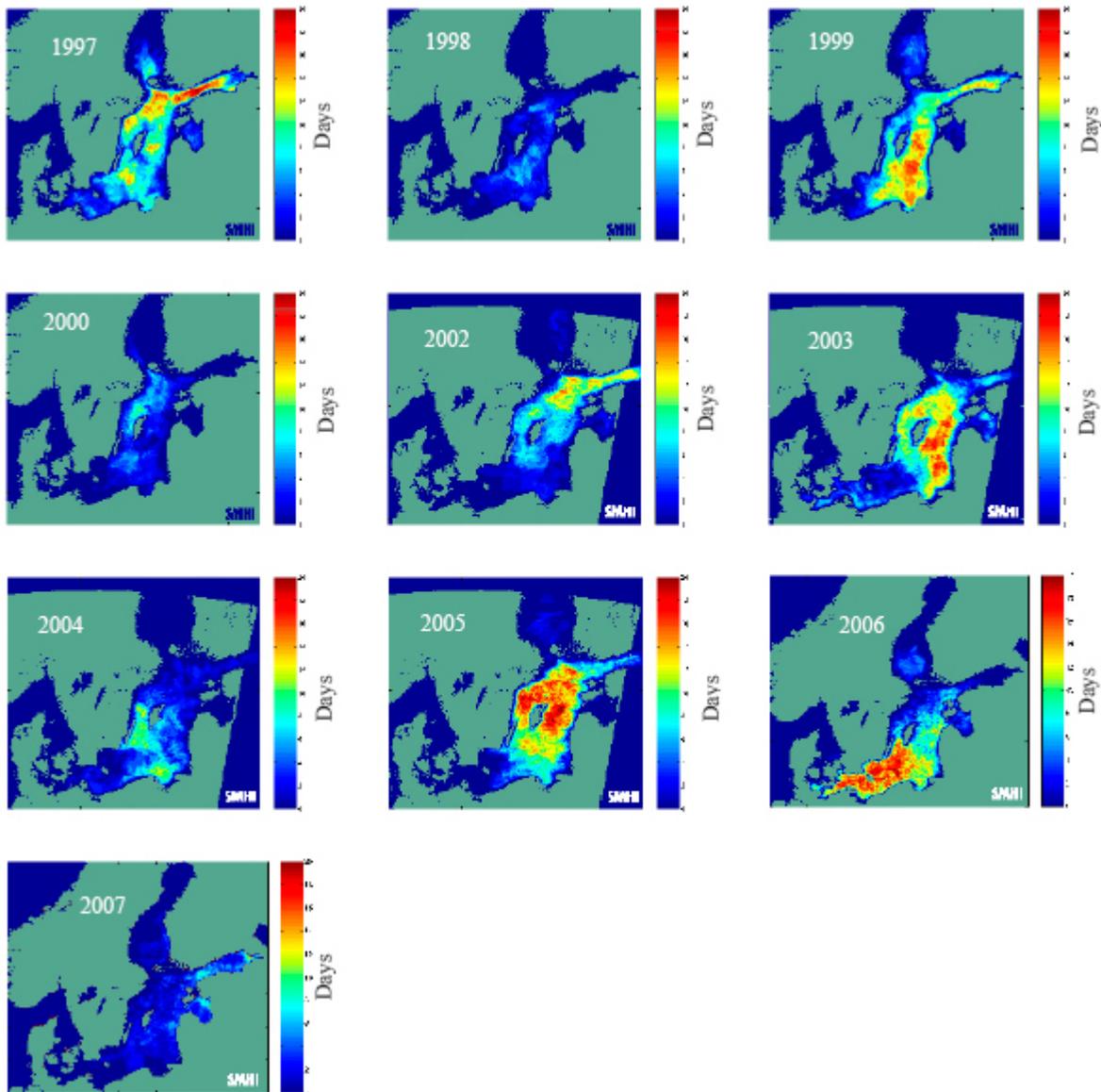
Normalized extent (3219 km<sup>2</sup>), duration (2 days) and intensity (7193 km<sup>2</sup>days) were all the lowest recorded during the period 1997-2007.



