Cyanobacteria biomass indicator

Information from the Phytoplankton Expert Group (PEG)

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Key Message

- Due to high variability, no clear trends in the biomass of the bloom forming cyanobacteria genera *Aphanizomenon, Nodularia* and *Anabaena* are visible for the period studied (2000-2010).

- The cyanobacterial biomass indicator supports the patchy distribution of cyanobacteria seen in satellite images and supports the need for data from different areas of the Baltic Sea. For example some years with low cyanobacteria biomass in the Arkona Sea and Bornholm Sea (2004, 2005) showed high biomass in the Eastern Gotland Sea.

- The Cyanobacteria biomass indicator and the widely used satellite data support each other. Whereas satellite data present spatial distribution patterns of surface accumulations, the Cyanobacteria biomass indicator delivers real biomass data (on genus level) from representative stations of each sea area.

Results and Assessment

Relevance of the indicator for describing developments in the environment

Bloom-forming cyanobacteria are an important component of the ecosystem. By their ability to fix molecular nitrogen they prevent severe nitrogen shortage and resulting starvation in all trophic levels of the ecosystem in the summer. However, human activity has imported a surplus of nutrients into the water for decades which turned the originally indispensable cyanobacteria into a nuisance because their nitrogen fixation counteracts the measures to reduce eutrophication, as specified in the following section.

Policy relevance and policy references

Cyanobacteria biomass seems to have increased at least since the 1960s (Finni et al. 2001). If nitrogen-fixing cyanobacteria occur in large blooms, they contribute to eutrophication, oxygen depletion in deep waters and intoxication. Already the displeasing outlook of the coloured surface scum may impair the touristic use of the coasts in summer. The changes in cyanobacteria biomass and composition represent changes in the ecosystem with far-reaching consequences. Their trends are of high relevance and interest. This Indicator Fact Sheet serves for long-term documentation of the cyanobacteria bloom development.

The previous series of Indicator Fact Sheets on a “Cyanobacteria bloom index” ended with the year 2007 (Kaitala and Hällfors 2008). Information about the spatial extension of the bloom, with help of satellite data, is available during every summer. The HELCOM Phytoplankton Expert Group (PEG) felt, however, that information on the cyanobacteria bloom development, based on biomass measurements, is still needed. For this reason, PEG starts a new "Cyanobacteria biomass indicator", which is related to the earlier "Cyanobacteria bloom index" but is not its continuation for the following reasons:

- The Cyanobacteria biomass indicator is based on samples taken on discrete stations during monitoring cruises instead of samples taken on highly frequented routes of ships of opportunity.
- The Cyanobacteria biomass indicator uses biomass data instead of an index based on semi-quantitative rankings.
- The Cyanobacteria biomass indicator separates the different sea areas instead of pooling all data of a hydrographically and biologically highly diverse region.
- The Cyanobacteria biomass indicator considers all regions of the Baltic Sea and not only the area between Helsinki and Travemünde.
- The Cyanobacteria biomass indicator uses samples covering the upper 10 m (in the Landsort Deep 20 m) instead of a single depth of approximately 5 m.

Assessment

Phytoplankton monitoring data from the last decade were collected from the stations shown in Fig. 1 and treated as explained in the technical information below. The seasonal means of the total biomass of the nitrogen-fixing filamentous cyanobacteria in the summer period (mainly June-August, in Bothnian Sea June-October) are presented in the same figure. As shown in an earlier Indicator Fact Sheet of PEG, phytoplankton trends may be even opposite in the different sea areas (Jaanus et al. 2007). Therefore, separate diagrams for the most relevant sea areas were produced. Specific information on the three bloom-forming cyanobacteria genera *Aphanizomenon, Nodularia* and *Anabaena* are shown in Fig. 2.

Data of the Bothnian Bay are not presented because cyanobacteria biomass was very low (< 40 µg/L, with only one exception). In the Bothnian Sea, peak values could reach 500 µg/L, but the seasonal averages remained rather low. Nevertheless, and despite lacking data from 2000-2003 at the moment of our analysis, we present the Bothnian Sea here because it seems that cyanobacteria biomass is increasing in this area (cf. Jaanus et al. 2007). It is of special interest that high cyanobacteria biomass was still found in autumn. Therefore, the period from June to October was considered exceptionally in the Bothnian Sea.

In the other regions, blooms are noticed from June to August (cf. seasonal pattern presented by Kaitala and Hällfors 2008). The highest blooms occurred in the Gulf of Finland with single peak values in 2002 (3670 µg/L), 2004 (7470 µg/L) and 2009 (4410 µg/L). The cyanobacteria biomass at the Landsort Deep station (BMP H3) appears relatively low for methodological reasons: This was the only station where the upper 20 m were sampled in contrast to 10 m in the other regions. As cyanobacteria prefer the upper water layers, the inclusion of the lower layer of the euphotic zone reduces the depth-integrated average. The cyanobacteria biomass might be more than double, especially for *Nodularia*, in the 0-10 m water layer.

