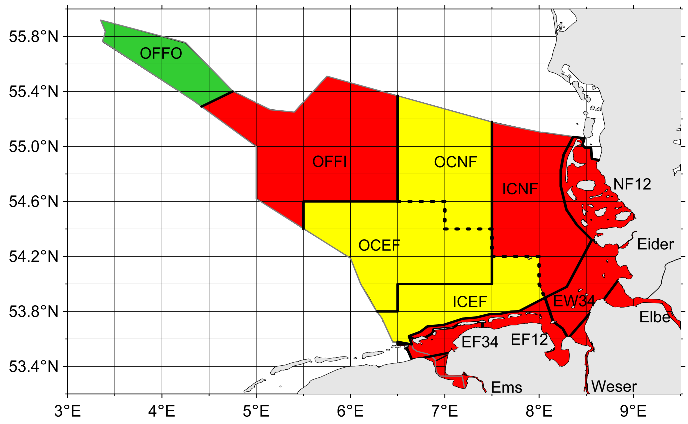
Third assessment of the eutrophication status of German coastal and marine waters 2006 – 2014 in the North Sea according to the OSPAR Comprehensive Procedure



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Abbreviations:

AlgFES	Algenfrüherkennungssystem, LLUR
AMBI	AZTI Marine Biotic Index
ARGE	Arbeitsgemeinschaft (river specific)
AWI	Alfred-Wegener Institut, Bremerhaven, Helgoland, List/Sylt
BLMP	Bund/Länder Messprogramm
BQI	Benthic Quality Index
BSH	Bundesamt für Seeschifffahrt und Hydrographie, Hamburg
COMP	Comprehensive Procedure
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphor (phosphate)
DOC	Dissolved Organic Carbon
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
EUC	Eutrophication Commitee (OSPAR)
FTZ	Forschungs- und Technologiezentrum Westküste, Büsum
IBMC	Institute for Biogeochemistry and Marine Chemistry, Hamburg
ICES	International Council for Exploration the Sea, Copenhagen
LLUR	Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein
MARNET	Marines Umweltmessnetz in Nord-und Ostsee (BSH)
MONERIS	Modelling Nutrient Emissions in River Systems
MTZ	Maximum Turbidity Zone
MURSYS	Meeresumwelt-Reportsystem (BSH)
NERI	National Environment Research Institute, Univ. Aarhus
NLKWN	Niedersächsisches Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz
NLÖ	Niedersächsisches Landesamt für Ökologie
N/P	Ratio of Nitrogen to Phosphorus
NS	North Sea
POC	Particulate Organic Carbon
PO_4	Phosphate
Q	Discharge Rate
RWS RIKZ	Rijkswaterstaat, National Institute for Coastal and Marine Management, The Hague
SD	Standard Deviations
Si	Silicate
SiO_2	Silicate
SPM	Suspended Particulate Matter
SWD	Surface Water Directive
TDN	Total Dissolved Nitrogen
TOC	Total Organic Carbon
TMAP	Trilateral Monitoring and Assessment Program (Wadden Sea)
TN	Total Nitrogen
TP	Total Phosphorus
UBA	Umweltbundesamt (German Environment Agency), Dessau, Berlin
WFD	Water Framework Directive

1. Summary

Outcome of COMP3, compared with COMP2

In the 3rd application of the OSPAR common procedure, 6 % of Germany's national waters were assessed as Non-Problem areas, 39 % as Potential Problem areas and 55 % as Problem Areas. In comparison the 2nd application assessed 0 % of Germany's national waters as Non-Problem areas, 20 % as Potential Problem areas and 80 % as Problem Areas. Compared to the 2nd application of the COMP the eutrophication status seems to have improved only in the offshore area OFFO (the area was previously classified as a potential problem area). The transitional and coastal waters remain highly eutrophic and are characterized by elevated concentrations of nutrients and chlorophyll-a (including phytoplankton indicator species), reduced light climate and partly by seasonal oxygen depletion. Large areas in the inner and outer coastal waters were classified as potential problem areas due to missing data for macrozoobenthos, organic carbon and phytoplankton indicator species.

Nutrient inputs stem from local rivers and the atmosphere, but also from trans-boundary nutrient transports, especially for outer coastal and offshore waters. Riverine nutrient loads and concentrations showed decreasing trends between 1980 and 2000/2005, followed by stagnations, indicating that further nutrient reduction measures are required. None of the main rivers (Elbe, Weser, Ems, Eider) achieved the target management level of 2.8 mg/l nitrogen that has been set in the national Surface Water Ordinance for TN at the limnic-marine border. Their discharge contributed 26 % of total annual TN inputs to the German Exclusive Economic Zone (GEEZ). Atmospheric nitrogen deposition contributed between 14 to 20%, indicating that this remains an important source. The nutrient regime in the GEEZ was dominated by trans-boundary nutrient inputs, transported either counter-clockwise by the residual coastal current (31 % of nitrogen inputs) or stemming from the mixing with Atlantic waters (28 %). Hence good status with respect to eutrophication in the GEEZ cannot be achieved through national nutrient reduction efforts alone, but relies significantly on reduction efforts by "upstream" Contracting Parties.

Description of area

The GEEZ includes about 43.097 km^2 with a mean water depth of about 20 m. In the ancient Elbe valley the water depth can reach >40m. The GEEZ is characterised by a salinity gradient starting with salinities below 18 within the estuaries and reaching 34.5 in outer coastal waters. Estuaries and extended shallow tidal flats of the Wadden Sea, sheltered by a belt of islands, form a main part of the coastline, representing inshore waters that are also assessed under the Water Framework Directive (WFD). In consideration of the prevailing salinity gradient the GEEZ was divided into 13 subareas: 2 offshore areas (> 34.5), 2 outer (33-34.5) and 2 inner coastal waters (30-33), 4 inshore WFD-waters (18-30) and 3 main estuaries (<18). The ancient Elbe valley constitutes the border between the East Frisian (EF) and North Frisian (NF) waters. The inshore waters of the WFD were summarised according to WFD types (NEA 1/2 and NEA 3/4) into 4 assessment areas (EF34, EF12, EW34, NF12) (EW = Elbe/Weser estuary). Compared to the 2nd application of the COMP the coastal waters with salinities of 30-34.5 have been further subdivided into four areas (ICEF, OCEF, ICNF, OCNF), distinguishing inner and outer coastal waters, while the other assessment areas remained the same.

Assessment procedure

The assessment was performed according to the OSPAR guidance for the COMP, considering the full set of mandatory and voluntary parameters (dissolved and total nutrients, nutrient ratios, chlorophyll-a, phytoplankton indicator species, macrophytes, macrozoobenthos, oxygen concentrations/saturation and organic carbon) for an initial assessment. The final assessment result was determined considering the variability of data and their confidence. Efforts have been undertaken to align COMP 3 with the assessment of "ecological status" under the WFD for the waters <1 nautical mile. WFD assessment levels have been applied and for the parameters macrophytes and macrozoobenthos WFD assessment results based on the period 2009-2013/14 have been used. The assessment levels of total and dissolved nutrients have been revised since the 2nd application and new assessment levels were used based on a harmonised approach for WFD waters and waters beyond 1 nautical mile. For the subareas thresholds were calculated according to main seasonal salinities, based on linear mixing diagrams with marine endmembers for concentrations of total nitrogen.

Improving future assessments
Monitoring has not significantly improved since COMP 2 and is still insufficient especially for the biological parameters (macrozoobenthos, chlorophyll-a, phytoplankton indicator species) in outer coastal and offshore waters. Efforts will be undertaken to make routine use of satellite data (Copernicus products) for the assessment of chlorophyll-a in the future. Furthermore, a routine procedure for the assessment of confidence should be further developed and applied. While it was tried to further align the COMP assessment with the assessment of ecological status under the WFD the degree of harmonisation is still not satisfactory. Germany is also striving for a stronger alignment with the eutrophication assessment method used in the Baltic Sea, with the ultimate aim to base COMP 4 on a semi-automated, quantitative and transparent assessment methodology.

2. Introduction

This third report on the eutrophication status of the German coastal and marine waters in the period 2006-2014 is based on the OSPAR Common Procedure as defined in the OSPAR agreement No. 2013-8, and on the guidance and examples on form and content of national reports (Annex 5 of the HASEC Summary Report 2015). OSPAR agreement No. 2013-8 (OSPAR, 2013) is an update of the Common Assessment Criteria for the Eutrophication status of the OSPAR Marine Area as agreed on by OSPAR in 2005 (OSPAR, 2005a; Ref. No. 2005-3; the successor of Ref. No. 2002-20), which have been used for the first (1985-1998) and the second (2001-2005) applications of the COMP. The results of the assessment of the German coastal and marine waters described in this report for the period of 2006-2014 are compared to the results with the two earlier applications of the Comprehensive Procedure (Brockmann et al. 2003, Anonymous 2003, Brockmann et al. 2007).

The OSPAR Common Procedure is an integrated assessment method to determine the eutrophication status of the German Exclusive Economic Zone (GEEZ). It consists of two parts, a screening procedure and the actual assessment of the eutrophication status called the Comprehensive Procedure, with the screening procedure being a "broad-brush" exercise to identify areas that are obvious non-problem areas and where there is no requirement to carry out a harmonised assessment using the iterative Comprehensive Procedure. Since such areas do not exist in the GEEZ only the Comprehensive Procedure, referred to as COMP, has been applied for the third assessment. COMP assesses coastal and marine waters as one of the three categories – Problem Areas with respect to eutrophication, Non-Problem Areas and Potential Problem Areas. The latter classification result is used where there are not enough data to perform an assessment or where the data available is not fit for the purpose.

The COMP assesses transitional, coastal and marine waters and therefore overlaps with the assessment of the "ecological status" under the Water Framework Directive (WFD) in the 1 nautical mile zone. In this area of overlap care has been taken to use the relevant WFD indicators and their assessment levels, to achieve, as far as possible, a harmonisation with the WFD assessment results. This approach follows the recommendation of the national "Koordinierungsrat" that was agreed in July 2015 (KoRa 2015a). The OSPAR COMP is also applied as a method to assess Descriptor 5 "Eutrophication" of the EU Marine Strategy Framework Directive. In this respect the third application will feed into the follow-up assessment according to Articles 8 and 9 of the MSFD due in 2018.

Concerning the history of eutrophication assessments of the GEEZ, COMP 1 (1985-1998) classified the inner parts as "Problem Area" in relation to eutrophication, due to high nutrient and chlorophyll-a concentrations, occurrence of harmful algae and episodic oxygen deficiency in the bottom water of stratified areas. The coverage of biological data was at that time not sufficient for a robust assessment. The German Wadden Sea has also been assessed specifically, resulting in a classification as Problem Area as well (van Beusekom et al. 2005a).

By COMP 2 (2001-2005) the inner coastal waters were still assessed as Problem Areas (Brockmann et al. 2007, OSPAR 2008). Offshore waters had been assessed as Potential Problem Areas due to seasonal oxygen depletion in stratified areas. The whole area is strongly affected by long-distance transports of nutrients and organic matter, passing the GEEZ from south/west to north. Trends of nutrient concentrations in the main local rivers indicated recent significant decreases for the Elbe and Weser, however, these reductions were masked by variable freshwater discharges (for details see § 5.5). In comparison to COMP 1 subareas have been further differentiated. Salinity gradients have been moved towards the coast, restricting the extension of inner coastal waters.

This report documents the third application of the COMP and is based on data of 2006 to 2014.

3. Description of the assessed area

The GEEZ covers an area of about 42.262 km^2, including the German Bight (about 24.400 km^2) and the coastal and transitional waters (Fig. 1).

3.1 Coordinates

The coordinates of the GEEZ are shown in Fig. 1 and listed in Tab. 1. At the border to the Netherlands near the coast coordinates are not yet determined.

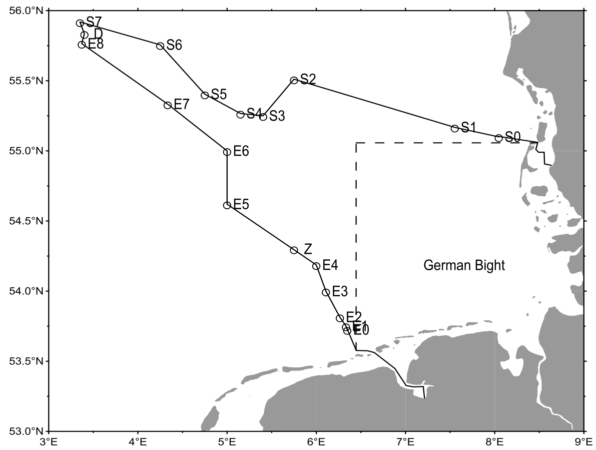

Fig. 1 Location of the German Exclusive Economic Zone (GEEZ). Respective coordinates for the numbers / letters are listed in Tab. 1.

Tab. 1 Coordinates of the German Exclusive Economic Zone. For a reference to the locations see Fig. 1.

Locations	Lat°	Lat'	Lat"	Lon°	Lon'	Lon"		Lat [dec]	Lon [dec]
E0	53	43	30.8	6	20	49.7		53.7252	6.3471
E1	53	45	3.0	6	19	58.3		53.7508	6.3329
E2	53	48	52.9	6	15	51.3		53.8147	6.2643
E3	53	59	56.8	6	6	28.2		53.9991	6.1078
E4	54	11	12.0	6	0	0.0		54.1867	6.0000
E5	54	37	12.0	5	0	0.0		54.6200	5.0000
E6	55	0	0.0	5	0	0.0		55.0000	5.0000
E7	55	20	0.0	4	20	0.0		55.3333	4.3333
E8	55	45	54.0	3	22	13.0		55.7650	3.3703
D	55	50	6.0	3	24	0.0		55.8350	3.4000
S7	55	55	9.4	3	21	0.0		55.9193	3.3500
S6	55	45	21.8	4	15	0.0		55.7561	4.2500
S5	55	24	15.0	4	45	0.0		55.4042	4.7500
S4	55	16	0.0	5	9	0.0		55.2667	5.1500
S3	55	15	0.0	5	24	12.0		55.2500	5.4033

S2	55	30	40.3	5	45	0.0		55.5112	5.7500
S1	55	10	3.4	7	33	9.6		55.1676	7.5527
S0	55	5	59.4	8	2	44.4		55.0998	8.0457
Z	54	18	0.0	5	45	0.0		54.3000	5.7500

3.2 General characteristics and subareas

The German Bight has a mean depth of 20 m (0 – 50 m) with only weak seasonal stratification (Fig.2). In offshore areas and especially along the ancient Elbe valley more than 30 m depth facilitates primary production within the upper mixed layer and seasonal oxygen depletion in enclosed bottom waters, interrupted by mixing and upwelling events in shallow parts (Topcu & Brockmann 2015).

The tidal flats, crossed by the estuaries, are exposed to tides of 2 - 3 m tidal range. They accumulate particulate material from the German Bight by estuarine circulation and asymmetric tides (Postma 1984) and are characterised by high turbidity.

Except for the rocky island of Helgoland, the German Bight is characterised by soft bottom sediments consisting mainly of coarse and fine sand (Figge 1981). Thermohaline stratification occurs during summer already at depths of >25 m, cutting-off bottom water from atmospheric oxygen transfer, but allowing sedimentation of particulate material. The flushing time of these water masses, which is normally in the range of 15 days, is prolonged in the outer bight to 33 days (Brockmann et al. 2003). Mean salinity gradients start with less than 10 within the estuaries and increase up to 35 in the outer parts (Fig. 3). The variability of salinity is mostly < 5 % in the outer coastal water and increases towards the estuaries to > 30 % due to changing discharges and wind pressure controlling the extension and shape of river plumes. Different frontal systems enhance the transient formation of steep gradients (Krause et al. 1986). The most prominent fronts are the river plume fronts. Within the inner estuaries, variability of nutrients and organic matter increases due to the fluctuations in freshwater discharges, retention and changing salinity gradients.

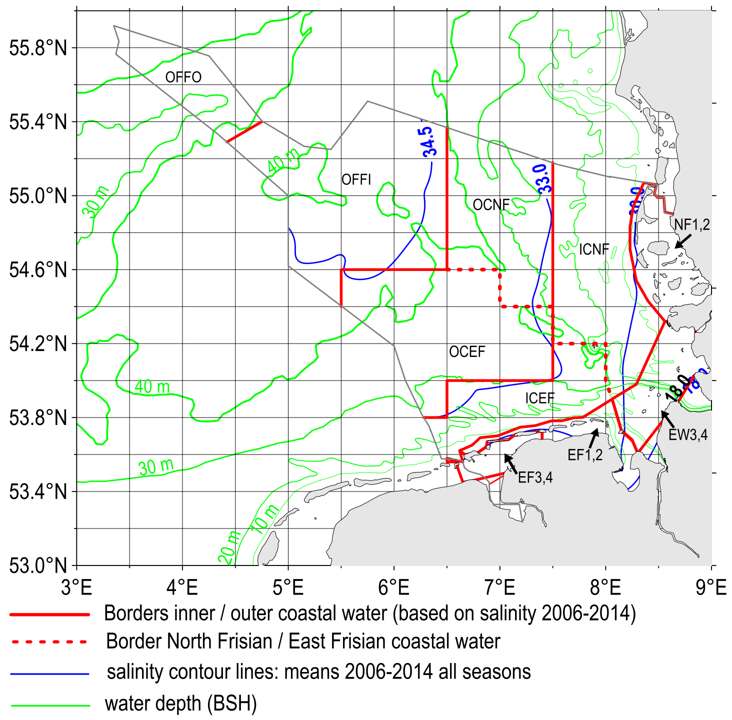

Fig. 2 Mean water depths in the GEEZ, subarea division, and selected mean salinity boundaries. The squares have a size of 716.5 km^2. Note that for some of the assessments smaller squares have been used with a size of 145.23 km^2. Red lines mark the borders between the assessment areas.

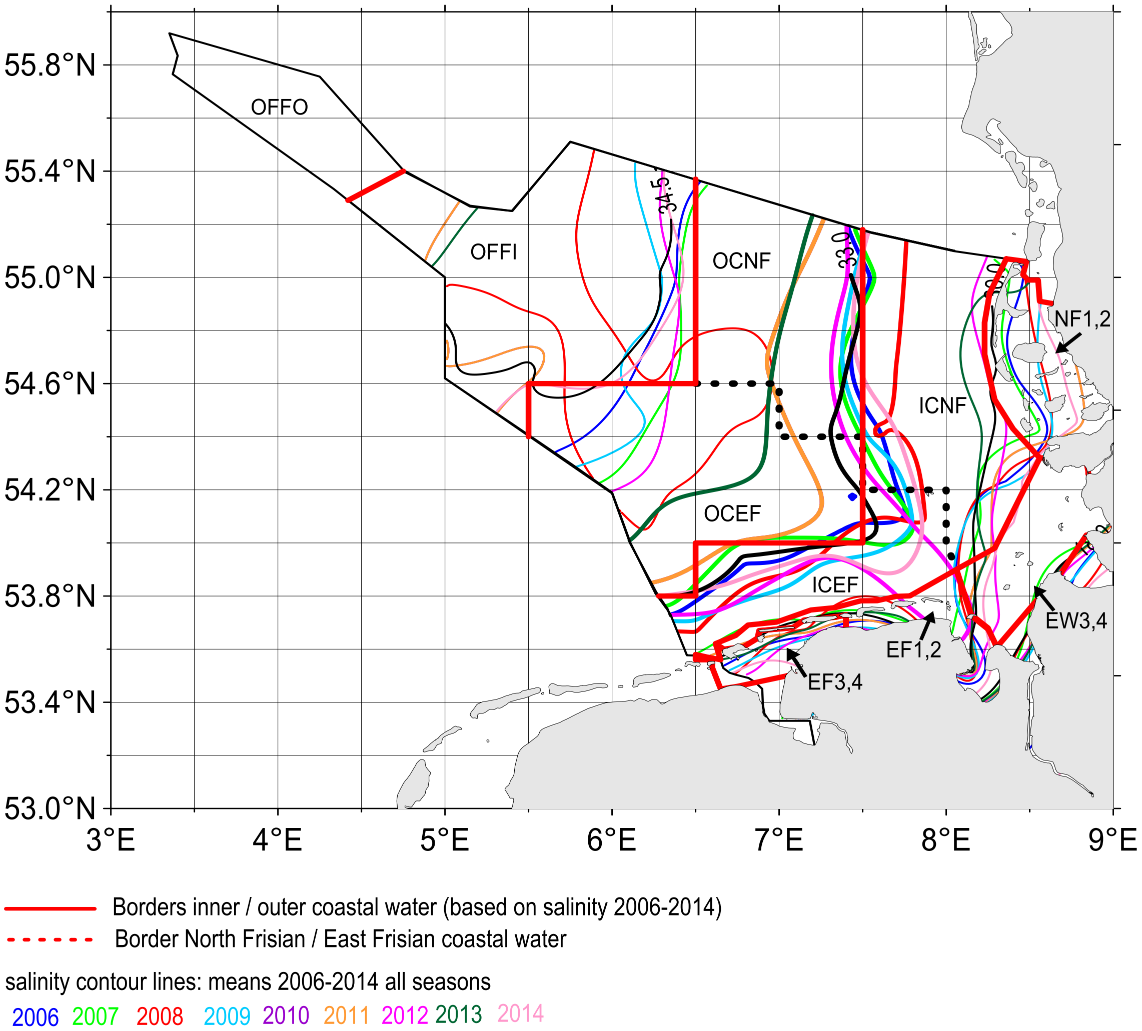

Fig. 3 GEEZ and neighbouring areas showing the variable salinity contours associated with the extension of river plumes. Salinity contour lines: 2006-2014 (annual averages). Red lines mark the borders between the assessment areas.

For the definition of assessment areas in the GEEZ the topography (Fig. 2) and main salinity gradients (Fig. 3) were considered, resulting in 5 different types:

- estuaries, limited by the river mouths (salinities 0-18), including dredged traffic channels,
- inshore waters of the WFD, including the Wadden Sea (salinities 18-30) (corresponding to the "Wadden Sea" as assessed in COMP 2),
- inner coastal water (salinities 30-33),
- outer coastal waters (salinities 33-34.5) (inner and outer coastal waters correspond together to "coastal waters" of COMP 2),
- inner and outer offshore waters (salinity > 34.5) including central North Sea waters.

Eastern and northern coastal waters and outer and inner offshore waters have been further divided, considering hydrodynamic aspects and dominating regional influences by the Elbe und Weser plumes, affecting mainly the northern coastal areas (Tab. 2).

Estuaries and extended shallow tidal flats of the Wadden Sea, sheltered by a belt of islands, form a main part of the coastline, representing inshore waters assessed by the WFD. Inner coastal waters (ICNF, ICEF) include mainly areas with < 30 m depth, outer coastal waters (OCNF, OCEF) areas between 30 and 40 m depth (Fig. 2). The outer offshore area (OFFO) is touched by the easterly

Dogger Bank (< 30 m). The division into subareas followed mainly the mean salinity gradients of 18, 30, 33, and 34.5 (Fig. 3).

Inter-annual variation of the main salinity gradients (18, 30, 33) was very small (Fig. 3). Only the boarder to offshore waters at 34.5 showed a higher variability. Subdivision of the GEEZ includes 13 areas, two areas each for offshore waters (salinity > 34.4), outer coastal waters (33-34.4), inner coastal waters (30-33), four inshore waters (18-30) according to the WFD and three estuaries (<18) (Tab. 2). In the one nautical mile zone WFD water bodies have been summaries to water body types, distinguishing NEA 1,2 and NEA 3,4 in order to limit the effort for the assessment and to analyse eutrophication processes at larger scales.

The subdivision, mainly related to the mean salinity gradients, reflects the degree of mixing as a dominant forcing of eutrophication gradients, directly influencing the indicators nutrients, Secchi depth, and chlorophyll-a. Water depths are in inner coastal waters mostly < 40 m, preventing seasonal stable stratification with densiclines mainly at 15 – 30 m. However, transitional stratification enables seasonal oxygen depletion especially along the ancient Elbe valley (Topcu and Brockmann 2015). Residence times are shortest in coastal waters due to tidal and residual currents (Lenhart et al. 2014).

Tab. 2 Sizes, depths, mean salinities and flushing times of subareas of the GEEZ.

Salinity ranges	Abbreviation code for subarea	Number of squares	Area km^2	Salinity range	Mean salinities 2006-2014	% of area with <3m depth	Mean salinity winter	Mean salinity growing season	Water residence time in days
>34.5	OFFO	17.5	2542	30-56	34.86	0	34.84	34.88	>40
>34.5	OFFI	67	9730	36-50	34.56	0	34.64	34.50	40
33-34.5	OCNF	38.5	5591	23-45	34.00	0	34.27	33.81	25
33-34.5	OCEF	50.5	7334	28-45	33.62	0	34.00	33.46	30
30-33	ICNF	48	6971	14-40	29.76	0	30.29	29.69	15
30-33	ICEF	26.5	3849	15-44	32.31	0	32.73	32.10	22
18-30	NF1,2	15.5	2251	<23	29.29	50	28.28	29.63	15
18-30	EF1,2	8.5	1234	<16	30.07	30	29.10	30.60	8
18-30	EW3,4	14	2033	10-20	25.46	40	25.19	25.75	5
18-30	EF3,4	5	726	<16	26.17	50	24.46	27.34	5
0-18	Elbe		327	<19	3.03	40	2.82	3.06	Unknown
0-18	Weser		182	<18	1.53	25	1.04	1.74	Unknown
0-18	Ems		327	<15	11.11	60	8.78	12.10	Unknown
0-18	All Estuaries				5.87		5.24	6.4	5
Sum		291	43098						

One square includes an area of 145.23 km^2. Shallow areas <3m [%] are rough estimates.

The Wadden Sea area includes extended shallow tidal areas of about 40 % or 3000 km^2 with water depths < 3 m.

The main shapes of mean salinity gradients were similar during growing season and winter. For calculation of assessment values for the different assessment areas salinity gradients have been applied for differentiation between the main river plumes and mixing areas (see Fig. 3). In the North Sea with its strong hydrodynamics such an approach is necessary. However, it means that the background levels and the assessment levels (boundaries for the good status) for each assessment area cannot be set as fixed values but slightly change for each assessment depending on mean salinities of the years assessed. Hence, the assessment levels applied necessarily differ from the assessment levels laid down in KoRa (2015b) for the offshore waters and in the Surface Water Ordinance (OGewV) for coastal waters.

Seasonal thermal stratification is most developed in deeper offshore areas, starting within the ancient Elbe valley (Fig. 4), forming the boundary conditions for trapping and decomposition of organic matter in enclosed bottom water, causing oxygen depletion.

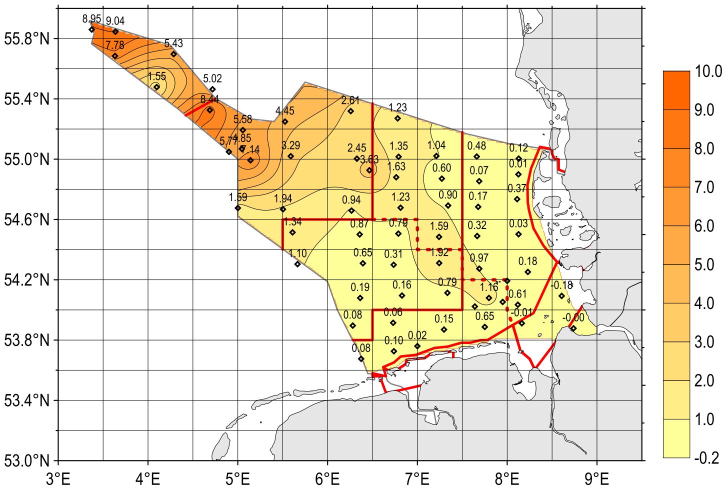

Fig. 4 Mean temperature difference [°C] between surface and bottom, July - October 1980-2010 (data source: ICES, BSH, IBMC).

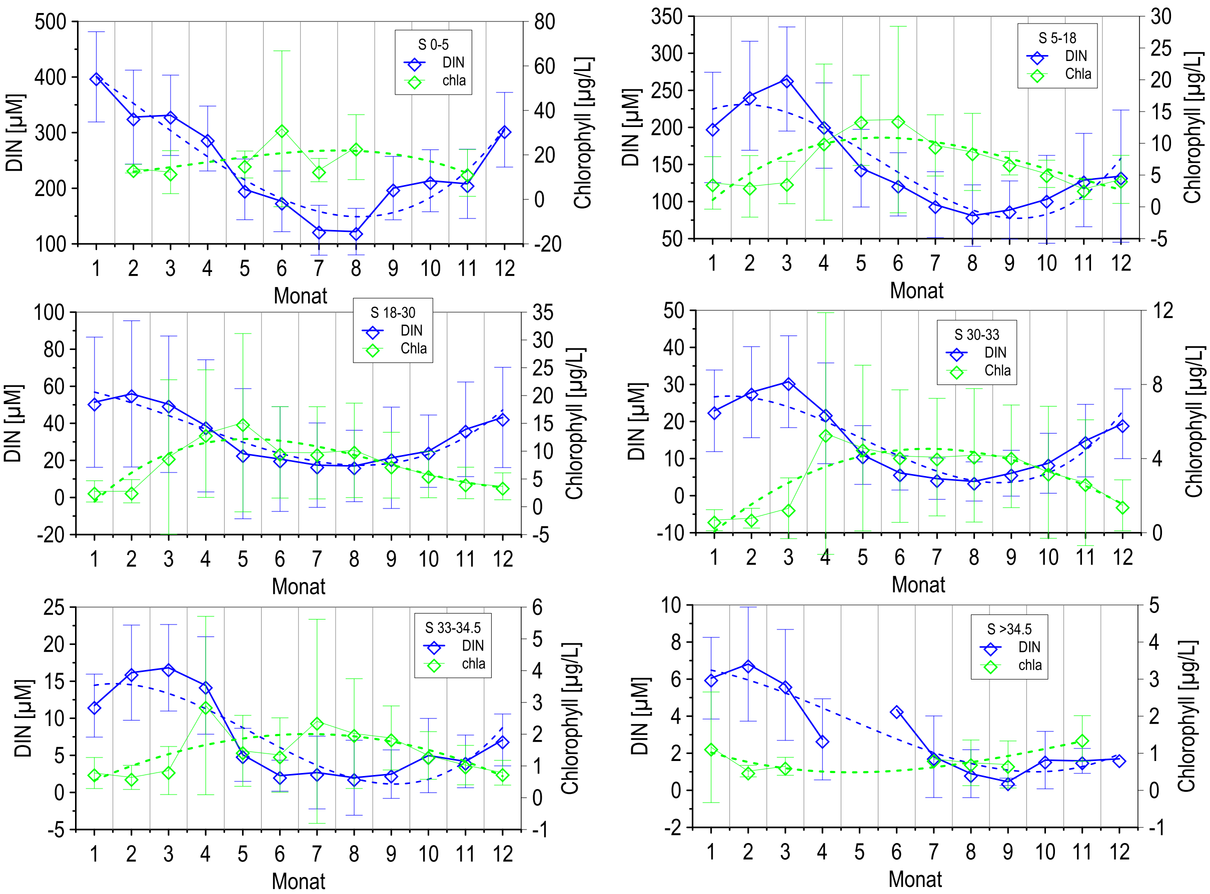

Fig. 5 Annual cycles of DIN and chlorophyll-a concentrations within salinity regimes of the GEEZ (surface, 2006-2014)) presented as monthly means and standard deviation.

Most parameters are assessed seasonally, e.g. DIN during winter (XI-II) and chlorophyll-a during growing season (III-X). Generally, the division of winter (XI-II) and growing season (III-X) corresponds to the seasonal cycling of DIN and chlorophyll-a, with DIN maxima during winter and chlorophyll-a maxima by primary production during the growing season. However, there are some deviations, reflected by annual concentration changes, which have been compiled in Fig. 5 for the different salinity regimes within the GEEZ. During March DIN maxima were observed in the lower estuaries and coastal waters, caused by elevated spring discharges. In the inshore and inner coastal waters chlorophyll-a increased already during March (Fig.5).

The GEEZ is passed by a residual coastal current to the north, transporting high loads of nutrients along the continental coasts (Otto et al. 1990). This coastal current dominates the nutrient regime within the belt of continental coastal water long-distance transports. Due to the shallow character, dilution is restricted, reflected by low salinities as well. Nutrients are received from local rivers, distant sources like the Channel, the East Anglia Plume (Weston et al. 2004, Skogen et al. 2004, Blauw et al. 2006) and the rivers Rhine and Meuse. In addition, there is atmospheric deposition of nitrogen, e.g. of NOx especially along the shipping lanes. These different sources of nutrients and organic matter are considered within budget calculations (see chapter 5.1.1.2).

The catchment area of the GEEZ includes the river-systems of the Elbe, Weser, Ems and Eider, discharging together about 1000 m^3/s (Tab. 3). The German part of the catchment area discharging to the North Sea has a size of 437.434 km^2 including discharges by the river Rhine. The German catchment area is characterised (for 2005) mainly by agricultural land (43 %), grassland (14 %) and natural areas (29 %) (Gadegast & Venohr 2015). Cities occupy about 8 % of the area, surface waters 2 % and open areas 4 %. Total direct freshwater discharges into the GEEZ were 4140 m^3/s (2005), with loads of 528 kt/y TN/and 18.6 kt/y TP. Freshwater discharges into the GEEZ are dominated by the Elbe (Tab. 3). The catchment area of the Rhine includes German areas as well. Its discharge flows into the continental coastal current (CCW), passing the GEEZ.

Tab. 3 Mean freshwater discharges 2006 – 2014.

	Discharge Q [km^3/y]	Standard Deviation (SD) of Q [km^3/y]	SD of Q [%]
Elbe	23.82	7.16	30.04
Weser	9.50	2.75	30.86
Ems	2.17	0.54	24.69
Eider	0.43	0.07	16.29
SH North Sea	1.83 (1.2 HZG)	0.22	12.20
SH Elbe tributaries	2.95	0.58	19.59
LS Elbe tributaries	no data		
LS North Sea	(0.8 HZG)		
Sum	41.5		
Rhine	83.10	8.57	10.31

SH: Schleswig-Holstein, LS: Lower Saxony, HZG: data from Helmholtz Zentrum Geesthacht

Freshwater discharges of the Rhine, Elbe and Weser show significant inter-annual variation. For the Elbe an increasing trend was observed since 2000 (Fig. 6) and for the Rhine a decreasing tendency (a statistically non-significant trend) dominated.

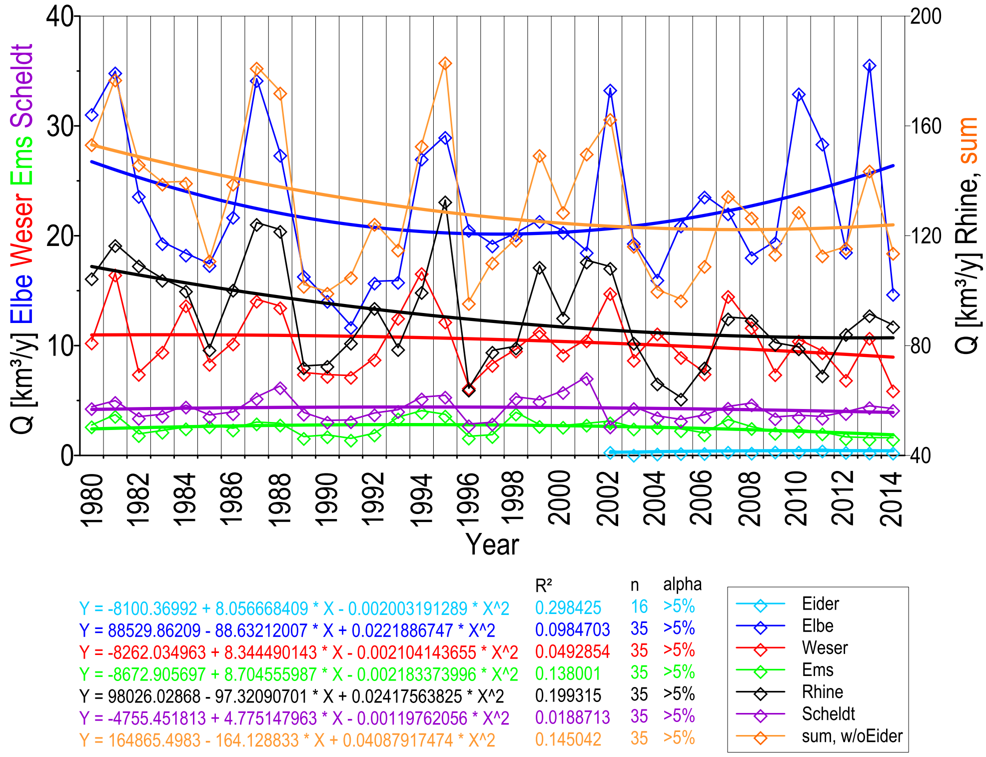

Fig. 6 Time series of freshwater discharges by the main continental rivers, 1980-2014 (based on daily data). For the Rhine all tributaries are included.

4. Methods and data

4.1 Inventories and confidence of gradients

The assessed area was divided into regular squares (22.2 x 32.2km^2, 0.2° latitude, 0.5° longitude) of 716.5 km^2 in order to calculate local means which are used for plotting mean gradients and their variability (Surfer, Golden software). Time series were plotted with Grapher (Golden Software) (see § 4.2).These squares allow an analysis of the sampling distribution in space.

