Spatial Distribution of the Winter Nutrient Pool

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Key message

Good news: DIN concentrations remain below those observed in the 1990s,

Bad news: DIP levels were again high in winter 2011-12, due in large part to a salt water inflow from the North Sea in November 2011, which lifted up phosphorus rich deep water sufficiently for it to be entrained into the surface layer. This was most apparent in the Baltic Proper, and contributed to the extensive cyanobacteria blooms during summer 2012 - which could have been considerably more intense had the weather been calmer.

Results and assessments

2011 - 2012 results

The first three figures illustrate the spatial distribution of the winter nutrient pool in the period December 2011 to February 2012. Data from the eastern and southern Baltic were unavailable for this period at time of writing and so are indicated in white.

As is usual, there is a concentration gradient for dissolved inorganic nitrogen (DIN) from the Bothnian Bay in the north, where concentrations are high, to the southern Baltic (near Gotland) and eastern Kattegat (Sweden's west coast) where concentrations are lower. In general, concentrations are higher close to land than offshore. Highest concentrations occur in the western Kattegat and along the Swedish Skagerrak coast (that is, at the ocean-ward limit of the HELCOM area).

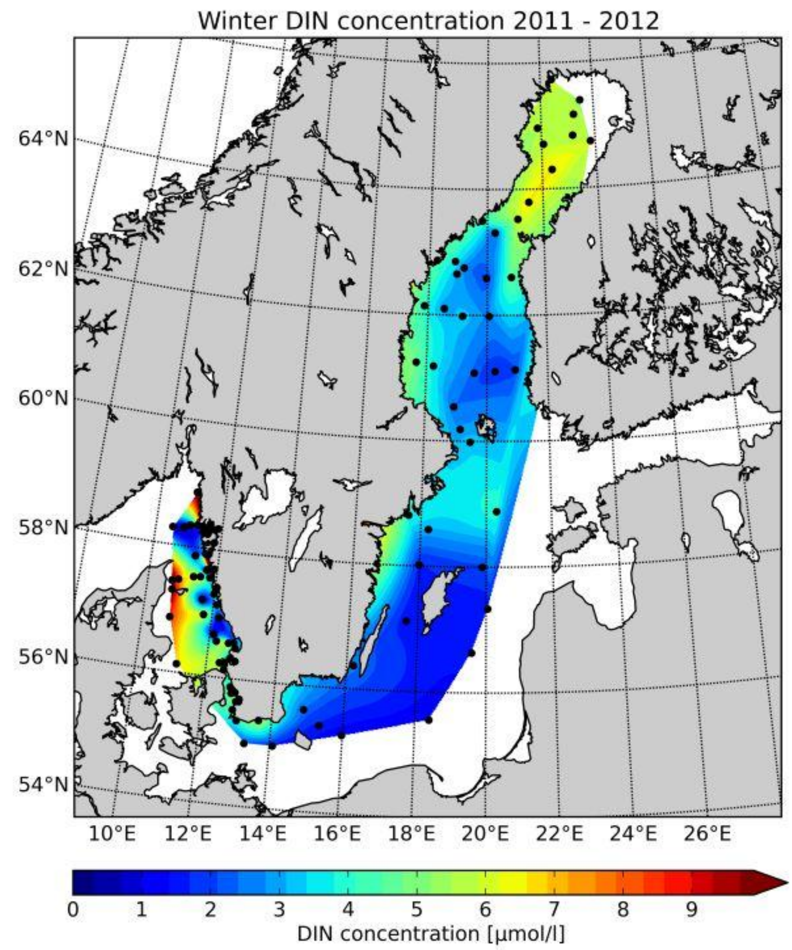

Figure 1. Estimate of DIN concentrations (µmol/l) in surface waters: December 2011 - February 2012.

