Climate exacerbates eutrophication in the North Sea

By Abigail McQuatters-Gollop

Phytoplankton are the primary producers in pelagic marine waters, the base of the marine food web, and an integral part of the ecosystem. Furthermore, plankton are closely coupled to environmental change, making them sensitive indicators of natural and anthropogenic ecosystem disturbance. As an area rich in resources, much of the North Sea is impacted by anthropogenic activities including fishing, shipping and oil, gas, and aggregate extraction; eutrophication is also a priority issue in some areas. 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 anthropogenic nutrients 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) North Sea 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 (CPR) survey (an upper-layer plankton monitoring programme active in the North Sea since 1931)) and quantitative remotely-sensed SeaWiFS chlorophyll *a* (chl *a*). The result was two new long-term (1948-2003) spatially comprehensive chl *a* datasets, providing quantitative estimates of phytoplankton biomass in open and coastal North Sea waters (n >52,000). Spatially referenced climatic and nutrient data were also obtained and separately extracted for these regions.

The new chl *a* datasets reveal that the coastal North Sea is consistently richer in phytoplankton biomass than the open North Sea. During the 1980s, a significant increase in chl *a* occurred in both open and coastal waters. This change was related to a climate-driven regime shift, a step-wise alteration in ecosystem composition and productivity at a regional scale (Figure 1, Beaugrand 2004). Since the regime shift, chl *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 as a result of policy measures and changes in agricultural practices (Figure 2). Coastal chl *a* is negatively correlated with coastal and riverine nutrients; this is surprising, as increases in plankton production are often associated with increasing nutrients and are a symptom of eutrophication. The relationship between phytoplankton and nutrients therefore appears to be non-linear in coastal North Sea waters (i.e. a reduction in nutrient load does not lead to an equivalent reduction in phytoplankton biomass).

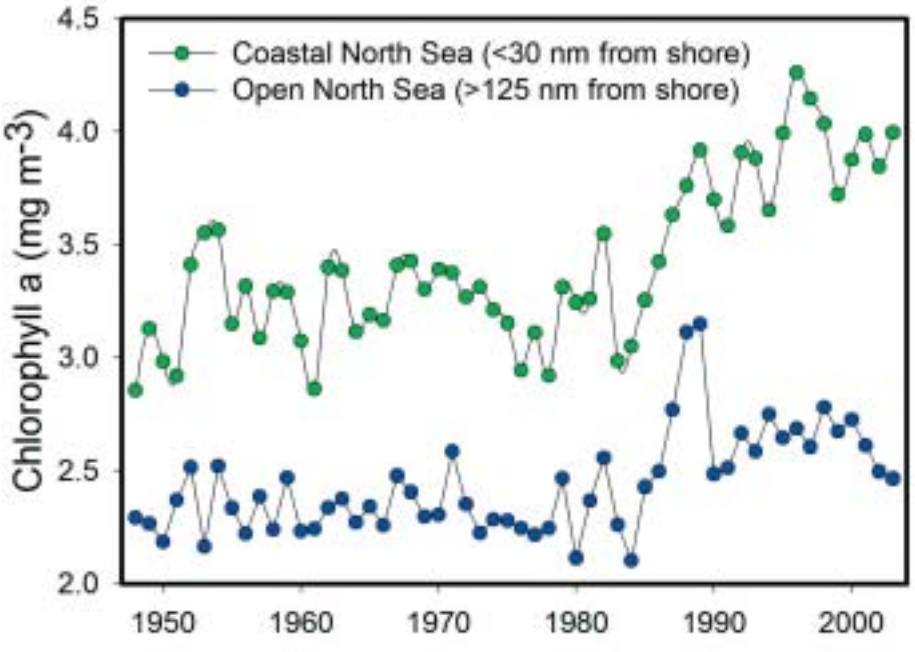

Figure 1. Time-series of the new chlorophyll *a* datasets (annual means) for the period 1948-2003 in the coastal and open North Sea.