4.1.1 Parameter specifications

Mainly surface samples (< 5m) were considered for nutrients, chlorophyll-a and phytoplankton, because

- (i) most of the data are sampled at the surface,
- (ii) nutrient rich river plumes are spreading at the surface of coastal waters and
- (iii) primary production is focussed on the surface in shallow turbid coastal waters.

However, in deeper coastal and offshore waters phytoplankton maxima may occur near the densi- and nutricline during summer. Data from near or at the bottom were taken for oxygen means and minima, macrophytes and macrozoobenthos.

TN and TP concentrations were considered seasonally and for all seasons as voluntary parameters, due to significant correlations between TN, chlorophyll-a and Secchi depth and to check for consistency with the inorganic nutrients DIN and DIP.

Ratios (M/M) between DIN and DIP were calculated for the winter time as indicators of the relative enrichment of N- and P-nutrients, compared to the Redfield ratio of 1:16 (M/M). As voluntary parameters DIN/Si and DIP/Si ratios have also been assessed, assuming that no significant changes have occurred for silicate discharges affecting offshore waters since historical reference conditions.

Chlorophyll-a means and maxima were both considered but for the final assessment only means were used. Phytoplankton indicator species were assessed despite low sampling rates. Remote sensing data for chlorophyll-a have been assessed but revealed only weak correlations with ground truth data. They were therefore not considered in the final assessment because there was no relevant additional information provided by these data. The duration of algal blooms could not be taken into account, due to a lack of data with high sampling frequencies.

For the assessment of the ecological status of the WFD the biological quality element (BQE) macrophytes is used, based on the abundance/quality of seagrasses as well as of green algae and saltmarshes/reeds (for Lower Saxony only). This BQE was also used for the COMP assessment in the 1 nautical mile zone to align with the WFD. The assessment of the abundance/quality of seagrasses under the WFD is restricted to eulitoral areas.

Secchi depth was assessed as an important parameter controlling the light regime. Since the shallow coastal waters of the Wadden Sea are characterised by naturally high turbidities Secchi depth was only assessed > 1 nautical mile.

Seasonal oxygen depletion in bottom waters is mainly controlled by stratification. Oxygen saturation, as the physiological most important parameter, was calculated from oxygen concentrations, salinity and temperature (Benson & Krause 1984). Oxygen minima have also been assessed since even short-lasting oxygen depletion can have significant effects (Topcu & Brockmann 2015).

The assessment of macrozoobenthos was based on dry weight in offshore waters, correlated with chlorophyll-a, allowing calculations of consistent thresholds. In coastal waters (1 nautical mile) the assessment of the BQE macrozoobenthos under the WFD has been used to align with the assessment of ecological status.

The voluntary parameters TN, TP, Si and their ratios were handled similar to the other nutrients.

Tab. 5 Parameter specifications of the parameters used in the third application of the COMP.

Cat.	**Parameter**	**units**	**Type of data**	**Locations**	**Season**
I	TN,TP	kt/y	Annual means	River	as
	DIN, PO_4, SiO_2	µM	Local means	Surface	w
	Nutrient ratios	M/M	Local and annual means	Surface	w
	TN, TP	µM	Local means	Surface	as
II	Chlorophyll, means, 90th percentiles	µg/L	Local means and 90th percentiles	Surface	gs
	Chlorophyll, max.	µg/L	Local maxima	Surface	gs
	Phytoplankton Indicator spec.	n/L	Abundance	Surface	gs*
	Macrophyte depths	m	Local mean extension	Bottom	gs
III	Oxygen deficiency	mg/L, % sat.	Local means	Bottom water	gs
	Macrozoobenthos	dw mg C/m^2	Local means	Bottom	gs**
	Macrozoobenthos	wetw mg C/m^2	Local means	Bottom	gs, as
	Organic carbon	µM	Local means	Surface	gs
SP	Salinity	-	Local means	Surface	as,gs,w
	Secchi depth	m	Local means	Water column	gs
	Suspended matter	mg/L	Local means	Water column	as

SP – supporting parameters; as – all seasons; w – winter (IX-II); gs- growing season (III-X);* at Helgoland and Norderney during all seasons;** mainly gs, AWI samples all seasons.

4.1.2 Inventories and data sources

Data were differentiated according to the assessment areas and squares of 716.5 km^2 (Fig. 2 & 3). For the investigation of the data coverage in time, monthly, seasonal and annual means were calculated.

Tab. 6 Data sources and analytical methods.

Parameter	Methods	Institution	References
Nutrient discharges	AA	FGG Elbe, FGG Weser, BfG, LLUR, NLWKN, RWS waterbase	
Nutrient gradients	AA	AWI, BSH, DOD, FGG Elbe, FGG Weser, FTZ, LLUR, NLWKN	AWI: Wiltshire 2015
Chlorophyll-a	Photometry AWI:HPLC	AWI, BSH, DOD, FGG Elbe, FGG Weser, FTZ, LLUR, NLWKN	AWI: Wiltshire 2015, since 2011
Phytoplankton indicator species	counting	AWI, BSH, LLUR, NLWKN,	AWI: Wiltshire 2015 Summarized flagellates and diatoms, IOW
Macrophytes, seagrass, green algae	Visual aerial surveys, ground truthing, remote sensing	NLWKN, NLPV, Nationalparkamt Wattenmeer Tönning, AWI, LLUR	cited reports
Makrozoobenthos*	AFDW, WetW	BSH, NLWKN, AWI, LLUR	J. Dannheim pers. comm.
Organic matter, TOC	CHN	FGG Elbe, FGG Weser, BSH, NLWKN, AWI, LLUR	calculated from organic nitrogen
Secchi depth	direct	BSH, NLWKN, AWI, LLUR	
SPM	weight	BSH, NLWKN, AWI, LLUR	

AA = AutoAnalyzer; Photometry mostly after Lorenzen, *only for the assessment of macrozoobenthos>1nm

Data have been provided by FGG Elbe, Weser, Ems; AWI, BAH, Helgoland + List, Wiltshire (2004); BSH + MUDAB, DOD, Hamburg; ICES, Copenhagen; EMEP, Bartnicki & Fagerli 2006; FTZ, Büsum; NLWKN Brake-Oldenburg; LLUR, Flintbek-Kiel; K. Reise, AWI, NERI, Roskilde, DK; RWS RIKZ, The Hague, NL (Fig.7). Reports on the regional development of macrophytes have been considered as well as other publications with regional relations.

4.1.3 Confidence: data coverage and variability

Sampling locations were nearly randomly distributed within the GEEZ, with increasing density towards the coasts where most eutrophication effects were observed (Fig. 7).

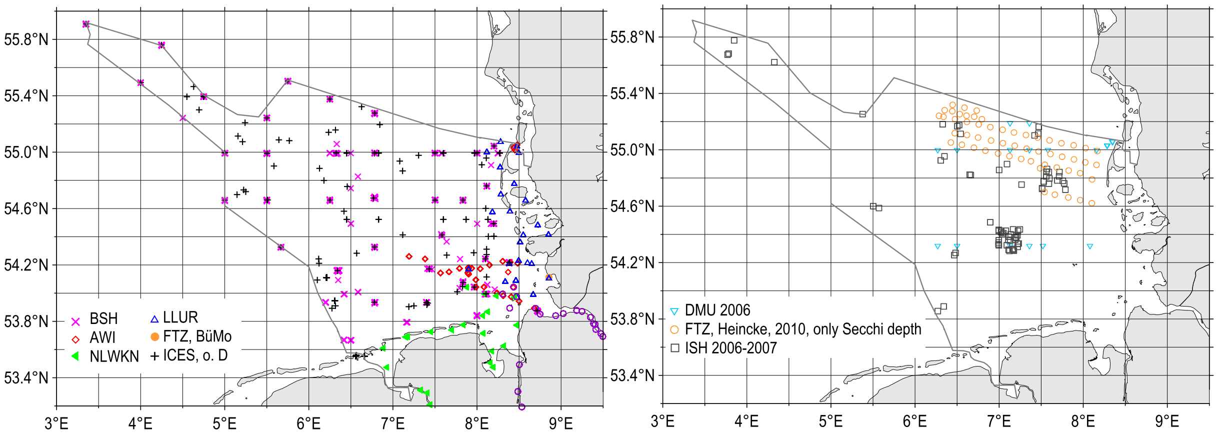

Fig. 7 Locations of stations and occasional samplings by the different institutions. Parameters are not specified.

The number of samples per area and regional variability of data have been compiled within the assessment tables (Annex Tab. A 25 and following). For DIN as an example the number of samples per square is presented (Fig. 8), reflecting the degree of regular spread samplings, indicating the low data density in outer coastal and offshore waters and high sampling frequencies at frequently sampled coastal stations at Norderney and Helgoland. This is the predominant sampling pattern for all key parameters. Means located on a square-line have been associated to the northern/eastern square.

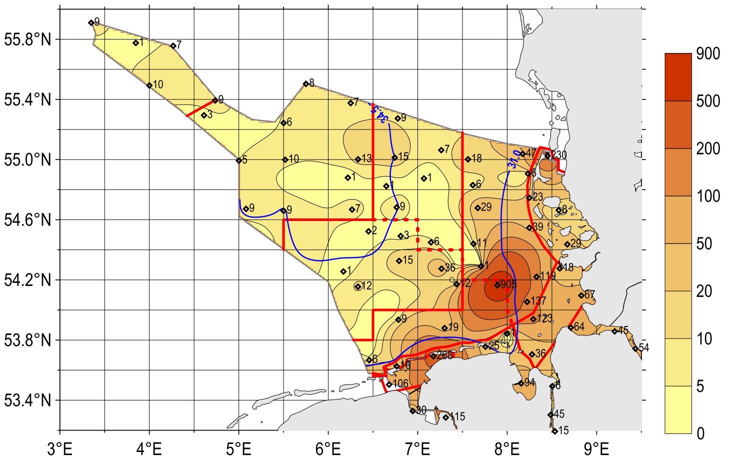

Fig. 8 DIN [n/square], winter (XI-II) means 2006 - 2014, surface data, square sizes 716.5 km², empty squares: no sampling.

Chlorophyll-a, cells of Phaeocystis spec. and other cells of phytoplankton indicator species have mostly been sampled in near coastal waters (Fig. 9 & 10).

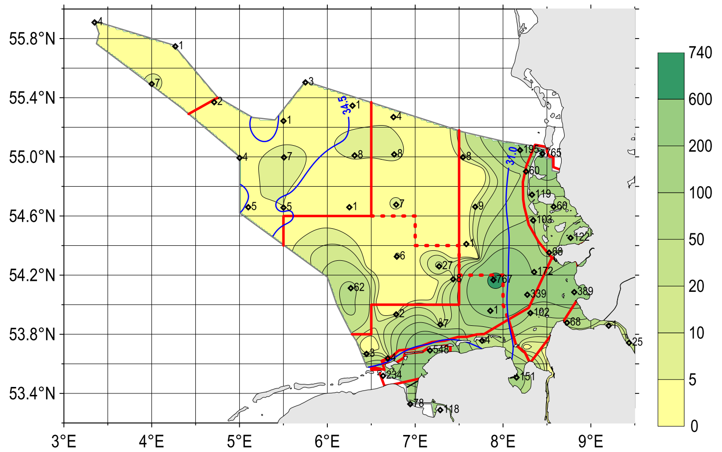

Fig. 9 Chlorophyll-a [n/square], growing season (III-X) means 2006 - 2014, surface data, square size 716.5 km^2, +0 indicates sampling for other parameters, empty squares: no sampling.

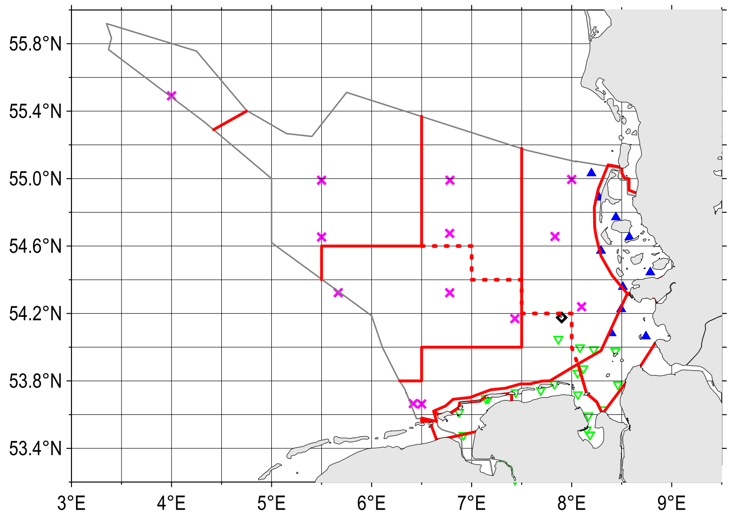

Fig. 10 Phytoplankton sampling locations 2006-2013.

× BSH 2008-2011 ◇ AWI 2006-2014
▲ LLUR 2006-2014 ▽ NLWKN 2006-2013

AWI, Helgoland Roads: diatoms, flagellates, Phaeocystis, Noctiluca
List: only flagellates and diatoms 2006-2013; LLUR, AlgFes 2006-2014;
BSH Monitoring 2008 -2011 (March and Oct/Nov); NLWKN Whv 2009, 2010, 2012, 2013, Norderney 2006-2013

Data for macrophytes were only available for intertidal areas. Beside local field assessments for the purpose of ground truthing extension and coverage were analysed by surveillance with airplanes. Sampling was performed during the growing season of different years during low tides.

Oxygen was sampled mostly 12 times and mainly during summer (July-September 2006-2014), at some coastal stations more frequently (Fig. 11).

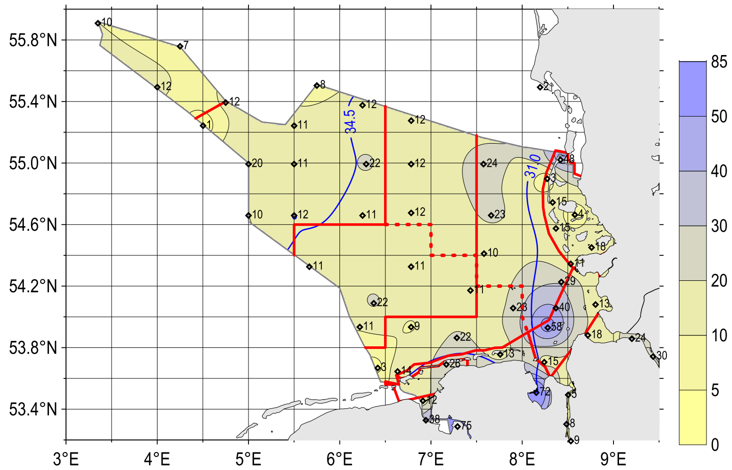

Fig. 11 Oxygen sampling [n/square], July-Oct., means 2006-2014, bottom data, square size 716.5 km^2. (in shallow inshore waters: surface data)

By combination of different sampling activities for macrozoobenthos a sufficient coverage could be achieved (Fig.12), allowing correlations with chlorophyll-a samplings within the same squares for the derivation of assessment levels in offshore waters. These data were supplemented by published data (Kröncke et al. 2004). In waters > 1 nautical mile mainly biomass and abundance were considered. Within the 1 nautical mile zone the assessment was based on WFD sampling locations and data.

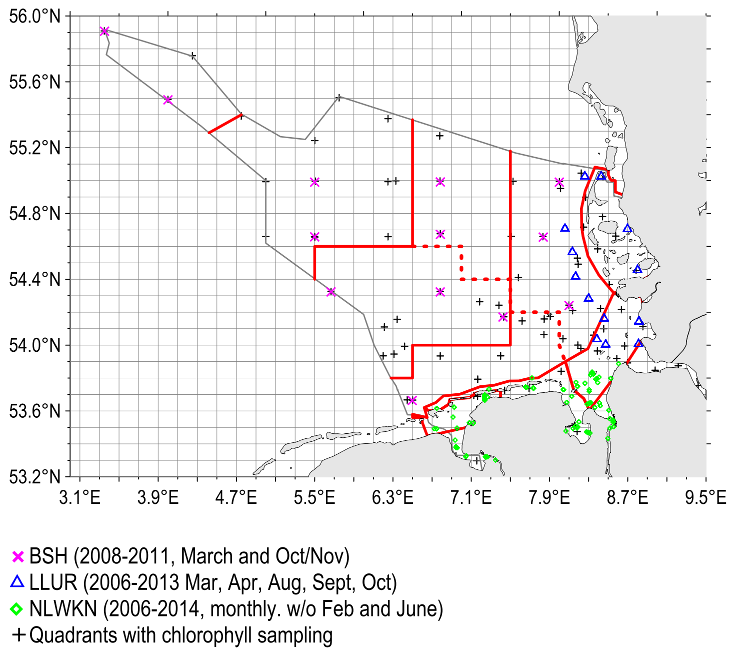

Fig. 12 Distribution of macrozoobenthos (ash free dry weight) sampling, all seasons 2006 – 2014 (square size: 145.3 km^2, applied for correlations).

Since sampling in eutrophication problem areas was mainly sufficient only a simplified procedure for confidence rating was applied. Variability (% standard deviation) was considered for confidence assessments, as well as number of samples per square or time sections as %, neglecting mostly sectorial in-balances of sampling. Only the % of squares and time sections without data were summed up for some parameters, neglecting gradients and concentration changes around empty sections, which affect the confidence of data as well (Brockmann & Topcu 2014).

Confidence rating of data coverage was as a first approximation simply performed by relation of the number of samples per area (Annex, Tables A 25 and following). The distribution of sampling in relation to gradients was not considered (Brockmann & Topcu 2014). The number of data/km^2 was combined with the variability, resulting in scores (Tab. 20), representing some random confidence because high variability reflects steep gradients/strong fluctuations as well. A complete confidence rating was performed only for chlorophyll-a. Deviations between recent data and assessment levels as % were estimated considering variability, to get an expression of "distance to target".

Locally or occasionally occurring eutrophication effects were smoothed by calculations of square means during the whole period (2006-2014) or annual means, including seasonal variability as well. Due to potential insufficient monitoring of oxygen and chlorophyll-a minima (oxygen) or maxima (chlorophyll-a) were considered in addition.

River discharges were mainly compiled as monthly estimates and were calculated considering freshwater flow (Q) upstream of the tidal estuaries and the concentrations within the upper tidal estuaries. Inflows from tributaries are integrated within the estuarine gradients. Effects of retention within the estuaries were not considered.

4.1.4 Calculation of indices and indicators

Nutrient ratios were calculated as M/M and oxygen saturation (%) after Benson & Krause (1984). 90^{th} percentiles of chlorophyll-a were calculated as a rough estimate from recent data or for assessment levels by multiplying the mean with a factor of 2. Assessment levels of maxima of chlorophyll-a were calculated by multiplying recent concentrations with a factor of 4, corresponding to recent correlations between means and maxima. Most applied conversions between parameters are based on recent correlations, as presented in § 4.3 for the calculation of assessment levels.

4.1.5 Calculation of gradients, mixing diagrams and budgets

Based on the same software (Surfer, Golden Software) maps, time series, annual means, 90^{th} percentiles, correlations, mixing diagrams, and variability (as standard deviation) have been calculated, allowing for the application of identical data sets, reducing contradictions. Annual means of recent data have been compiled for overall assessments because inter-annual variability was low, reflected by the absence of significant trends between 2006 and 2014. There were only small differences to means calculated from individual values, which had been calculated for internal controls.

4.2 Calculation and quality of time series

4.2.1 Calculation of time series

Annual means of river loads were calculated from monthly data of concentrations and freshwater discharges, measured upwards the tidal parts of the rivers (Ems: Terborg/Herbrum, Weser: Brake/Intschede, Elbe: Seemannshöft/Neu-Darchau). Mean loads were calculated from concentrations and freshwater discharges (Q). Means of different rivers were weighted according to their freshwater discharges (Q). Shifts of concentrations within the estuaries were estimated based on the slopes of annual mixing diagrams. Generally, long time series were calculated as annual/seasonal means for selected salinity regimes. Time series were calculated from annual means, smoothing irregular sampling per year, using Surfer (Golden Software).

Phytoplankton data, plotted as cell counts/L, were restricted to the assessed time period, due to uncertainties of the analyses for longer time periods (Wiltshire & Dürselen 2004). Chlorophyll-a data and other time series were calculated as assessment area means.

4.2.2 Confidence of time series

Quality of time series for the assessment periods is indicated by their inter-annual variability within the subareas, which is presented together with mean concentrations for direct comparisons in Tabs. 25 ff. The annual amount of seasonally focussed samplings is also presented in § 5.2. The degree of homogenous sampling distribution (e.g. months) during seasonal time periods was not considered because inter-annual variability was low, assuming that annual sampling was mainly balanced. For these reasons, variability and data coverage were presented for means of the whole period (Tabs. 25ff). Confidence of monthly sampling within the subareas was calculated only for chlorophyll-a as an example.

4.3 Definitions of assessment levels

The eutrophication assessment 2006-2014 according to the OSPAR Common Procedure was based on revised assessment levels. For COMP 1 and 2 assessment levels were derived from natural background concentrations by adding a 50% allowable deviation (OSPAR 2008). The background concentrations have been based on pristine nutrient concentrations assuming a mainly forested Germany without any population. This approach led to assessment levels that were unrealistically low and were also not in agreement with the assessment levels used for chlorophyll-a under the WFD. Hence, there was a need to revise the approach. The revision focussed on nutrients. The catchment model MONERIS (MOdelling Nutrient Emissions in RIver Systems) was used to calculate historic nutrient inputs of 1880 (Gadegast & Venohr 2015). 1880 was assumed to be a suitable reference year since anecdotal evidence exists that although there was already a considerable coastal population discharging nutrients to the sea, seagrasses were still abundant in coastal waters. Furthermore, for 1880 historic data were available. Historic nutrient concentrations of 1880 (as a mean over all rivers) were 1.63 mg/l for TN, 1.29 mg/l for DIN and 0.04 mg/l for TP.

The rivers entering the German North Sea are characterised by large estuaries that have, in the past, retained large amounts of nutrients. Nowadays, this nutrient retention function has been compromised by regulating and deepening these estuaries. For the derivation of historic coastal and marine nutrient concentrations it has been assumed that the estuaries retained 50% of nitrogen (based on Seitzinger 1988). For phosphorus, estuaries mainly serve as a source and therefore no retention was assumed. Background concentrations for nutrients were then derived by extrapolating historic nutrient concentrations of 1880 (for TN and DIN -50% retention, for TP no retention) along salinity gradients (calculated based on mean salinities 2000-2005 and recent marine endmembers) into the sea. Assessment levels were obtained as usual by adding 50% to the background concentrations and adapted to salinity gradients by linear correlations. The resulting assessment levels for TN are higher than the old assessment levels but still remain considerably below recent concentrations. The resulting assessment levels for DIN and TP are not much higher compared to the old assessment levels. The new assessment levels for TN, TP and DIN are summarised in KoRa 2015b. The MONERIS model was not able to derive historic nutrient concentrations for DIP. Since this is, however, an obligatory parameter in the COMP, assessment levels were derived based on correlations with TP.

Correlations between TN and chlorophyll-a were used to derive chlorophyll-a assessment levels based on the revised TN assessment levels. This approach largely confirmed the chlorophyll-a assessment levels currently used under the WFD and therefore these were not revised. A weakness of the current approach is the linear interpolation of riverine nutrient concentrations into the open sea that disregards the high dynamics of coastal and offshore waters. To overcome this weakness work is currently undertaken in Germany to use a modelling approach to derive nutrient concentrations based on historic nutrient inputs. Depending on the outcome of such an approach there might be a need to further revise the assessment levels for nutrients and chlorophyll-a in the future. Meanwhile, the new assessment levels for nutrients are used as a basis for the 3rd application of COMP.

Nevertheless, the nutrient assessment levels from KoRa (2015b) could not be applied directly but were adapted to recent salinities (2006-2014). Thresholds for nutrient ratios DIN/DIP (16 M/M), DIN/Si (1M/M), and DIP/Si (0.06) [M/M] were taken from Redfield et al. 1963. Missing seasonal nutrient data and assessment levels for the other seasons and parameters were calculated based on recent correlations between the parameters (Fig. 13). Table 7 provides an overview of the assessment levels derived for the rivers based on historical nutrient concentrations of 1880. Assessment levels for the respective “assessment areas” were calculated based on linear mixing diagrams (Fig. 14, 15) between mean thresholds of the main rivers (74 µM TN) and recent mean offshore concentrations (salinity > 34.5) of 9.65 µM TN (marine mixing end-member) (Tab. 8). For rivers, seasonal assessment levels for nutrients were derived from annual assessment levels based on recent correlations (Fig. 13).

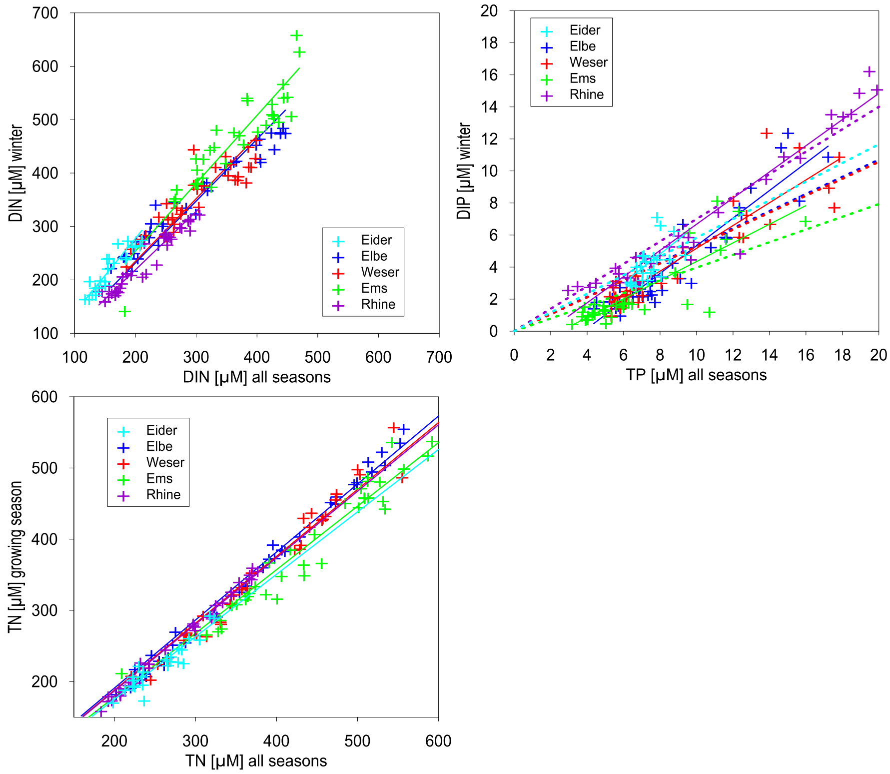

Fig. 13 Correlations between annual and seasonal means for DIN, TP and TN (1980-2014) (Rhine 1980-2013, Eider 1991-2014).

Tab. 7 Assessment levels for nutrient concentrations for rivers during all seasons. Results for TN, DIN and TP are based on (Gadegast & Venohr 2015; KoRa 2015b). For the MSFD descriptor 5 these assessment levels are not applied. Riverine concentrations are assessed against a management target value for TN and river-specific assessment levels for TP based on the Surface Water Ordinance from 2016 (Oberflächengewässerverordnung).

Parameter	**TN as**	**DIN as**	**TP as**	**DIP w**	**TN as**	**TN gs**	**DIN as**	**DIN w**	**TP as**	**DIP w**	**DIP w***	**TOC gs**	**2006-2010**
Unit	mg/L	mg/L	mg/L	mg/L	µM	µM	µM	µM	µM	µM	µM	µM	Q [m³/s] as
Rhine	1.41	1.14	0.052	0.039	100	94	81	89	1.67	1.16	1.26	32	2635
Ems	1.85	1.45	0.040	0.031	132	118	103	131	1.29	0.52	0.99	5	106
Weser	1.79	1.49	0.051	0.039	128	120	106	125	1.65	0.87	1.25	237	335
Elbe	1.95	1.46	0.072	0.054	139	133	104	121	2.32	1.23	1.76	794	704
Eider	1.42	1.12	0.027	0.021	101	89	80	111	0.87	0.52	0.67		25
w. mean	1.63	1.29	0.040	0.043	112	105	89	123	1.77	1.13	1.38		sum 3806
w. mean w/o Rhine	1.88	1.46	0.062	0.047	134	127	104	100	2.00	1.01	1.52		sum 1171

as = all seasons, w = winter, gs = growing season (III-X), # = calculated based on KoRa (2015b) applying recent salinity correlations, * calculated from coastal water correlation between TP and DIP, without estuaries (DIP µM = 0.759 TP µM), TOC were calculated from TN
DIPw = 0.7586564872*TP as (DIP w S>30) aus indiv. Fluss-Korrelationen

Tab. 8 Statistical parameters of the seasonal correlations of annual means versus winter means within the rivers as a basis for the calculation of seasonal nutrients assessment levels (in µM).

	DIN as - DIN w	n	R^2	alpha
Elbe	Y = 1.159 * X	35	0.99	<0.1 %
Weser	Y = 1.174 * X	33	0.99	<0.1 %
Ems	Y = 1.270 * X	34	0.99	<0.1 %
Rhine	Y = 1.094 * X	33	0.99	<0.1 %
Eider	Y = 1.389 * X	24	0.99	<0.1 %
	TN as - TN gs			
Elbe	Y = 0.955 * X	35	0.99	<0.1 %
Weser	Y = 0.940 * X	35	0.99	<0.1 %
Ems	Y = 0.893 * X	35	0.99	<0.1 %
Rhine	Y = 0.935 * X	34	0.99	<0.1 %
Eider	Y = 0.877 * X	24	0.99	<0.1 %
	TP as - DIP w	n	R^2	alpha
Elbe	Y = 0.535 * X	35	0.91	<0.1 %
Weser	Y = 0.528 * X	34	0.92	<0.1 %
Ems	Y = 0.397 * X	35	0.83	<0.1 %
Rhine	Y = 0.700 * X	34	0.98	<0.1 %
Eider	Y = 0.583 * X	22	0.95	<0.1 %

For offshore waters recent means (2006-2014) as mixing marine end-members were applied as assessment levels because it is assumed that these offshore areas are not affected by eutrophication. In effect this means that the acceptable deviation added to the reference conditions was adjusted depending on the salinity and varied between 50% for coastal waters and 0% for marine end members. Hence assessment levels for offshore areas are not exceeding recent concentrations. Between the marine end members as recent concentrations and the river concentrations mixing diagrams were calculated to derive assessment levels in coastal waters (Fig. 14 & 15). By this, gradients of threshold concentrations were estimated in relation to recent salinities, allowing for region-specific assessments. Freshwater discharges (Q) and nutrient loads were calculated for mean freshwater discharges (2006-2014).

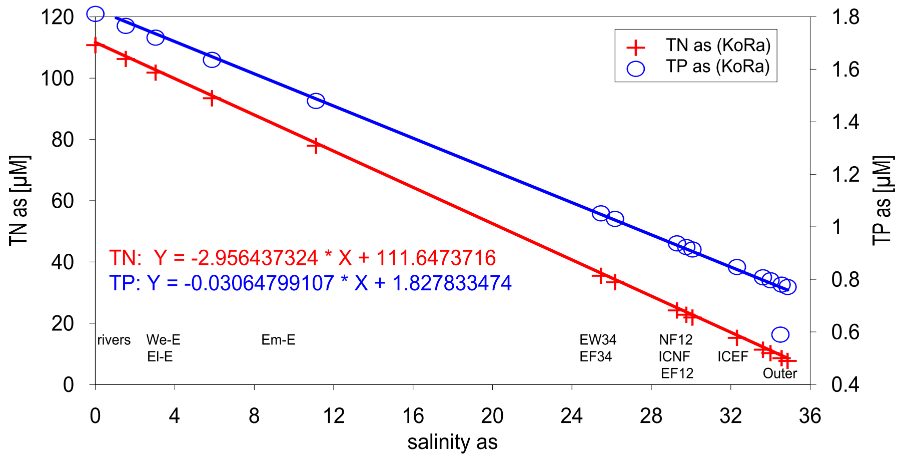

Fig. 14 Mixing diagrams for TN and TP between marine endmembers and means of assessment levels for the German Rivers and the Rhine for TN and TP (KoRa 2015b). Offshore Endmember = with Dogger Bank, S 34.5-35, data from all seasons.

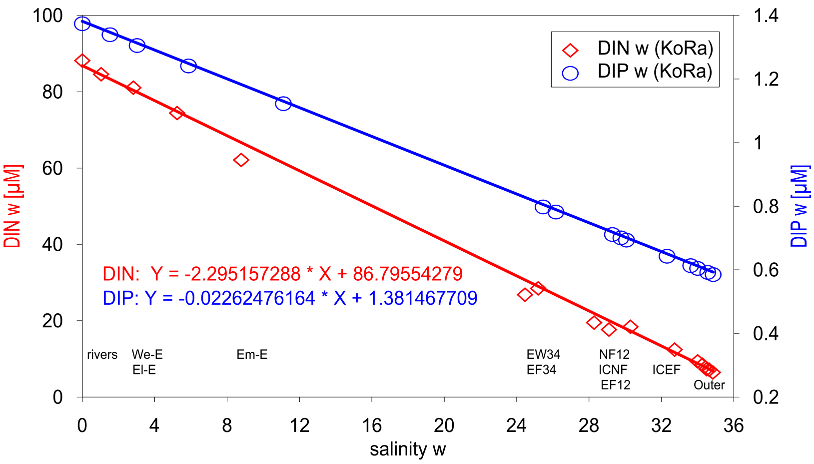

Fig. 15 Mixing diagrams for winter DIN and DIP between marine endmembers and means of WFD assessment levels for the rivers for DIN (based on KoRa 2015) and DIP (from recent correlations with TP). Offshore end-member means from 1980-2014, S 34.5-35, winter data.

Tab. 9 Assessment levels for nutrients, chlorophyll-a, Secchi depth, macrozoobenthos and total organic carbon (TOC) within the different subareas based on mean salinities (2006-2014) for all seasons (as), growing season (gs) (III-X) or winter (w). Secchi depth is not assessed in coastal and transitional waters. For the assessment of macrozoobenthos in coastal and transitional waters results from the WFD were used.

Area	Sal as	Sal w	Sal gs	TN* as	DIN w	TN** as	TN gs	TP as	DIP w	Chla gs	Chla 90 th	Secchi gs	MZB gs	TOC gs
				µM	µM	µM	µM	µM	µM	µg/L	µg/L	m	g/m²	µM
OFFO	34.86	34.84	34.88	8.60	7.1	8.5	7.79	0.78	0.59	1.31	2.62	10.56	2.26	39.3
OFFI	34.56	34.64	34.5	9.47	7.8	9.7	8.82	0.79	0.60	1.48	2.96	9.43	2.56	44.5
OCNF	34	34.27	33.81	11.13	9.1	11.7	10.67	0.81	0.61	1.79	3.59	7.91	3.10	53.9
OCEF	33.62	34	33.46	12.25	10.0	12.7	11.62	0.82	0.62	1.95	3.90	7.31	3.38	58.6
ICNF	29.76	30.29	29.69	23.66	19.0	23.9	21.78	0.93	0.71	3.66	7.32	4.10	6.33	109.9
ICEF	32.31	32.73	32.1	16.12	13.1	16.8	15.28	0.86	0.65	2.57	5.14	5.68	4.44	77.1
NF12	29.29	28.28	29.63	25.05	20.2	24.1	21.94	0.95	0.72	3.75	7.50		6.49	110.7
EF12	30.07	29.1	30.6	22.75	18.3	21.2	19.33	0.92	0.70	3.75	7.50		6.49	97.5
EW34	25.46	25.19	25.75	36.38	29.1	35.5	32.40	1.06	0.81	5.5	11.00		9.51	163.5
EF34	26.17	24.46	27.34	34.28	27.5	30.8	28.11	1.04	0.79	5.5	11.00		9.51	141.9
Elbe-E	3.03	2.82	3.06	102.69	81.7	102.6	93.55	1.73	1.31					472.2
Weser-E	1.53	1.04	1.74	107.13	85.2	106.5	97.11	1.78	1.35					490.2
Ems-E	11.11	8.78	12.1	78.80	62.8	75.9	69.19	1.49	1.13					349.2
all E	5.87	5.24	6.4	94.29	75.0	92.7	84.55	1.65	1.25					426.8
rivers	0	0	0	111.64	88.8	111.7	101.8	1.82	1.38					513.8
End-members	34.5	34.5	34.5	9.65	7.94	9.65	8.8	0.60	0.57					

Sal = salinity, MZB = macrozoobenthos (ash free dry weight), MEM = marine mixing end-members (salinity > 34.5),* related to salinities all seasons, ** related to salinities during growing seasons, applied e.g. for correlations with chlorophyll a

Nutrients ratios, such as DIN/DIP or DIN/Si and DIP/Si are indicative of anthropogenic influences (e.g. inbalanced reduction of N and P inputs), assuming that Redfield N/P ratios of 16 (M/M) reflect natural conditions. Silicate discharges are less affected by anthropogenic influences in the North Sea area and it is assumed that they have not changed since pre-industrial time. Assessment levels for DIN/Si and DIP/Si ratios were transferred from recent offshore conditions (salinities 34.4-35, without the Dogger Bank area).

