Marine Pollution Bulletin 136 (2018) 68–78

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Eutrophication assessment in the transit area German Bight (North Sea) 2006–2014 – Stagnation and limitations

U. Brockmann[a,*], D. Topcu[a], M. Schütt[a], W. Leujak[b]

[a] Hamburg University, Inst. for Geology, Dept. Biogeochemistry, Max Brauer Allee 60, 22765 Hamburg, Germany
[b] Federal Environmental Agency, Wörlitzer Platz 1, 06844 Dessau, Germany

ARTICLE INFO

Keywords:
Eutrophication
German Bight
Oxygen depletion
Trans-boundary effects

ABSTRACT

The eutrophication status of the German Bight (North Sea) has been assessed the third time since 1998 according to the OSPAR-Comprehensive Procedure between 2006 and 2014. Since the 1980s nutrient discharges and atmospheric nitrogen deposition had declined significantly but chlorophyll *a* and nutrient concentrations remained above assessment levels inshore and in inner coastal waters, reflecting continuing eutrophication. Recently local river discharges stagnated or increased again and total nitrogen remained above a reduction target of 200 μM. Most nutrients and conversion products were imported by a coastal current, passing the German Bight. Organic matter was trapped in offshore bottom waters in the ancient Elbe valley, causing repeated annual oxygen minima (< 6 mg/L) and a classification as Problem Area. Effects of national reduction measures are limited in the transit area German Bight because improvements in open coastal waters require international efforts, based on comprehensive analyses.

Eutrophication is one of the most extended and investigated processes of anthropogenic forcing in coastal waters (coastal waters), changing ecosystems completely (Nixon, 1995; Howarth, 1998, Cloern, 2001), especially by oxygen depletion which is predicted to increase by climate change (Diaz and Rosenberg, 2008; Conley et al., 2011). CO_2 increases will enhance eutrophication effects as well (Tagliabue et al., 2011). For these reasons, regular assessments of eutrophication processes are required, quantifying regional nutrient budgets, discharges/depositions and succeeding eutrophication effects. Within OSPAR, eutrophication was assessed by the Comprehensive Procedure (COMP) in the North Sea area (OSPAR, 2005) on a regular basis since 1985, now the third time for the period 2006–2014. Main results for the German Exclusive Economic Zone (GEEZ) are presented, supplemented by some process data. The GEEZ, includes about 41.300 km^2 with 6.355 km^2 shallow inshore waters (Wadden Sea and estuaries), 22.802 km^2 shallow coastal (around 20 m depth) and 12.127 km^2 offshore waters (< 50 m) and is characterised by salinity gradients between 18 at the estuaries and > 34.5 offshore (Fig. 1).

The North Sea is one of the most contaminated areas by anthropogenic nitrogen inputs (Caraco, 1995; Howarth, 1998), but manifestations of eutrophication processes differ significantly along the North Sea coasts: mixing gradients of continental rivers draining large catchment areas (by the Rhine 185,000 km^2 and by the Elbe 146,500 km^2) are extended along the shallow coasts, different to steep coasts where mixing is reduced to near shore areas, restricting eutrophication effects to inshore waters mainly (OSPAR, 2008). A residual current, moving anti-clock-wise along the southern North Sea coasts (Otto et al., 1990), cross the transit area of the GEEZ, stretched in the south-eastern North Sea between shallow tidal flats inshore and offshore waters (> 40 m) along the ancient Elbe Valley (Fig. 1). Advected dissolved and suspended material, including nutrients, plankton and organic matter originating from other coastal regions (Kautsky, 1986), contributes to local eutrophication, by crossing the GEEZ When the seasonally stratified ancient Elbe Valley is passed, part of particulate organic matter will be trapped in bottom waters by sedimentation. Its decomposition contributes to local seasonal oxygen depletion (Topcu and Brockmann, 2015). Hickel et al. (1993) reported increasing nutrients and phytoplankton concentrations in the inner German Bight, based on regular monitoring since 1962, and significant eutrophication effects had been observed, including fish and zoobenthos kills (Dethlefsen and von Westernhagen, 1983; Von Westernhagen and Dethlefsen, 1985). Accordingly, during the first two COMP assessment periods, main parts of the GEEZ had been indicated as Problem Areas (Brockmann et al., 2003, 2007) which was now repeated. Selected results of the recent COMP-3 assessment (OSPAR, 2017a) have been compiled in this paper reflecting main effects of continuing eutrophication problems in the transit area German Bight between 2006 and 2014, despite significant nutrient reductions in local rivers. Results

* Corresponding author.
E-mail address: brockmann@uni-hamburg.de (U. Brockmann).

https://doi.org/10.1016/j.marpolbul.2018.08.060
Received 12 April 2018; Received in revised form 24 August 2018; Accepted 27 August 2018

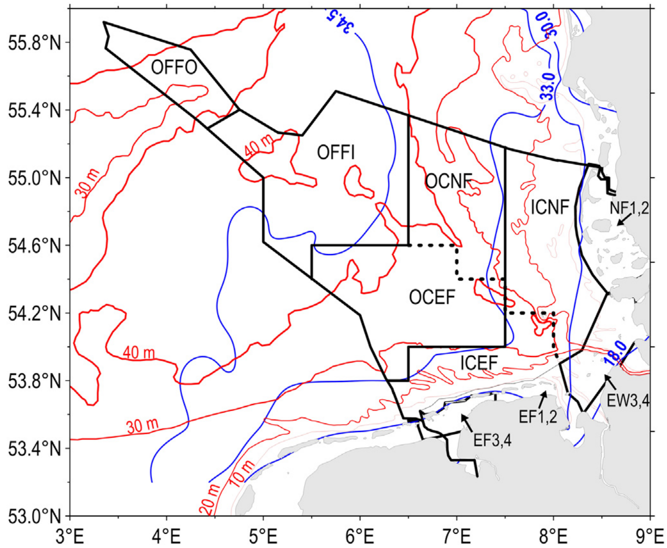

Fig. 1. Boarders of assessed subareas within the GEEZ with water depths [m] (red) and mean salinities 2006–2014 (blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of these regional eutrophication assessments have been extracted within integrated OSPAR reports (OSPAR, 2008, 2017b) and the North Sea Qualitative Status Reports (QSR, 2000, 2010).

