Biogeochemical cycles in the Baltic Sea

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Marine biogeochemistry deals with budgets and transformations of biogeochemically reactive elements such as carbon, nitrogen and phosphorus. The biogeochemical cycles are also regulated by physical processes such as mixing and transports, deep-water renewal and the development of a seasonal thermocline in the Baltic Sea (Fig. 1).

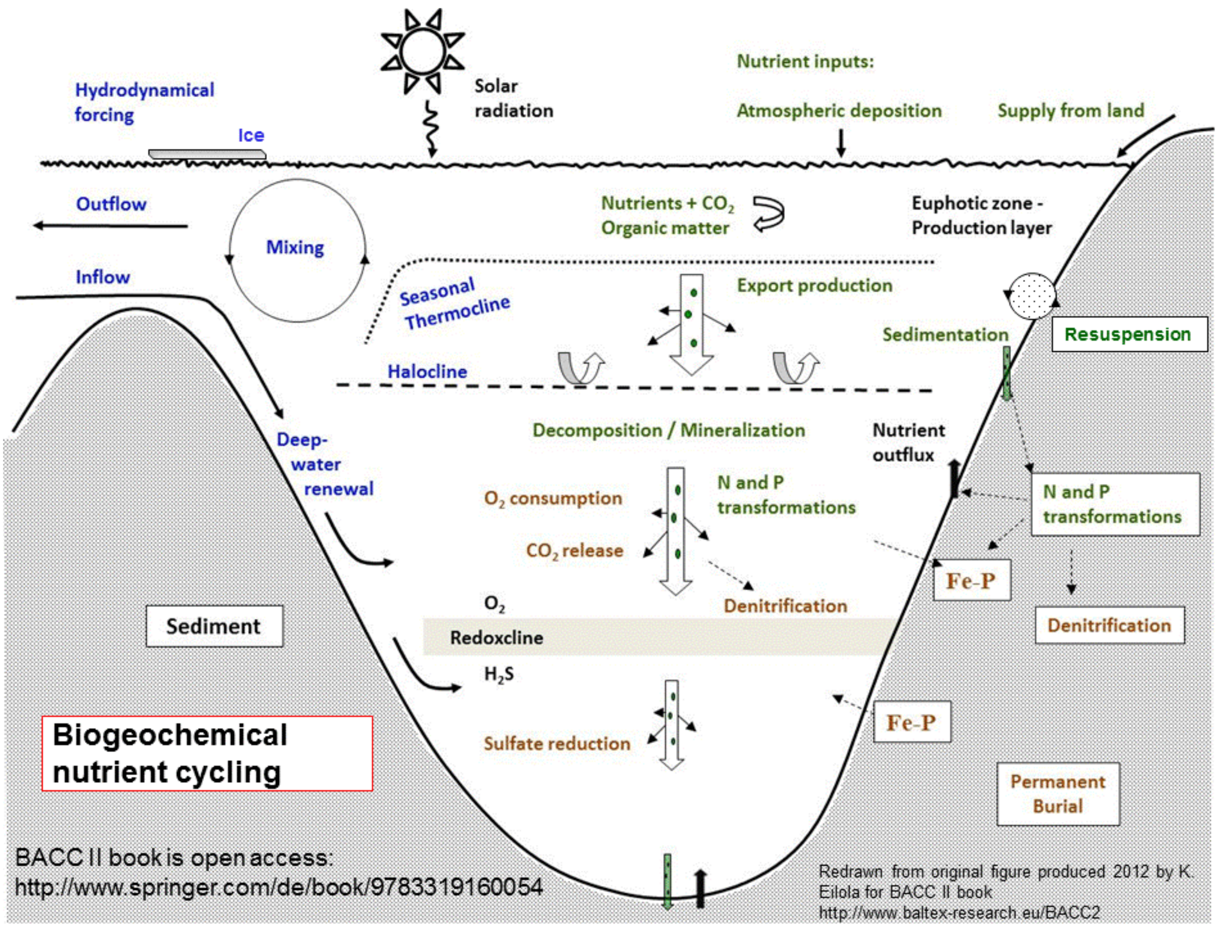

Fig.1 Schematic overview of important biogeochemical and forcing processes within the Baltic Sea (BACC II). The original figure has been redrawn and complemented with symbols of ice and sediment resuspension.