The Kattegat/Belt Sea Danish data is not included in the report because cyanobacteria are not relevant in the Danish Straits and Kattegat as they appear only in low amounts.. German data from Mecklenburg Bight revealed that heavy cyanobacteria blooms did not occur. Monthly means of July 2001 and 2006 reached almost 200 µg/L but were still under the cyanobacteria bloom threshold which was suggested by Wasmund (1997) at 200 µg/L. It has to be noted that the peak values are generally higher than the seasonal means presented here. This threshold was exceeded only once (on 27.7.2006) in this area.

Because of the high variability, no clear trend can be noticed. A visual comparison of the sea areas shows that the long-term patterns are different. This is not surprising as satellite images revealed already basin-wide differences in bloom distribution. The annually updated Indicator Fact Sheet on cyanobacteria blooms in the Baltic Sea (Hansson and Öberg 2010) shows highest concentration in an area that we called "Southern parts of Eastern Gotland Basin" in contrast to the "Northern parts of Eastern Gotland Basin" in 2010; this forced us to keep these two areas apart. We can confirm high cyanobacteria biomass in the southern parts of Eastern Gotland Basin in July 2010 (216 µg/L), but this value decreased drastically by averaging with the low June and August data. The southern parts of Eastern Gotland Basin combines characters of the adjacent northern parts of Eastern Gotland Basin (peaks in 2002, 2004 and 2005) and the Bornholm Sea (peak in 2006). The year 2008 showed high biomass in all regions of the central and southern Baltic Proper, which is supported by satellite images of Kahru, Savchuk and Elmgren (unpublished information).

The comparison with the Cyanobacteria bloom index (Kaitala and Hällfors 2008) for the overlapping period from 2000 to 2007 shows only little correspondence. The Cyanobacteria bloom index was especially high in 2007 when the Cyanobacteria biomass indicator was rather low in the areas passed by the ship of opportunity (Gulf of Finland, Eastern Gotland Sea, Bornholm Sea, Arkona Sea). The Cyanobacteria bloom index was rather low in 2004 and 2005, when also the Cyanobacteria biomass indicator was low in the Arkona Sea and Bornholm Sea. It is interesting that the Cyanobacteria biomass indicator was high in the Eastern Gotland Sea, particularly in its northern parts, at the same time. Integration over all these areas, as done by the Cyanobacteria bloom index, would widely level out these differences. The Cyanobacteria biomass indicator wants to retain these naturally occurring differences, which make them better comparable with satellite images.