Dissolved inorganic phosphorus (DIP) concentrations are to a certain extent the reverse of the DIN concentrations: concentrations are very low in the Bothnian Bay, and increase as you head southwards into the Bothnian Sea, the Baltic Proper and Danish Straits. Concentrations are again highest closest to land. In the Baltic Proper, this is due in large part to upwelling along the Swedish east coast, from the Hanö Bight northwards. This occurs because the deep waters of the Baltic Proper have very high phosphorus levels, and when the wind blows from the west, the deep water 'wells up' along the Swedish coast. During the autumn of 2011, inflowing water from the North Sea caused more DIP than usual to be transported upwards into the surface layer, with the result that DIP concentrations in the surface water were much higher than usual. This contributed to the extensive cyanobacteria blooms observed during summer 2012.

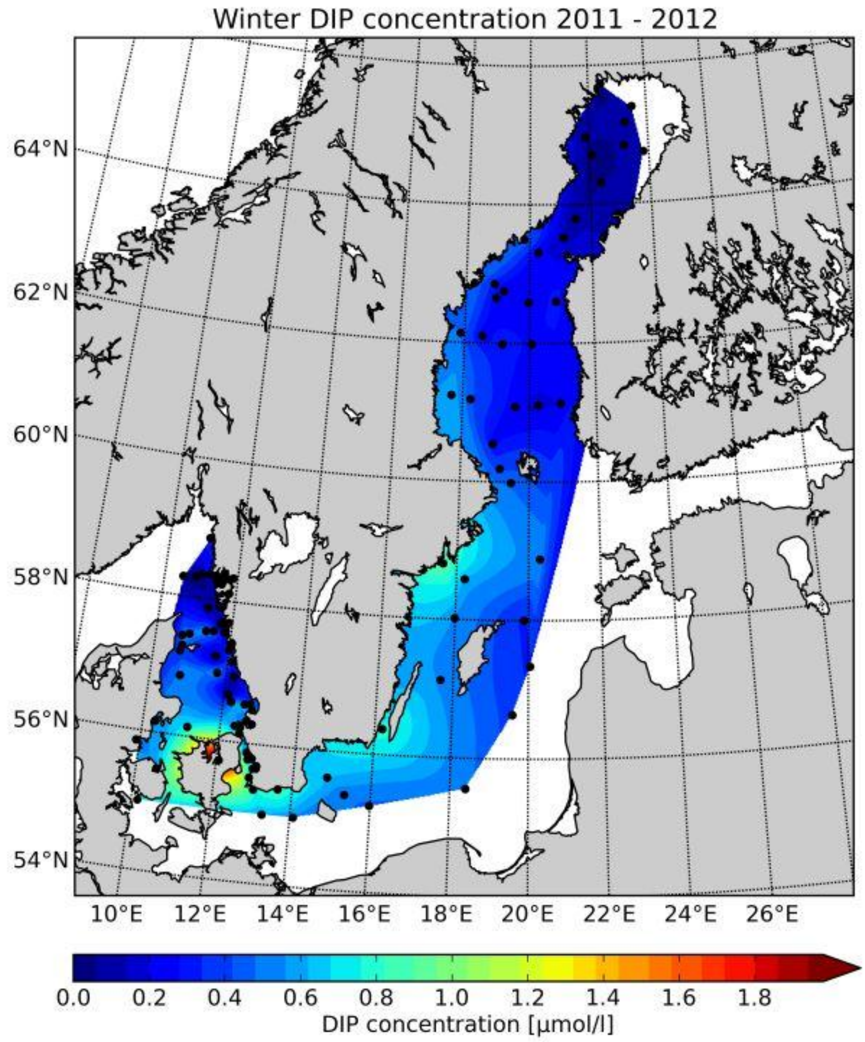

Figure 2. Estimate of DIP concentrations [µmol/l] in surface waters: December 2011 - February 2012.

Due to the immense land run-off, there has always been an excess of silicate in the Baltic Sea, unlike in other European seas such as the North Sea, where silicate shortages can occasionally limit algal production. As such, the natural excess of silicate is not considered a eutrophication problem.

Silicate concentrations are, like DIN concentrations, highest in the Gulf of Bothnia, as the great rivers deliver large amounts to the bay. This is even the case in the Bothnian Sea. In the Baltic Proper, concentrations are higher along the Swedish coast due in large part to wind-induced upwelling (the oxygen-free deep waters of the Baltic Proper contain high concentrations of silicate). High concentrations in the Danish Straits are probably caused more through resuspension of material rather than direct run-off from land.

