

Towards a natural Wadden Sea

Bouwe R. Kuipers* and Govert J. van Noort

The present Wadden Sea was formed less than 1000 years ago, when large floods eroded the dunes and the coastal moorland, and covered it with sand. The Dutch rivers that entered the area had a minor nutrient load. With the increasing use of artificial fertilizer in agriculture in the twentieth century, phosphate and nitrate discharge by the Rhine became very large and peaked in the 1980's. The eutrophication stimulated the productivity of the Wadden Sea but also caused anoxic spots in the German Bight. After the improvement of the waste water treatment, the nutrient discharge of the rivers largely decreased. The phosphorus load of the Rhine was back at 'normal' level by 1990 already but it took more than a decade to notice effects on the Wadden Sea. Bacterial assays clearly showed that nowadays phosphate limitation stops the spring plankton bloom. The smaller primary production will have lowered the animal production as well. We should get used to the idea that a natural Wadden Sea is not as rich in biomass as during the decades of eutrophication.

'The tide flows in, the tide flows out, twice every day returning....(song by the Matthew Brothers, Oban, Scotland, 1975)

As Prof. L. van Straaten of the Groningen University long ago used to demonstrate with a 'Russian Peat Corer' to his students, the sediment of the Wadden Sea tidal flats consists basically of a 1-1.5m thick layer of dune sand (fine, wind selected sand), deposited over 'Holland Peat'. This peat layer is at some places more than 18 m thick and was formed during the 'Holocene land formation' after the last Ice Age. It is the accumulated fossilized plant debris of extensive - and, due to the rise of the sealevel, also slowly rising - freshwater swamps behind the barrier of dunes which protected them from the North Sea. Human settlements were still present in these bogs as late as the early Middle Ages, as appears from a.o. fragments of 11th-century pottery and traces of huts and a well, found under the sand, on the surface of the peat, in the middle of what is now Balgzand tidal flat in the western Wadden Sea.

As witnessed by early medieval records of disastrous floods - which no doubt were accompanied by a new transgression of the sea - the dunes eroded and the once closed barrier fell apart into individual Frisian islands and large tidal inlets. The sea swallowed thousands of km² of medieval coastal moorland and covered the peat with sand. Ever since, the resulting Wadden Sea is flooded twice daily with water from the North Sea. Actually, the tides bring Dutch coastal water, a

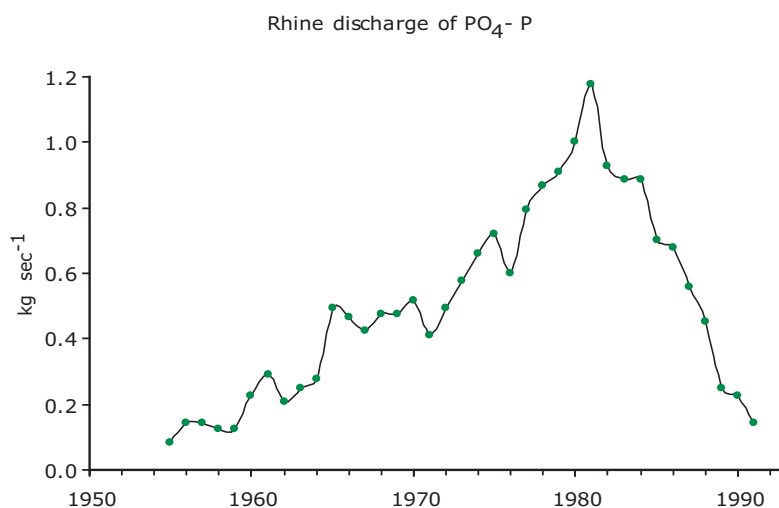


Fig. 1. Dissolved phosphate discharge of the Rhine since 1955. Based on data of Rijkswaterstaat (Cadée and Hegeman 1993, NJSR 31: 147-152)

mixture of seawater and the freshwater discharges of the rivers Scheldt, Meuse and the Rhine, into the estuary. It seems likely that during the first several ages of the young Wadden Sea, these rivers did not bring the spectacular amounts of nutrients that were regarded normal in the 20th century. Therefore, production in the area must have been less than in our time. On the other hand, the system was much larger since it still included the Zuiderzee and considerable other parts of the Wadden Sea that were later closed off or reclaimed for agriculture.

During the industrial revolution in the 19th century and after the introduction

of artificial fertilizer (1850), the Wadden Sea gradually received an increasing input of nutrients (especially nitrogen) and organic matter. In that time waste water was not treated at all. Moreover, from WW II to 1980, the phosphorus discharge of the Rhine increased 9-fold. As a consequence, primary and secondary production became so high that during several decades the estuary offered virtually inexhaustible feeding grounds for migrating birds and fishes. However, especially in the German part, anoxic waterlayers and black spots on the seabed began to show up as signs of a