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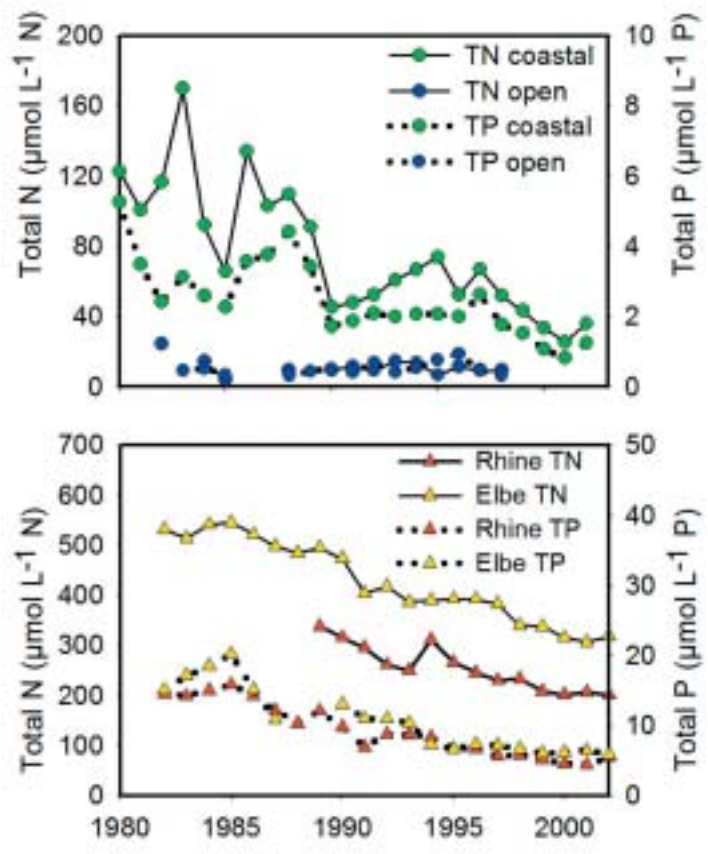
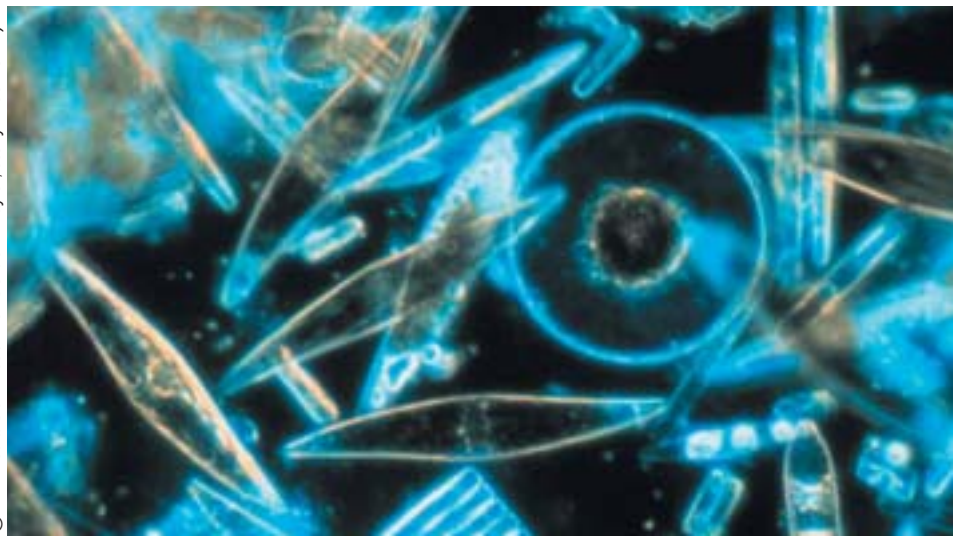


Figure 2. Annual TN and TP in the coastal North Sea and Elbe and Rhine rivers have decreased since the early 1980s.

by nutrients. The changes observed in chl *a* are positively correlated with warming sea surface temperature (SST) and a positive phase of the North Atlantic Oscillation (NAO). At the same time, inflow of clear water from the North Atlantic also increased, resulting in greater transparency of coastal North Sea waters. The relationships between climate and chl *a* differ in coastal and open areas, with open chlorophyll regulated by Atlantic inflow, winter NAO and SST, and with coastal chlorophyll most influenced by SST and water transparency. This indicates that as North Sea waters become warmer and clearer, the phytoplankton growing season is extended and the normally light-limited coastal phytoplankton can utilize available nutrients more effectively.



Phytoplankton.

Discarded oil drums.

Since the regime shift, the North Sea has maintained a higher level of chl *a* in both open and coastal waters. Additionally, although riverine and coastal nutrient concentrations are decreasing, coastal chl *a* continues to rise. This suggests that, due to regional changes in climate, coastal North Sea waters are increasingly susceptible to nutrient enrichment, and stricter nutrient reduction measures are required in order to prevent further eutrophication in the coastal North Sea.

For more information

McQuatters-Gollop, A., Raitsos, D.E., Edwards, M., Pradhan, Y., Mee, L.D., Lavender S.J. and Attrill, M.J. (2007). A long-term chlorophyll data set reveals regime shift in North Sea phytoplankton biomass unconnected to nutrient trends. *Limnology and Oceanography* **52**, 635-648.

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Beaugrand, G. (2004). The North Sea regime shift: evidence, causes, mechanisms and consequences. *Progress in Oceanography* **60**, 245-262.

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