Chlorophyll-a assessment levels were based on the WFD NEA GIG values and TN values from linear correlations between reference values for rivers (KoRa 2015b) and marine end members (MEM) (Fig. 14) and recent correlations between TN and chlorophyll a (Fig. 16). Chlorophyll a 90th percentiles and maxima were calculated from recent correlations between means, 90th percentiles, and maximum values as factor 2 (for 90th percentile) or factor 4 (for maxima).

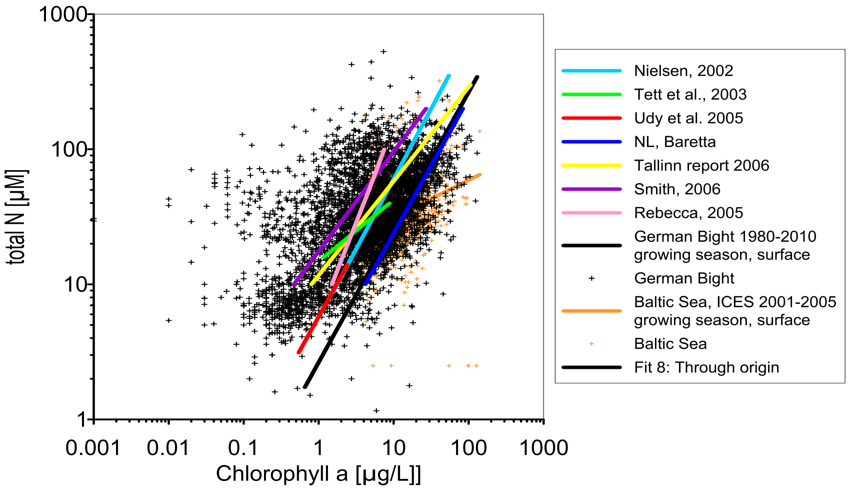

Fig. 16 Recent correlations between TN and chlorophyll-a during growing season in the North Sea, compared with correlations in other areas.

Assessment levels for Secchi depth were calculated from TN during growing season (Fig. 17). Assessment levels for macrozoobenthos dry weight for open sea areas were calculated from chlorophyll-a (Fig. 19) and confirmed by other correlations (Beukema et al 2002, Topcu et al. 2007 b), reflecting the dependence of zoobenthos on available biomass. For macrophytes and macrozoobenthos in the 1nautical mile zone, WFD assessment levels for the biological quality element macrophytes and macrozoobenthos and data from the most recent WFD assessment cycle (2009-2013/14) were used. Macrophytes were not assessed in waters > 1nautical mile since their extension is limited due to poor light availability in greater depths (except around Helgoland). Data from Helgoland were not available for the assessment.

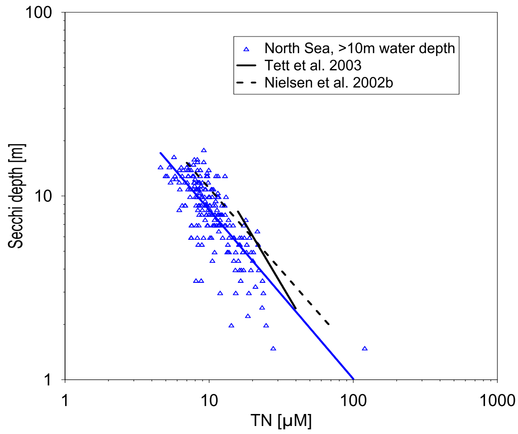

Fig. 17 Recent correlations between Secchi-depth and TN concentrations.
Offshore data 2003-2013: $\ln(Y) = -0.920 * \ln(X) + 4.245$, $n = 218$, $R^2 = 0.580$, alpha <0.1.

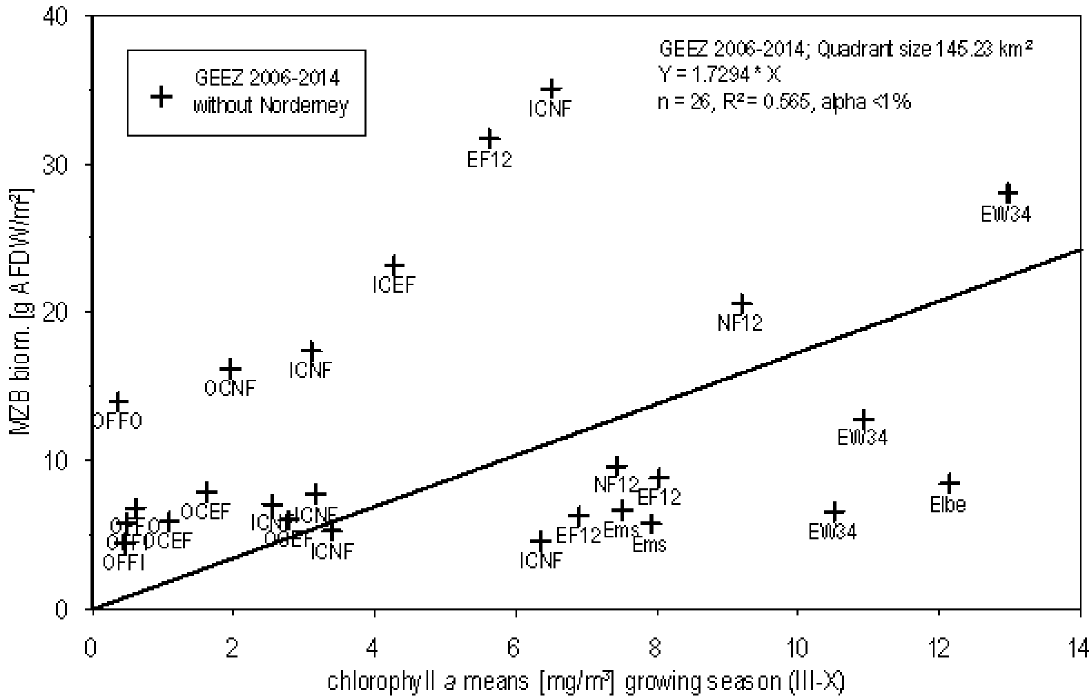

Fig. 18 Recent correlations between macrozoobenthos biomass (AFDW) [g/m²] and chlorophyll-a [mg/m³] within identical squares (145.23 km²), without Norderney station.

For phytoplankton indicator species no natural background concentrations have been defined, but elevated levels (OSPAR 2005, EUC (2) 2006 a) which are listed below (Tab. 10).

Tab. 10 Elevated levels (assessment levels) of cell concentrations of area-specific indicators species.

Area specific species	Area specific elevated concentrations [cells/L]
Dinophyis spec.	10^2
Alexandrium spec.	10^2
Odontella sinensis	10^3
Noctiluca scintillans	10^4
Prorocentrum spec.	10^4
Gynodinium mikimotoi	10^4
"Chattonella" spec.	$2*10^5$
Chrysochromulina polylepis	10^6
Phaeocystis spec.	10^6
Pseudo-nitzschia spec.	10^6

"Trigger levels", proposed by Norway for *Chattonella* spec. and *Pseudo-nitzschia* spec. have been included within the table of elevated levels of area-specific phytoplankton indicator species (EUC (2) 2006 a). It has to be mentioned that cell numbers of 100/L are at the detection limit of most of the applied techniques.

TOC assessment levels were calculated from organic nitrogen (TN-DIN) and the corresponding assessment levels based on correlations between these parameters (Fig. 20).

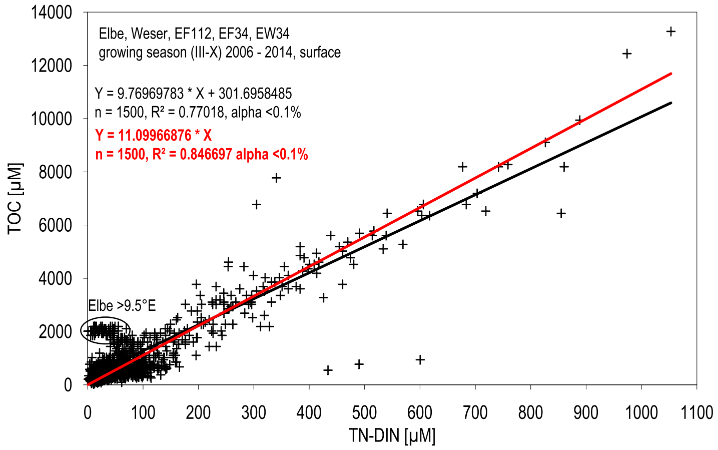

Fig. 20 Recent correlations between recent TOC and ON (TN-DIN).

Elevated levels of oxygen concentration as depletion have been defined by OSPAR (2005) as 6 mg/L, “considering to cause no problems”. 6 mg O_2/L correspond to an oxygen saturation of 66 % (at 10° C, salinity 34). Nevertheless, to consider detrimental effects of oxygen depletion on macrozoobenthos it is necessary to also assess the duration and extension of oxygen depletion, which is difficult given the limited monitoring of this parameter (Topcu et al. 2009). For oxygen assessments it has to be considered that seasonal oxygen depletion in bottom waters of shallow areas can be interrupted several times by densicline erosion (Topcu and Brockmann 2015) and the estimated values reflect often only a transitional state. Since short time oxygen depletion has already significant ecological effects (Villnäs et al. 2013), oxygen minima were assessed as well.

4.4 Methods for consideration of environmental factors

Salinity as an indicator for the degree of mixing between freshwater and marine water was considered for the definition of subareas, and applied in mixing diagrams. Calculation of assessment levels were related to mean regional salinities of subareas (see § 4.3). Biological processes are significantly affected by the residence time, controlling the formation and duration of phytoplankton blooms and the oxidation of organic matter. The variability of seasonal stratification can be taken as indicator for the disturbance of bloom development or oxygen depletion. Due to restricted monitoring in relation to these processes, chlorophyll-a maxima and oxygen minima have been assessed.

The variability of freshwater flow and mixing was considered within the presentation of time series by assessing the nutrient concentrations rather than the loads. Local variability of thermal stratification can be considered for validation of chlorophyll-a and oxygen data.

Light limitation as estimated by Secchi depths is dependent on suspended particulate matter, water depths, humic substances and chlorophyll. Due to significant light limitation chlorophyll-a was not assessed in estuaries. For the estimation of nutrient sources budget calculations have been performed, considering advection and atmospheric deposition.

4.5 Meta- data and reporting to ICES

Data have been taken from ICES database, the German Oceanographic Data Centre (DOD), the MUDAB (Meeresumweltdatenbank) and from national authorities, especially for recent data that were not yet in the ICES or DOD database (Tab. 11).

5 Eutrophication assessment

5.1 Data analyses and presentation, including quality assurance, variability

5.1.1 Nutrient enrichment

5.1.1.1 Nutrient river discharges

Highest mean TN concentrations were found in the Ems, highest TP concentrations in the Eider (Tab. 12). According to the freshwater discharges weighted mean concentrations (2006-2014) were 254 µM TN (3.56 mg/L) and 5.39 µM TP (0.167 mg/L). Inter-annual variability was for the freshwater discharges higher than for the nutrient concentrations, affecting the variability of discharges (Tab. 12). Direct discharges of nutrients to the GEEZ are dominated by the Elbe and Weser, contributing 145 kt TN /y and 6.6 kt TP/y (Tab. 13).

Tab.12 Nutrient concentrations in the main German rivers 2006-14 (annual means).

	Elbe			**Weser**			**Ems**			**Eider**			**Weighted means**		
	Q km³/y	TN [µM]	TP [µM]	Q km³/y	TN [µM]	TP [µM]	Q km³/y	TN [µM]	TP [µM]	Q km³/y	TN [µM]	TP [µM]	Q km³/y	TN [µM]	TP [µM]
2006	23.7	225.2	5.79	7.6	253.3	5.45	2.06	350.5	3.76	0.34	265.9	7.02	33.7	241.0	5.59
2007	22.2	239.3	5.78	14.6	301.2	5.67	3.27	434.2	5.59	0.46	317.6	8.06	40.5	268.9	5.77
2008	18.2	231.1	5.82	11.8	287.5	5.32	2.62	364.6	4.40	0.37	269.0	7.50	33.0	254.9	5.62
2009	19.5	237.8	5.58	7.5	266.7	5.83	2.18	208.7	6.06	0.48	233.9	7.04	29.7	243.6	5.69
2010	33.1	275.3	4.52	10.6	313.6	6.13	2.36	400.6	3.96	0.46	264.3	7.21	46.5	293.2	4.94
2011	28.5	261.2	5.22	9.5	244.5	5.48	2.13	332.0	3.91	0.57	235.2	7.84	40.7	260.9	5.24
2012	18.7	201.9	5.38	7.0	220.8	5.48	1.69	313.7	3.17	0.44	229.8	7.31	27.8	214.3	5.29
2013	35.7	271.8	4.36	10.8	288.7	5.81	1.63	328.0	5.03	0.39	213.0	7.62	48.6	279.1	4.83
2014	14.8	219.9	5.71	6.0	242.9	5.32	1.61	344.9	3.72	0.38	222.0	6.67	22.9	233.8	5.49
Mean 2006-14	23.8	240.4	5.35	9.5	268.8	5.61	2.17	341.9	4.40	0.43	250.1	7.37	35.9	254.4	5.39
SD	7.16	24.66	0.56	2.75	30.86	0.27	0.54	62.63	0.96	0.07	32.46	0.44	8.69	24.22	0.33
SD%	30.04	10.26	10.38	28.93	11.48	4.82	24.69	18.32	21.81	16.29	12.98	5.93	24.20	9.52	6.16

Q = freshwater flow.

Tab. 13 Nutrient discharges for the main German rivers 2006-14 (annual means).

	Elbe			Weser			Ems			Eider			Sum		
	Q km³/y	TN kt/y	TP kt/y	Q km³/y	TN kt/y	TP kt/y	Q km³/y	TN kt/y	TP kt/y	Q km³/y	TN kt/y	TP kt/y	Q km³/y	TN kt/y	TP kt/y]
2006	23.7	84.2	4.2	7.6	29.8	1.6	2.06	12.4	0.30	0.34	1.52	0.07	33.7	127.9	6.15
2007	22.2	83.2	3.9	14.6	66.3	2.7	3.27	21.7	0.88	0.46	2.16	0.12	40.5	173.4	7.50
2008	18.2	65.8	3.0	11.8	53.9	2.2	2.62	16.2	0.51	0.37	1.59	0.09	33.0	137.5	5.81
2009	19.5	72.5	3.2	7.5	31.3	1.4	2.18	5.1	0.44	0.48	1.77	0.11	29.7	110.7	5.10
2010	33.1	138.1	4.6	10.6	55.1	2.2	2.36	15.8	0.34	0.46	1.95	0.11	46.5	211.0	7.19
2011	28.5	125.9	4.4	9.5	41.3	1.7	2.13	13.0	0.34	0.57	1.95	0.16	40.7	182.2	6.54
2012	18.7	60.0	3.0	7.0	24.5	1.2	1.69	8.6	0.20	0.44	1.42	0.10	27.8	82.1	4.51
2013	35.7	143.2	4.9	10.8	48.8	2.2	1.63	9.1	0.26	0.39	1.28	0.10	48.6	202.4	7.49
2014	14.8	47.3	2.6	6.0	21.7	1.0	1.61	8.2	0.21	0.38	1.29	0.08	22.9	78.5	3.92
Mean 2006-14	23.8	91.1	3.75	9.5	41.4	1.8	2.17	12.2	0.39	0.43	1.66	0.10	35.9	145.1	5.66
SD	7.16	35.6	0.81	2.75	15.6	0.55	0.54	5.11	0.21	0.07	0.32	0.03	8.69	49.67	1.42
SD%	30.0	39.0	21.68	28.93	37.5	30.6	24.7	41.8	54.5	16.3	19.0	24.2	24.2	34.2	19.1

Q = freshwater flow.

Trends between 2006 and 2014 were mostly non-significant. Longer-term trends of river nutrient concentrations showed decreasing tendencies since 1980 (Fig. 21-36) which, however, stagnated for TP and DIP since 2000/2005, and for nitrogen since 2005 (Fig. 23 & 24). TN concentrations for the main rivers Elbe, Weser, Ems and Eider and the mean concentrations weighted according to freshwater discharges showed decreasing linear trends since 1980 (Fig. 21). The concentrations can be compared with the management level of 2,8mg/l (200 µM) that was set under the WFD for all German North Sea rivers under the assumption that this level will allow the achievement of “good ecological status” in coastal waters. None of the rivers reached the management level for the period 2006-2014. The river Elbe had an average concentration of 3,4mg/l, the Weser 3,8 mg/l, the Ems 4,8mg/l and the Eider 3,5 mg/l. The methodology to assess riverine concentrations at the limnic-marin border is currently still under discussion in the LAWA (“Länderarbeitsgemeinschaft Wasser”) and hence the comparison provided here against the management level is provisional.

For TP no management level has been set under the assumption that the good/moderate class boundaries set for the rivers in the national Surface Water Ordinance (OGewV) will be sufficient to achieve good ecological status under the WFD (Eider 0.3 mg/l = 9.3 µM, Elbe, Weser, Ems 0.1 mg/l = 3.1 µM) . Similarly, good/moderate class boundaries exit for DIP in the Surface Water Ordinance (all rivers 0,02 mg/l = 0.65 µM). For TP the concentrations of the river Eider stagnated at about 7 µM, whereas TP concentrations within the other rivers decreased significantly, approaching 4 µM recently. Hence all rivers except the Eider have concentrations that still lie above the good/moderate boundaries set for TP in the national Surface Water Ordinance (Fig. 22). Considering polynominal fits (Fig. 23 & 24), the decreases within the main rivers occurred for TN until 2008 and for TP until 2001-2008, stagnating or increasing recently. The decreasing tendencies were also reflected by the loads of the main rivers (Fig. 25 – 28) with decreases of about 150 kt/y TN and 11 kt/y TP for all main rivers since 1980. TN loads decreased especially until 2000 for the dominating river Elbe and for TP until 1993, slowing down since than (Fig. 27 & 28).

Similar tendencies were observed for DIN and DIP concentrations (Fig. 29-32), showing decreasing trends by linear regressions within all rivers, including the Eider. Polynomic regressions revealed stagnations since about 2008 for DIN within the Elbe and Ems and for DIP in the Elbe and Weser. In the Ems and Eider recently DIP concentrations decreased again. Loads of DIN decreased as a sum for all rivers by about 100 kt/y since 1980, with this trend mainly caused by the river Elbe (Fig. 33). To the decrease of DIP loads by 8 kt/y also the Weser contributed (Fig. 34). Polynomic fits revealed an increasing tendency for DIN loads within the Elbe since 2003 (Fig. 35). DIP loads decrease especially until 1990 (Fig. 36). Generally, decreasing tendencies continued in recent years.

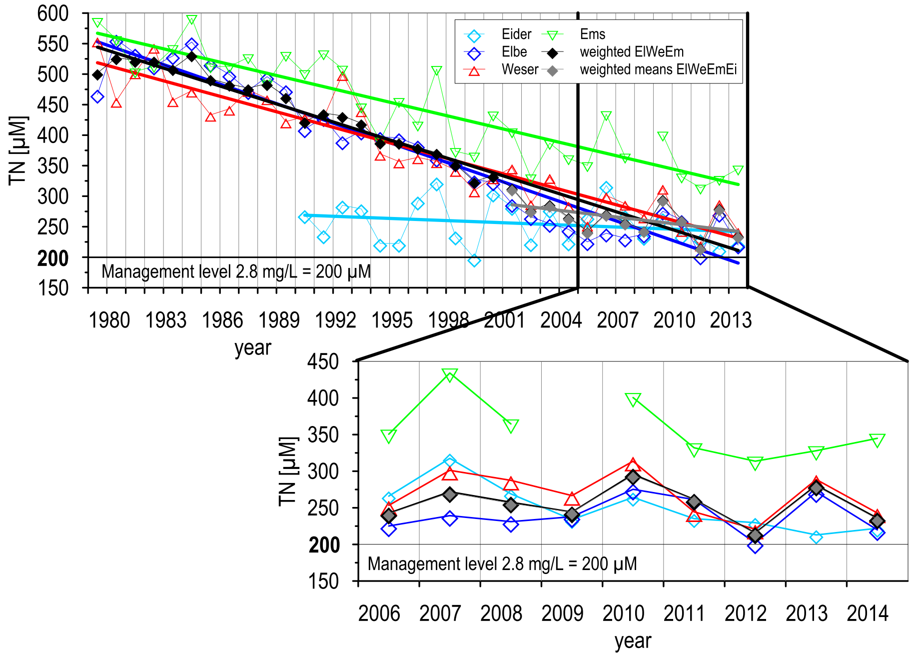

Fig. 21 Long-term trends (1980-2014) of annual mean TN concentrations in German North Sea rivers with linear regression lines and a zoom-in on recent developments 2006-2014. The concentrations are compared against the management level (black line) set in the national Surface Water Ordinance (OGewV) of 2,8mg/l (or 200µM).

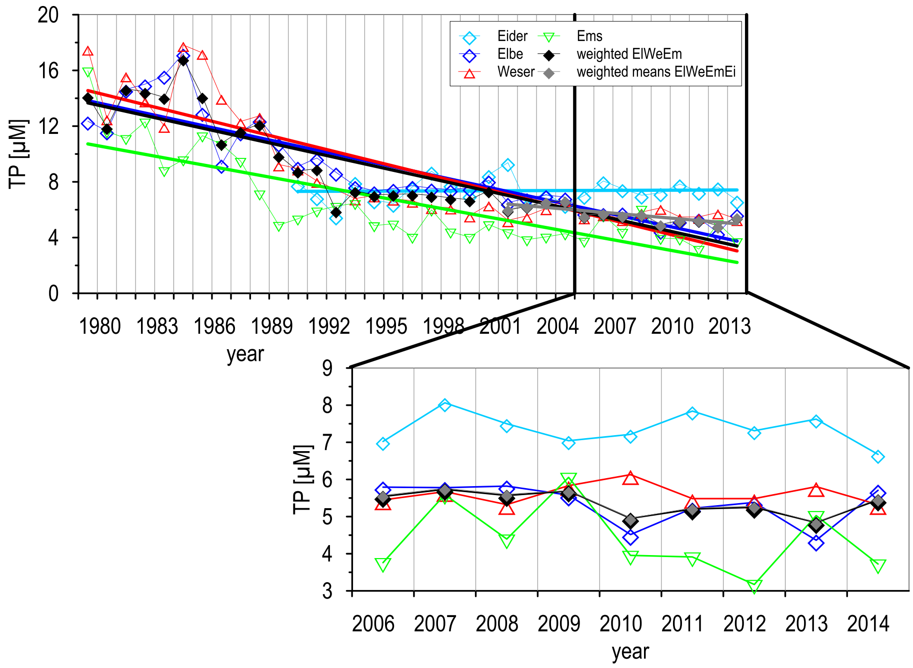

Fig. 22 Long-term trends (1980-2014) of annual mean TP concentrations in German North Sea rivers with linear regression lines and a zoom-in on recent developments 2006-2014.

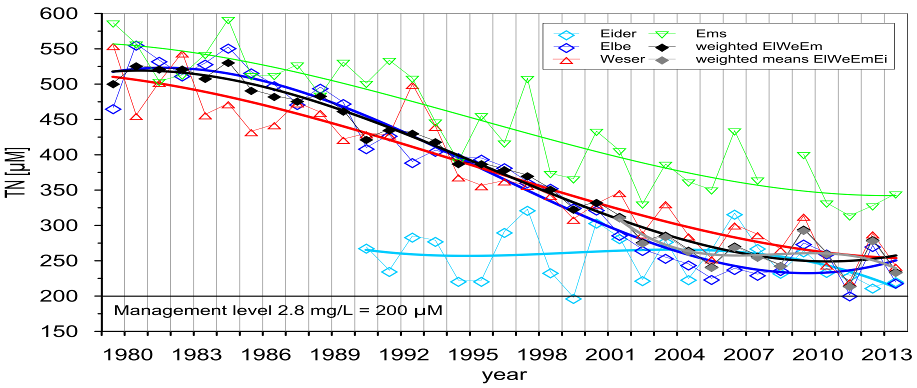

Fig. 23 Long-term trends (1980-2014) of annual mean TN concentrations in German North Sea rivers with polynomic regression lines.

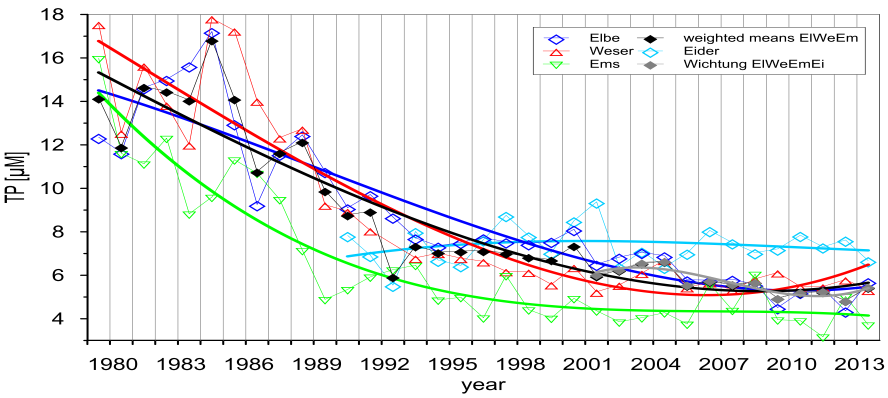

Fig. 24 Long-term trends (1980-2014) in annual mean TP concentrations in German North Sea rivers with polynomic regression lines.

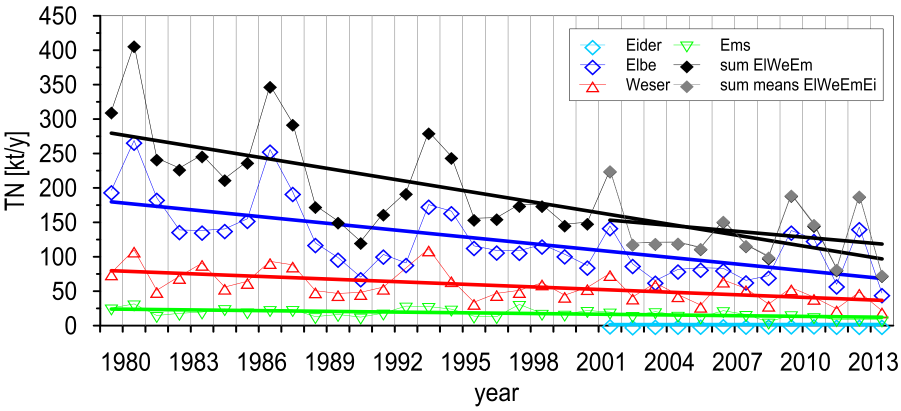

Fig. 25 Long-term trends (1980-2014) in annual TN loads in German North Sea rivers with linear regression lines.

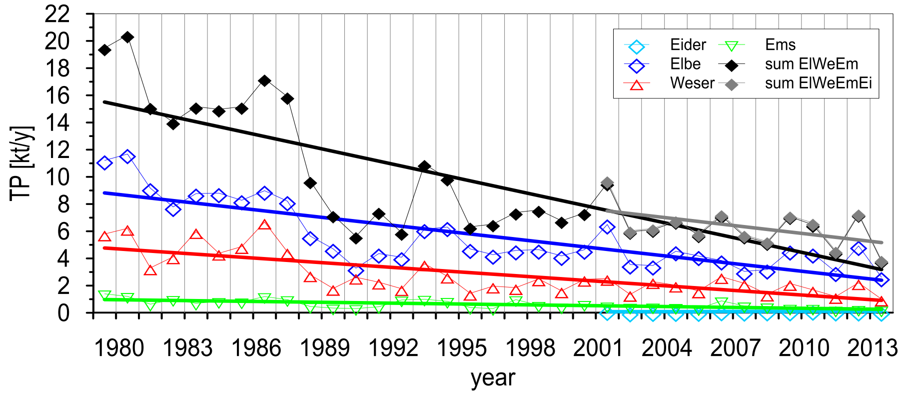

Fig. 26 Long-term trends (1980-2014) in annual TP loads in German North Sea rivers with linear regression lines.

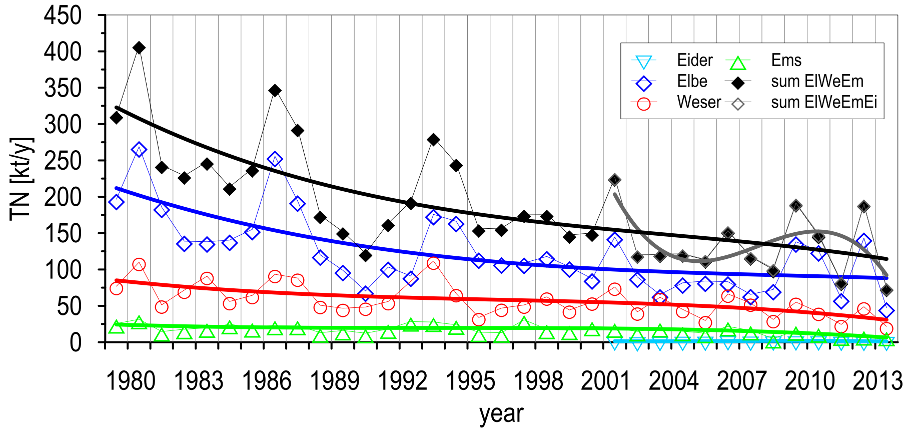

Fig. 27 Long-term trends (1980-2014) of annual TN loads in German North Sea rivers with polynomic regression lines.

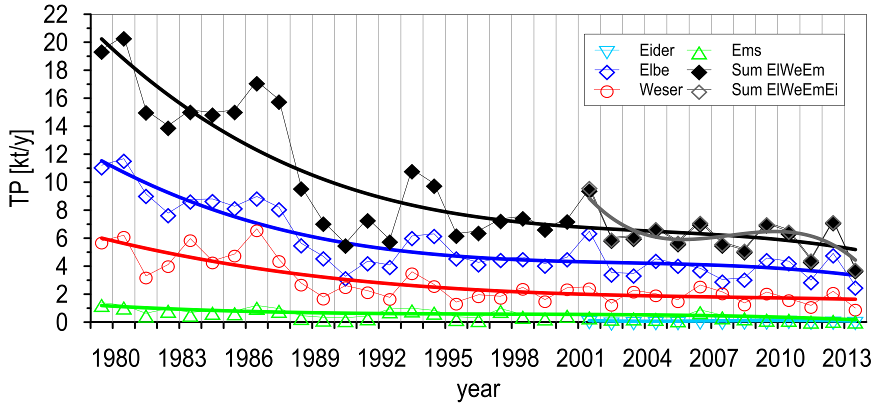

Fig. 28 Long-term trend (1980-2014) of annual TP loads in German North Sea rivers with polynomic regression lines.

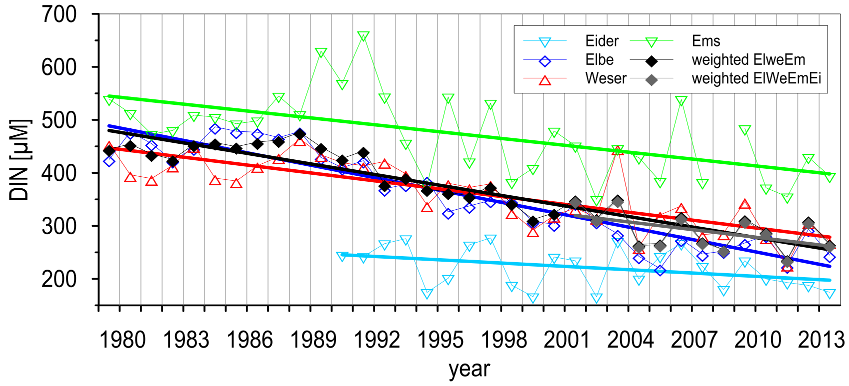

Fig. 29 Long-term trend (1980-2014) of winter (XI-II) mean DIN concentrations in German North Sea rivers with linear regression lines.

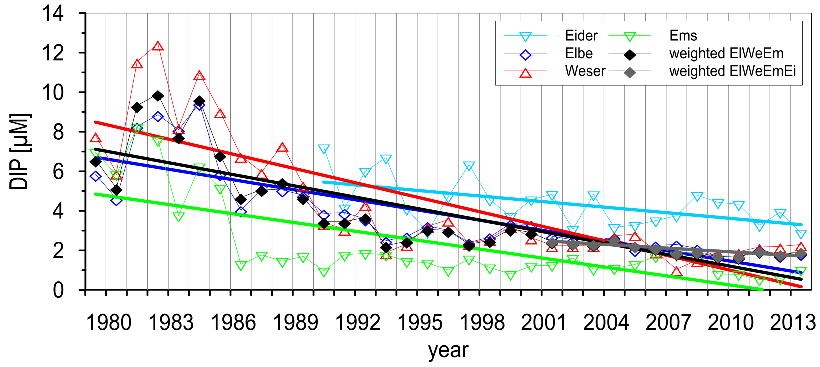

Fig. 30 Long-term trend (1980-2014) of winter (XI-II) mean DIP concentrations in German North Sea rivers with linear regression lines.

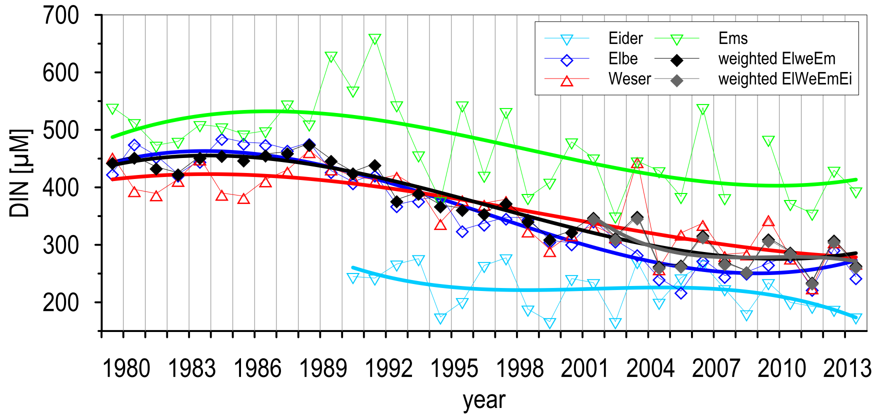

Fig. 31 Long-term trend (1980-2014) of winter (XI-II) mean DIN concentrations in German North Sea rivers with polynomic regression lines.

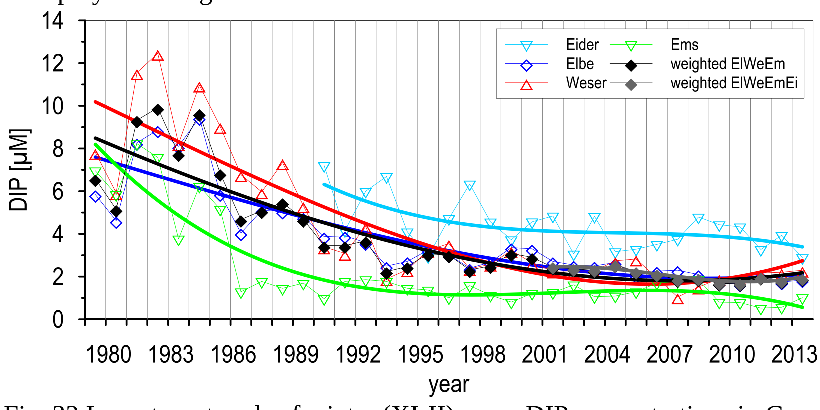

Fig. 32 Long-term trends of winter (XI-II) mean DIP concentrations in German North Sea rivers with polynomic regression lines.

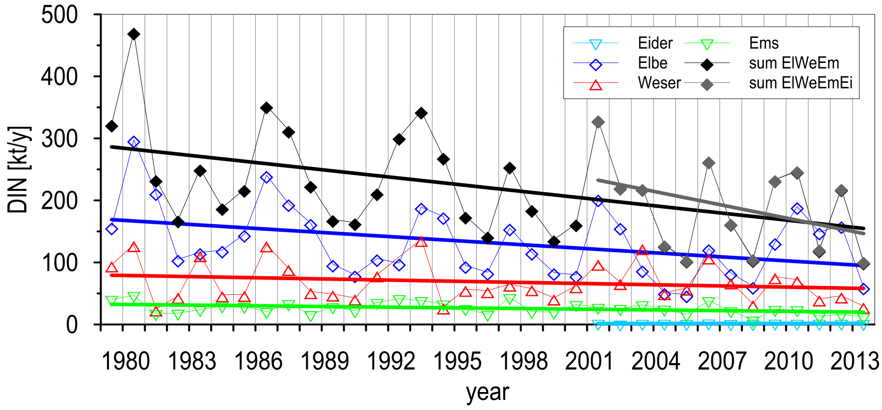

Fig. 33 Long-term trends (1980-2014) in winter (XI-II) DIN loads in German North Sea rivers with linear regression lines.