Data have been collected from the ICES data bank and national data centres (DOD, MUDAB, NIOZ), and most recent data from regional originators (NLWKN-Lower Saxony, LLUR-Schleswig-Holstein, AGs Elbe, Weser, Ems). Data were analysed by horizontal gradients (surface or near bottom water), mixing diagrams, correlations between parameters, seasonal cycles, and trends, including variability. Most of the analyses have been performed with the Golden Software programmes "Surfer" and "Grapher". For detailed assessments, the GEEZ area was divided into regular squares of 145.2 km^2, allowing consistent calculation of gradients (Fig. 2), assessments, and confidence rating. According to the recent salinity gradients and WFD-requirements, 11 subareas (Fig. 1) had been defined: 2 offshore areas (OFFO + OFFI, salinity > 34.5), 2 outer (OCNF, OCEF, 33–34.5) and 2 inner coastal waters (ICNF, ICEF, 30–33), 4 inshore WFD-waters according to the WFD code (NF 12, EW 34, EF 12, EF 34, salinities 18–30) and 3 (combined) transitional waters including the main estuaries (Elbe, Weser, Ems, < 18). Inshore-areas (salinities < 30) have been assessed according to the WFD as well, and inner and outer coastal waters were divided for North- and East Frisian areas, thus considering direct effects by the river plumes of Elbe and Weser on North Frisian waters. Results of the WFD assessments were transferred to the OSPAR-COMP 3 to avoid contradicting assessments for inshore waters.

The assessment was performed according to the OSPAR guidance for the COMP (OSPAR, 2015), considering the full set of mandatory parameters (dissolved and total nutrients, nutrient ratios, chlorophyll *a*, phytoplankton indicator species, macrophytes, macrozoobenthos (MZB), oxygen concentrations/saturation, and organic carbon), supplemented by long term trends and annual cycles of some key parameters. Mainly mean seasonal surface concentrations or bottom values (for oxygen and MZB) were assessed as annual means (minima for oxygen concentrations, and maxima for chlorophyll additionally) within subareas and finally combined according to the number of years with concentrations above or below thresholds, considering data coverage.

Correlations for harmonising assessment levels were based on means within geographical squares (square sizes of 145.2 km^2, see Fig. 2) or seasonal annual means of subareas. Considering data limitation, a simplified confidence rating was performed including data coverage in space and time and percentage of standard deviations. A complete confidence rating (Brockmann and Topcu, 2014) was applied for chlorophyll *a*. Insufficient data caused local assessments as potential problem area. Data restrictions for event detections like plankton blooms and transitional oxygen depletion are considered by assessing chlorophyll maxima and oxygen minima reflecting the variability of data forced by transitional thermal stratification. Assessment levels for total nitrogen (TN) and dissolved inorganic nitrogen (DIN) concentrations in rivers have been calculated from hind-cast models based on data compilations at early industrial agriculture practices and moderate population density during 1880 (Gadegast and Venohr, 2015). These values were transferred to coastal waters by mixing diagrams with recent mean offshore concentrations (salinity 34.5–35, without Dogger Bank area for inorganic nutrients) (Table 1). Assessment levels for phosphate (DIP) have been deduced from recent correlations with total phosphorus (TP). TP had been correlated with TN adopting relations

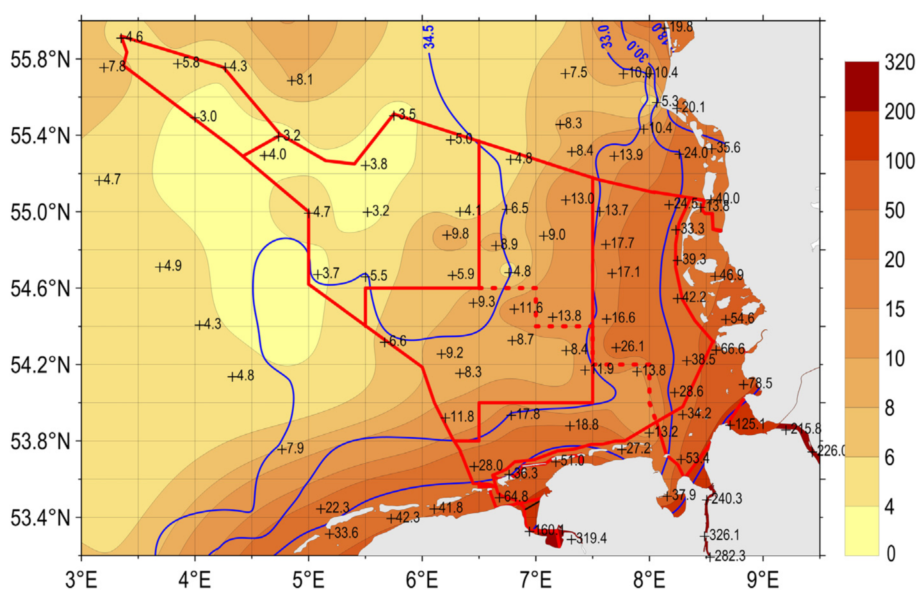

Fig. 2. Mean surface concentrations of DIN [μM] during winter 2006–2014 (crosses indicate mean sampling locations and the values indicate means per square of 145.2 km^2).