

Climate Exacerbates Eutrophication in the North Sea

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Phytoplankton are the primary producers of pelagic marine waters, the base of the marine food web, and thus an integral part of the ecosystem. Furthermore, plankton are closely coupled to environmental change, making them sensitive indicators of environmental disturbance. During the 1980s the North Sea experienced changes in phytoplankton biomass, abundance, composition, and seasonal cycles of production as part of a climate-driven region-wide regime shift (Beaugrand, 2004). As an area rich in natural resources, much of the North Sea is impacted by anthropogenic activities including fishing, shipping, oil, gas, aggregate extraction and eutrophication. The combination of climatic and anthropogenic pressures has created difficulties in separating climate-induced changes in phytoplankton production from those caused by eutrophication.

Because of its proximity to land, the coastal North Sea is more heavily affected by land-based nutrients sources than the open North Sea. To differentiate between changes in phytoplankton production caused by climate and those caused by eutrophication, two new quantitative phytoplankton datasets were created, one for the open (>125 nm from shore) and one for the coastal (<30 nm from shore) North Sea. These datasets were created based on the relationship between the Phytoplankton Colour Index (a semi-quantitative estimate of phytoplankton

biomass obtained from the Continuous Plankton Recorder survey, an upper-layer plankton monitoring programme active in the North Sea since 1931) and quantitative remotely sensed SeaWiFS chlorophyll *a* (1997-2003). The result was two new long-term spatially comprehensive chlorophyll *a* datasets, providing quantitative estimates of phytoplankton biomass in open and coastal North Sea waters ($n > 52,000$). Climatic and nutrient data were also obtained and separately extracted for these regions.

The new chlorophyll *a* datasets reveal that the coastal North Sea is richer in phytoplankton biomass than the open North Sea. During the 1980s, a significant increase in phytoplankton biomass related to the regime shift occurred in both open and coastal waters (Fig. 1). Since the regime shift, chlorophyll *a* has remained at a higher level in both open (13%) and coastal (21%) regions. In the coastal North Sea, chlorophyll continues to increase.

Although phytoplankton biomass has increased since the regime shift, nutrient concentrations in the coastal North Sea and Elbe and Rhine rivers have decreased significantly (Fig. 2). Coastal chlorophyll *a* is negatively correlated

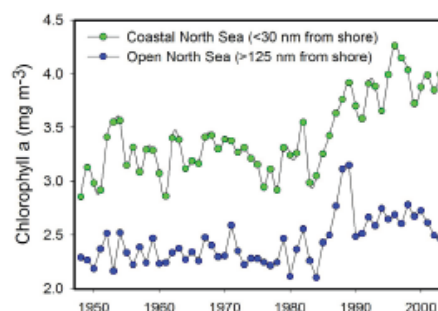


Fig. 1. Time-series of the new Chl *a* datasets (annual means) for the period 1948-2003 in the coastal and open North Sea.

with coastal and riverine nutrients; this is surprising, as traditionally increases in plankton production are triggered by increasing nutrients and are thought to be a symptom of eutrophication. However, changes in North Sea chlorophyll *a* were found to be closely related to warming Sea Surface Temperature, wind stress, a period of positive NAO, increased inflow of clear water from the North Atlantic, and an increase in water transparency in the coastal North Sea, indicating a close relationship between North Sea phytoplankton and climate.

As North Sea waters becomes warmer and clearer, the phytoplankton growing season is extended and the normally light-limited coastal phytoplankton can more effectively utilise available nutrients. Although riverine and coastal nutrient concentrations are decreasing (due to policy measures and changes in agricultural practices), coastal chlorophyll *a* continues to rise. This suggests that, due to changes in climate, coastal North Sea waters are increasingly susceptible to eutrophication, and stricter nutrient reduction measures are required in order to prevent further eutrophication in the coastal North Sea.

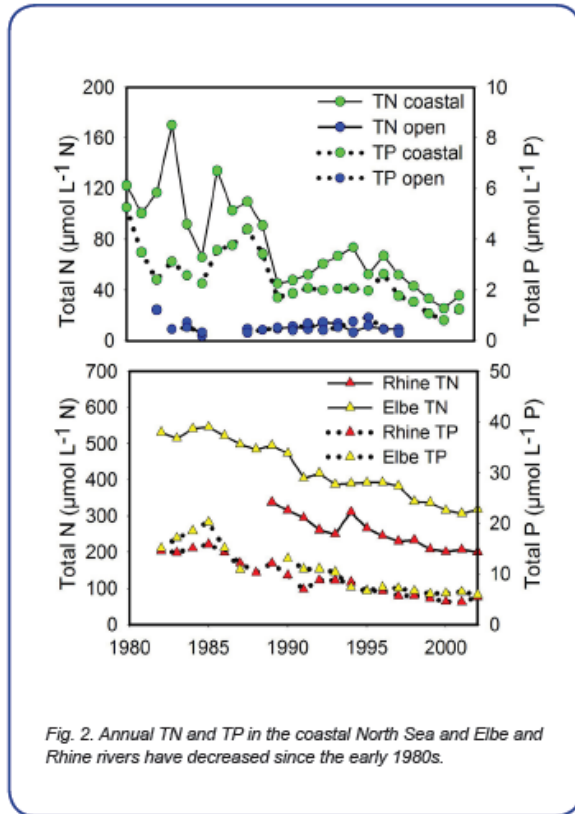


Fig. 2. Annual TN and TP in the coastal North Sea and Elbe and Rhine rivers have decreased since the early 1980s.

References

Beaugrand, G. 2004. The North Sea regime shift: Evidence, causes, mechanisms and consequences. *Prog. Oceanogr.* 60: 245-262