Inorganic carbon is usually in excess while the major limiting nutrients of annual biomass production in the surface waters of the Baltic Sea are dissolved inorganic nitrogen and dissolved inorganic phosphorus. Some evidence also exists for the use of dissolved organic nitrogen and dissolved organic phosphorus as nutrients and in addition, nitrogen fixation by cyanobacteria may add new bioavailable nitrogen. The production of organic matter is controlled by solar energy and the availability of nutrients supplied by internal recycling and external inputs. The decomposition of exported sinking organic matter consumes oxygen and causes oxygen deficiency in deeper poorly ventilated parts of the Baltic Sea. Large increases in nutrient supplies to the Baltic Sea (Fig. 2) during the last century caused eutrophication and worsened the water quality (e.g. increased areas with hypoxic and anoxic bottom waters) in large parts of the Baltic Sea. The high nutrient concentrations and other symptoms of eutrophication remained even though the loads were decreased after about 1980. This was explained by increased nutrient fluxes from the sediments (Gustafsson et al. 2012).

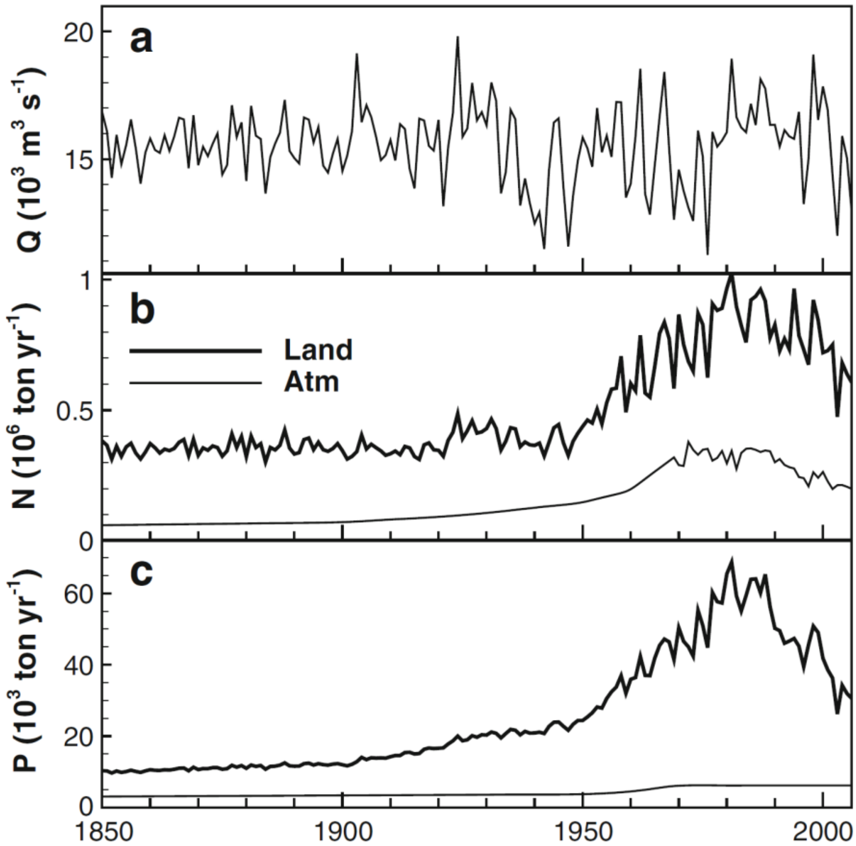

Fig. 2. Historical development of river water discharge (a), waterborne and atmospheric inputs of total nitrogen (b) and total phosphorus inputs (c) to the Baltic Sea (Gustafsson et al. 2012)

Nutrient budgets show that major fractions of the nitrogen and phosphorus loads remain in biogeochemical sinks within the Baltic Sea. E.g. Wulff and Stigebrandt (1989) estimated from a budget model that about 90% of the supplied nitrogen and phosphorus (1979-1981) went to the internal sinks. Almroth et al. (2015) estimated from coupled physical-biogeochemical model results 83% removal of phosphorus supplied in the period 1980-2008. The ensemble of biogeochemical models presented by Meier et al. (2012) indicated internal losses of about 97% of nitrogen and 85% of phosphorus supplies in the period 1978-2007. The climate scenarios (Meier et al. 2012) suggested that the sinks become weaker in the warmer future climate (2069-2097), especially for phosphorus. Only about 67% of the supplied phosphorus in the reference case went to internal sinks. The corresponding number for nitrogen losses was 95%.

Nutrients supplied from external and internal sources that are not accumulated inside the Baltic Sea will eventually enter the surface layers and become exported through the shallow sounds to the Kattegat and Skagerrak. An intensified internal nutrient cycling also has an impact on the exchanges of nutrients between shallow and deep regions and counteracts the nutrient load reductions suggested by the Baltic Sea Action Plan (Eilola et al. 2012). The capacity of the Baltic Sea to internally remove nitrogen and phosphorus from the pelagic nutrient cycling therefore plays a vital role for the biogeochemical cycles and the surface layer nutrient concentrations.

In this lecture we will discuss some general characteristics of the biogeochemical cycles in the Baltic Sea with an emphasis on the internal sources and sinks of nitrogen and phosphorus and the regulating factors.

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