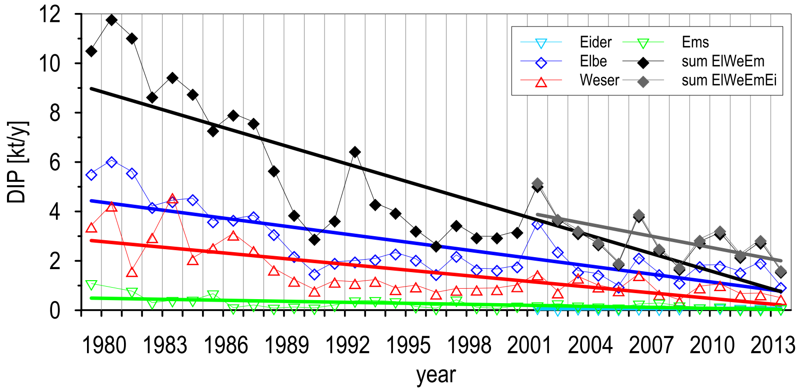

Fig. 34 Long-term trends (1980-2014) in winter (XI-II) DIP loads in German North Sea rivers with linear regression lines.

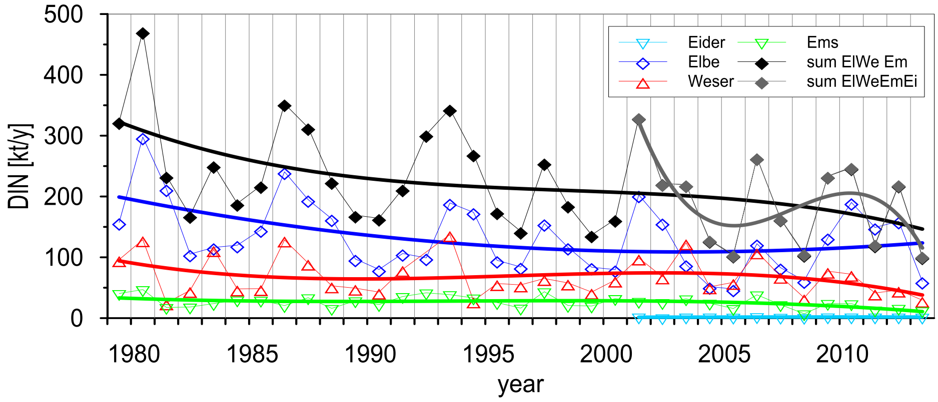

Fig. 35 Long-term trends (1980-2014) in winter (XI-II) DIN loads for German North Sea rivers with polynomic regression lines.

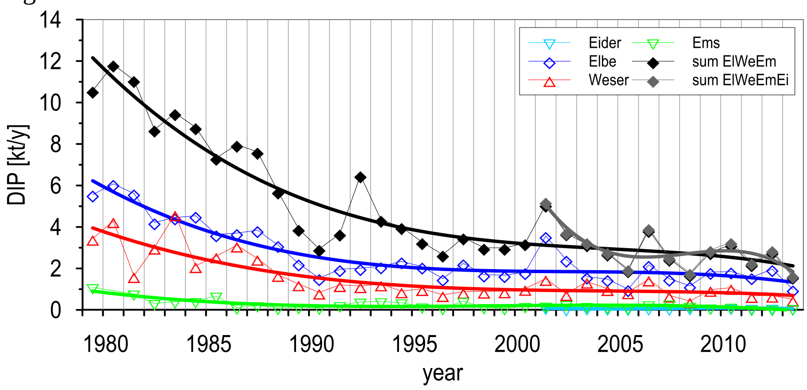

Fig. 36 Long-term trends (1980-2014) in winter (XI-II) DIP loads in German North Sea rivers with polynomic regression lines.

5.1.1.2 Budgets

Budgets have been calculated for TN and TP for the years 2006-2012 (F. Grosse & H. Lenhart, pers. comm.) based on the model HAMSOM (Backhaus 1985), atmospheric depositions (EMEP, OSPAR 2007) and river discharges, considering sedimentation and benthic remineralisation by the model ECOHAM (Pätsch & Kühn 2008, Lorkowski et al. 2012). Means are compiled in Tab. 14. Atmospheric nitrogen deposition was taken from EMEP (Bartnicki & Fagerli 2006).

For the inner coastal waters (ICEF + ICNF) lateral advection (the transboundary transport of nutrients from outside the German GEEZ into the GEEZ) constitutes the main in- and output with about 560 kt N/y, followed by river discharges to the German GEEZ of 150 kt N/y, contributing 21 % and atmospheric deposition contributing 3% to total inputs to the inner coastal waters (Tab.14). In the outer coastal waters (OCEF + OCNF) and offshore areas (OFFO+ OFFI) nutrient concentrations are dominated by lateral advections. Inter-annual fluctuations cause a variability of about 10 %. The budget was nearly balanced. The same holds for TP, where rivers contributed 6.4 % to the inner coastal waters (Tab. 15). The total budgets of the GEEZ included transports between the different areas and represent only totals for river discharges, atmospheric deposition and losses by denitrification. There was no net-sedimentation assumed for phosphorus within the shallow GEEZ, due to frequent resuspension. Inter-annual standard deviations were highest for riverine nitrogen discharges.

Tab. 14 Nitrogen budgets in the GEEZ, means 2006-2012.

Nitrogen Budget (TN)	ICEF+ICNF	OCEF+OCNF	OFFO+OFFI	total GEEZ	SD [%]
volume km^3	301	462	460	1223	
Atmospheric deposition Kt/y*	21.6	11.1	7.8	40.5	2.3
River discharges to the GEEZ Kt/y				148.8	23.4
Denitrification Kt/y	93.4	50.9	31.4	175.8	4.4
Inflow Kt/y	555.9	1315.4	1957.2	2406.4	9.3
Outflow Kt/y	634.3	1276.4	1933.8	2422.4	10.2
Balance Kt/y	-1.4	-0.8	-0.3	-2.6	

* EMoSEM 2015

Tab. 15 Phosphorus budgets in the GEEZ, means 2006-2012.

Phosphorus budget (TP)	ICEF+ICNF	OCEF+OCNF	OFFO+OFFI	total GEEZ	SD [%]
River discharges Kt/y	5.81			5.81	4.1
Inflow Kt/y	90.64	230.46	375.17	447.64	6.0
Outflow Kt/y	96.75	230.63	375.22	453.97	6.3
Balance Kt/y	-0.30	-0.17	-0.05	-0.52	

By comparison between recent data and estimates for reference conditions (Brockmann et al. 2007), it is evident that nutrient concentrations within the GEEZ are elevated by trans-boundary transports to about two to three times of the natural background values. This surplus is a manifold of recent river discharges, but it needs to be taken into account that these nutrients partly also stem from German nutrient discharges to the river Rhine. Budget calculation for COMP 2 for the German Bight 2001-2005 (Brockmann et al. 2007) revealed contributions of river discharges of 11 % TN and 4.5 % TP. These are, despite significant reductions, similar to recent percentages due to the modified sizes of assessment areas. The modelled nitrogen losses by denitrification of 175.8 kt/y correspond to a rate of 4.16 g/m^2y or 33.9 $\mu M/m^2h$, which is in the range of 8 – 48 $\mu M/m^2h$ found in the Wadden Sea (Jensen et al. 1996) or recently estimated losses of 2.8 g/m^2 per season in the northern continental coastal waters (Topcu & Brockmann 2015).

Tab. 16 Sources of TN to the GEEZ areas 2006-2012*

Sources/imports of TN [%]	inner CW	outer CW	offshore
atmosphere	11.9	16.3	13.4
GE rivers	52.7	9.6	1.8
NL rivers	11.8	21.6	14.6
BE rivers	0.7	1.4	1.1
FR rivers	3.2	6.2	4.9
Channel	3.8	7.7	6.2
UK rivers	5.2	10.9	9.8
North Atlantic	9.3	23.8	45.9

* modelled by F. Grosse and H. Lenhart (2015)

Coastal waters of the GEEZ were predominantly influenced by the discharge of German rivers (52.7%), while for outer coastal waters and offshore waters the importance of transboundary nutrient transport increases (Tab. 16). TN in offshore waters is dominated by the inflow from the North Atlantic (45.9%). Contributions from the Netherlands, dominated by the Rhine, and UK rivers were significant for outer coastal waters and offshore waters, as was atmospheric depositions. Data for the atmospheric deposition were based on EMEP data in EMoSEM 2015. According to more recent data the contribution by atmospheric deposition in the GEEZ would be much higher (38 kt/yr compared to 21kt/yr) (Shamsudheen & Bartnicki 2016) (see also chapter 5.1.1.3).

5.1.1.3 Atmospheric nitrogen deposition

The EMEP MSC-W model has been applied to estimate the amount of atmospheric nitrogen deposition onto the GEEZ (including the coastal areas, altogether 33.100km^2) (Shamsudheen & Bartnicki 2016). In 2013 37.7 kt nitrogen deposited onto the GEEZ, of which 58.7% (22.1kt) was reduced nitrogen and 41.3% (15.5kt) oxidised nitrogen. Neglecting transboundary nutrient transport atmospheric deposition amounts to 20% of the nutrient inputs to the GEEZ, indicating that this remains an important source.

Fig. 37 shows the time series of oxidised, reduced and total nitrogen deposition between 1995 to 2013. The total nitrogen deposited to the GEEZ of the North Sea in 2013 was only 0.01% less than that in 1995 and hence remained at the same level as 20 years ago. A significant downward trend in the deposition of all components can be noticed in the beginning of the 2000s but then the deposition increases towards the end of the decade. Nevertheless, when the nitrogen deposition was normalised, reducing the influence of variable meteorology, a clear downward trend became apparent (Fig.37). The normalised total nitrogen deposition decreased from 44.2 kt/yr in 1995 to 34.0 kt/yr in 2013, which amounts to a reduction of 23%. The decrease was mainly due to a decreased of the deposition of oxidised nitrogen. The normalised deposition of oxidised nitrogen decreased by 35.6% and that of reduced nitrogen only by 11.1% between 1995 to 2013 (Shamsudheen & Bartnicki 2016).

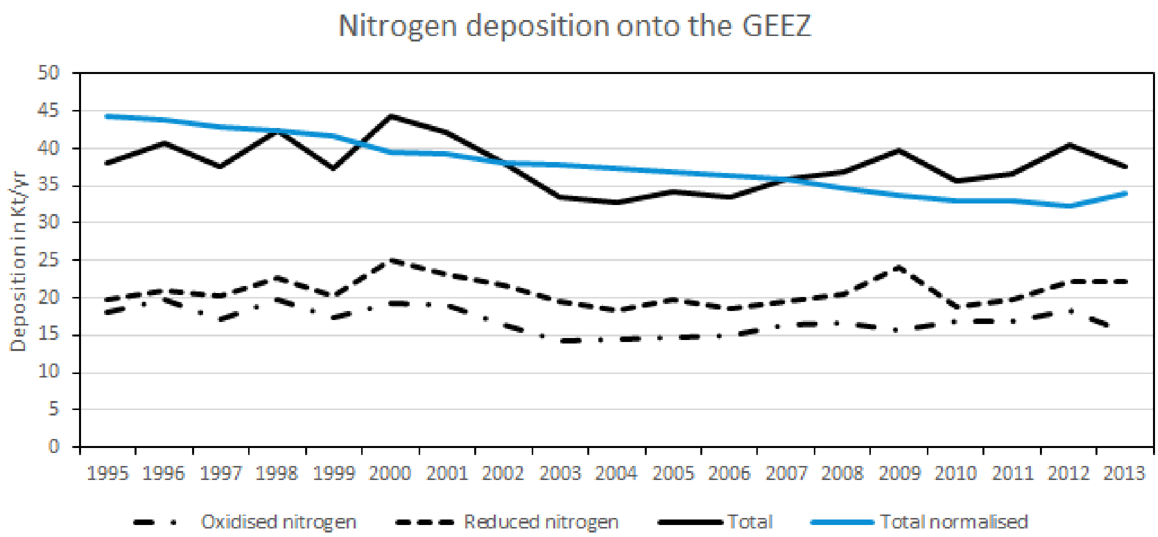

Fig. 37 Annual deposition of oxidised, reduced and total nitrogen onto the GEEZ between 1995-2013**.**

A source apportionment has also been carried out by EMEP for 2013 and the 10 major sources and their contribution are shown in table 17 below (Shamsudheen & Bartnicki 2016). Oxidised nitrogen stemmed mainly from Great Britain, Germany, North Sea ship traffic, France and Netherlands. For reduced nitrogen, that is not transported over large distances, almost half of the deposition stemmed from Germany, followed by the Netherlands, France, Great Britain and Denmark.

Tab. 17 Source apportionment for oxidised, reduced and total nitrogen deposition to the GEEZ of the North Sea for 2013.

Sources	% Contribution to oxidised N	Source	% Contribution to reduced N	Source	% Contribution to total N
GB	20.8	DE	46.9	DE	35.0
DE	18.2	NL	18.2	GB	13.3
NOS	15.0	FR	9.3	NL	12.9
FR	9.9	GB	8.1	FR	9.5
NL	5.5	DK	5.9	NOS	6.2
PL	4.7	BE	2.8	DK	4.4
BE	4.2	PL	1.8	BE	3.3
BAS	2.9	IE	1.2	PL	3.0
ATL	2.7	ES	1.1	ES	1.4
BIC	2.5	SE	0.7	BAS	1.2

NOS = North Sea ship traffic, BAS = Baltic Sea ship traffic, ATL = Atlantic ship traffic, BIC = boundary and initial conditions

5.1.1.4. Source apportionment

The northern catchment area is characterised by long freshwater residence times (> 100 days) of the groundwater and the southern mountainous part by short residence times (< 2 days) (Venohr et al. 2014), affecting the nutrient dynamics.

A source apportionment for nitrogen and phosphorus was carried out using the catchment model MoRe. For the time period 2012-2014 43.8% (7.7 kt/yr) of the phosphorus inputs came from agriculture and 35.5% (6.2 kt/yr) from points sources (mainly sewage treatment plants). The contribution of agriculture has been calculated by summing up erosion, groundwater, surface runoff and drainage. For nitrogen 71.0% (250.8kt/yr) of the nutrient inputs came from agriculture and only 21.2% (75kt/yr) from point sources. Table 18 below shows the full results of the source apportionment for the period 2012-2014. Fig. 38 and 39 show a time series of the source apportionment for nitrogen and phosphorus. Since the time period 1983-1987 nitrogen inputs have decreased by 56.0% (450.6kt/yr) and phosphorus inputs by 73.8% (49.6kt/yr).

Tab. 18 Nutrient sources within the German catchment area of the North Sea for 2012-2014 (from MoRe, UBA 2016).

	N in kt/yr	N in %	P in kt/yr	P in %
Atmospheric deposition	6.9	2.0	0.15	0.9
Erosion	5.7	1.6	2.74	15.6
Groundwater	172.5	48.8	3.35	19.1
Surface runoff	18.5	5.2	0.9	5.1
Drainage	54.1	15.3	0.7	4.0
Urban areas	20.7	5.9	3.5	20.0
Point sources	75.0	21.2	6.2	35.3
Sum	353.4		17.5	

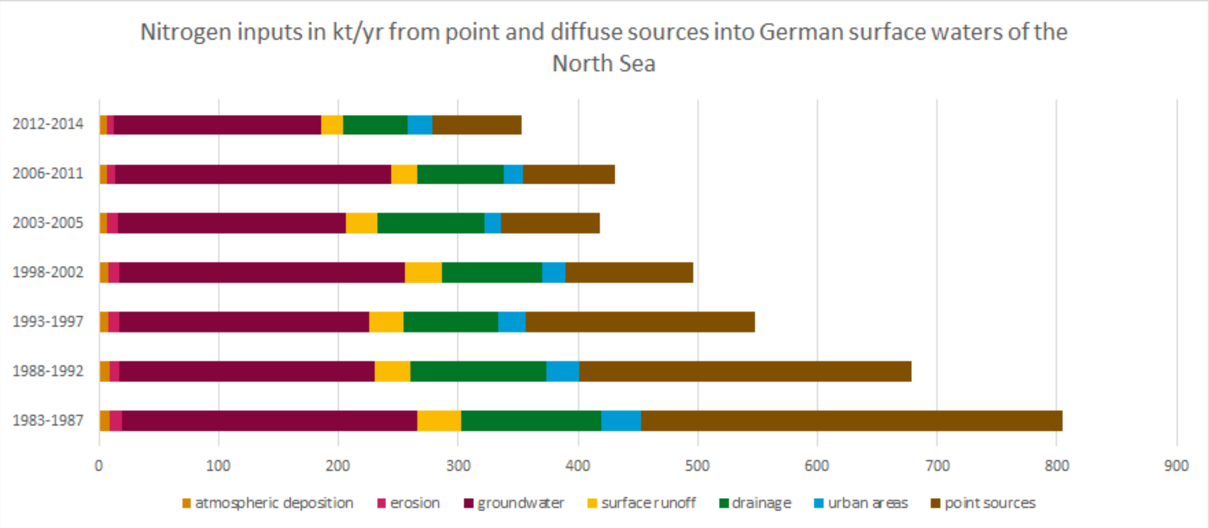

Fig. 38 Nitrogen inputs in kt/yr from point and diffuse sources into German surface waters of the North Sea, calculated with the models MONERIS and MoRe (Source UBA 2016).

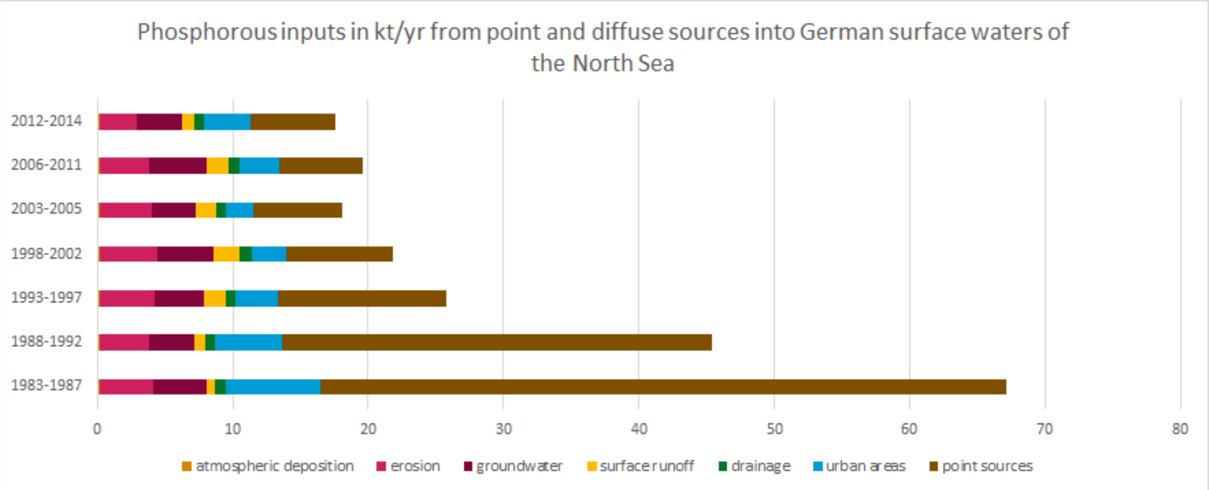

Fig. 39 Phosphorus inputs in kt/yr from point and diffuse sources into German surface waters of the North Sea, calculated with the models MONERIS and MoRe (Source UBA 2016).

5.1.1.5 Winter DIN + DIP gradients, mixing diagrams, trends

Steep gradients between > 50 µM DIN / > 1 µM DIP along the coasts and < 5 µM DIN/ < 0.5 µM DIP offshore indicate the dominant effect of mixing between fresh and marine waters and the high influence of riverine nutrient discharges (Fig. 40 & 42). These processes can be illustrated in mixing diagrams for DIN and DIP (Fig.44). High nutrient concentrations were spread along the continental coast, driven by the continental coastal current, arriving with similar concentrations as found in the GEEZ (Fig.40 & 42).

Long-term trends in nutrient concentrations showed differences between the different assessment areas caused by the salinity regimes and mixing processes. Changes of DIN concentrations within the estuaries by about 100 µM between 1980 and 2013 (Fig. 41) corresponded to a large degree to changes of concentrations in the rivers and riverine loads. For the Elbe estuary a decreasing trend dominated, whereas within the Weser estuary an increase until 2007 and within the Ems estuary a more recent increase was observed. Within the inshore WFD waters and the inner coastal waters decreasing tendencies dominated until 2007, followed by a stagnation or increasing tendencies. In the outer coastal and offshore waters mostly decreasing tendencies continued until 2013 according to polynomic regressions since 1995. However, annual means increased for the outer East Frisian coastal water (OCEF) since 2008 in spite of the strongest decreasing overall tendency.

DIP concentrations dropped significantly by a few µM within all estuaries since 1996, followed by recent increases as indicated by polynomic regressions for the Weser and the Elbe estuaries (Fig. 43). Decreasing tendencies dominated in inshore and inner coastal waters until 2005, followed by increasing trends. In the outer coastal waters decreases were more significant than in the inner offshore water (OFFI), whereas in OFFO an increasing tendency was indicated. Most regressions were significant ($\alpha < 5$ %), except the ones in offshore waters. For DIN trends were not significant in OCEF, EF 12, Ems and Eider estuaries, and for DIP not in OCNF, EF 12, and the Eider estuary.

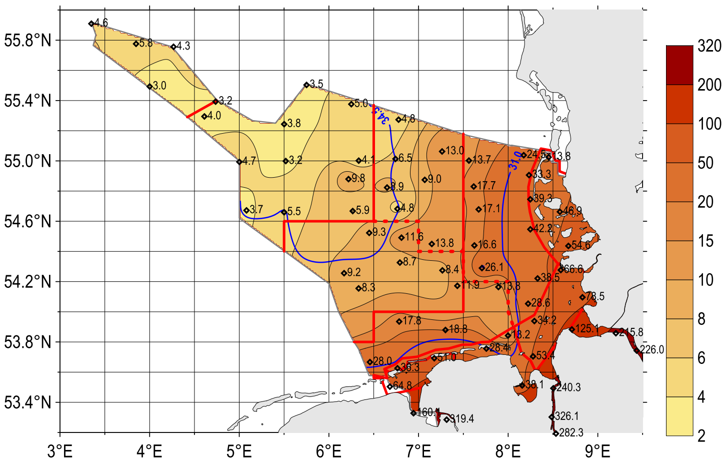

Fig. 40 Gradients of DIN [µM], winter (XI-II) means 2006 - 2014, surface data. In this and the following figures diamonds indicate mean sampling locations and the values indicate the mean per square.

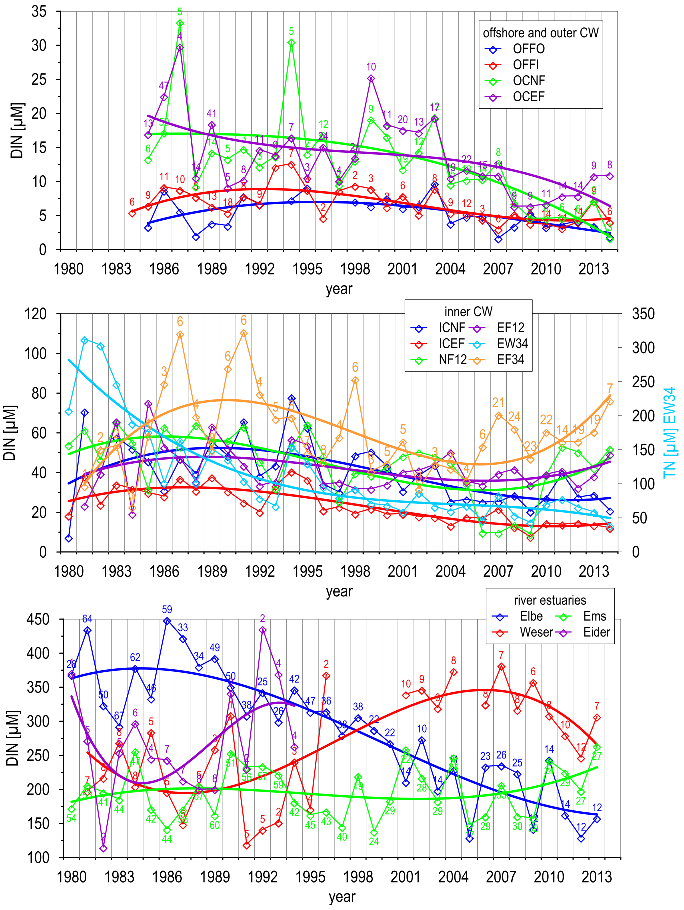

Fig. 41 Long-term trends in DIN concentrations per assessment area and per river estuary (not including the limnic-marine boundary) (1980-2013/14). For the Eider there were no data available since 1994.

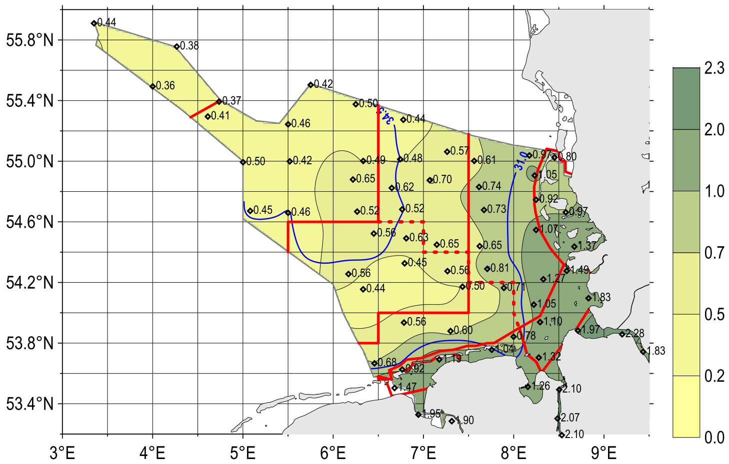

Fig. 42 Gradients of DIP [µM] in the GEEZ, winter (XI-II) means 2006 - 2014, surface data.

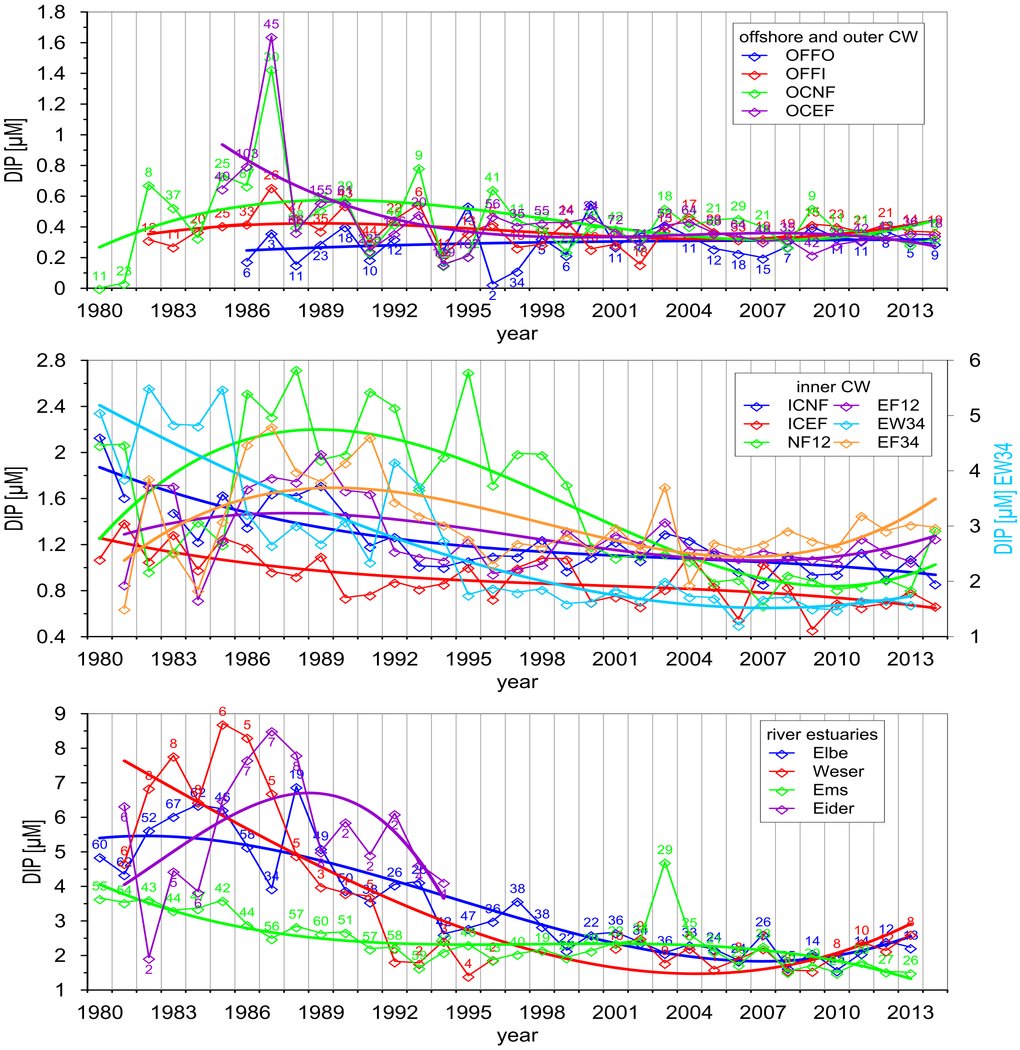

Fig. 43 Long-term trends in DIP concentrations per assessment area and per river estuary (1980-2013/14). For the Eider there were no data available since 1994.

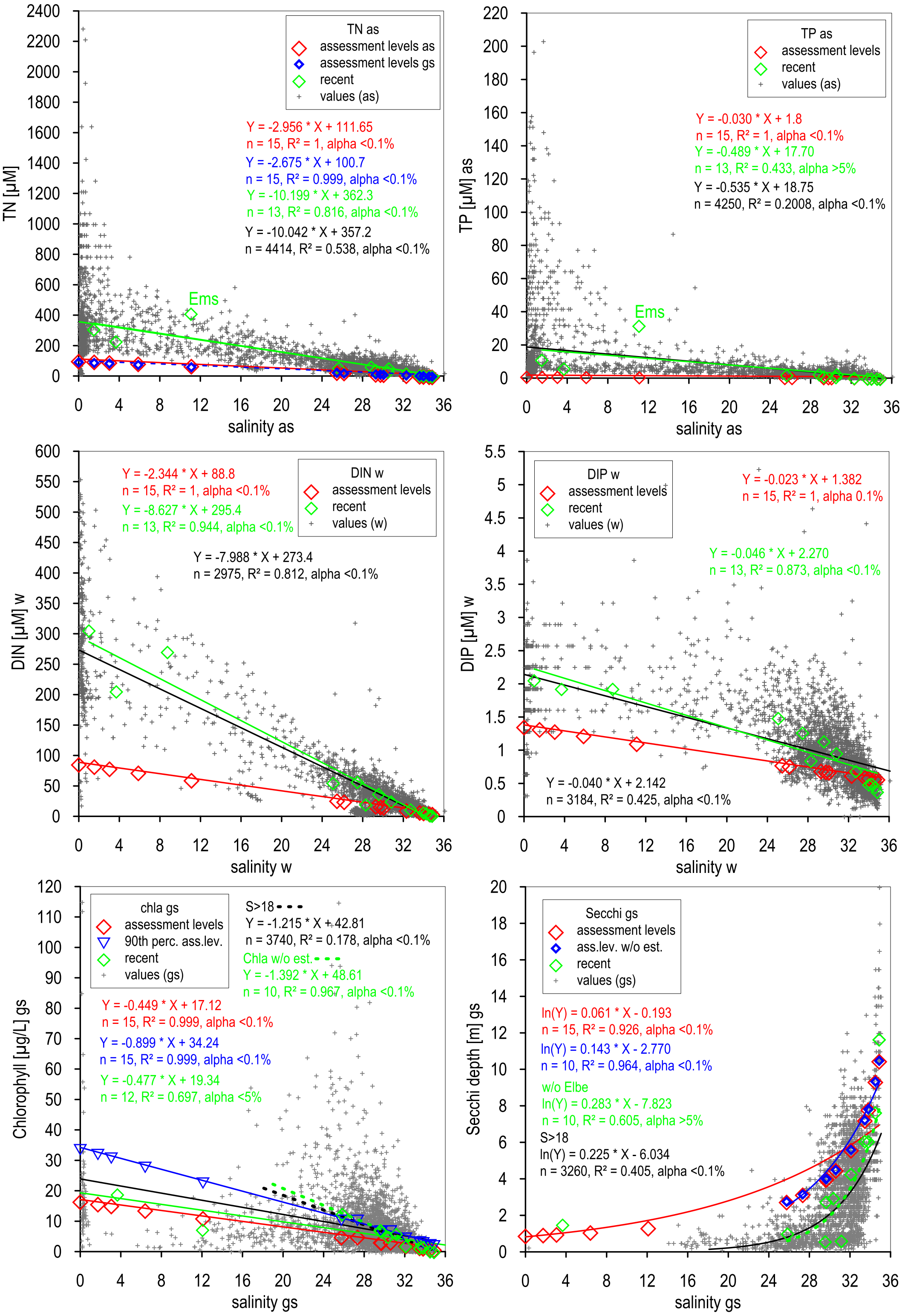

Fig. 44 Mixing diagrams for recent data (2006 – 2014) and for assessment levels (1880+50%). w/o est. = without estuaries.

Mean annual DIN concentrations varied in offshore waters around 4 µM with an inter-annual variability of about 30 % (Tab. Annex A 26). The number of samples/year was rather low (<10) and by this not representative for the OFFO and OFFI areas of 2500 and 9700 km^2 (Tab. 2). However, regional annual variability ranged between 10 and 190 %, indicating changing annual gradients. Within the outer coastal waters OCNF and OCEF DIN concentrations were around 9 µM with a standard deviation of 17 % and low sampling frequencies with <10 in ONCF of 5600 km^2 and around 10 in the 7300 km^2 large OCEF. In the inner coastal waters mean DIN concentrations reached 14 µM

(ICEF) and 20 µM (ICNF). The variability was 27 and 35 % and sampling frequencies were around 40/y in ICNF and 100 in the ICEF. In the ICNF of 7000 km^2 the sampling frequency was close to sufficient and in the ICEF with about 4000 km^2 sufficient, assuming a random distribution of sampling locations. In the inshore waters DIN concentrations ranged between 30 and 60 µM as inter-annual means with a variation of 14-60 %. A variation of 60 % was observed in the NF12 area, at sampling frequencies between 20 and 50/y, which is sufficient within this 2000 km^2 large area. Sampling frequencies around 20-30/y were achieved within the other inshore areas, indicating sufficient coverage in spite of regional variation per year of up to 90 % and focussing sampling at some coastal stations.

Mean annual DIP concentrations were around 0.6 µM in offshore and outer and inner coastal waters, with inter-annual variations between 10 and 29 % and annual regional variability of 8-60 % and similar sampling frequencies as for DIN (Tab. A 27). Mean concentrations increased in inner coastal waters to 0.7 and 0.9 µM and surpassed 1 µM in most of the inshore waters. Variability ranged around 30 % within the GEEZ.

5.1.1.6 Nutrient ratios: DIN/DIP

DIN/DIP ratios (M/M) were offshore < 10, in outer coastal waters 13 and 16 and approached to about 25 in inner coastal waters, to 40 inshore and > 100 within the estuaries (Tab. A 28).

5.1.2 Direct effect parameters

5.1.2.1 Chlorophyll-a

Mean annual chlorophyll-a concentrations were in outer offshore waters below 1 µg/L (Fig. 45) but sampling frequencies were rather low (mostly < 5/y) and during some years especially offshore no sampling was performed (Tab. A 28, Fig.9). Concentrations increased towards the coast, in outer coastal waters to 2 µg/L and in inner coastal waters to 3-6 µg/L, with high variability (Fig. 43). In inshore waters concentrations ranged between 5 and 13 µg/L, surpassed by the Elbe estuary with 20 µg/L. In the inner East Frisian coastal water there were no data during some years, as well as in the Elbe estuary. For the Weser estuary there were no chlorophyll-a data available for the assessment. Inter-annual variability was mostly around 30 % but annual variability reached nearly 100%, reflecting steep local gradients caused by sub-seasonal fluctuations. An exception were the offshore area and the outer North Frisian coastal water (OCNF) with only 47-63 % inter-annual variability (Fig. 46). Regional trends of chlorophyll-a concentrations were generally not homogeneous within the different assessment areas (Fig. 47), affected partly by low annual sampling numbers, as indicated for estuaries and outer and offshore waters. Most polynominal regressions were not significant ($\alpha > 5$ %), with the exception of NF 12, EF 12, EW 34 and the Ems estuary. These showed a peak in chlorophyll-a concentrations around the 1990ies within the inner coastal and some inshore waters and a decreasing trend since then. Opposite to the nutrients DIN and DIP chlorophyll-a concentrations varied within the same order of magnitude within all subareas, however, controlled by different processes, such as vertical mixing/light climate and nutrient availability. Due to the restricted sampling rates there were no significant regional trends within the different assessment areas.