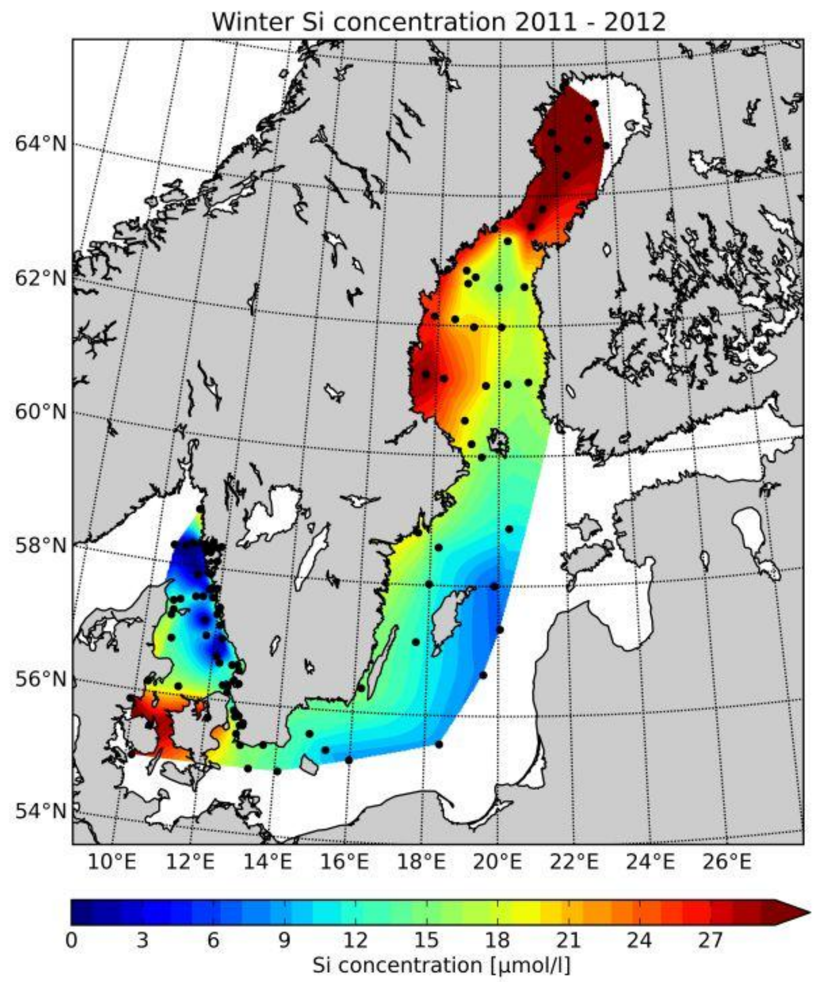

Figure 3. Estimate of silicate concentrations [µmol/l] in surface waters: December 2011 - February 2012.

Compared to the decade stretching from 1993 - 2002, DIN concentrations during winter 2011 - 2012 were considerably lower: generally between 2 and 3 µmol/l in the offshore Baltic Proper, and even lower in the eastern Kattegat. Some areas (the Swedish east coast north of Öland and the south western Bothnian Sea) do not show the same reduction.

Dissolved inorganic phophorus (DIP) concentrations do not show such a positive development. In Danish waters and all along the Swedish coast, concentrations were much higher (0.15 - 0.4 µmol/l) higher than in 1993 - 2002. The difference in silicate gives a similar picture, and this strongly suggests that these two results are caused by similar processes: the lack of oxygen in the deep water of the Baltic Proper releases both DIP and silicate from the bottom sediment into the water column. Wind-induced upwelling and inflows from the North Sea during 2011 then brought this deep water to the surface, particularly along the Swedish east coast.

The uneven nature of the results in the Kattegat (north of the Danish Straits) is due to the more dynamic nature of these waters, where the North Sea and Baltic Sea meet. The exact position of the various currents changes rapidly between surveys, and the spring bloom can even start in the middle of winter here, making results for just this area much more patchy.