References

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Data

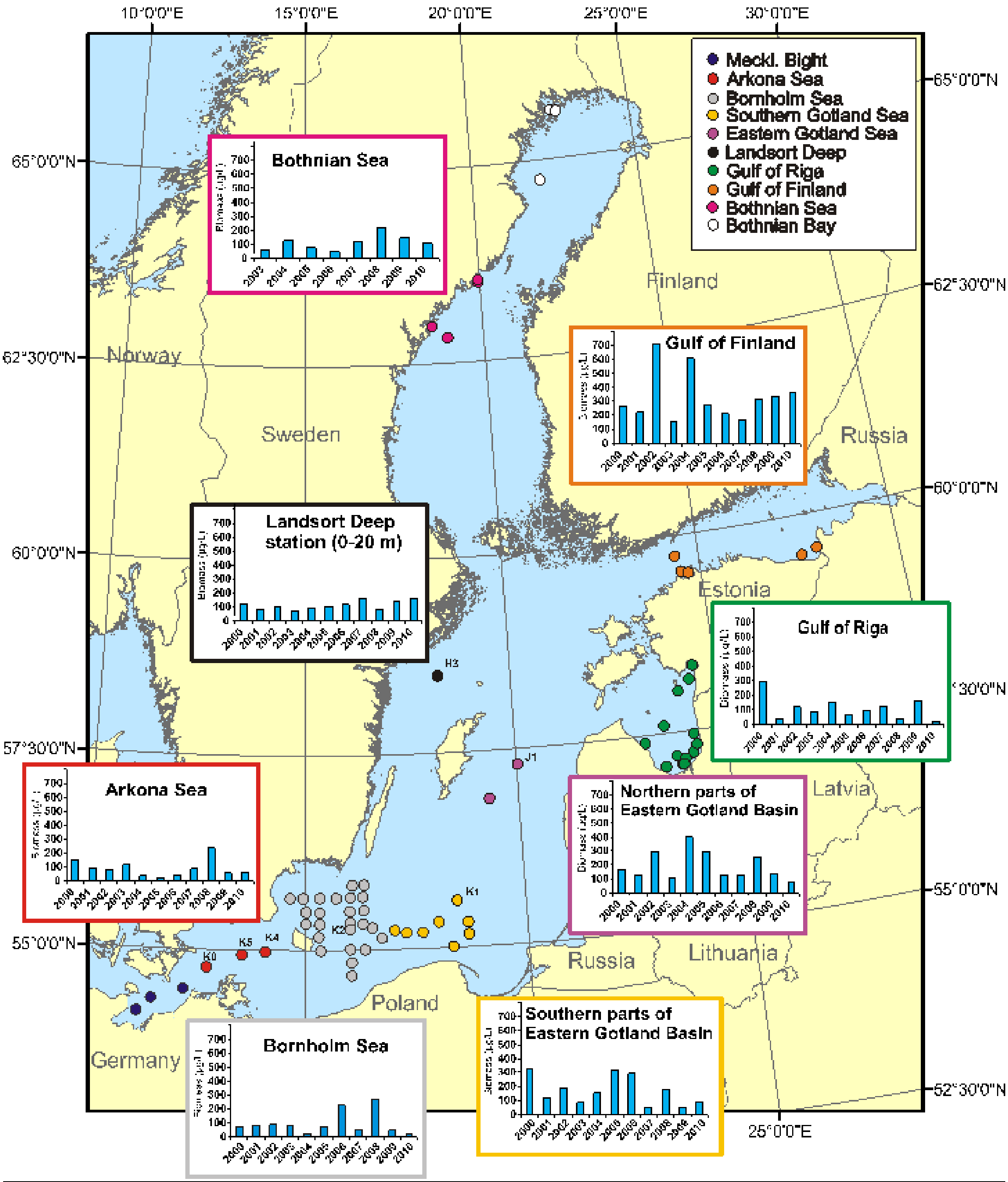

Fig. 1: Map of the stations, containing one graph on cyanobacteria biomass per area; means of the growth period for the years 2000-2010.