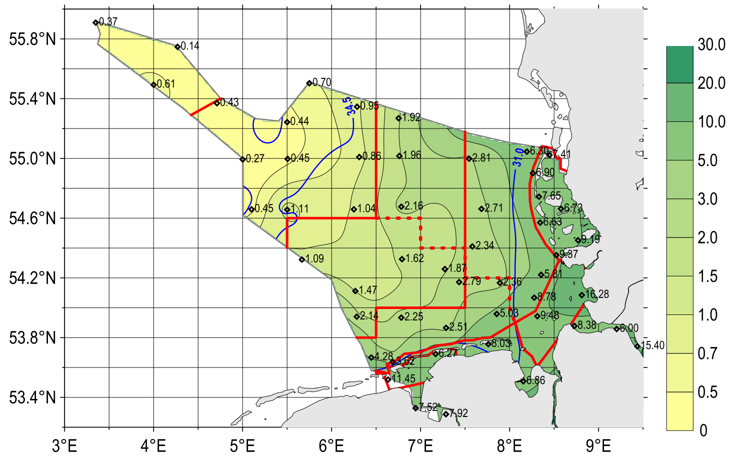

Fig. 45 Mean Chlorophyll-a concentrations [µg/L], growing season (III-X) 2006 – 2014, surface data.

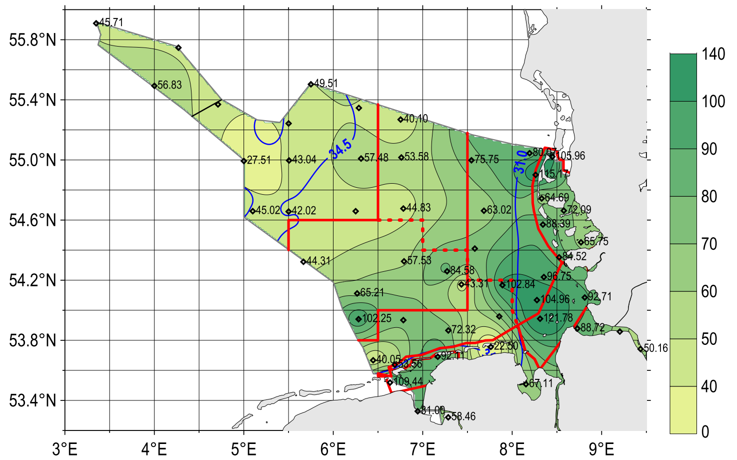

Fig. 46 Standard deviation [%] of mean chlorophyll-a concentrations, growing season means 2006 - 2014, surface data.

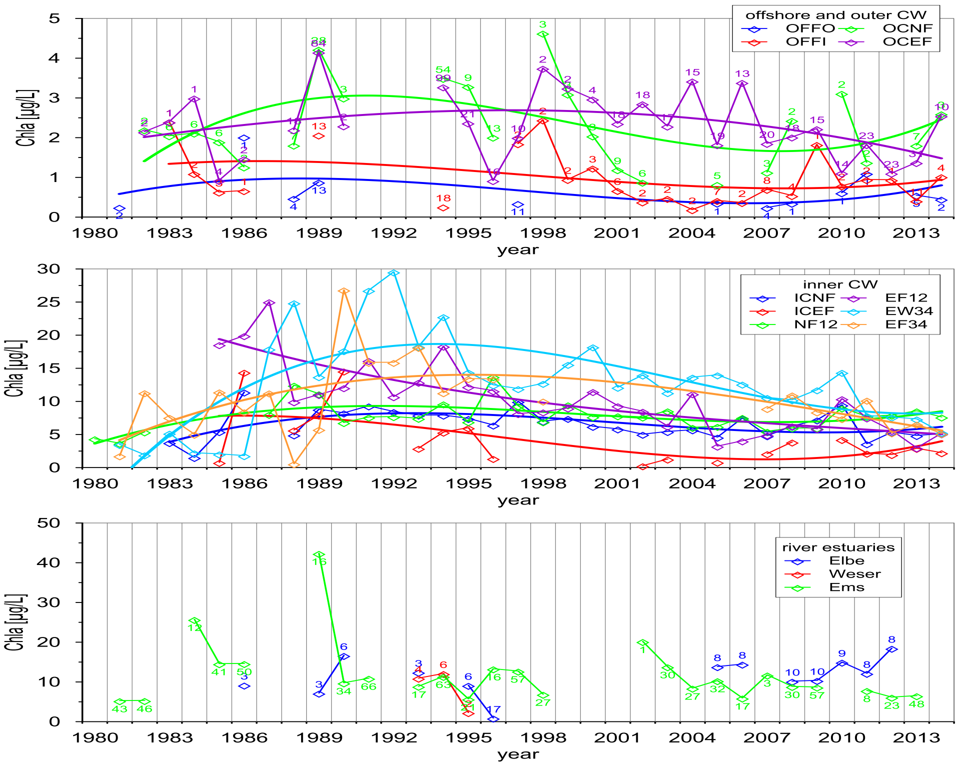

Fig. 47 Long-term trends of annual mean chlorophyll-a concentrations in the different assessment areas and for three main rivers.

90th percentiles were calculated annually for each assessment area. These were mostly twice the mean concentrations (Tab. 30), increasing from offshore waters with 3 µg/L to 12-28 µg/L in inshore waters (Fig. 48). Chlorophyll-a maxima surpassed offshore 2.5 µg/L, in coastal waters 26 µg/L and inshore waters 67 µg/L (Tab. A 31, Fig. 49). Phytoplankton, and by this chlorophyll-a concentrations, were reduced in some inner coastal waters and the estuaries due to light limitation. Inter-annual variability ranged around 50 %.

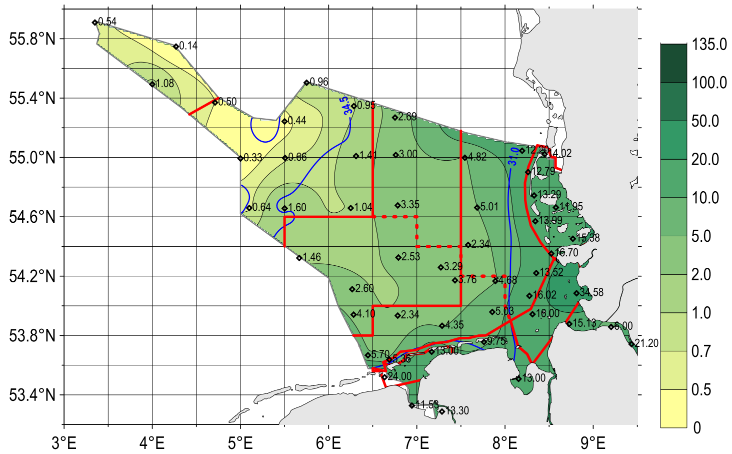

Fig. 48 90th percentiles of chlorophyll-a [µg/L], growing season (III-X) means 2006 – 2014, surface data.

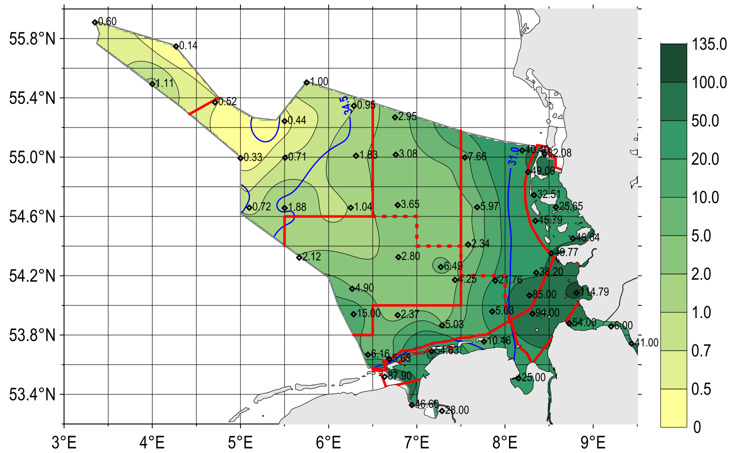

Fig. 49 Chlorophyll-a maxima [µg/L], growing season (III-X) means 2006 - 2014, surface data.

5.1.2.2 Phytoplankton: area specific indicators

Cells of phytoplankton indicator species were offshore and in coastal waters only sampled during few years. There were hardly any Phaeocystis cells detected in offshore waters. Abundances were especially high at frequently sampled coastal stations with means for the period 2006-2014 of up to 3.6 $*10^6$ cells/L (Fig. 50). There were two spots with elevated concentrations in the inner North and East Frisian coastal waters. Sampling frequency and coverage was rather low, especially in offshore waters (Tab. A 31). Inter-annual variability was often > 100%, mostly surpassed by the mean annual regional variability, reaching within some subareas > 300%. Annual mean cell numbers remained below 10^6 cells/L offshore and increased towards inshore waters to > $4*10^6$ cells/L, with high inter-annual fluctuations of >100%. Regional annual variability reached, as a mean for the assessed period, 300%, indicating high fluctuations and steep gradients. Maximum cell numbers surpassed $100*10^6$ cells/L at Norderney during several years.

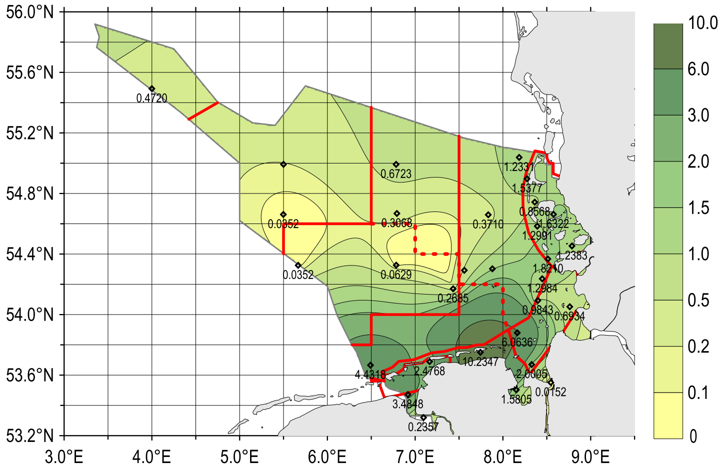

Fig. 50 Mean *Phaeocystis* spec. cell numbers [cells / L * 10^6], months III-X, 2006-2014.
Data sources: AWI, Helgoland Roads 2006-2014;   LLUR, AlgFes 2006-2014; BSH Monitoring 2008 und 2010, 0); NLWKN Whv 2009,2010,2012, 2013, N'ney 2006-2013

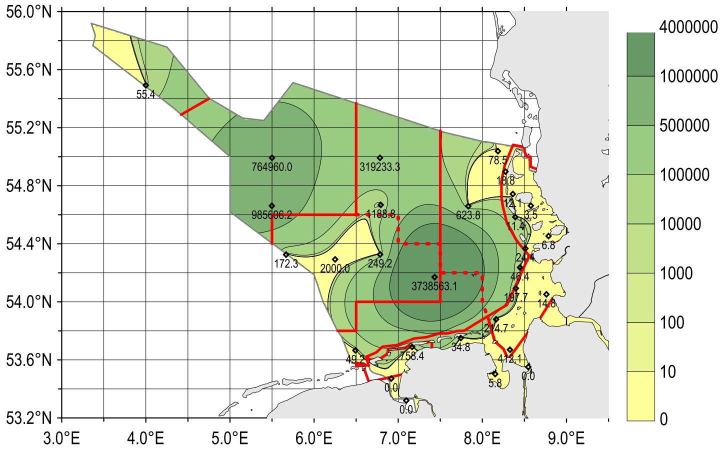

Fig. 51 Mean *Dinophysis* spec. abundance [cells / L] during the growing season (III-X) 2006-2014.
Data sources: NLWKN 2006-2013, AlgFes (LLUR) 2006-2014, BSH Monitoring 2008 -2011

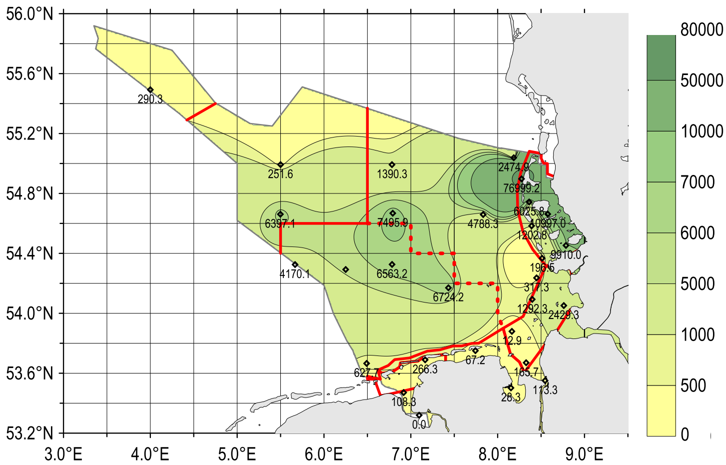

Fig. 52 Mean *Prorocentrum* spec. abundance [cells / L] during the growing season (III-X) 2006-2014.
Data sources: NLWKN 2006-2013, AlgFes (LLUR) 2006-2014, BSH Monitoring 2008 -2011

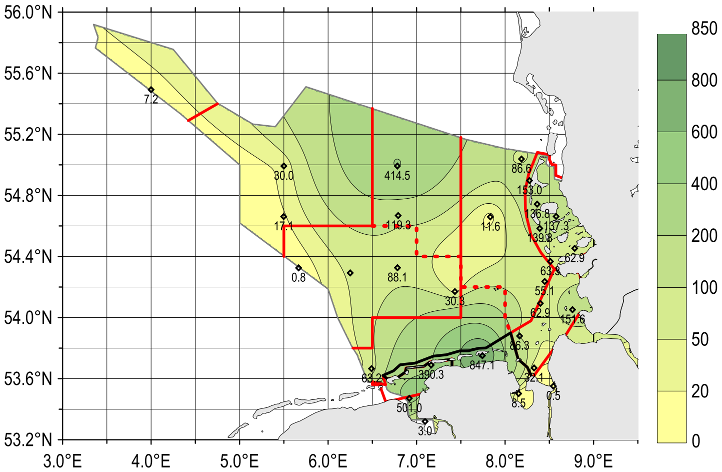

Fig. 53 Mean *Pseudo-nitzschia* spec. abundance [cells*10^3 / L] during the growing season (III-X) 2006-2014. Data sources: NLWKN 2006-2013, AlgFes (LLUR) 2006-2014, BSH Monitoring 2008 -2011

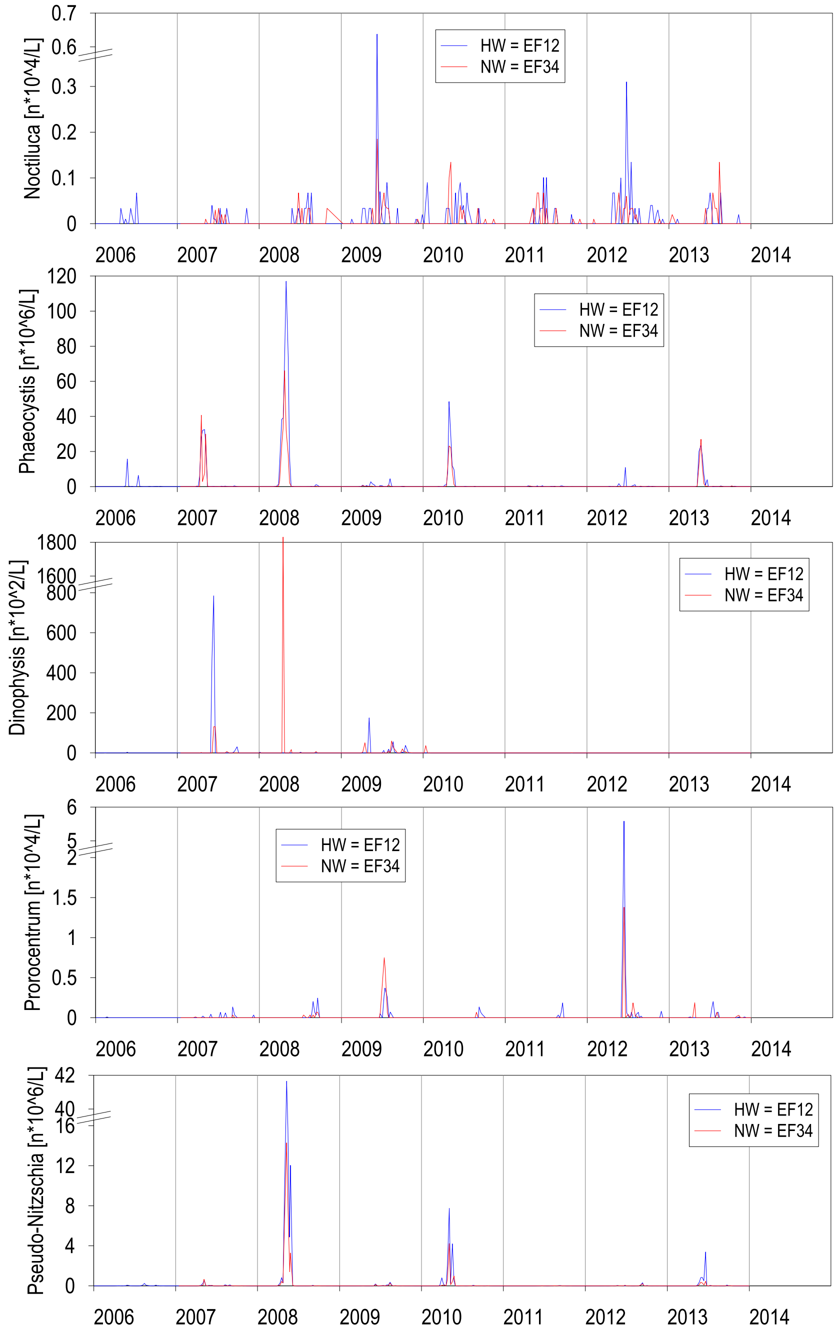

Fig. 54 Abundances of selected phytoplankton indicator species at Norderney exceeding assessment the species specific level (assessment areas EF 12 and EF 34).

High annual means (> $2*10^2$) of *Dinophysis* spec. (*Dinophysis acuta*) cells were detected in the inner offshore water (OFFI), the outer coastal waters, and some inshore waters (Tab. A 33). Means of squares showed a clear separation between high abundances in OFFI and OCNF (Fig. 51). Time series at Norderney (Fig. 54) reflected a restricted local Dinophysis occurrence between 2007 and 2009, whereas in inner coastal and inshore waters Dinophysis cells were observed nearly during every year.

Annual mean cell numbers of *Prorocentrum* spec. surpassed 10^5 cells/L in nearly all water masses during 2008 but not in EF12 and EF34 (Tab. A 34). High means were observed in squares of the north-eastern waters (ICNF) and at the border between the outer coastal waters (Fig. 52).

Pseudo-nitzschia cells were detected with high means in squares (>400 000 cells/L) in the outer North Frisian coastal water and EF 12 inshore (Fig. 53 and Tab. A 35), and with high annual means above 10^6 cells/L in East Frisian inshore waters (EF 12, EF 34) during 2008 and in OCNF during 2009.

Significant mussel intoxication due to algal toxins has been detected only during fall 2014 in the Jade Bight above a threshold and at the coast of Schleswig- Holstein below thresholds during fall 2014 (pers. comm. L. Nausch, Neumünster; Effkemann, Cuxhaven).

5.1.2.3 Macrophytes

The abundance and extension of seagrasses, and partly of saltmarshes and macroalgae have regionally been investigated, however, restricted to eulitoral areas by counting or remote sensing (Dolch et al. 2010, 2013, Reise et al. 2015, 2014, Brandt et al. 2014). Assessment results have been taken from the most recent WFD assessment (see table 25), covering the period 2009-2013/14 (Tab. 24).

5.1.2.4 Secchi depth

Recent mean Secchi depths decreased from offshore waters with >10 m to turbid near coastal waters to around 3m in inner coastal waters (Fig. 55, Tab. A 36). In inner coastal waters Secchi depth decreased significantly (α<0.1 %) since 1980 (Fig. 56). Secchi depth was not used as an assessment parameter in coastal waters due to naturally high turbidity.

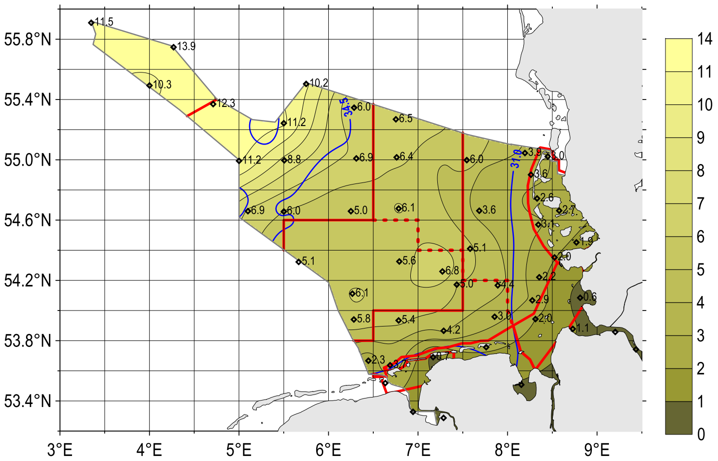

Fig. 55 Mean Secchi depth [m] during the growing seasons (III-X) 2006-2014. Coastal waters were not assessed.

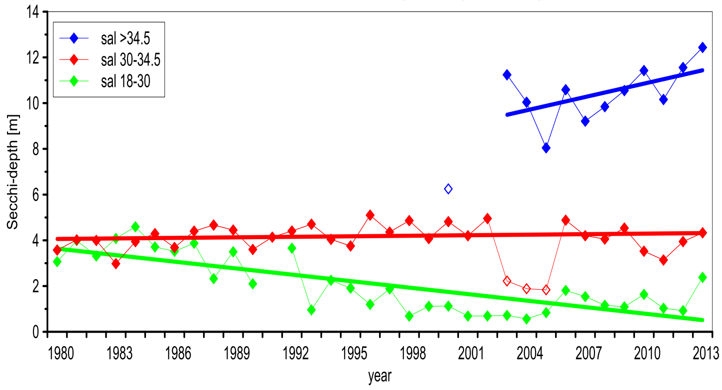

Fig. 56 Recent trends of seasonal (III-X) annual means of Secchi depths within the southern North Sea (50-56°N), separated for salinity regimes.

5.1.3 Indirect effect parameters

5.1.3.1 Oxygen deficiency

Mean seasonal oxygen concentrations ranged in bottom waters between 7.5 and 10 mg/L with lowest values offshore (OFFI) and in the ancient Elbe valley along the border between ICNF and ICEF (Fig. 57). Oxygen concentrations near the bottom were in shallow areas nearly similar as at the surface due to vertical mixing. The exceptions were deep dredged estuarine channels, where vertical oxygen gradients are possible, indicating high oxidation rates. Oxygen concentration were highest (>7.6 mg/L) along the shallow coastal water due to elevated primary production, indicated by high chlorophyll-a concentrations. In the estuaries of Elbe and Ems concentrations dropped below 7.5 mg/L. In the bottom water of the inner offshore area (OFFI) mean concentrations were below 7 mg/L, indicating enhanced oxidation of organic matter below the thermocline. The inter-annual variability was low (Tab. A 38), but the sampling frequency was low as well (Fig. 11), mostly around 10/year, restricted to the season July-October.

Strongest inter-annual changes of oxygen concentrations were observed within the estuaries of the Elbe and Eider (Fig. 58). However, sampling frequency within the Eider was limited, as indicated by the low number of annual data. There were no significant trends (α > 5 %), except for the Elbe estuary with a recent decrease.

Oxygen minima of 4.6 mg/L were observed within the outer coastal water off North-Friesland (OCNF), corresponding to a saturation of 57 % (Fig.56). Minimum oxygen saturation (Fig.60) dropped regionally to <60 %. Mean and maximum oxygen depletion (Fig. 61 and 62) reached more than 3 mg/L in the areas OFFI and OCNF, indicating longer lasting sedimentation and decomposition of organic material transported by the coastal current to seasonally stratified areas (Topcu & Brockmann 2015).

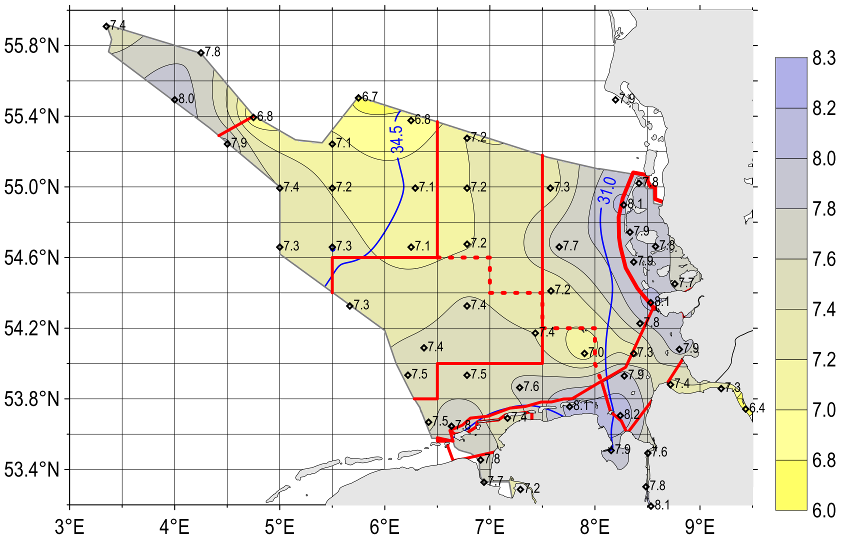

Fig. 57 Mean oxygen concentrations [mg/L] during July-Oct. 2006-2014 near the bottom.

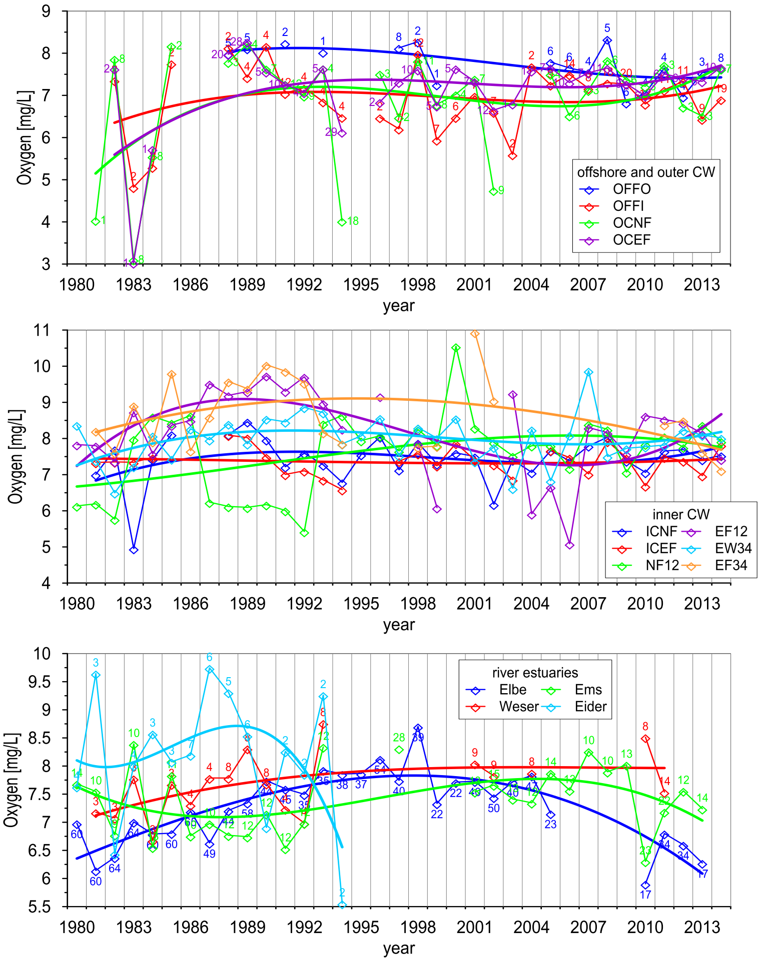

Fig. 58 Trends of seasonal oxygen concentrations in the bottom waters in different assessment areas and main rivers.

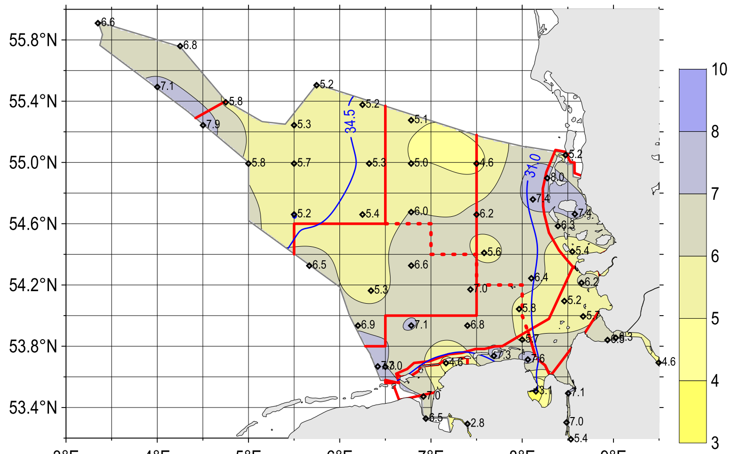

Fig. 59 Oxygen minima [mg/L] during July-Oct. 2006-2014 in bottom waters.

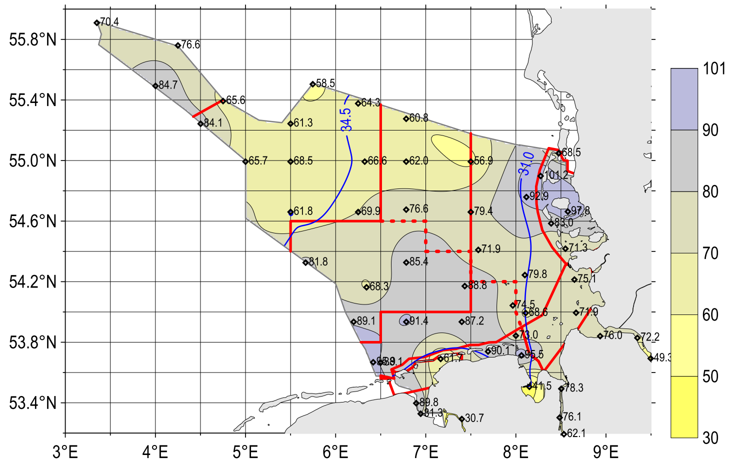

Fig. 60 Minimum oxygen saturation [%] during July-Oct. 2006-2014 near the bottom.

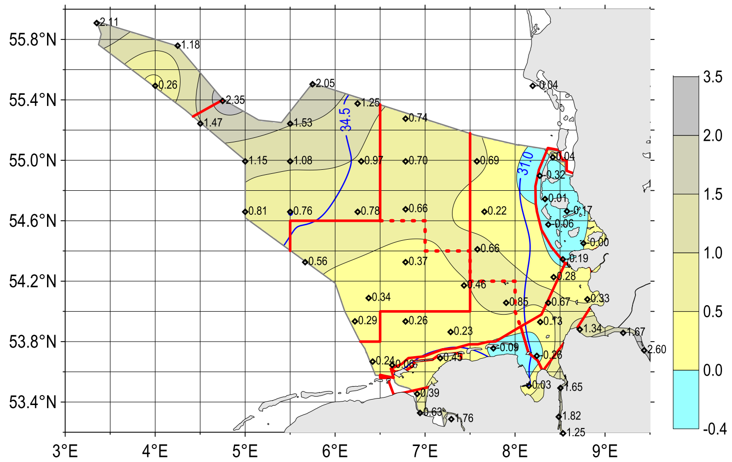

Fig. 61 Mean oxygen depletion [mg/L] during July-Oct. 2006-2014 near the bottom.

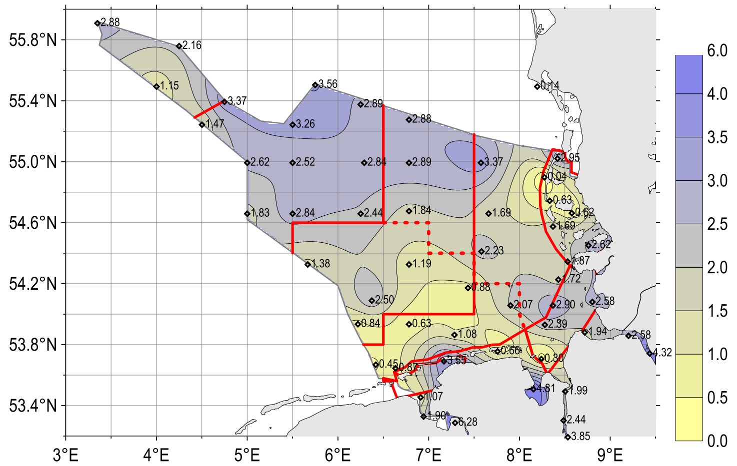

Fig. 62 Maximum oxygen depletion [mg/L] during July-Oct. 2006-2014 near the bottom.

Mean oxygen saturation was offshore around 85 %, increasing towards the shallow coastal waters (Tab. A 38). Correspondingly, oxygen depletion decreased from offshore areas with >1 mg/L to 0.5 mg/L in coastal waters. Inshore waters were partly over-saturated by elevated primary production, indicated by high chlorophyll-a concentrations (Tab. A 29). Mean seasonal oxygen depletion near the bottom decreased from offshore areas with > 1mg/L to oversaturation in shallow coastal waters and increased again within the estuaries (Tab. A 39). For the inter-annual gradients standard deviations were high. Due to the far reaching ecosystem effects of oxygen depletion and the fact that monitoring was restricted (Fig. 11), minimum oxygen concentration (Tab. A 41) and maximum oxygen depletion (Tab. A 42) have been assessed as well. Minimum annual oxygen saturation dropped in offshore areas and in the estuaries of Elbe and Weser, and during some years also in coastal waters and the Ems estuary, below 70 % (Tab. A 40, Fig. 58). Correspondingly, maximum depletion passed offshore and in the estuaries of Elbe and Weser and during some years in coastal waters and in the East Frisian inshore water (Jade Bight) 2 mg/L (Tab. A 42, Fig. 59).

5.1.3.2 Macrozoobenthos

For the coastal and transitional waters the assessment was based on recent WFD assessment results (2009-2013/14) for the biological quality element macrozoobenthos (see also Tab.25 and Tab. A 43). Further offshore macrozoobenthos was estimated as ash free dry weight (AFDW) and wet weight (WW). Very large organisms that live on the sediment and occasionally occur in the grab samples were not excluded from the analysis and this could bias the results. The significant correlation of AFDW with chlorophyll-a (see Fig. 19) according to Beukema et al. 2002 and Hargrave & Peer 1973 allowed the calculation of assessment levels for reference conditions (1880) based on chlorophyll-a (Fig. 63, Tab. A 43). Wet weights and numbers of organisms were not considered due to their high variability. High biomasses (> 1g/m^{2}AFD) were observed in inshore waters (Fig. 64), decreasing to < 0.2 g/m^2 offshore. There are no data for the Elbe estuary. Number of species was mostly around 100/area/y. Regional standard deviations were up to 74 %. Mean sizes of macrozoobenthos organisms were calculated from AFDW/n (Fig. 65). They showed an increase since 1993, reaching around 2002 a stagnation and dropping recently. Sizes varied between the different assessment areas that had sufficient data. Smallest animals were reported from inner North Frisian waters (NF12).

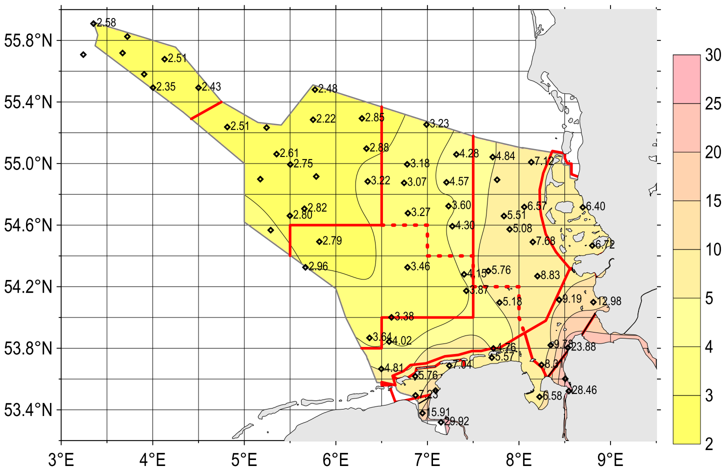

Fig. 63 Mean gradients of assessment levels for macrozoobenthos biomass (AFDW, g/m^2) in the GEEZ. Although coastal waters were not assessed using this parameter gradients are still shown.

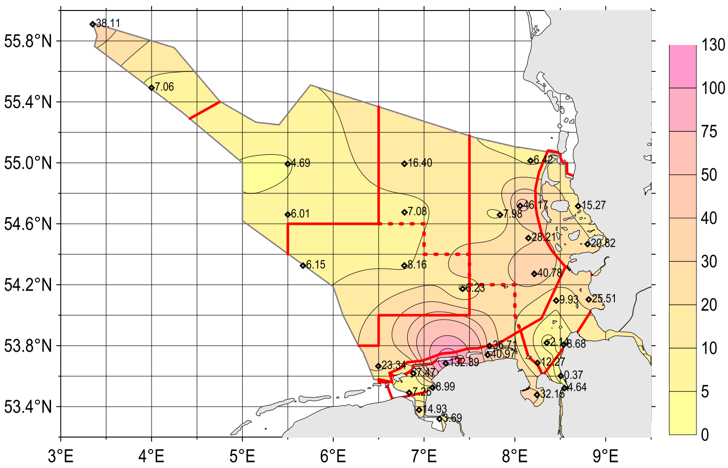

Fig. 64 Mean macrozoobenthos biomass [g/m^2] (AFDW), all seasons, 2006-2014. Although coastal waters were not assessed using this parameter biomasses are still shown.