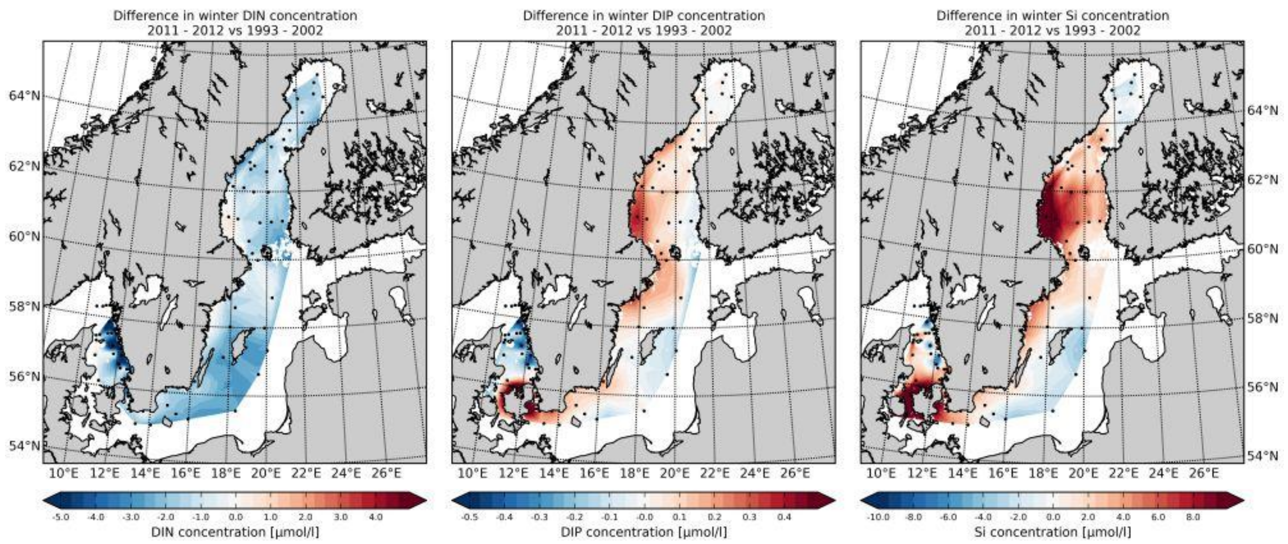

Figure 4. Difference between winter 2011-12 nutrient concentrations (DIN: left; DIP: centre; Silicate: right) and the 1993-2002 means.

Relevance of the indicator for describing developments in the environment

Eutrophication is the excess of nutrients. The spatial distribution of the primary bio-available nutrients (surface waters, during winter) highlights problem areas, and shows the availability of nutrients for the spring bloom. Changes in the spatial distribution may indicate changes in the hydrography, or the effect of remedial works. Mapping the excess winter:DIP may serve as a warning for areas where cyanobacteria blooms are likely. Some cyanobacteria are toxic.

Dissolved inorganic nutrients are essential for phytoplankton development. While rivers deliver phosphorus to the Baltic, most of this phosphorus is chemically bound to particles, and is not directly available for biological use. Some dissolved inogranic phosphorus (DIP) enters the Baltic with inflows of salt water, but the most significant source at present appears to be that released from bottom sediments during periods of anoxia. Deep water DIP can become bio-available if it is transported to the surface waters, but this transport is hampered by the permanent stratification. After the inflows of winter 2002 – 3, phosphorus concentrations in the surface water of the Baltic Proper increased significantly, and concentrations remain high today. The Baltic Sea Action Plan requires countries around the Baltic to reduce discharges of phosphorus to the marine environment.

Dissolved Inorganic Nitrogen (DIN) is composed of nitrate, nitrite and ammonium compounds, which are also required by phytoplankton. While DIN concentrations are much higher than DIP in surface waters, marine phytoplankton require 15 - 16 times as much DIN as DIP, often causing a lack of DIN to limit phytoplankton activity. Where DIN is used up, those bacteria that can fix nitrogen from the air can still flourish, making use of the remaining DIP, and causing blooms. Cyanobacteria have this ability, and so flourish in the Baltic. Nitrogen is cycled within the water column and sediment, while 'fresh' nitrogen is also supplied, directly or via rivers, by agricultural run-off and sewage discharges, and also through atmospheric deposition. The Baltic Sea Action Plan requires countries around the Baltic to reduce discharge of nitrogen to the marine environment.