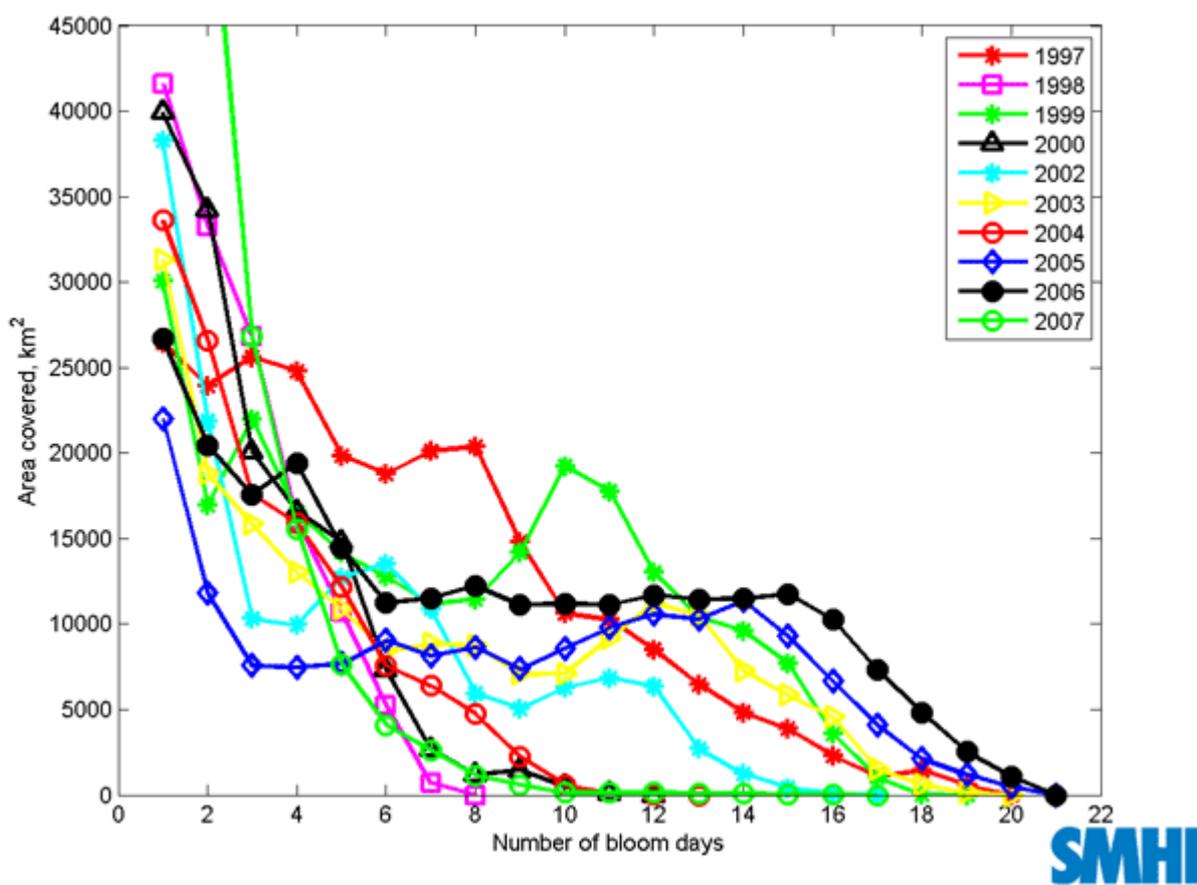
**Figure 1.** Number of days during 2007 with surface accumulations of cyanobacteria observed in each pixel based on NOAA-AVHRR satellite imagery.



**Figure 2.** Daily extent of surface accumulations of cyanobacteria in the Baltic Sea during 2007, 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.



**Figure 3.** Summary of number of days with cyanobacterial observed in each pixel during the period 1997-2007, 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, 1997-2007. 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 between the period 1997-2007. The results are based on the yearly summaries. Note that the numbers presented are rounded to nearest integer. See definition of normalized extent, duration and intensity above.

| Year                               | 1997  | 1998  | 1999  | 2000  | 2001 | 2002  | 2003  | 2004  | 2005  | 2006  | 2007 |
|------------------------------------|-------|-------|-------|-------|------|-------|-------|-------|-------|-------|------|
| Extent (A) km <sup>2</sup>         | 8009  | 12240 | 9621  | 6061  | -    | 5448  | 6386  | 5384  | 6572  | 9149  | 3219 |
| Duration (T) Days                  | 6     | 3     | 7     | 3     | -    | 5     | 7     | 3     | 8     | 8     | 2    |
| Intensity (I) km <sup>2</sup> days | 49821 | 31214 | 68342 | 17461 | -    | 26474 | 42841 | 17726 | 55319 | 73452 | 7193 |

**Reference**

Hansson, M. Cyanobakterieblomningar i Östersjön, resultat från satellitövervakning 1997-2005, SMHI Oceanografirapport nr 82, 2006, ISSN: 0283-7714.

Karhu, M., O.P. Savchuk, and R. Elmgren, 2007, "Satellite measurements of cyanobacterial bloom frequency in the Baltic Sea: Interannual and spatial variability". In Press. Karhu, M., 1997, Using Satellites to Monitor Large-Scale Environmental Change: A case study of the Cyanobacteria Blooms in the Baltic Sea. Monitoring algal blooms: New techniques for detecting large-scale environmental change. Landes Bioscience.

Karhu, M., U. Horstmann and O. Rud, 1994, Satellite Detection of Increased Cyanobacteria Blooms in the Baltic Sea: Natural Fluctuation or Ecosystem change?, *Ambio* Vol. 23 No. 8.

Larsson, U., and L. Andersson, 2005, Varför ökar inte kvävet när fosfor ökar?, Miljötilståndet i Egentliga Östersjön, rapport 2005, Stockholms marina forskningscentrum.

SMHI, R/V Argos cruise report, archive 2007. Under reports.

[http://www.smhi.se/oceanografi/oce\\_info\\_data/home\\_en.html](http://www.smhi.se/oceanografi/oce_info_data/home_en.html)

SMHI, AlgAware report, archive 2007. Under reports.

[http://www.smhi.se/oceanografi/oce\\_info\\_data/home\\_en.html](http://www.smhi.se/oceanografi/oce_info_data/home_en.html)

## 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](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:** Establishing a method to use different data from different sensors to detect cyanobacterial blooms and to make use of drift models to forecast the movements of blooms.

An evaluation of drift forecast of cyanobacterial blooms performed during the summer 2007 will be performed during autumn 2007 and spring 2008, with the aim to present a new system for drift forecast in the summer 2008.

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

[Author's name(s)], [Year]. [Baltic Sea environment fact sheet title]. HELCOM Baltic Sea Environment Fact Sheets. Online. [Date Viewed], <http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/>.