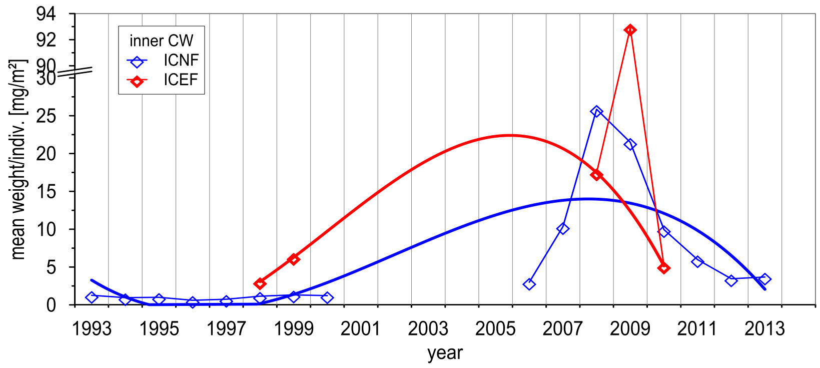

Fig. 65 Mean macrozoobenthos biomass 1993-2014 in the GEEZ, all seasons (afdw mg/m² / total n indiv.). Coastal waters were not assessed.

Total fit: Y = -38754150.3 + 57889.299 * X - 28.824 * X^2 + 0.00478 * X^3

n = 17, R^2 = 0.537017, alpha <5%

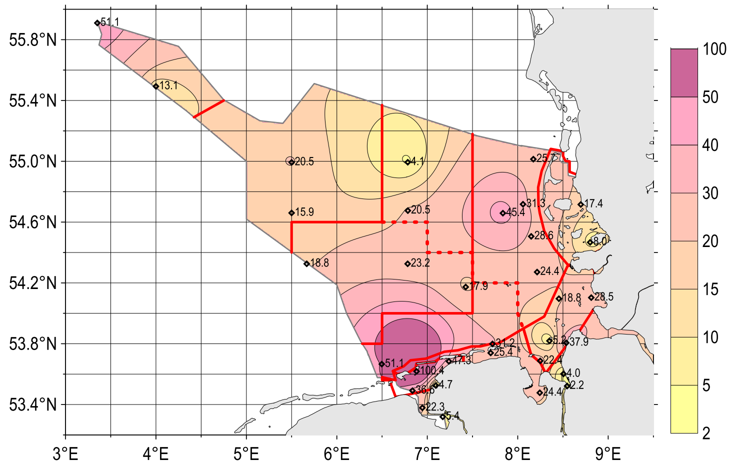

Fig. 66 Macrozoobenthos mean sizes in the GEEZ, all seasons 2006-2014 (AFDW mg/m²/total n indiv.). Although coastal waters were not assessed using this parameter mean sizes are still shown.

Macrozoobenthos organisms were smallest offshore and in the North Frisian outer coastal water and largest in the inner North and East Frisian coastal waters (Fig. 66). In the North Frisian inshore water (NF12) and EW34, connected with the Weser estuary, small animals were detected as well. There was only a weak correlation with local oxygen depletion or (invers) with oxygen saturation, indicating dominance of small animals at locations with high depletion. The assessment of the macrozoobenthos biomass beyond 1 nautical mile is not used for the MSFD assessment of descriptor 5 eutrophication since it is not regarded as adequate for this purpose.

5.1.3.3 Organic carbon

TOC concentrations were highest in the Elbe with 780 µM, followed by the Weser with 260 µM and the Ems with 9 µM (Tab. 18). This is opposite to TN concentrations (Tab.11). There were no TOC data within offshore and outer coastal waters and also not in the NF12 area (Tab. A 44). TOC means reached in inner coastal waters > 150 µg/L, surpassed partly 500 µg/L inshore, and 1 mg/L within the estuaries. Variability of concentrations was rather low < 10 %, but inter-annual variability of loads reached 37 %.

Tab. 18 Annual TOC concentrations and loads during growing season 2006-2014 within the main rivers.

Elbe	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Mean**
TOC µM	816.2	843.8	769.4	781.8	748.4	821.8	778.1	748.2	691.7	777.7
SD	62.8	135.9	68.8	104.0	63.8	90.5	71.7	110.7	77.4	46.1
SD	7.7	16.1	8.9	13.3	8.5	11.0	9.2	14.8	11.2	5.9
n	18	16	15	16	16	13	16	14	16	140

TOC kt/y	263.3	175.7	143.0	187.6	295.4	203.3	156.5	314.4	113.8	205.9
SD	248.5	56.0	95.8	122.2	147.0	46.8	84.6	261.5	35.0	70.0
SD%	94.4	31.9	67.0	65.1	49.8	23.0	54.0	83.2	30.7	34.0
Weser										
TOC µM	454.6	468.8	461.5	436.5	515.5	400.0	439.6		441.7	452.3
SD	106.7	95.7	88.1	52.9	136.9	67.1	81.3		102.7	106.7
SD%	23.5	20.4	19.1	12.1	26.6	16.8	18.5		23.3	7.3
n	9	8	8	8	7	8	8	0	8	64
TOC kt/y	39.2	59.4	58.9	39.7	49.6	25.7	29.1		28.1	41.2
SD	27.6	25.7	57.5	37.0	34.6	10.5	12.8		6.4	13.5
SD%	70.3	43.4	97.7	93.1	69.7	41.0	44.0		23.0	32.8
Ems										
TOC µM		1114.6	937.5	1067.7	1067.7	817.9	801.0		803.6	924.5
SD		306.89	157.75	942.47	184.28	166.84	152.98		171.52	127.85
SD%		27.5	16.8	88.3	19.8	20.4	19.1		21.3	13.8
n	0	4	4	8	4	7	8	0	7	42
TOC kt/y		63.2	33.0	37.5	36.6	42.4	24.9		21.5	37.0
SD		43.4	11.7	19.8	16.7	39.8	14.7		10.1	13.7
SD%		68.6	35.6	52.6	45.6	93.9	59.0		46.7	36.9

Since few measured data were available for TOC significant correlations with organic nitrogen were used to calculate TOC for assessment areas with sparse data (Tab. 19).

Tab. 19 Annual means of TOC concentrations, calculated from correlated organic nitrogen concentrations (TN-DIN) in the GEEZ during growing season.

	TOC µM calc.	TOC SD %	TOC gs n samples	TOC n /quadr/y	TOC 1880 µM*	TOC WFD **	TOC dev. % from 1880	TOC measured dev.%***
OFFO	67.93	20.38	29	0.9	42.8	39.3	50	
OFFI	71.51	15.26	65	0.6	48.9	44.5	54	
OCNF	85.91	23.98	35	0.5	58.4	53.9	52	
OCEF	130.23	20.08	160	1.8	62.7	58.6	105	
ICNF	172.07	44.81	178	2.1	126.4	109.9	46	75
ICEF	139.22	38.29	106	2.2	89.7	77.1	69	125
NF12	237.07	58.11	61	2.3	119.2	110.9	106	
EF12	411.37	112.17	511	37.9	109.5	97.6	268	267
EW34	296.63	89.49	335	14.9	212.0	163.5	35	268
EF34	430.71	47.90	312	34.7	138.3	141.9	211	215
Elbe-E	655.62	209.72	514	57.1	640.8	472.2	1	102
Weser-E	869.46	279.55	145	32.2	623.1	490.2	41	128
Ems-E	2187.07	358.98	348	77.3	457.3	349.2	384	919

* calculated from TN estimates by Gadegast & Venohr (2015), ** calculated from TN, WFD-means (KoRa 2015b). *** from Tab. A 44 with differences from WFD means (**)

TOC has mainly been analysed within inner coastal waters, including the estuaries (Fig. 67). Missing data could be calculated by significant correlations with organic nitrogen (ON) (Fig. 20). A comparison with measured TOC concentrations showed similarities except for EW34, where measured TOC was about twice the calculated value. TOC concentrations decreased from about 700 µM in the estuaries to <50 µM offshore (Fig. 68).

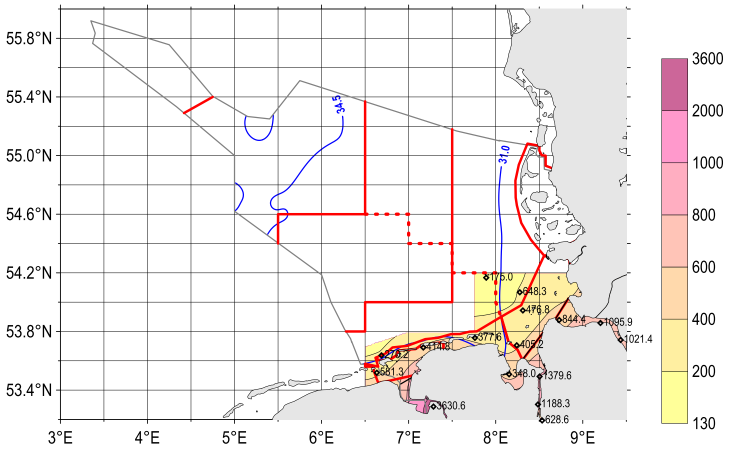

Fig. 67 Measured TOC concentrations [µM] in the growing season (III-X) means 2006-2014, surface data.

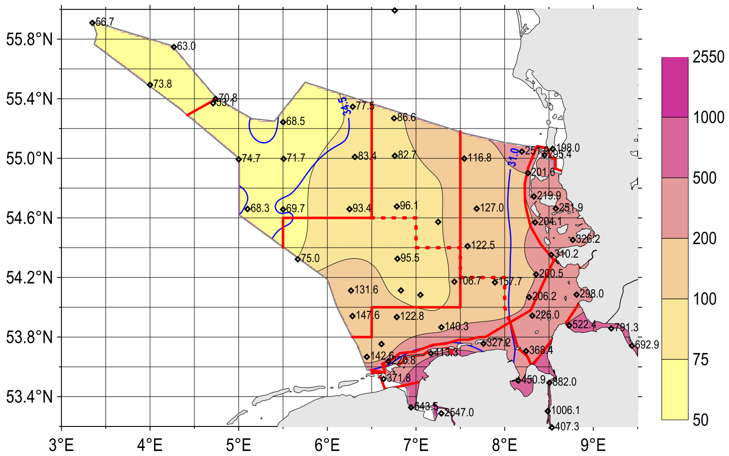

Fig. 68 TOC concentrations [µM] in the growing season (III-X) means 2006-2014, calculated from relationships with TN-DIN (y = 11.0997*X; n = 1500, R^2 = 0.847, alpha <0.1 %).

5.1.4 Other possible effect parameters

No significant occurrences of algal toxins or mussel infections have been reported besides some local effects below assessment levels during fall 2014 (pers. comm.).

5.1.5 Supporting environmental factors

Freshwater discharge rates of the main rivers were presented together with nutrient discharges (Tab. 12) and presented as trends (see Fig. 6). Salinity gradients have been presented with the definition of subareas, reflecting the mixing regimes (see Fig. 3) which were also visualised by mixing diagrams (see Fig.44). Temperature is most important for seasonal thermal stratification controlling the duration of bottom water oxygen depletion (see Fig. 4).

Secchi depths have been assessed because the light climate controls the utilisation of nutrients near-shore and affects the possible extension of macrophytes (Nielsen et al. 2002 a,b) (see Tab. 36). Since Secchi depth is correlated with TN concentrations (Fig. 17), it is a tool or proxy for assessing eutrophication effects.

5.1.6 Voluntary parameters (TN, TP, Si, DIN/Si, DIP/Si)

TN and TP were partly considered already in § 5.1.1.1 & 2 for the assessments of river discharges, budgets or in § 5.1.3.3 for the calculation of missing data of TOC. Generally, these parameters are a prerequisite to calculate nutrient budgets and they support the confidence of nutrients, chlorophyll-a, Secchi depth and macrozoobenthos. Silicate and its ratios with inorganic nutrients during winter were treated similarly to DIN/DIP ratios (§ 5.1.1.4).

5.1.6.1 Total N and P

TN and TP concentrations remained below assessment levels in offshore waters but surpassed these values increasingly towards the coast (Tab. A 45 & 46). Surface gradients of TN concentrations reflected the high nutrient loads of the continental coastal current propagating along the coast from east to north, passing the GEEZ. This current is fed by local river loads, as indicated for inshore waters with mean (2006-2014) concentrations > 50 µM (Fig. 69). By dilution – indicated by parallel salinity gradients – TN concentrations dropped in the offshore waters below 10 µM. Variability within the squares was especially high (> 50 %) within areas with fluctuating inputs, such as near the river plumes and the East-Anglia inflow (Fig. 70).

Trends within the GEEZ assessment areas revealed extreme changes within the estuaries, with nearly opposite tendencies within the Elbe (mainly decreasing) and the Weser (reaching a maximum around 2006), whereas the increasing trend within the Ems estuary continued (Fig. 71). Besides the changing river concentrations and loads these differences were probably caused by dredging activities, modifying the interactions between inorganic and organic nutrients and thereby influencing the retention of total nutrients. Both in the coastal and offshore waters decreasing tendencies dominated for TN concentrations, caused by decreasing river discharges and decreases in the atmospheric deposition Shamsudheen & Bartnicki 2016).

Mean surface concentrations of TP were highest within the inshore waters of the Wadden Sea (> 2 µM) and within the estuaries (> 5 µM), dropping towards offshore in OFFO below 0.5 µM (Fig. 72). As for TN the highest variability (> 40 %) was observed near the coast and within the area of the East Anglia plume (Fig. 73). Regional trends showed an extreme TP increase within the Ems estuary by about 20 µM, probably caused by dredging activities, remobilising particulate phosphorus (Fig. 74). Within the inshore and inner coastal waters stagnating TP concentrations, decreasing trends (ICEF, ICNF) and interim maxima (EF 12) were observed as well. Within the outer coastal waters decreasing trends were stronger than in the offshore areas with more stagnating tendencies. Polynominal regressions for TN were mostly significant (α > 5 %) in OFFO, OCEF, ICEF, EF 12, EW 34 and within the Elbe and Weser estuaries. Polynomial regressions for TP were significant for OCNF, OCEF, ICEF, EF 12, EW 34 and the Elbe and Ems estuaries.

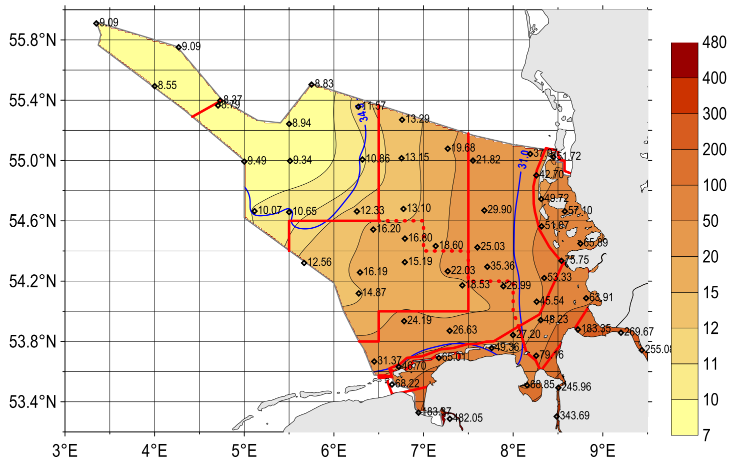

Fig. 69 Mean TN [µM] concentrations, 2006-2014, all seasons, surface data.

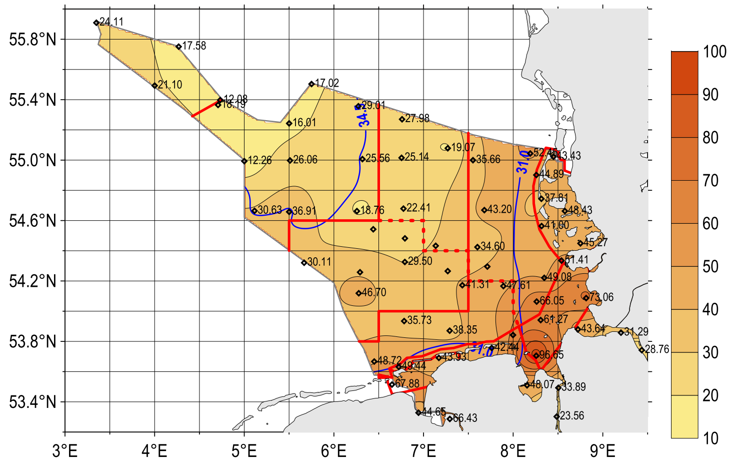

Fig. 70 Standard deviation of mean TN concentrations, 2006-2014, all seasons, surface data.

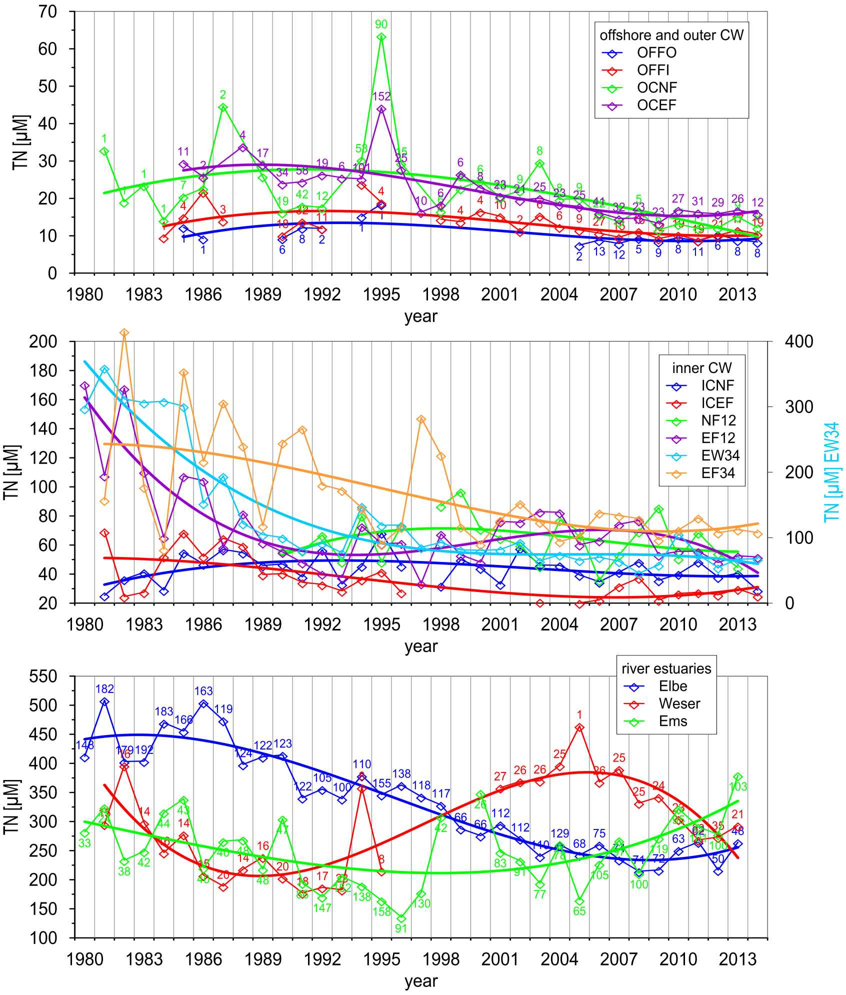

Fig. 71 Long-term trends 1980-2013/14 in TN concentrations for the different assessment areas and main rivers.

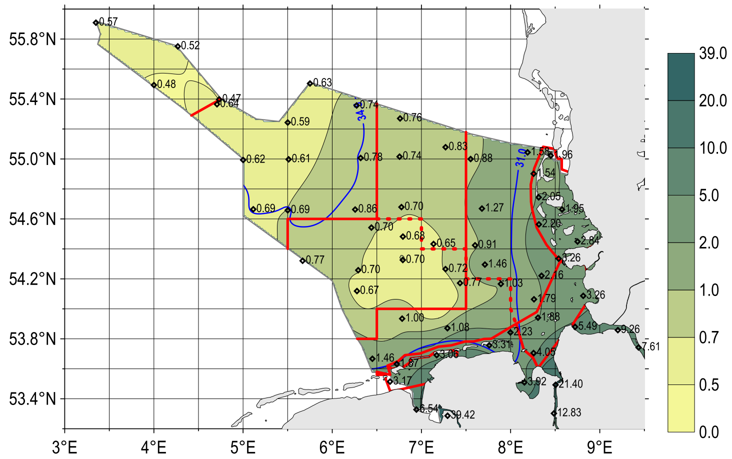

Fig. 72 Mean TP [µM] concentrations, 2006-2014, all seasons, surface data.

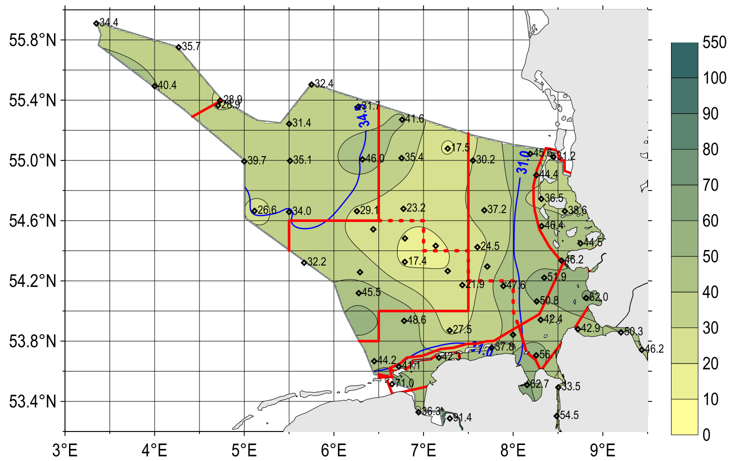

Fig. 73 Standard deviation of mean TP concentrations, 2006-2014, all seasons, surface data.

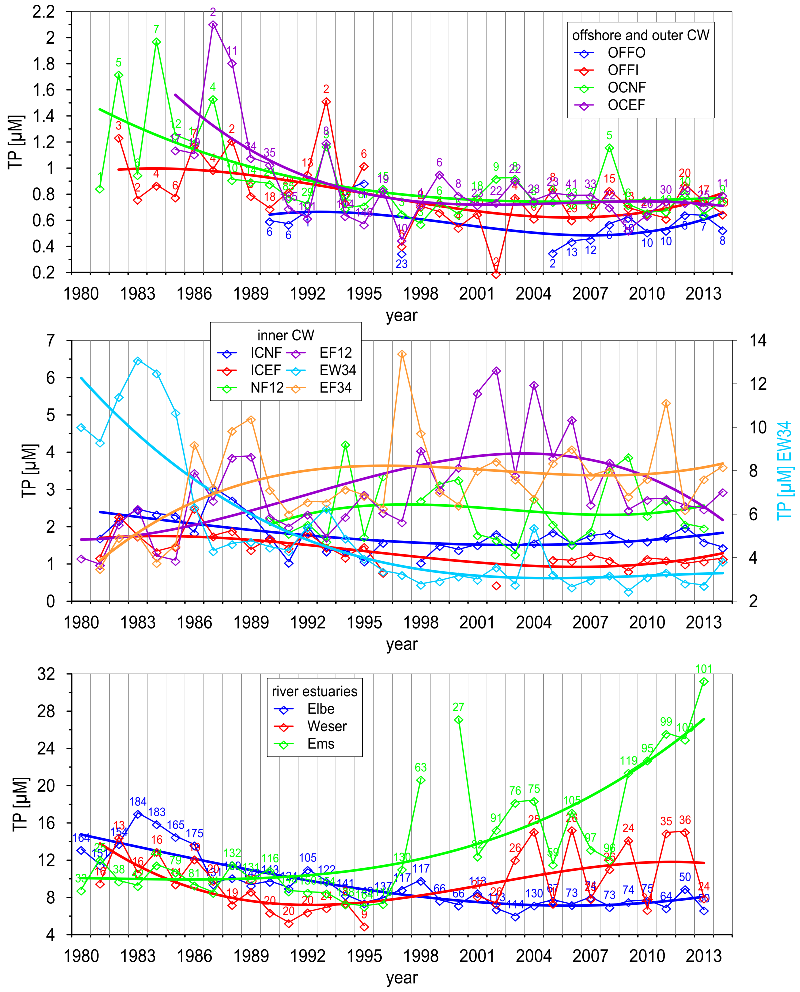

Fig. 74 Long-term trends 1980-2013/14 in TP concentrations for the different assessment areas and main rivers.

5.1.6.2 Silicate

Silicate concentrations were below 5 µM during winter in offshore waters and increased towards estuaries to more than 100 µM (Tab. A 47). There were no silicate data for the Weser. Annual mean winter DIN/ Si ratios ranged mostly between 1 and 2 (M/M) (Tab. A 48). Winter phosphate/silicate ratios increased from the estuaries (<0.05 M/M) to inner coastal waters (about 0.08 M/M) to offshore waters (>0.1), reflecting mixing between silicate rich freshwater and relatively silicate poor marine waters throughout the years (Tab. A 49).

5.2 Parameter-related assessments

5.2.1 Degree of nutrient enrichment

Nutrient concentrations and accordingly nutrient loads of the main rivers (Tab. 13, A 26, A27, A 45, A 46) surpassed the assessment levels significantly, e.g. the Elbe by 72 % for TN and 247 % for TP. Long-time trends of TN and TP showed decreasing tendencies, which, however, stagnated since about 2000 (Fig. 21-28).

DIN and DIP concentrations varied in offshore areas around the assessment levels during winter and surpassed within the outer coastal waters (OCNF and OCEF) the assessment levels during some years (Tab. A 26 & 27). In the inner coastal waters (ICEF) and the inshore North Frisian water (NF 12), the DIN concentrations remained below the assessment level during some years, but surpassed it in the other inshore waters by 50 % and in the estuaries by 80 – 170 % every year. DIP concentrations met the assessment levels offshore and mostly within the outer coastal waters, but surpassed them mostly every year within the inner coastal and inshore waters and within the estuaries (up to 400 % within the Ems) (Tab. A 27).

Nutrient ratios of DIN/DIP [M/M] were assessed in relation to Redfield ratios of 16. This ratio was surpassed in the OCEF and increasingly towards the coasts in inner coastal waters and adjacent assessment areas (Tab. A 28), due to elevated riverine nitrogen discharges, reaching extreme ratios > 100 within the estuaries.

5.2.2 Direct effects

Chlorophyll-a means, 90th percentiles, and maxima (Tab. A 29-31) remained below assessment levels in offshore waters and during most years also in the outer coastal waters and the ICEF. They mostly surpassed the levels in ICNF and in inshore waters they surpassed the levels during every year. Within the estuaries recent annual means remained mostly below assessment levels, indicating light limitation. The 90th percentiles in offshore waters and in the outer coastal waters were below assessment levels. They surpassed assessment levels in the inner North Frisian coastal water and all inshore waters (NF12, EF12, EW34, EF34) frequently and in the Elbe estuary only during some years. Chlorophyll-a maxima surpassed the regional assessment levels frequently within the inner North Frisian coastal water (ICNF), the North Frisian inshore water (NF12) and in the Elbe/Weser (EW 34) inshore waters during some years significantly, indicating insufficient sampling in relation to the occurrence of blooms. Mean chlorophyll-a concentrations were during some years higher than the assessment levels within the outer coastal waters, but inter-annual means surpassed these values not significantly (Tab. A 29). In the NF inner coastal waters, assessment levels were surpassed more frequently, and permanently (up to 80%) within the inshore waters (NF12, EF12, EW34, EF34). Within the estuaries light limitation dominated, preventing phytoplankton production in spite of high nutrient levels.

Numbers of Phaeocystis cells did not surpass the threshold of 10^6 cells/L in offshore waters, but in the outer East Frisian coastal water in 2013, the inner North Frisian coastal water since 2012 and frequently in inshore waters (Tab.A 32, Fig. 50). However, other phytoplankton indicator species like *Dinophysis* spec., *Prorocentrum* spec. and *Pseudo-nitzschia* spec. surpassed species-specific thresholds in offshore waters significantly (Tab. A 32-35 see Fig. 51-53). Time series at Norderney reflected during several years surpassing of thresholds (Tab. 10) by phytoplankton indicator species, such as Noctiluca during 2009, Phaeocystis and Dinophysis during 2007 and 2008, etc. (see Fig. 54). At Helgoland (ICEF) Phaeocystis cell numbers surpassed thresholds during a couple of years as well (ICEF).

Due to short-time blooms and different frequencies of phytoplankton sampling, data are representative only at frequently sampled stations at Helgoland and Norderney, whereas most data from coastal and offshore waters, which were sampled less frequent, represent only snapshots. For this reason, besides means also maxima of phytoplankton indicator species should be considered, corresponding to the reporting of chlorophyll-a maxima.

Due to the dominating soft-bottom character of the substrate in the German Bight (except Helgoland and wind parks with natural or artificial hard substrate), mostly seagrasses (*Zostera noltiii* mainly) and green algae are relevant for an eutrophication assessment. Abundance of green algae and seagrasses are affected by eutrophication processes oppositely and are used as indicators for eutrophication (Nielsen et al. 2002 a,b). An increase of green algae due to increased nutrients and a decrease of seagrasses by light limitation have been observed since the 1970s (Reise 2006). The growth of different species of green algae, mostly *Enteromorpha* spec., is accelerated by high nutrient concentrations (van Beusekom et al. 2005, Reise 2006), lead to increased turbidity, causing in turn a light limitation of seagrasses (such as *Zostera marina* or *Zostera noltii*) and correspondingly, a reduction in the extension of seagrasses with increasing depths. Beside eutrophication effects also other factors affect the extension of seagrass beds, like grazing or enhanced hydrodynamics in front of embankments (Dolch et al. 2010). Especially intertidal seagrass beds are affected by hydrodynamics, reducing density, extensions and shoot lengths at exposed sites (Schanz & Asmus 2003). At the beginning of the 20th century *Zostera marina* was still observed in shallow sublitoral areas, but was decimated by the fungus *Labyrinthula zosterae* during the 1930th and did not recovered since then, probably caused by changed hydrodynamics, increased turbidity and eutrophication.

The extension and density of macrophyte distributions along the German Wadden Sea coast was only estimated within the eulitoral (BLMP 2012), revealing significant increases of seagrass coverage in the northern Wadden Sea since the 1990s (Reise et al. 2015), In the Ditmarsher Wadden Sea, north of the Elbe estuary, seagrass coverage was reduced to about 10 %, with strong inter-annual fluctuations between 2007 and 2012 (Dolch et al. 2010, 2015). In the Wadden Sea of Lower Saxony, mostly within the sheltered Jade estuary, the extension of seagrasses between 2008 and 2013 has doubled (Brandt et al. 2014). However, regionally decreases were observed as well, leading to assessments according to the WFD between moderate and mostly bad, related to the percentages of coverage (Brandt et al. 2014, Dolch et al. 2015). Green algae coverage has decreased in 2014 to 0.2 %, which was the lowest monitored value in the Wadden Sea of Schleswig-Holstein (Reise et al. 2015). In Lower Saxony in contrast, the green algae coverage remained on a higher level between 5-12% as an annual maximum (data, NLWKN).

Generally there are no indications that seagrasses recently occur in the sublitoral (K. Reise pers.comm.). Nevertheless, detailed recent information on the sublitoral occurrence of seagrass does not exist. However, for the Wadden Sea along the coast of Schleswig-Holstein an increasing coverage by intertidal seagrass occurrence was observed (Reise et al. 2013), following decreasing tendencies during COMP 2 (2001-2005). Recent increases of eulitoral seagrasses were reported for the Wadden Sea at Lower Saxony as well (Brandt et al. 2013). A decrease of green algae, observed between 2001 and 2005 (from 91 km^2 down to 17 km^2) in the northern Wadden Sea, continued. However, in 2006 again 48 km^2 were covered, dominated by *Enteromorpha* and recently by *Chaetomorpha*, indicating ongoing eutrophication (Reise 2006, van Beusekom et al. 2005). Recently (2012-2015) again high green algae coverage has been reported for the southern Wadden Sea (data, NLWKN).

Secchi depth remained below calculated assessment levels within the inner offshore waters (OFFI) and more significantly within the near coastal waters (Tab. A 35). Within shallow inshore waters, where the Secchi depth is most relevant for the extension of macrophytes, the calculated assessment levels were about 2 m but recent Secchi depth was often below 1m. Considering a tidal amplitude of 2- 3 m, a significant area of inner coastal waters will be affected by light limitation. Whether this affects the extension of seagrass beds cannot be judged since the recent monitoring of seagrasses is limited to eulitoral areas that receive sufficient light during low tides. The assessment of Secchi depth also needs to be viewed critically, since assessment levels that were derived based on the new assessment levels for TN where in shallow areas always below the water depths, which indicates sufficient light until the ground.

5.2.3 Indirect effects

5.2.3.1 Oxygen deficiency

Mean annual oxygen depletion reached in offshore areas 1-2 mg/L, corresponding to a mean saturation of < 80 % (Tab. A 38 & 40). Since these means are based on low monitoring frequencies with mostly less than 5 measurements/y within the OFFO area and less than 20 measurements/y in the OFFI area, these data are not representative for oxygen depletion events, controlled by the variable stratification. For this reason, values for minimum saturation and maximum depletion have been calculated, indicating oxygen problems in bottom waters more realistically (see Fig. 59 & 60). These values indicated saturation values < 70 % offshore during many years and during some years even in outer coastal waters. Local hot spots of oxygen depletion were identified in the inner offshore water, the outer North Frisian coastal water, in the Jade bight and estuaries (Fig. 62).

5.2.3.2 Macrozoobenthos

There were no direct indications that macrozoobenthos was affected by oxygen depletion. However, despite of bottom trawling and dredging biomass was generally increased in relation to assessment levels (Tab. A 42). This increase indicates eutrophication effects since the biomass of macrozoobenthos is significantly correlated with chlorophyll-a (see Fig. 19). Pearson & Rosenberg (1978) described the changes of macrozoobenthos biomass, abundance and species numbers in relation to increasing concentrations of organic matter. At low organic loads (natural background conditions) biomass is moderate, abundance low and species numbers are relatively high. With increasing loads of organic matter, biomass will reach maximum concentrations as well as species numbers. This is the so called "transition stage" (Pearson & Rosenberg 1978). With further increasing organic loads the abundance will further increase and will reach a maximum (peak of opportunists). In parallel, species numbers decrease and biomass will form a secondary maximum. An increase of biomass and density of macrozoobenthos organisms has been reported by Kröncke (1995) and Thatje & Gerdes (1997) as well, particularly for small short-lived species such as polychaetes, bivalves, ophiuroids and echinoids and was related to eutrophication (cited by Boos & Franke 2006). Sizes of macrozoobenthos organisms decrease due to hypoxia (Diaz & Rosenberg 1995, Conley et al. 2009). The sizes of macrozoobenthos organisms, simply calculated from total biomass (AFDW) and number of species, has increased in the German Bight area since 1983 (Fig. 66), reflecting effects of decreasing eutrophication by decreasing nutrient discharges and reduced biomass production. Small animals according to mean weights of individuals (mg/m2 AFDW/n) were observed in areas with oxygen minima in the OCNF and near the EW 34.

The significant correlation between the biomass of macrozoobenthos and chlorophyll-a (see Fig. 19) indicates the transient stage as well, reflected by the increased biomass concentrations along the coasts (see Fig. 65), where high concentrations of organic matter were detected in the upper mixed layer (see Fig. 68). Correspondingly, the recent biomass data surpass the calculated assessment levels within all subareas during every sampled year, with the exception of the estuaries (Tab. A 45).

Since many reasons for changes of macrozoobenthos communities are discussed, such as climate change, fishery, alien species, pollutants and nutrients (Franke & Gutow 2004, Reichert & Buchholz 2006), it is difficult to relate zoobenthos-changes exclusively to eutrophication. Even near coastal stations were affected by local climate variation such as ice coverage (Kröncke & Reiss 2010). However, the distribution of macrozoobenthos biomass (Fig. 64) reflected to some degree the German Bight topography (Fig. 2), with reduced oxygen values in deep areas (Fig. 61 & 62), like the ancient Elbe valley and OFFI/OFFO area.

High macrozoobenthos abundances off the coast of Schleswig-Holstein could be interpreted as a transitional stage, dominated by opportunistic species (Pearson & Rosenberg 1978). Therefore most parts of the GEEZ are characterised as "transition zone", characterised by high macrozoobenthos biomasses. This interpretation is supported by recent gradients of organic matter (see Fig. 67 & 68) and the sediment composition (Kröncke et al. 2004). Furthermore, at a station in the German Bight, benthic communities were correlated with the chlorophyll content in the sediment, indicating utilisation of fresh material (Kröncke et al. 2004). However, it has been shown that seasonal changes of abundance and biomass were especially high in the central German Bight in comparison to offshore stations (Reiss & Kröncke 2004). Especially cold winters can affect the benthos community (Schroeder 2003, Reiss et al. 2006). For these reasons, the above assessment, based on "mean" annual biomass concentrations should additionally be confirmed by seasonal investigations.