Silicate is supplied to the Baltic via rivers, as a result of weathering processes. It is recycled in the marine system. An excess of silicate is typical of the Baltic, because of the large supply of river water, and the high concentrations present in the deep anoxic water. Excess silicate is not considered problematic in the Baltic.

Policy relevance and policy references

Eutrophication, or an excess of nutrients, is one of the major problems facing the Baltic Sea. A major part of the HELCOM Baltic Sea Action Plan is focussed on reducing eutrophication and the negative impacts it has on the Baltic Sea ecosystem. Even European Directives, such as the Water Framework Directive and the Marine Strategy Framework Directive identify eutrophication as a major hinder which could prevent the Baltic Sea from achieving Good Environmental Status in the near future.

The HELCOM COMBINE programme uses nutrient data to help quantify the effects of anthropogenic activities. This Baltic Sea Environment Fact Sheet contributes to the programme's requirement for information on:

- the winter pool of nutrients
- the supply of nutrients and nutrient limitation in coastal waters

Typical conditions 1993 - 2002

Concentrations of DIN are highest in coastal waters from the southern Belt Sea to the inner Gulf of Finland. Levels are also high in the Bothnian Bay. This is unsurprising as the major source of DIN to the Baltic is land run-off. Variability in winter DIN (indicated by the standard deviation plot in Figure 1) is predominantly due to variability in land run-off, so is highest near the sources of DIN. Variability is higher also in the Kattegat, due to the dynamic frontal activity here.

Mean winter surface DIN (left) and standard deviation (right) are based on each year's gridded winter surface observations from 1993 - 2002 inclusive. Surface refers to the upper 0 - 10 m. Units are micro-moles/litre. Figure 1. Mean winter surface DIN (left) and standard deviation (right) based on each year's gridded winter surface observations from 1993 - 2002 inclusive. Surface refers to the upper 0 - 10 m. Units are micro-moles/litre.

Highest DIP concentrations are usually also found in the Belt Sea, the southern Baltic coast and the inner Gulf of Finland, though levels are also significant along the Swedish east coast and in the Kattegat. Lowest levels are found offshore, in particular in the Gulf of Bothnia. This is because while some DIP originates from land sources, a large reservoir also exists in the deep water of the Baltic, which can come to the surface during upwelling events, which occur near the coasts.

Highest silicate concentrations are found in the Bothnian Bay. The great rivers surrounding this bay transport large amounts of silicate released through natural weathering processes. In many seas, silicate is used up during the spring bloom, and a shortage of silicate can restrict phytoplankton growth. This never happens in the Baltic, because the natural supply of silicate is greater than plankton can use - even after the damming of the rivers in the north, which might have been expected to reduce the flow of silicate to the sea. There are also very high concentrations of silicate in the deep water of the central Baltic.

References

Anon., 2000, 'Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive)', in Official Journal of the European Union 327, 22 December 2000, pp. 1–73. Available online at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT

Anon, 2008, 'DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)', in Official Journal of the European Union 25.6.2008 L 164/19 - 164/40. Available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0056:en:NOT

Helcom COMBINE Manual (Annex C), http://www.helcom.fi/Monas/CombineManual2/CombineHome.htm, December 2003. Data This study used data collected under the HELCOM COMBINE programme, and archived for HELCOM by ICESsupplemented with data collected by SMHI 2007/8.

Data sources

Data come primarily from the HELCOM data archive held at the International Council for the Exploration of the Sea (http://www.ices.dk). Data collected for the HELCOM COMBINE programme are collected and analyzed according to fixed, agreed techniques which are the same for all HELCOM countries. Laboratories participate in quality assurance consortia such as QUASIMEME and are almost uniformly ISO accredited for good laboratory practice.

These data were supplemented by coastal data collected as part of Swedish regional monitoring programmes and made available by the oceanographic data centre at SMHI through the database SHARK (Svenska Havs ARKiv).

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