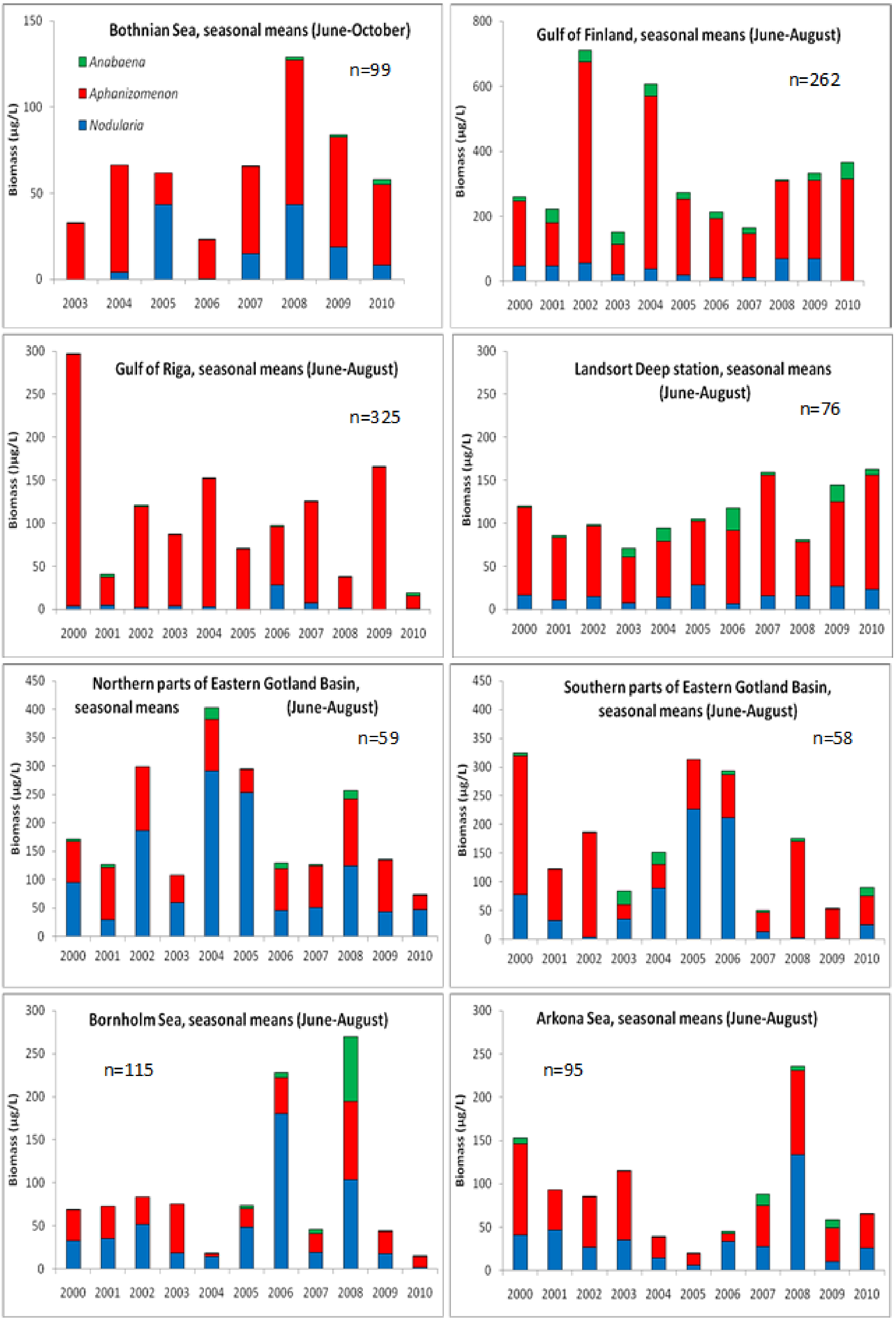

Fig. 2: Mean biomass (wet weight) of the three bloom-forming cyanobacteria genera in the different Baltic Sea areas during their blooming period (Note the different scales).

Metadata

Technical information

1. Source: Estonian, German, Latvian, Lithuanian, Polish and Swedish national monitoring data (cf. list of authors). Sampling locations are presented in Fig. 1. Original purpose of the data: Phytoplankton monitoring programs in the frame of HELCOM.

2. Description of data: Biomass data (wet weight in µg/L) in integrated samples (0-10 m, less at some coastal stations; 0-20 m at the Landsort Deep).

3. Geographical coverage: Entire Baltic Sea (see Fig. 1).

4. Temporal coverage: Summer 2000-2010 (June-August, in the Bothnian Sea June-October)

5. Methodology and frequency of data collection: Information based on national monitoring samples analyzed and identified by phytoplankton experts, using the mandatory HELCOM methods http://www.helcom.fi/groups/monas/CombineManual/AnnexesC/en_GB/annex6/, specified by Olenina et al. (2006). Sampling frequency variable in dependency of the national monitoring cruises. At least one sample per month was available. This precondition could also be fulfilled by pooling nearby stations. The number of samples is indicated in each diagram in Fig. 2.

6. Methodology of data manipulation: The precondition of at least one sample per month could be fulfilled in the representative open sea stations by combining the different national monitoring data. In coastal areas under the responsibility of only one country, many data (e.g. from Lithuania and Poland) had to be rejected because of too low sampling frequency. Other coastal data (e.g. from Estonia and Latvia) could be used, leading to a high number of data in the Gulf of Finland and the Gulf of Riga (cf. Fig. 2).

From the single data, monthly means were calculated, which served as basis for calculation of seasonal mean values.

Quality information

1. Strength and weakness (at data level): The main problem is the sampling. Samples are taken only at few stations and with a low seasonal coverage. This under sampling problem, occurring generally at ship-based sampling, is dramatic if high patchiness occurs. Especially the buoyant cyanobacteria are inhomogeneous in their horizontal and vertical distribution. The vertical inhomogeneity is tackled by the integrated sampling down to 10 or even 20 m depth. The equipment is however not designed for representative sampling of surface scums. The low sampling frequency by the few national monitoring cruises is improved by combining the different national data taken at the central HELCOM stations.

The analysis of the samples is less problematic. Admittedly, the method suffers from inhomogeneity in cyanobacteria distribution in the samples if splitting of the sample is necessary and not the complete sample is counted. If the sample is taken, its analysis is highly reliable.

2. Reliability, accuracy, robustness, uncertainty (at data level): Data on the reliability and precision are not available. The sampling problems are discussed above; they have natural reasons. The microscopical counting is a robust method of high accuracy. In contrast to indirect methods (satellites, pigments etc.), the objects can directly be recognized, counted and measured. Moreover, the contribution of the different species, with different environmental requirements, can be recognized and evaluated. The calculation of biomass from the counting results is highly reliable.

3. Further work required (for data level and indicator level): The national monitoring programmes must not be shortened. In order to assure a sufficient sampling frequency, the combined efforts of different countries to sample at least the central key station in each sea area have to be maintained or even extended. In the following annual updates of the Cyanobacteria biomass indicator also a retrospective extension of the analysed time series to the past (the 1990s) is envisaged.

FOOTNOTES

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