5.2.3.3 Organic matter

Elevated discharges of organic matter (Tab. 17, 18, 44) mostly surpassed the assessment levels (Tab. 9), contributing significantly to the concentrations of organic carbon in the estuaries and in the German Bight. Recent measured TOC concentrations surpassed in inner coastal waters and inshore waters the assessment levels by 53- >600 % (Tab. A 44), mostly increasing towards the inshore waters. TOC, or organic nitrogen (TN-DIN) is an important parameter linked to oxygen depletion

(Topcu and Brockmann 2015). Calculated TOC values surpassed the assessment levels also offshore and in the outer coastal waters. The particulate material was trapped in the Wadden Sea and bottom water of stratified areas. There it contributed to oxidative degradation processes, causing oxygen depletion. The few recent measurements of POC in the open GEEZ surpassed the assessment levels of 200 µM significantly (Tab. A 44), as did the more frequent measurements towards the coastal subareas. TOC, and the correlated organic nitrogen (see Fig. 20) and its elevated gradients (see Fig. 68) indicated as integrating parameters the eutrophication status of GEEZ areas as Problem Areas. They are also linked to oxygen depletion (Topcu and Brockmann 2015).

5.2.4 Other possible effects

Other possible effects like algal toxins and mussel infection events have not been reported to be significant.

5.2.5 Compiled parameter assessment

The assessment results per parameter for each assessment year and each of the assessment areas are shown in Tab. 20, resulting in an initial assessment.

Tab. 20 Compilation of annual scores for the parameter-related assessments 2006-2014 per assessment area. "+" indicates that the parameter exceeds the respective assessment levels or that there are increased trends, shifts or changes (for parameters that decrease with increasing eutrophication the parameter is lower than the assessment level), "-" indicates that the parameter satisfies the respective assessment level and that there are no increasing trends, shifts or changes; "?" indicates that there are insufficient data to make an assessment or that the data are not fit for the purpose or that only means could be calculated. Parameters are assessed annually, resulting in 9 scores per parameter for the period 2006-2014. The final assessment is indicated by the colour (green = in good status, red = not in good status, yellow = assessment is uncertain) and is determined by which score dominates for the 9 assessment years (example: 5 times "+" and 4 times "-" = "+"). For the assessment areas that are also assessed under the WFD (EF34, EW34, EF12, NF12) assessment results for biological quality elements macrophytes and macrozoobenthos are provided for the time period 2009-2013/14 and there is only one assessment result for the whole period. This assessment result was obtained by scrutinising the assessment results for the single water bodies and by then taking the assessment result that dominated. A quantitative approach could not be applied since only WFD assessment results but no WFD data were available for the biological quality elements.

Cat.	Parameter	Rivers	Est.	EF 34	EW 34	EF 12	NF 12	ICEF	ICNF	OCEF	OCNF	OFFI	OFFO
I	TN,TP inputs	+++++ ++++											
	DIN w	nr	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	----+ ++++	++--+ +++-	+++++ ++++	++--- --++	++--- ----	----- ----	----- ----
	DIP w	nr	----- ---?	-+++- ++++	+++++ ++++	+++++ ++++	----- ---+	-++-+ -++-	+++++ ++++	----- ----	-+-+- ----	+---- ----	----- ----
	DIN/ DIP w	nr	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	-+--+ ++++	++-++ ++++	+++++ ++++	++-++ +-++	+++-- ----	----- ----	----- ----
II	Chl a, means gs	nr	nr	---++ -+++	+++++ ++++	+++++ ++++	+++++ ++++	?-+?+ --++	+++++ -+++	+-++- ---+	?-+?+ -?++	---+- ----	?--?- -?--
	Chl a, 90th gs	nr	nr	?++++ +-++	+++++ ++++	-++++ ++++	?++++ ++++	?--?+ --+-	+++++ ++++	+---- ----	?--?- -?--	?--?- -?--	?--?- -?--
	Phaeocystis	nr		?++-+ --+?	+++-+ --+?	----- -++-	-+--- -+++	??+?- ????	----- -+++	----- --+--	??-?- ????	??-?- ????	??-?- ????
	Dinophystis	nr		?+++- ---?	--+-- +---	-+-+- ---?	----- ----	??--- -???	+++++ ---+	??-++ -???	??++- -???	??++- +???	??-+- -???
	Prorocentrum	nr		?---- ---?	----- ----	---- ---?	--+-- ----	??--- -???	--+-- ----	??--+ -???	??+-- -???	??--+ -???	??--- -???
	Pseudo-nitzschia	nr		?-+-- ---?	----- ----	--+-- ---?	----- ----	??--- -???	----- ----	??--- -???	??-+- -???	??--- -???	??--- -???
	Secchi Depth gs	nr						+++++ ++++	+++++ ++++	+++++ ++++	?++++ ++++	-++++ ++-+	?---+ -?+-
	Macrophytes	nr		+	+	+	-						
III	O_2mean <6mg/L gs	nr	????- ---?	????? ----	+---- ----	+---- ----	---?- ----	----- ----	----- ----	----- ----	----- ----	----- ----	----- ----
	O_2 mean <85 % gs	nr	????+ +--?	????? ----	+---- ----	+--?- ----	---?- ----	----- ----	----- ----	----- ----	+---- --+-	----+ --++	---++ ++--
	O_2min. <6mg/L gs	nr	????+ +--?	????? ---+	-+-+- ---+	+--+- ---+	+--?- ----	----+ --+-	++-++ ---+	--+-- ----	+---- -----	+-+-+ +-++	---+- ----
	MZB gs	nr	-	+	+	-	+	??+++ ????	+++++ +++?	??++- ????	??+++ ????	??++- ????	??-+- ????
	TOC gs	+++++ ++++	+++++ +???	????? ++?+	+?+++ ++?+	+++++ ++++	????? ????	????? ?+?+	????? ?+?+	????? ????	????? ????	????? ????	????? ????
IV	Toxins	nr	----- ----	----- ----	----- ----	----- ----	----- ----	nr	nr				
V	TN as	+++++ ++++	+++++ +++?	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++-+ -+++	+-+-+ +++-
	TP as	+++++ ++++	+++++ ---?	+++++ ++++	+++++ ++++	+++++ +++	+++++ ++++	+++++ ++++	+++++ ++++	+++-- ++++	++++- ++-+	+++++ ++++	--++- -++-

nr = not relevant, MP= Macrophytes, MZB = Macrozoobenthos, V, SU = supplementary, as = all seasons, gs = growing season, w = winter

Nutrient discharges surpassed the assessment levels significantly, affecting estuaries, inshore and inner coastal waters. Nutrient concentrations remained within the outer coastal waters and offshore waters below assessment levels, DIP also within NF 12 and the estuaries. The direct effect parameters chlorophyll-a and Secchi depth were above assessment levels within inshore waters and the North Frisian inner coastal water (ICNF). Low chlorophyll-a concentrations in estuaries indicated light limitation. The phytoplankton indicator species *Phaeocystis* spec. and *Dinophysis* spec. surpassed thresholds in inshore waters and in the inner North Frisian coastal waters (Tab. 19). Cell numbers of *Prorocentrum* spec. and *Pseudo-nitzschia* spec. remained below thresholds. Especially in outer coastal and offshore waters sampling was not sufficient. However, the variability of cell numbers was very high (Tab. 19). The indirect effect parameters macrozoobenthos and organic carbon surpassed assessment levels in inshore waters. The recent increase of small macrozoobenthos species and distribution in relation to seasonally oxygen-limited areas indicates direct eutrophication effects. Organic carbon, calculated from organic nitrogen, was in all areas above assessment levels.

Effect parameters remained below assessment levels in the inner East Frisian coastal water (ICEF), outer coastal and offshore waters. An exception was OFFI with minimum oxygen values < 6 mg/L during 6 years, indicating extended oxygen depletion because of insufficient monitoring and variable thermal stratification. However, data for macrozoobenthos and organic matter were not available for OFFI.

Assessments showed for DIN and DIN/DIP ratios in the offshore areas good conditions (NPA) as well as for the chlorophyll-a means, 90th percentiles and maxima but sampling effort was limited (Fig. 75-77). DIP was not assessed because new assessment levels could not be derived for this parameter (KoRa 2015b, Gadegast & Venohr 2015).

Phytoplankton indicator species had mostly been sufficiently sampled in inshore waters, indicating mostly NPAs. There were no problems with mean oxygen concentrations, due to repeated erosion of thermoclines within the shallow area and probably also due to insufficient sampling. Oxygen minima and oxygen minimum saturation revealed problems offshore (OFFI) and in coastal waters (ICNF) connected with most shallow inner coastal waters, indicating imports of oxygen depleted estuarine waters. Regional assessments of MZB and TOC were restricted by data. In most assessment areas where sufficient data were sampled, problems were indicated by elevated TOC concentrations or MZB biomass reflecting a transitional eutrophication stage (Pearson & Rosenberg 1978). TN concentrations exceeded assessment levels offshore and in outer coastal waters by less than 10 %, which was below the regional variability, and were for this reason not a significant problem (Tab. A 45). Towards the coasts deviations approached to more than 100 %, surpassing data variability.

5.3 Consideration of supporting environmental factors

5.3.1 Data quality (SD, confidence)

Quality of data has been considered throughout the data presentations (§ 5.1) and is summarised in Tab. 21. Generally, monitoring was mostly sufficient in coastal areas with eutrophication problems, but reduced in offshore waters. Trends between 2006 and 2014 were generally not significant.

Tab. 21 Compilation of data coverage (n) and inter-annual variability (standard deviation %) for the parameter-related assessments 2006-2014. Macrophytes are not included since they were not assessed beyond 1 nautical mile and within 1 nautical mile the assessment was based on the WFD results.

Cat.	Param.		Rivers	Est.	EW 34	EF 34	NF 12	EF 12	ICNF	ICEF	OCNF	OCEF	OFFI	OFFO
	DIN	n SD%	1	1 1	1 1	1 1	1 2#	1 1	1 1	1 1#	1 2#	1 1#	1 1	2 1#
	DIP	n SD%	1	1 1	1 1	1 1#	1 1	1 1	1 1	1 1#	1 1#	1 1#	1 1	2 1
	DIN/ DIP	n SD%	1	1 2	1 2	1 1	1 2	1 1	1 2	1 2	1 1	1 2	1 2	2 1
II	Chl a, means	n SD%	nr	nr	1 1	1 1#	1 1	1 1	1 1	1 1#	3 1#	1 1#	2 2#	2 2#
	Phaeocystis	n SD%	nr	nr	1 3	1 3	1 3#	1 3#	1 3	?	?	1 2	?	?
	Dinophysis	n SD%	nr	?	1 3#	1 3#	1 1	1 3#	1 1	?	?	?	?	?
	Prorocentrum	n SD%	nr	?	1 3#	1 3	1 3#	1 3	1 3	?	?	?	?	?
	Pseudonitzschia	n SD%	nr	?	1 3#	1 3#	1 3#	1 3#	1 3#	?	?	?	?	?
	Secchi depth	n SD%	nr	?	1 1	1 1	1 1	1 1	1 1#	1 1#	2 nr 1	1 nr 1#	2 nr 1#	2 nr 1#
III	O_2 conc.	n SD%	nr	?	1 1	1 1	1 1	1 1	1 1	1 1	3 1	2 1	2 1	1 1
	MZB	n SD%	nr		WFD As.	WFD As.	WFD As.	WFD As.	1 3#	?	?	?	?	?
	TOC	n SD%	1 1	1 1	1 1	?	?	1 1	?	?	?	?	?	?

Scores for n: 1 = > 2 samples/square, 2 = 1-2 samples/square, 3 = < 1sample/square 2006-2014
Scores for SD: standard deviation of inter-annual means [%]: 1 = < 50%, 2 = 50-100%, 3 =>100%
# indicates overlapping of standard deviation (%) and mean deviation from assessment level (%)
? = insufficient data
Yellow indicates missing data (scores >3 for n and >2# for SD). These scores are considered within the final assessment.

In addition to completely missing data, low data coverage and variability was considered, especially in cases where the variability of the assessment value overlaps with the assessment level. Variability was highest in near coastal waters due to tidal actions, controlling mixing gradients and stratification. The standard deviation of single annual square means was often higher than those of inter-annual means. The meaning of low variability of single square means, even standardised as %, is limited because it is dependent on the range of values which is e.g. for oxygen concentrations limited to below 30% due to the concentration ranges between 0 and 8 mg/L but which can pass >500 % for cell numbers. The high variability of oxygen depletion inshore and in ICNF was not considered, due to the shallow character of these areas, preventing thermal stratification. Areas which were initially assessed as problem areas but where the inter-annual means were close to the assessment levels (<21% deviation) and considering the inter-annual variability the assessment levels could have been met were classified as non-problem areas. This was, however, rarely the case and where it did occur, e.g. for chlorophyll-a means, the 90th percentiles confirmed the assessment as a non-problem area.

The number of sampling (n) was related to the number of squares/area (1 square = 716.5 km^2) but the distribution of samples within the squares was no considered. Additionally, the numbers were summed up for the whole period. Score 1 for n means that between 2006 and 2014 at least 1 sample/716.5 km^2 has been taken somewhere within the subarea. For this reason the rough differentiation reflects for the scores 2 and 3 significant insufficient sampling rates.

The results of the final assessment, considering data coverage and variability, are shown in Tab.22.

Tab. 22 Final parameter-related assessment 2006-2014 based on Tab.20 but considering in addition data coverage and variability as outlined in Tab.20. For further explanations see Tab.20.

Cat.	Parameters	Rivers	Est.	EF 34	EW 34	EF 12	NF 12	ICEF	ICNF	OCEF	OCNF	OFFI	OFFO
I	TN,TP inputs	+++++ ++++											
	DIN w	nr	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	----+ ++++	++--+ +++-	+++++ ++++	++--- --++	++--- ----	----- ----	----- ----
	DIP w	nr	----- ---?	-+++- ++++	+++++ ++++	+++++ ++++	----- ---+	-++-+ -++-	+++++ ++++	----- ----	-+-+- ----	+---- ----	----- ----
	DIN/ DIP w	nr	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	-+--+ ++++	++-++ ++++	+++++ ++++	++-++ +-++	+++-- ----	----- ----	----- ----
II	Chl a, means gs	nr	nr	---++ -+++	+++++ ++++	+++++ ++++	+++++ ++++	?-+?+ --++	+++++ -+++	+-++- ---+	?-+?+ -?++	---+- ----	?--?- -?--
	Chl a, 90th gs	nr	nr	?++++ +-++	+++++ ++++	-++++ ++++	?++++ ++++	?--?+ --+-	+++++ ++++	+---- ----	?--?- -?--	?--?- -?--	?--?- -?--
	Phaeocystis	nr	-	?++-+ --+?	+++-+ --+?	----- -++-	-+--- -+++	??+?- ????	----- -+++	----- --+--	??-?- ????	??-?- ????	??-?- ????
	Dinophysis	nr	-	?+++- ---?	--+-- +---	-+-+- ---?	----- ----	??--- -???	+++++ ---+	??-++ -???	??++- -???	??++- +???	??-+- -???
	Prorocentrum	nr	-	?---- ---?	----- ----	---- ---?	--+-- ----	??--- -???	--+-- ----	??--+ -???	??+-- -???	??--+ -???	??--- -???
	Pseudo-nitzschia	nr	-	?-+-- ---?	----- ----	--+-- ---?	----- ----	??--- -???	----- ----	??--- -???	??-+- -???	??--- -???	??--- -???
	Secchi depth gs	nr						+++++ ++++	+++++ ++++	+++++ ++++	?++++ ++++	-++++ ++-+	?---+ -?+-
	Macrophytes	nr		+	+	+	-						
III	O_2mean <6mg/L gs	nr	????- ---?	????? ----	+---- ----	+---- ----	---?- ----	----- ----	----- ----	----- ----	----- ----	----- ----	----- ----
	O_2 mean <85 % gs	nr	????+ +--?	????? ----	+---- ----	+--?- ----	---?- ----	----- ----	----- ----	----- ----	+---- --+-	----+ --++	---++ ++--
	O_2min. <6mg/L gs	nr	????+ +--?	????? ---+	-+-+- ---+	+--+- ---+	+--?- ----	----+ --+-	++-++ ---+	--+-- ----	+---- -----	+-+-+ +-++	---+- ----
	MZB gs	nr		+	+	-	+	??+++ ????	+++++ +++?	??++- ????	??+++ ????	??++- ????	??-+- ????
	TOC gs	+++++ ++++	+++++ +???	????? ++?+	+?+++ ++?+	+++++ ++++	????? ????	????? ?+?+	????? ?+?+	????? ????	????? ????	????? ????	????? ????
IV	Toxins	nr	----- ----	----- ----	----- ----	----- ----	----- ----	nr	nr				
V	TN as	+++++ ++++	+++++ +++?	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++++ ++++	+++-+ -+++	+-+-+ +++-
	TP as	+++++ ++++	+++++ ---?	+++++ ++++	+++++ ++++	+++++ +++	+++++ ++++	+++++ ++++	+++++ ++++	+++-- ++++	++++- ++-+	+++++ ++++	--++- -++-

Complete confidence rating, performed as an example for chlorophyll-a in a separate study (Brockmann & Topcu 2014), resulted in a confidence of 74.27 % for area coverage between 2006 and 2014, assessing N-S profiles. Consistency of monthly sampling between 2006 and 2014 was within the WFD areas NF 12, EF 12, EW 34 and EF 34 complete = 100 % (means that in each month of the assessed season there was sampling), dropped in the inner coastal waters ICNF and ICEF to 79 and 49 % respectively, in the outer East Frisian coastal water (OCEF) to 65 % and within the outer North Frisian coastal water (OCNF) and in offshore areas OFFO and OFFI to less than 10 %. These results were not considered in table 20 where annual data within the corresponding seasons were considered.

5.3.2 Environmental factors

The different environmental factors like salinity, hydrodynamics and gradients of SPM are mainly considered within the typology, differentiating between estuaries, inshore, coastal and offshore waters. Considering the direction of the residual current and observed gradients of nutrients, organic matter and chlorophyll-a, it is evident that high biomass concentrations and associated nutrients will be transported through the German Bight and (ii) huge amounts of phytoplankton/organic matter will reach the German Bight from offshore, mostly as import from Dutch coastal and offshore waters, as indicated by budget calculations (§ 5.1.1.2). A part of this particulate material will be trapped within the Wadden Sea and the estuaries, increasing the local eutrophication effects (van Beusekom 2005 a,b) and another part will contribute to oxygen depletion in outer coastal and offshore waters (§ 5.1.3.1) .

Salinity gradients increased from the estuaries (<1) towards offshore areas (>34.5) consistently during all seasons indicating the dominant control of mixing. The gradients off the coast of Lower Saxony were steeper than at the shallower coast of Schleswig-Holstein. Variability was mainly below 5%, but increased toward estuaries to more than 30%. During winter the outer salinity gradients were steeper, due to the blocking of river plumes by westerly wind forcing. During growing season the opposite is the case, due to increased freshwater discharges. The seasonal variability remained similar. Salinity-related nutrient concentrations were presented within mixing diagrams, allowing an overview of recent data within the whole area and their relation to assessment levels (see Fig. 44).

Vertical temperature gradients control the exchanges between the mixed surface and bottom layer. In seasonally stratified areas oxygen depletion will occur. Vertical density gradients by spreading river plumes are less stable, due to the shallow near coastal waters.

Due to high concentrations of suspended matter within the estuaries phytoplankton will be light limited and cannot be assessed for eutrophication. The light limitation is to a large degree caused by elevated concentrations of suspended matter (SPM). In open waters, concentrations were around 10 mg/L and surpassed 100 mg/L in the shallow Wadden Sea and in the estuaries of the rivers Elbe and Ems. Van Beusekom (pers.comm.) found strong (10 – 50 mg/L) seasonal changes of SPM, with less than 20 mg/L during summer in the North Frisian Wadden Sea (pers. comm.). Secchi-depth data, estimated during growing season, decreased from the central North Sea (> 10 m) towards the shallow German coast dropping below 2 m. This distribution generally corresponded to those of suspended matter.

Secchi depth has increased at Helgoland during the last 37 years by about 1-2 m (Wiltshire & Manly 2004), but decreased in inner coastal waters from about 4 m during 1980 to 1 m (Fig. 55). Mean Secchi depth during summer was 12 m offshore, decreasing in coastal waters to < 3 m and towards the Wadden Sea and estuaries to less than 1 m. This gradient is caused by increasing resuspension in shallower areas. Windparks affect vertical mixing and will support the growth of hard-bottom macrozoobenthos species.

5.4 Overall assessment

For the overall assessment the results of the initial and final classification have been combined for direct comparability (Tab. 23).

Tab. 23 Initial and final classification considering all elements. As an aggregation rule “one-out-all-out” between the categories II-III of effect-parameters is used for the initial classification. Categories I, II and/or III/IV are scored ‘+’ in cases where one or more of its respective assessment parameters is showing elevated levels during more than five years. The parameters causing an assessment as PA are indicated in the column “overall appraisal”.

Area	**Category I** Degree of nutrient enrichment		**Category II** Direct effects		**Category III and IV** Indirect effects/ other possible effects				**Initial classification**	Overall appraisal of all relevant information, confidence	**Final classification**
Estuaries	NI	+	Ca	nr	O_2	?	At		Problem area, 2006-2014	OC	PA
	DI	+	Ps	nr	Ck	+					
	NP	+	Mp	?	Oc	+					
EW 34	NI		Ca	+	O_2	-	At	-	Problem area, 2006-2014	Ca, Ps	PA
	DI	+	Ps	+	Ck	+					
	NP	+	Mp	+	Oc	+					
EF 34	NI		Ca	+	O_2	?	At	-	Problem area, 2006-2014	Ca Ps,O_2	PA
	DI	+	Ps	+	Ck	+					
	NP	+	Mp	+	Oc	?					
NF 12	NI		Ca	+	O_2	-	At	-	Problem area, 2006-2014	Ca	PA
	DI	+	Ps	-	Ck	+					
	NP	+	Mp	-	Oc	?					
EF 12	NI		Ca	+	O_2	-	At	-	Problem area, 2006-2014	Ca Ps#,Oc	PA
	DI	+	Ps	-	Ck	-					
	NP	+	Mp	+	Oc	+					
ICNF	NI		Ca	+	O_2	+	At	-	Problem area, 2006-2014	Ca Ps? Ck#,O_2	PA
	DI	+	Ps	+	Ck	+					
	NP	+	Mp	nr	Oc	?					
ICEF	NI		Ca	+*	O_2	-	At	-	Non Problem area, 2006-2014	Ck? Oc?	PPA
	DI	+*	Ps	?	Ck	?					
	NP	+	Mp	nr	Oc	?					
OCNF	NI		Ca	-	O_2	-	At	nyr	Non Problem area, 2006-2014	Ck?,Oc?	PPA
	DI	-	Ps	?	Ck	?					
	NP	-	Mp	nr	Oc	?					
OCEF	NI		Ca	-	O_2	-	At	nyr	Non Problem area, 2006-2014	Ck? Oc?	PPA
	DI	-	Ps	?	Ck	?					
	NP	+	Mp	nr	Oc	?					
OFFI	NI		Ca	-	O_2	+	At	nyr	Potential Problem area, 2006-2014	O_2 min, Ck? Oc?	PA
	DI	-	Ps	?	Ck	?					
	NP	-	Mp	nr	Oc	?					
OFFO	NI		Ca	-	O_2	-	At	nyr	Non Problem area, 2006-2014	Ck? Oc?	NPA
	DI	-	Ps	?	Ck	?					
	NP	-	Mp	nr	Oc	?					

#: overlapping of variability with deviations between recent means and assessment level.
Parameters affecting the final assessment are underlined.

Key to the table

NI Riverine inputs, trans-boundary and atmospheric inputs and direct discharges of total N and total P

DI Winter DIN and/or DIP concentrations

NP Increased winter N/P ratio

Ca Maximum and mean chlorophyll *a* concentration

Ps Area-specific phytoplankton indicator species

Mp Macrophytes including macroalgae

O_2 Oxygen deficiency as defined by OSPAR

Ck Changes/kills in zoobenthos and fish kills

Oc Organic carbon/organic matter

At Algal toxins (DSP/PSP mussel infection events)

+ = Increased trends, elevated levels, shifts or changes in the respective assessment parameters

- = Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameters

? = Not enough data to perform an assessment or the data available is not fit for the purpose

nr = not relevant, nyr = not yet relevant
#: overlapping of the variability of the mean assessed value with the assessment level.
Parameters affecting the final assessment are underlined.

The initial classification according to OSPAR 2013-08, Tab. 3, considering for classification as Problem Areas effect parameters only and based on the compilation of summarised annual scores (Tab. 18) resulted in PA for estuaries, inshore waters and inner North Frisian coastal water (ICNF), due to elevated chlorophyll-a concentrations, phytoplankton indicator species, macrozoobenthos biomass and reduced light climate.

For the final classification, due to missing data of macrozoobenthos and organic matter (indicated within Tab.22, column “overall appraisal”), ICEF and outer coastal waters were classified as PPA. The inner offshore water OFFI was classified as PPA as well, due to oxygen minima > 6 mg/L during most of the assessed years, insufficient oxygen data and their high variability (Tab. 19).

The results of the final classification for COMP3 were comparable with COMP2.

Final assessment results of COMP3 per parameter are shown graphically in Fig. 75-77. DIN and N/P ratios showed a consistent assessment with an exceedance of assessment levels close to the shore and in inner coastal waters and good status in offshore waters (Fig 75). For DIP the pattern was less clear, with some estuaries being assessed as good status while coastal waters were not in good status. Chlorophyll-a and secchi depth also showed consistent assessment results and similar patterns as for the nutrients (Fig.76). For phytoplankton indicator species, MZB and TOC potential problem areas were dominating due to missing data (Fig. 76 & 77).

Oxygen depletion was most relevant in deeper areas, including the estuaries (Fig. 61 & 77). Oxygen depletion also occurred in the connecting inner North Frisian coastal water that are affected by local river discharges and are characterised by minimum oxygen saturation (Fig. 60) and maximum oxygen depletion (Fig. 62). Oxygen depletion within the deeper (ancient Elbe valley) open coastal waters is partly caused by organic matter accumulation originating from long-distance transports.

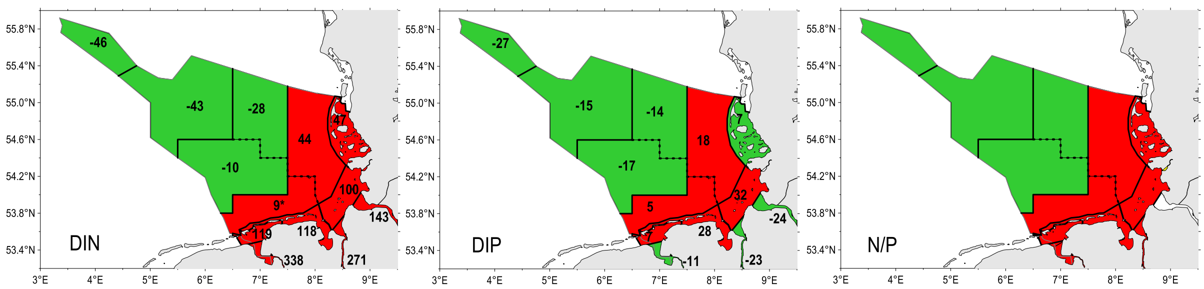

Fig. 75 Final assessments of nutrient enrichment (green = status good, red = status not good) with % deviations from the assessment levels per assessment area.

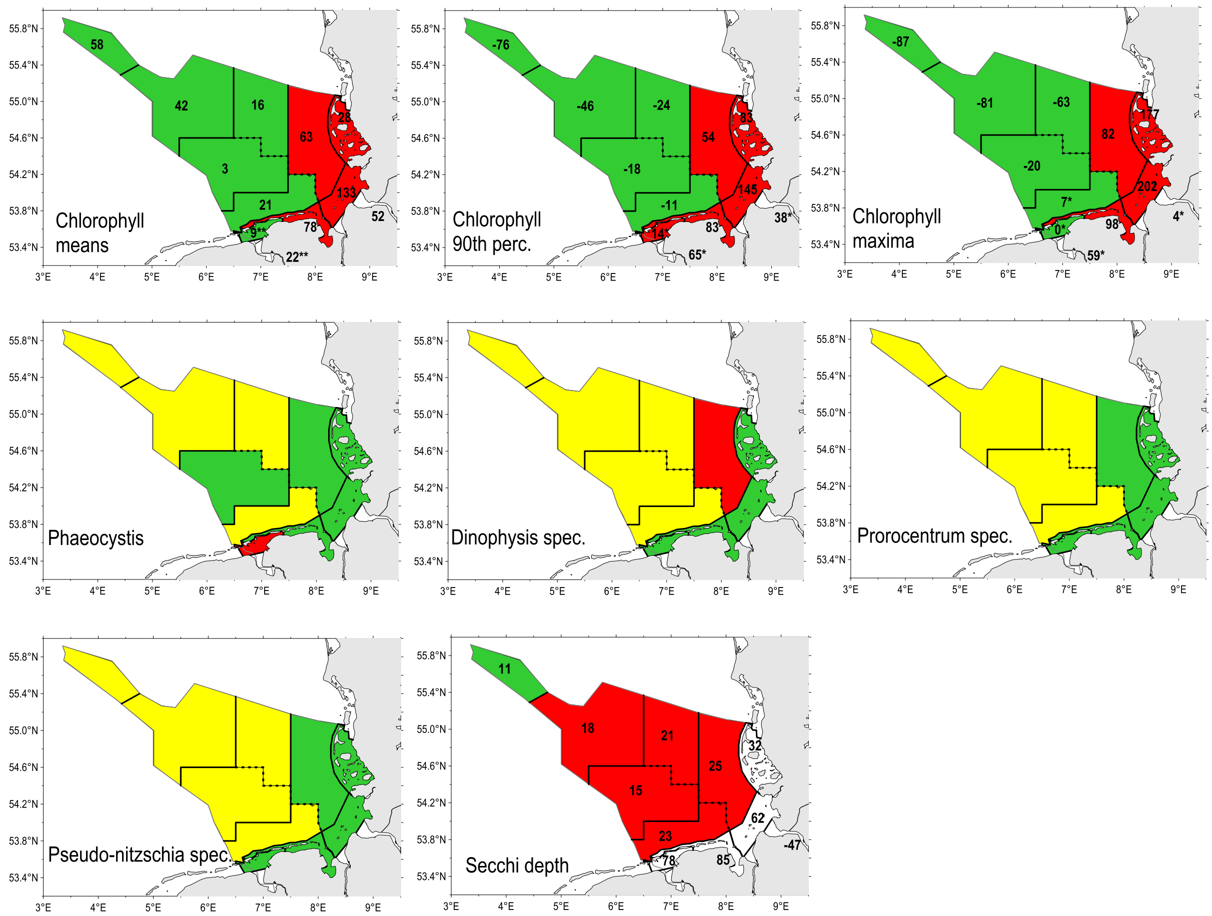

Fig. 76 Final assessments of the direct effect parameters chlorophyll-a, selected phytoplankton indicator species (green = status good, red = status not good, yellow = uncertain) and of secchi depth per assessment area. For secchi depth the % deviation from the assessment levels is shown.

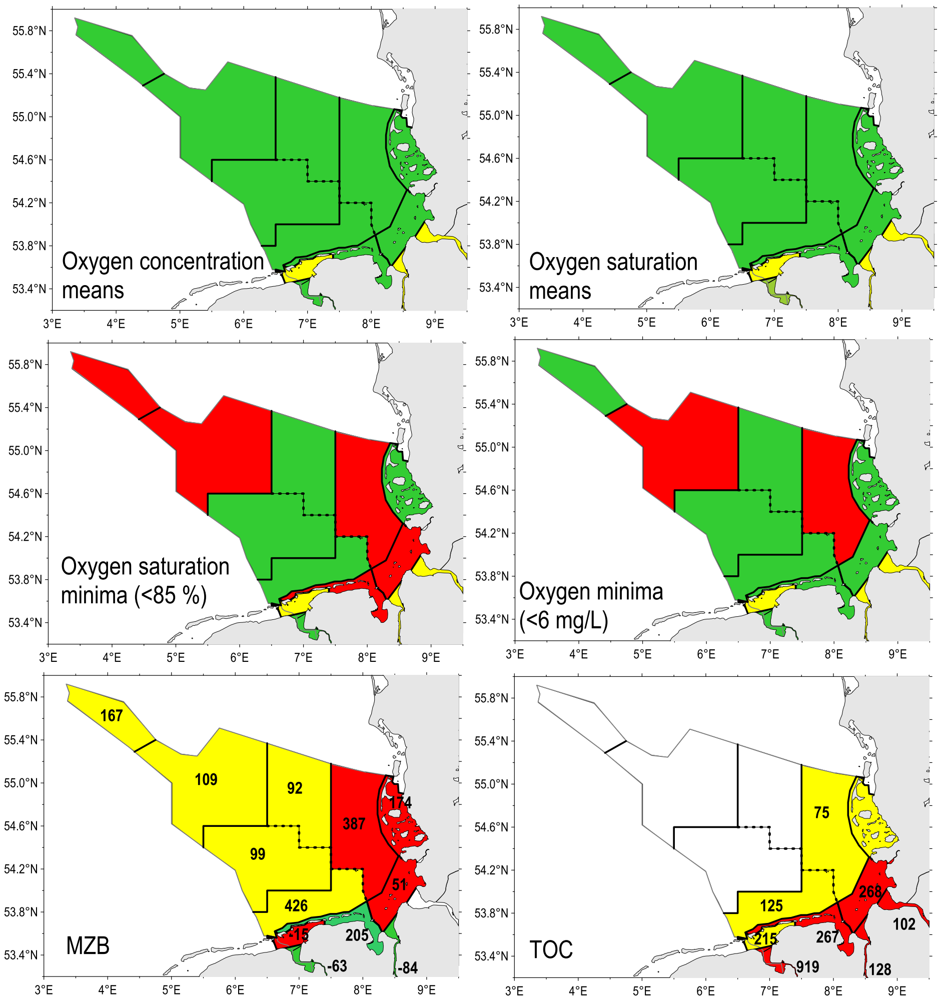

Fig. 77 Final assessments of indirect effect parameters (green = status good, red = status not good, yellow = uncertain, white = not assessed) with % deviations from the assessment levels per assessment area.

The initial and final classifications have been compiled as maps (Fig. 78 & 79). Large parts of the inner German Bight area were still classified as Problem Area.

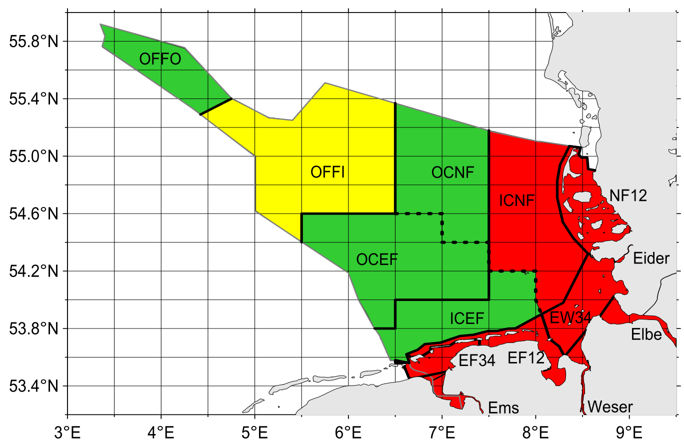

Fig. 78 COMP3 combined initial classification of the GEEZ 2006-2014.

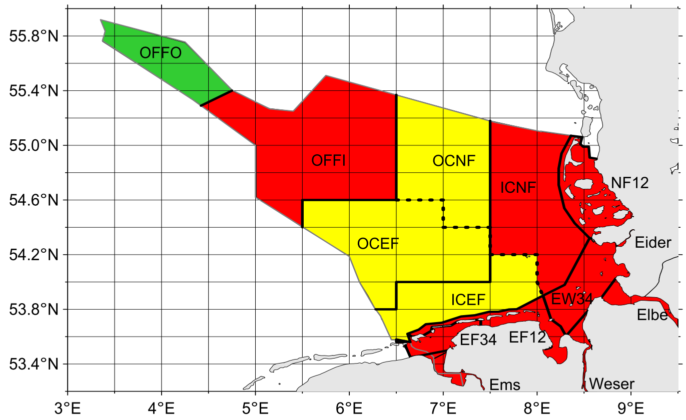

Fig. 79 COMP3 combined final classification of the GEEZ 2006-2014.

In inshore and inner coastal waters elevated chlorophyll-a concentrations and phytoplankton indicator species indicate eutrophication effects. Due to the high turbidity in lower estuaries, chlorophyll cannot be assessed there. By self-shadowing phytoplankton will not respond linearly to nutrient reductions in near coastal waters. The extension of macrophytes was restricted to intertidal areas. Absent sublitoral macrophytes keep turbulence and concentrations of suspended matter high by a feed-back mechanism, supported by hydrodynamics, affecting the extent of seagrass beds (Schanz & Asmus 2003). Biomasses of macrozoobenthos were increased in relation to assessment levels, but there were only restricted data in outer coastal and offshore waters. In spite of a lack of corresponding datasets, gradients of zoobenthos (see Fig. 64) showed partly lower values at locations of seasonally reduced oxygen concentrations (see Fig. 57). Changes of mean macrozoobenthos sizes indicated a longer lasting increase and recent decreases, probably linked to changing nutrient discharges. Generally, the zoobenthos status was defined as transient in relation to eutrophication. High levels of organic matter, which will contribute to oxygen consumption as well, indicate continuing eutrophication processes.