*Corresponding author: brkuipers@zonnet.nl

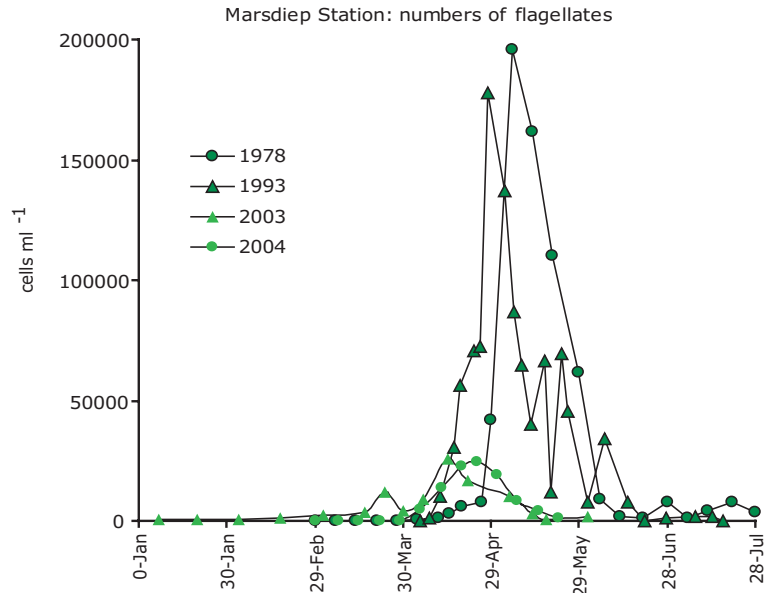


Fig. 2. Comparison of the flagellate spring blooms in 2003 and 2004 with those in 1978 and in 1993 (Cadée and Hegeman 1993; Brussaard et al. 1996, MEPS 144: 211-221).

beginning deterioration of our coastal system. Measures taken to reduce the eutrophication of the European surface waters and rivers resulted in a successful cleaning of the Rhine: the phosphorus discharge in 1990 was already back at the level of 1950 (Fig. 1). Possibly due to release of phosphorus from reserves in the seabed (and certain ongoing inputs from the land), it took many years before a significant change in the Wadden Sea in response to the cleaning of the Rhine could be established. However, since 2000 the water has become visibly clearer, the phytoplankton blooms are much smaller than during the decades of eutrophication and thick layers of foam on the beaches belong to the past. The benthic invertebrate biomass and production seems presently to decrease as well.

In order to verify if the present small spring phytoplankton blooms are actually phosphorus limited, experiments were done in the Marsdiep during the spring of 2003 and 2004. Samples were collected weekly from the NIOZ-jetty in the main tidal inlet of the western Wadden Sea, where the abundance and productivity of phytoplankton has been

monitored by NIOZ for almost 40 years now. Our experiments were bacterial bioassays using bacterioplankton, the performance of which is less complicated than bioassays with algae. Bacteria were simply separated from all other plankton by filtration through 0.8 µm pore size filters and, much easier than with phytoplankton, bacteria were incubated in the dark. Due to their much smaller size (which means a relatively larger body surface), bacteria are as least as good in taking up dissolved nutrients from the water as algae. So a shortage indicated by such bacterial bioassays holds certainly for phytoplankton at the same time.

The results were quite clear: at the time when a spring bloom really began to accelerate in the past, the algae in the Marsdiep stopped growing in 2003 and 2004 (Fig. 2). The phosphate-concentration was at that moment close to zero (0.048 µM) and the bacteria in our experiments grew faster only if the addition contained phosphate (P). While single additions of carbon (C) or nitrate (N) had little effect, bacterial growth rate responded strongly – with 5-8 times higher growth rates - between 19 April

and 10 May 2004 to additions of CNP, NP and P alone (Fig. 3).

It is quite certain that algae in the Marsdiep suffered from the same severe P-depletion, causing the very early ending of the spring phytoplankton bloom, which for decades lasted a month longer and functioned as the main annual food pulse for the huge benthic invertebrate populations of the Wadden Sea. The conclusion seems clear: the future of the wildlife in the Wadden Sea has from now on become dependent on the scarce input of phosphate into the system. This has, however, also a positive side: the future situation seems much more 'natural' than that under the heavy eutrophication during the 20th century.

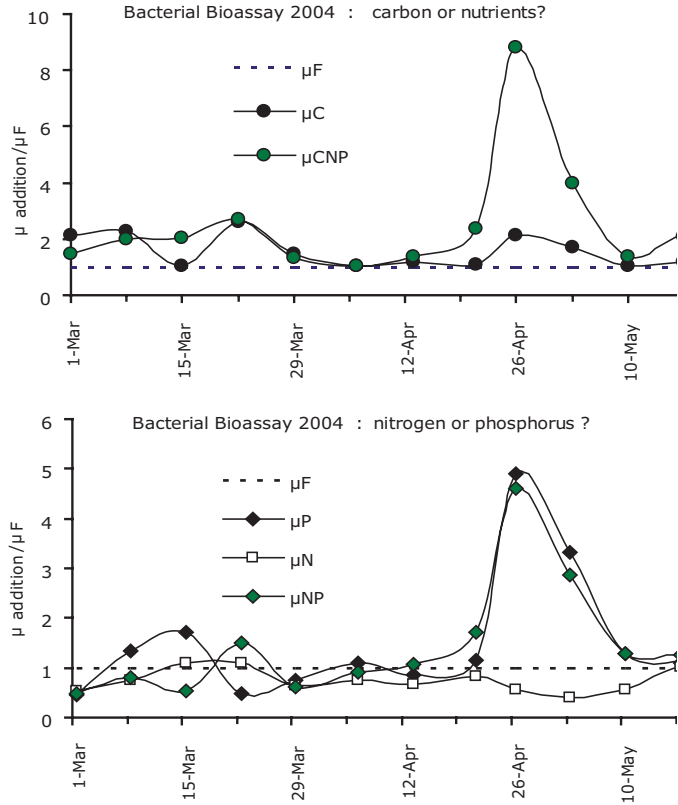


Fig. 3. Bioassay results for 2004 on the effects of additions of nitrate (μN), phosphate (μP) and/or carbon (μC) compared to the control without addition (μF).