5.5 Comparison with the preceding eutrophication assessments according to COMP

Altogether the eutrophication status has not improved between COMP2 and COMP3 (Fig.80). The inner coastal waters EW34, EF34, NF12, EF12 remained Problem Areas with respect to eutrophication. OFFO changed from Potential Problem Area to Non-Problem Area but OFFI changed from Potential Problem Area to Problem Area and OCNF, OCEF and ICEF changed from Problem Area to Potential Problem Area.

Due to significant gradients within coastal waters, a higher differentiation of coastal areas was performed for COMP3 compared to COMP 2. There were no significant changes in relation to the second COMP (Fig. 80), probably caused by stagnating nutrient concentrations in recent years of the rivers (Fig. 30 & 31), including the Rhine and the Scheldt with their high loads of TP which were advected to the GEEZ as well (Tab. 13 & 14). The first COMP for the period 1985-1998 (Anonymous 2003, Brockmann et al. 2003, 2007) was mainly based on nutrients, local time series and occasional surveys of chlorophyll. During the COMP 2 period the monitoring had been improved but was for the 3rd COMP for key parameters like oxygen and organic carbon still not sufficient. Especially combined monitoring of interacting parameters was only seldom performed. This can be for instance a reason why no effects on the zoobenthos due to oxygen depletion were observed. For this reason maxima or minima should be considered in addition to the standard parameters, supplemented by TN and TP, combining nutrients and organic matter. Loads are dependent on changing freshwater discharges. New assessment levels for nutrients and some correlated parameters have been derived for COMP3 but, although they were for some parameters more relaxed, had no significant effect on the assessment results Tab.24).

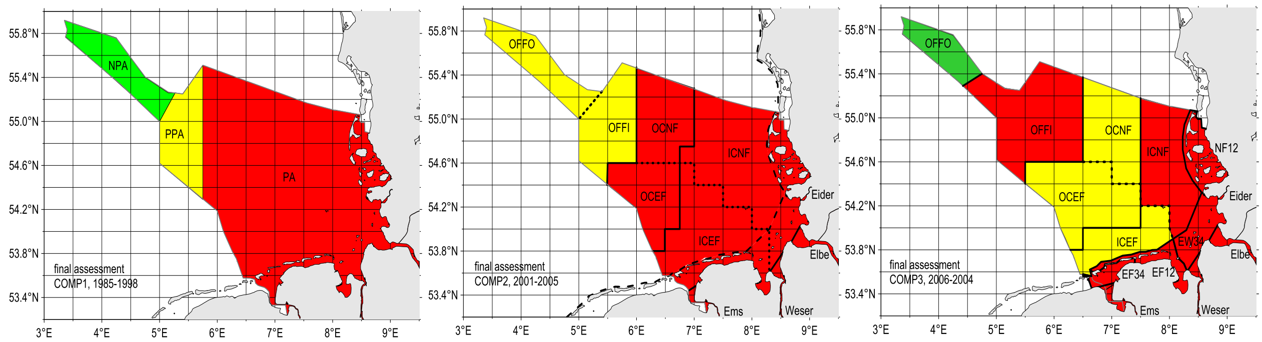

Fig. 80 Comparison of final classifications for COMP1 (1985-1998), COMP2 (2001-2005), and COMP3 (2006-2014).

Tab. 24 Comparison of reference levels (re.lev.) and assessment levels (ass.lev.) between COMP1, COMP2 and COMP 3 for waters with a salinity 18-34.5 and >34.5. Note that estuaries (salinity 0-18) are not included.

Cat.	Parameter	Salinity 18-34.5		Salinity 18-34.5		Salinity 18-34.5		Salinity >34.5		Salinity >34.5		Salinity >34.5	
		COMP 1		COMP 2		COMP 3		COMP 1		COMP 2		COMP 3	
		ref.lev	ass.lev.	ref.lev	ass.lev.	ref.lev	ass.lev.	ref.lev	ass.lev.	ref.lev	ass.lev.	ref.lev	ass.lev.
I	TN inputs (kt/a)	77*	115.5	10.6	15.9	40.6	60.9						
	TN µM as	169		17.4	26.1	74.5	111.7						
	TP inputs (kt/a)	2*	3	0.56	0.84	1.46	2.20						
	TP µM as	1.99		0.41	0.62	1.21	1.82						
	DIN (µM)	19	28.5	7-9	10.5-13.5	6-19.3	9-29	10	15	7	10.5	4.7-5.3	7-8
	DIP (µM)	0.65	0.975	0.4	0.6	0-4-0-5	0.6-0.8	0.6	0.9	0.4	0.6	0.4	0.6
	Nutrient ratios DIN/DIP(M/M)	16	24	17-25	26-38	16	24	16	24	16	24	16	24
	DIN/Si (M/M)	2	3				na	2	3				na
	TN (µM)	15	22.5	11-14	16.5-21	7.3-24	11-36			11	16.5	5.7-6.3	8.6-9.5
	TP (µM)	0.5	0.75	0.6-0.7	0.9-1.05	0-5-0-7	0.8-1.1			0.7	1.05	0.53	0.79
II	Chlorophyll, mean (µg/L)	10	15	2-3	3-4.5	1.3-4	2-6	2	3	2	2.3	0.9-1.0	1.3-1.5
	Chlorophyll, max. (µg/L)			8-10	12-15	5.2-16	8-24			8	9	3.6-4.0	5.2-6
	Phytoplankton Ind. spec. (cells/L)			OSPAR 2005			OSPAR 2005			OSPAR 2005			OSPAR 2005
	Macrophytes depth (m)			10	15	6-12	4-8					13.5-15	9-10
III	Organic carbon (µM)			14-20	21-30	36-109	54-164			14	16	26.7-29.3	40-44
	Oxygen conc. (mg/l)	8	8	6	6	6	6			6	6	6	6
	Oxygen saturation (%)	100	100	85-87	84	85	85	<80	<80	87	84	85	85
	Macrozoobenthos AFD (g/m^2)			9.10	14-15	2.1-6.3	3.1-9.5			9	10	1.5-1.7	2.3-2.6
	Secchi depth (m)			6-8	4-5	6-12	4-8			8	5-7	13.5-15	9-10

*Based on a freshwater discharge rate of 38.93 km^3/y for 2006-2010; na = not applied, AFDW = ash free dry weight

6. Comparison and links with European related policies

6.1 WFD

The assessment of the ecological status that has been performed under the WFD for transitional and coastal waters reflects the predominant pressure in these waters, which is eutrophication. Hence, in the areas where the OSPAR COMP assessment and the WFD assessment overlap it is desirable that assessment results do not contradict each other to provide a consistent signal to managers. Nevertheless, the parameters used and spatial and temporal aggregation rules differ between COMP and the WFD. To ensure, as far as feasible, harmonisation between the two assessment methods Germany has adopted in 2015 a recommendation on how the coastal waters should be assessed (KoRa 2015a). According to this recommendation the OSPAR COMP can be applied to coastal and transitional waters as long as it is ensured that the WFD parameters and their respective assessment levels are used. COMP3 follows this recommendation. For the biological quality elements macrophytes and macrozoobenthos the latest WFD assessment results are used. These were only available for the period 2009-2013/14 and could not be updated due to time constraints. However, since populations of macrophytes and macrozoobenthos do not change rapidly it can be assumed that the WFD assessment result is valid for the COMP. Phytoplankton is not assessed as one biological quality element as under the WFD. Rather, chlorophyll-a and phytoplankton indicator species are assessed separately under COMP3 using the relevant WFD class boundaries for chlorophyll-a and Phaeocystis in coastal waters. The physico-chemical parameters nutrients, Secchi depth and oxygen are assessed only as supporting parameters under the WFD while for COMP 3 they are assessment parameters with the same weight as the biological parameters. Secchi depth has not been assesses in coastal waters <1nautical mile, neither for COMP3 nor for the WFD, since it is assumed not to be a reliable indicator of eutrophication due to naturally high turbidity in this area. The WFD does not assess nutrient loads for the classification of the ecological status but a management level of 2.8mg/l TN at the limnic-marine border has been set that helps to establish the link to nutrient reduction efforts. A further difference between the WFD assessment of ecological status and COMP3 are the spatial scales. The WFD assesses water bodies while COMP3 assesses larger areas by combining water bodies to water body types. Lastly, COMP uses only 3 classes for the assessment while the WFD uses 5. In principle, the COMP approach could also be differentiated into five classes.

Currently the transitional and coastal waters of the GEEZ are highly eutrophic. This is one reason why currently assessment results of COMP 3 and WFD are largely in good agreement (Tab 25). With future improvements in the eutrophication status differences in the two assessment methods might become more apparent. Meanwhile, efforts are ongoing to further harmonise WFD and COMP assessments.

Tab. 25 Comparison of COMP-3 assessment results (2006-2014) and WFD assessments of the "ecological status" (2009-2013/14) for the coastal assessment areas <1nautical mile. Colour code for WFD: blue = high status, green = good status, yellow = moderate status, orange = poor status, red = bad status, u = unknown, white = not assessed. For COMP 3 the assessment results for NF12, EW34, EF12 and EF34 were obtained by scrutinising the assessment results for the single water bodies and by then taking the assessment result that dominated. A quantitative approach could not be applied since only WFD assessment results but no WFD data were available for the biological quality elements.

COMP area	WFD area	Phytoplankton		Macrophyten		MZB		TN		TP	
		COMP	WFD	COMP	WFD	COMP	WFD	COMP	WFD	COMP	WFD
Helgoland	N5 5000 04.03										
NF 12	N1 9500.01.01				-						
	N1 9500.01.02				-						
	N2 9500.01.03										
	N2 9500.01.04										
	N2 9500.01.05										
	N2 9500.01.06										
EW 34	N3 9500.02.01				u						
	N3 9500.03.01				u						
	N4 9500.02.02										
	N4 9500.03.02										
	N3 5000.04.01				u						
	N4 5000.04.02										
	N4 5900.01								-		-
EF 12	N1 4900.01				u				-		-
	N2 4900.01								-		-
	N1 3100.01				u				-		-
	N2 3100.01								-		-
EF 34	N3 4900.01				u				-		-
	N4 4900.01								-		-
	N4 4900.02								-		-
	N3 3990.01				u				-		-
	N4 3100.01								-		-
Elbe-E	T1 5000-01		u								
Eider-E	T2 9500.01		u				u				
Weser-E	T1 4000-01		u						-		-
Ems-E	T1 3990-01		u						-		-
all estuaries											

6.2 Nitrates Directive

Nitrate as the main inorganic nutrient is still discharged by the rivers in very high amounts. Also from estuaries to coastal waters, DIN winter concentrations are so high that they contribute significantly to eutrophication effects. For this reason, these water masses could be addressed as "polluted" concerning the Nitrates Directive. However, during growing season DIN and the dominating nitrate become a limiting factor outside the areas controlled by the river plumes.

In the German Bight the DIN-nitrogen will be mostly transferred to organic compounds at first, which form a pool of more or less fast utilisable nutrients, enhancing eutrophication processes, such as reduced light climate or oxygen depletion in stratified bottom waters. Finally, nitrate will be removed from the aquatic system to a large degree by denitrification, mainly dependent on the organic load and residence time.

The results of the COMP2 assessment and preliminary results of the COMP3 assessment have been reported for the assessment according to the Nitrates Directive in 2015.

6.3 Marine Strategy Framework Directive

The German initial assessment for article 8 of the MSFD carried out in 2012 has relied on the results of the 2nd COMP supported by the WFD assessment of "good ecological status" for an assessment of

Descriptor 5 “eutrophication”. The follow-up assessment due in 2018 will rely on the results of COMP 3.

7. **Links to common indicator assessments**

The OSPAR common indicators for eutrophication are winter nutrient concentrations, chlorophyll-a concentrations, oxygen concentrations and Phaeocystis cell numbers. All of these indicators are also assessed in the German COMP. Nevertheless, a comparison of the assessment results is difficult due to a number of reasons. Firstly, the common indicators focus on trend assessments while COMP3 assesses the status against national assessment levels. Secondly, the assessment areas differ, with averaging of assessment results over very large areas for the common indicators (Southern North Sea) and much smaller areas used for the national COMP. Thirdly, the OSPAR common indicators are mainly based on ICES data and there are known gaps for German data in the ICES database concerning the common indicators. It is therefore not astonishing that for instance the findings of Chlorophyll-a are not in agreement. In national waters there were no trends in Chlorophyll-a concentrations during 2006-2014 while the common indicator found a decreasing trend in the Southern North Sea. The agreement is better for nutrient concentrations, where both the German COMP 3 assessment and the common indicator found increasing to stable tendencies in recent years.

8. Perspectives

8.1 Implemented and planned measures

The assessment outcome indicates that the eutrophication status of the GEEZ has not improved since 2005 due to stagnating riverine nutrient inputs as well as ongoing transboundary transports and continued high atmospheric deposition of nitrogen. Further effective measures are required to reduce nutrient inputs in the future. As a first step Germany has set a management target for TN at the limnic-marine border of 2.8 mg/L of the major rivers Elbe, Ems, Weser and Eider, necessitating nutrient reductions between 30% for the Weser and 48% for the Ems until 2027 at the latest (LAWA 2014). While this management target has been initially set for the achievement of “good ecological status” under the WFD it is assumed that it will also lead to the achievement of “non-problem area Status” with respect to eutrophication (and hence good status under OSPAR and the MSFD).

Nutrient inputs from point sources such as sewage treatment plants have been successfully reduced in the past and the potential for upgrading these treatment plants is almost exhausted. Reductions therefore need to come from the agricultural sector. An important means to achieve this will be the revision of the national fertiliser ordinance, regulating the application of fertiliser in agriculture. Concerning atmospheric nutrient inputs the obligations under the Gothenburg Protocol will ensure a substantial reduction in NOx and NH_3 up to 2020. NOx-emissions from shipping will be substantially reduced with the designation of the North Sea as a “Nitrogen Emissions Control Area” (NECA) in 2021.

8.2 Outlook

8.2.1. Expected trends

Trend calculations generally show that reductions in nutrient inputs are not immediately followed by corresponding decreases of phytoplankton biomass (ASMO 1998). The reasons are mainly buffering capacities of sediments and long-distance transports of nutrients and organic matter in coastal waters, besides improving light climate due to decreasing self-shading of phytoplankton in less eutrophied areas. Therefore, nutrient reductions, following measures at the main land-based sources which also might have a certain distance to the receiving estuaries and seas, will affect trends in the coastal waters only after a long time span (10 – 30 years). Nevertheless, chlorophyll concentrations could decrease by about 20 %, following a nutrient load reduction (DIN & DIP) of 50 % according to different predictive model runs (EUC 2007).

Further reduction of nutrient concentrations in the rivers will partly be masked by highly variable discharges, but recently stagnating nutrient concentrations in the main rivers indicate a lack of effective measures to reduce riverine nutrient concentrations. However, by ecological rehabilitation and restoration, combined with nutrient reductions, even the eutrophication effects within lowland basins and their aquatic systems can be improved, if physical, chemical and ecological principles will be applied (Nienhuis et al. 2002 a, b).

Increasing temperature due to climate change intensifies seasonal thermo-haline stratification and by this accumulation of organic matter in bottom layers, causing oxygen depletion. Increased stratification will also enhance the development of flagellates, utilising nutrients from deep layers. Higher temperatures will affect the seasonal cycling of nutrient elements e.g. by top-down control of phytoplankton spring blooms by zooplankton, the latter surviving during winter. Non-native species from southern areas will be enhanced by increasing temperatures and might influence or change phytoplankton composition. The mean annual temperature of the North Sea has increased since 1993 by about 1° C (Topcu & Brockmann 2015).

Changes of freshwater discharges, due to climate change, will affect loads and concentrations of individual rivers and its tributaries in a different way (Behrendt, pers. comm.). Generally, by lower freshwater discharges, concentrations will increase but loads will decrease, improving the state of the coastal water. Eutrophication effects may be masked by contaminants, e.g. by inhibiting primary production, shifting the effects “downstream”. With increasing climate change flood events become more frequent. These have the potential to flush large amounts of nutrients into the sea during a very short time, affecting in particular coastal waters. The Elbe flood in June 2014 flushed 21000 tons of nitrogen and 930 tons of phosphorus into the sea (compared to a mean load in June between 1992-2005 of only 3200tons of nitrogen and 70 tons of phosphorus) (Weigelt-Krenz et al. 2014).

Even after significant further reduction of nutrient river discharges, the German Bight will receive large amounts of nutrients and organic matter from ”upstream” areas, which are dominant sources for inshore waters as well. These transboundary nutrient inputs need to be significantly reduced for the GEEZ to achieve “non-problem area status” with respect to eutrophication.

Since the German Bight and the Wadden Sea are sensitive areas by nature, due to long residence time, stratification and trapping of particulate material, anthropogenic induced eutrophication problems are generally difficult to eliminate.

By construction of windparks the benthic community will be modified by the expansion of hard-bottom macrofauna like *Mytilus edulis*, affecting the whole ecosystem, e.g. by increased filtration and biomass production. The monitoring of algal toxins should therefore be expanded to the windpark areas. The macrophyte disease probably still prevents the restoration of sublitoral seagrasses, in addition to near shore light limitation.

8.2.2. Improvement of the assessment

It is still evident that eutrophication monitoring in the German Bight should be improved, especially for TN, TP, chlorophyll, phytoplankton, macrophytes, organic matter, oxygen in bottom waters and macrozoobenthos. Shortcomings in chlorophyll sampling can be at least partly compensated by utilisation of remote sensing data.

Establishment of a more quantitative relation between eutrophication parameters would improve the assessment. Consideration of seasonal effects could improve understanding of eutrophication processes, such as formation of blooms, accumulation of organic material and seasonal development of oxygen depletion in bottom layers of stratified areas. In this respect, the definition of “natural” oxygen depletion should be improved as well.

Further work is foreseen on the revision of assessment levels in particular for the nutrients and chlorophyll-a, supported by a modelling approach using a coupled model system with high spatial resolution. Assessment methods need to be improved especially for phytoplankton indicator species and macrozoobenthos communities, where relationships between these parameters and other eutrophication parameters are currently weak due to many interfering processes.

Further research is needed to quantify the link between anthropogenic nutrient loads and the occurrence of phytoplankton “indicator species” which are now indicating Problem Areas. In addition, detailed studies for an effective assessment of the highly variable abundance and composition of macrozoobenthos are needed, also to differentiate seasonally the effects of different forcing (e.g. climate, eutrophication, fishery, dredging, alien species invasions).

Lastly, Germany aims for a further harmonisation of the eutrophication assessment methods of OSPAR and HELCOM, since North Sea and Baltic Sea waters should be assessed with comparable methods. Investigations are ongoing to apply the “HELCOM Eutrophication Assessment Tool” HEAT 3.0 to the GEEZ. First results look promising. HEAT 3.0 ensures a simple and transparent assessment method that can be automatized, thereby substantially reducing the work load associated with eutrophication assessments.

9. Conclusions

Main parts of the GEEZ and German Bight are still an eutrophication Problem Area with high chlorophyll-a concentrations along the coasts, occurrence of l phytoplankton indicator species, restriction of seagrasses, annual benthic green algal blooms, oxygen depletion in bottom waters, elevated organic matter concentrations and high macrozoobenthos biomasses. Due to significant correlations between different eutrophication indicators/parameters, the assessment is robust in spite of missing data in space and time.

However, monitoring of TN, TP, POC, DOC, oxygen and especially of the biological quality components should be intensified, also to identify local sources or to differentiate between natural and anthropogenic forced processes, such as seasonal oxygen depletion, affecting complete ecosystems. Application of remote sensing methods should be improved and used for supplementation of chlorophyll sampling in the field.

Due to interactions with many other stressors, robustness of parameters concerning eutrophication effects should be reinvestigated, considering climate change, synergistic effects and invasion of non-indigenous species. The basis for developing different assessment indices should be the different sensitivity of species to specific stressors. Definitions of natural background conditions may be improved in relation to progressing research. For instance, the occurrence of low numbers of harmful phytoplankton species (“regional specific indicator species”), surpassing “elevated levels” is a weak indicator for eutrophication if it is not substantiated with knowledge on acute hydrodynamic conditions and ecosystem kinetics.

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Annexes – Assessment Tables

The colours in the tables indicate the assessment result (green = below assessment level or non-problem area, red = above assessment level or problem area, yellow = not enough data to make a judgement or potential problem area). Only the coloured numbers have been used for assessment purposes, while other numbers provide only supplementary information. In the column "Final" the final assessment results are provided.

Tab. A 26 Inorganic nitrogen (DIN) [µM] during winter 2006-2014, inter-annual means, assessment levels (1880+50%) and deviations [%] within the subareas. In this and the following tables "Means single values" have been calculated by averaging all available data from the 2006-2014 period. "Means inter-annual" have been calculated by averaging first for single years and then averaging the 9 years from the 2006-2014 period.

DIN	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single values	Means inter-annual	Assessment level	% dev.	Final
OFFO	Mean [µM]	5.79	1.70	3.40	5.37	4.53	4.00	4.21	3.48	1.85	3.89	3.81	7.1	-46	
	Std.dev [µM]		0.41	0.71	1.31	2.57	2.17	2.19	2.40	0.38	2.02	1.40			
	Std.dev%		24.0	20.8	24.5	56.7	54.3	51.9	68.9	20.6	52.0	36.6			
	n	1	4	2	6	3	5	7	4	2	34	9			
OFFI	Mean [µM]	4.46	3.03	5.22	3.82	5.06	3.17	4.05	7.11	4.08	4.38	4.44	7.8	-43	
	Std.dev [µM]	0.06	3.36	2.20	0.41	1.71	1.73	2.20	1.44	7.59	2.90	1.25			
	Std.dev%	1.3	111.2	42.2	10.7	33.8	54.6	54.3	20.2	186.1	66.3	28.0			
	n	3	6	6	8	9	14	14	9	6	75	9			
OCNF	Mean [µM]	10.36	12.77	6.85	4.63	6.40	4.70	4.46	7.19	1.73	7.83	6.57	9.1	-28	
	Std.dev [µM]	1.82	7.91	0.21	0.33	0.96	3.16	3.45	0.52	0.13	4.96	3.33			
	Std.dev%	17.5	61.9	3.1	7.1	15.1	67.3	77.4	7.2	7.2	63.4	50.7			
	n	14	8	2	3	3	6	6	3	3	48	9			
OCEF	Mean [µM]	10.91	10.89	6.39	6.39	8.79	7.86	7.89	10.82	10.96	9.07	8.99	10.0	-10	
	Std.dev [µM]	2.94	6.49	5.60	3.73	4.01	5.94	5.67	2.78	9.47	5.55	1.95			
	Std.dev%	26.9	59.6	87.7	58.3	45.6	75.5	71.9	25.7	86.4	61.2	21.8			
	n	15	14	9	9	7	14	14	9	8	99	9			
ICNF	Mean [µM]	25.08	25.99	28.81	20.26	29.61	39.76	27.08	28.43	20.58	27.23	27.29	19.0	44	
	Std.dev [µM]	11.27	17.42	18.12	13.14	12.90	34.43	19.03	13.19	15.53	19.58	5.76			
	Std.dev%	44.9	67.0	62.9	64.9	43.6	86.6	70.3	46.4	75.5	71.9	21.1			
	n	35	40	39	34	27	43	41	36	51	346	9			
ICEF	Mean [µM]	16.97	21.79	12.69	7.75	14.98	14.02	14.71	13.64	12.30	14.07	14.32	13.1	9	
	Std.dev [µM]	9.03	10.23	8.52	4.16	7.49	9.51	10.54	9.35	8.45	9.39	3.77			
	Std.dev%	53.2	47.0	67.2	53.7	50.0	67.8	71.7	68.6	68.6	66.7	26.4			
	n	86	86	111	107	94	112	128	112	109	945	9			
NF12	Mean [µM]	10.06	10.78	14.71	9.40	38.45	49.17	43.83	42.09	48.51	22.34	29.67	20.2	47	
	Std.dev [µM]	3.01	11.78	13.53	8.68	11.07	27.49	16.73	8.80	18.25	20.03	17.83			
	Std.dev%	29.9	109.3	91.9	92.3	28.8	55.9	38.2	20.9	37.6	89.7	60.1			
	n	54	58	57	48	44	20	12	17	21	331	9			
EF12	Mean [µM]	36.07	40.57	43.49	36.89	41.48	42.71	34.77	31.46	51.20	39.59	39.85	18.3	118	
	Std.dev [µM]	19.03	20.90	19.30	13.54	16.03	14.62	17.73	8.54	12.22	17.39	5.84			
	Std.dev%	52.8	51.5	44.4	36.7	38.6	34.2	51.0	27.1	23.9	43.9	14.7			
	n	37	36	38	37	38	22	31	13	14	266	9			
EW34	Mean [µM]	44.49	78.38	52.41	42.59	68.07	77.51	64.23	57.88	39.26	57.72	58.31	29.1	100	
	Std.dev [µM]	21.60	43.64	37.33	25.55	29.40	52.06	48.14	29.32	29.70	38.37	14.74			
	Std.dev%	48.6	55.7	71.2	60.0	43.2	67.2	74.9	50.7	75.6	66.5	25.3			
	n	25	17	30	27	33	34	32	39	37	274	9			
EF34	Mean [µM]	53.30	69.30	62.25	47.25	60.65	55.53	55.75	60.64	76.41	59.44	60.12	27.5	119	
	Std.dev [µM]	32.70	33.59	35.83	14.23	38.36	22.70	19.97	16.93	17.17	28.15	8.71			
	Std.dev%	61.3	48.5	57.6	30.1	63.2	40.9	35.8	27.9	22.5	47.4	14.5			
	n	6	21	24	23	22	14	19	19	7	155	9			
Elbe-E	Mean [µM]	241.45	239.64	227.99	162.81	262.69	175.48	150.29	157.52	155.11	208.15	197.90	81.5	143	
	Std.dev [µM]	63.73	46.15	57.72	62.30	56.83	47.58	50.42	71.93	91.25	68.25	44.30			
	Std.dev%	26.4	19.3	25.3	38.3	21.6	27.1	33.5	45.7	58.8	32.8	22.4			
	n	33	36	35	35	21	19	19	18	4	218	9			
Weser-E	Mean [µM]	325.18	382.14	317.23	358.10	308.92	279.84	247.16	307.37		308.33	315.74	85.2	271	
	Std.dev [µM]	59.85	31.34	52.40	36.48	31.06	79.10	70.38	80.27		70.38	42.09			
	Std.dev%	18.4	8.2	16.5	10.2	10.1	28.3	28.5	26.1		22.8	13.3			
	n	8	7	8	6	8	10	12	7	0	66	8			
Ems-E	Mean [µM]	224.03	290.74	229.51	221.48	338.21	292.34	267.19	339.29		272.96	275.35	62.8	338	
	Std.dev [µM]	122.24	108.47	119.13	109.76	126.90	136.05	135.19	128.87		128.47	48.21			
	Std.dev%	54.6	37.3	51.9	49.6	37.5	46.5	50.6	38.0		47.1	17.5			
	n	19	21	19	25	16	21	19	20	0	160	8			

Tab. A 27 Inorganic phosphorus (DIP) [µM] during winter 2006-2014, inter-annual means, assessment levels (1880+50%) and deviations [%] within the subareas.

DIP	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single values	Means inter-annual	Assess-ment levels	% dev.*	Final
OFFO	Mean [µM]	0.46	0.23	0.40	0.46	0.46	0.36	0.41	0.45	0.39	0.40	0.40	0.59	-32	
	SD [µM]		0.09	0.05	0.09	0.16	0.18	0.19	0.10	0.16	0.15	0.07			
	SD [%]		39.4	12.5	19.1	34.0	48.7	46.9	22.4	41.1	36.3	18.4			
	n	4	4	2	6	3	5	7	3	6	40	9			
OFFI	Mean [µM]	0.60	0.40	0.46	0.47	0.54	0.39	0.43	0.54	0.45	0.47	0.48	0.60	-21	
	SD [µM]	0.05	0.13	0.08	0.05	0.03	0.11	0.14	0.06	0.11	0.11	0.07			
	SD [%]	7.6	31.1	16.8	11.0	5.9	28.8	32.7	10.8	25.2	24.5	15.0			
	n	9	6	6	8	9	14	14	9	15	90	9			
OCNF	Mean [µM]	0.58	0.62	0.39	0.79	0.51	0.41	0.32	0.49	0.39	0.52	0.50	0.61	-18	
	SD [µM]	0.06	0.13	0.06	0.49	0.06	0.07	0.09	0.01	0.10	0.19	0.15			
	SD [%]	10.0	20.1	14.5	62.2	12.5	16.9	29.5	1.7	26.3	36.5	29.3			
	n	17	8	2	4	3	6	6	3	6	55	9			
ONCEF	Mean [µM]	0.60	0.60	0.52	0.35	0.48	0.43	0.47	0.56	0.47	0.51	0.50	0.62	-20	
	SD [µM]	0.05	0.13	0.07	0.08	0.07	0.14	0.21	0.17	0.13	0.15	0.08			
	SD [%]	7.7	22.0	14.3	23.9	15.3	33.8	44.0	30.6	28.4	29.1	16.5			
	n	21	14	9	10	7	14	14	10	9	108	9			
ICNF	Mean [µM]	0.96	0.87	1.11	0.92	0.99	1.14	0.90	1.07	0.85	0.98	0.98	0.71	38	
	SD [µM]	0.29	0.29	0.38	0.32	0.36	0.57	0.39	0.39	0.37	0.39	0.10			
	SD [%]	30.4	33.0	34.3	34.1	36.4	49.8	43.0	36.8	42.8	40.0	10.6			
	n	53	40	38	34	27	44	41	36	51	364	9			
ICEF	Mean [µM]	0.55	1.03	0.84	0.46	0.71	0.66	0.69	0.79	0.67	0.71	0.71	0.65	9	
	SD [µM]	0.29	0.57	0.30	0.14	0.38	0.32	0.25	0.46	0.24	0.37	0.16			
	SD [%]	53.1	55.0	35.5	31.0	53.9	48.6	36.8	58.0	36.3	52.4	23.1			
	n	91	85	111	108	94	110	127	107	110	943	9			
NF12	Mean [µM]	0.90	0.69	0.93	0.88	0.81	0.85	0.90	0.82	1.28	0.87	0.90	0.72	24	
	SD [µM]	0.21	0.24	0.13	0.29	0.30	0.24	0.15	0.24	0.86	0.31	0.16			
	SD [%]	23.6	34.3	14.0	32.7	37.5	28.4	17.1	28.9	66.9	35.7	18.0			
	n	60	58	58	49	45	51	49	51	21	442	9			
EF12	Mean [µM]	1.13	1.15	1.12	1.14	1.11	1.33	1.16	1.04	1.31	1.16	1.17	0.70	67	
	SD [µM]	0.33	0.32	0.22	0.28	0.32	0.37	0.31	0.20	0.34	0.31	0.09			
	SD [%]	29.3	27.8	19.7	24.8	28.8	27.4	26.4	19.4	26.4	26.6	8.0			
	n	38	36	38	37	38	22	31	13	14	267	9			
EW34	Mean [µM]	1.20	1.64	1.68	1.46	1.45	1.64	1.65	1.57	1.39	1.51	1.52	0-81	88	
	SD [µM]	0.54	0.47	0.47	0.45	0.51	0.79	0.46	0.66	0.52	0.57	0.16			
	SD [%]	45.2	28.5	28.3	30.7	35.3	48.3	27.9	42.0	37.7	38.0	10.5			
	n	33	21	35	27	37	36	33	44	44	310	9			
EF34	Mean [µM]	1.15	1.21	1.32	1.24	1.17	1.46	1.32	1.38	1.35	1.29	1.29	0.79	63	
	SD [µM]	0.38	0.46	0.29	0.18	0.22	0.53	0.37	0.34	0.26	0.34	0.10			
	SD [%]	32.7	37.8	21.8	14.2	18.7	36.5	27.7	24.4	18.9	26.7	7.9			
	n	6	21	24	23	22	14	19	19	7	155	9			
Elbe	Mean [µM]	1.79	2.40	1.58	2.28	1.48	1.95	2.26	2.10	1.58	1.95	1.94	1.31	48	
	SD [µM]	0.44	1.53	0.77	0.47	0.47	0.38	0.37	0.43	0.79	0.83	0.35			
	SD [%]	24.8	64.0	48.8	20.6	31.5	19.5	16.3	20.7	50.3	42.5	18.1			
	n	35	36	35	35	34	19	19	19	4	234	9			
Weser	Mean [µM]	1.90	2.21	1.57	1.56	2.00	2.38	2.15	2.63		2.08	2.05	1.35	52	
	SD [µM]	0.66	0.92	0.68	0.24	0.42	0.64	0.42	0.43		0.64	0.37			
	SD [%]	34.6	41.6	43.1	15.6	21.1	26.8	19.6	16.5		31.0	18.2			
	n	8	7	8	6	8	10	12	8		67	8			
Ems	Mean [µM]	2.00	2.50	1.76	1.86	1.59	2.16	1.87	1.75		1.95	1.94	1.13	71	
	SD [µM]	0.58	1.38	0.47	0.51	0.71	0.74	0.61	0.35		0.77	0.29			
	SD [%]	29.1	55.2	26.8	27.6	44.8	34.3	32.5	20.0		39.4	14.8			
	n	19	21	19	25	16	21	19	19	0	159	8			

SD = standard deviation

Tab. A 28 Ratios of inorganic nitrogen and phosphorus (DIN/DIP) [M/M] during winter 2006-2014, inter-annual means.

DIN/DIP	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means Inter-annual
OFFO	Mean [µM]		7.95	8.56	11.61	9.40	10.84	10.11	10.37	9.94	10.09	9.85
	Std.dev [µM]		2.27	0.72	1.03	2.01	1.18	1.18	0.80	3.27	1.77	1.19
	Std.dev%		28.5	8.4	8.9	21.3	10.9	11.7	7.7	32.9	17.5	12.1
	n	0	4	2	6	3	5	7	3	2	32	8
OFFI	Mean [µM]	6.96	6.34	11.12	8.13	9.21	7.58	9.01	13.32	9.15	9.08	8.98
	Std.dev [µM]	0.09	4.45	3.37	1.02	2.64	3.00	3.74	2.77	15.10	5.20	2.16
	Std.dev%	1.3	70.1	30.3	12.5	28.7	39.6	41.6	20.8	165.1	57.3	24.0*
	n	3	6	6	8	9	14	14	9	6	75	9
OCNF	Mean [µM]	18.31	19.06	17.71	8.53	12.44	10.89	12.42	14.54	5.84	14.75	13.30
	Std.dev [µM]	0.08	0.09	0.09	0.09	0.08	0.10	0.08	0.10	0.11	6.69	4.54
	Std.dev%	0.4	0.5	0.5	1.0	0.7	0.9	0.7	0.7	1.9	45.3	34.1
	n	14	8	2	3	3	6	6	3	3	48	9
OCEF	Mean [µM]	18.03	17.23	12.43	18.89	17.77	17.48	14.92	21.18	20.15	17.41	17.56*
	Std.dev [µM]	3.95	7.65	10.21	10.96	6.47	10.36	7.87	6.08	14.49	8.76	2.63
	Std.dev%	21.9	44.4	82.1	58.0	36.4	59.3	52.8	28.7	71.9	50.3	15.0
	n	15	14	9	9	7	14	14	9	8	99	9
ICNF	Mean [µM]	32.16	28.87	26.79	20.96	29.52	33.51	28.32	27.83	24.73	28.03	28.08
	Std.dev [µM]	21.25	15.01	15.47	10.35	9.50	23.33	16.50	12.79	16.45	16.72	3.75
	Std.dev%	66.1	52.0	57.8	49.4	32.2	69.6	58.3	46.0	66.5	59.7	13.4
	n	35	39	38	34	27	43	41	36	51	344	9
ICEF	Mean [µM]	42.34	33.22	15.15	17.11	21.77	23.07	22.49	18.42	18.46	22.80	23.56
	Std.dev [µM]	36.32	32.13	9.87	7.92	8.06	14.97	16.10	10.34	12.20	19.59	8.77
	Std.dev%	0.06	0.13	0.06	0.49	0.06	0.07	0.09	0.01	0.10	85.9	37.2
	n	84	83	111	107	94	110	127	107	109	932	9
NF12	Mean [µM]	12.73	16.24	15.26	12.75	50.34	46.86	45.51	42.17	48.46	25.75	32.26
	Std.dev [µM]	5.86	13.23	12.24	10.62	14.07	25.66	16.09	9.11	28.96	21.41	17.26
	Std.dev%	46.0	81.5	80.2	83.3	28.0	54.8	35.4	21.6	59.8	83.1	53.5
	n	54	58	57	48	44	19	12	17	21	330	9
EF12	Mean [µM]	31.52	36.96	37.86	32.69	38.36	33.30	33.80	31.11	42.05	35.27	35.30
	Std.dev [µM]	15.64	18.17	13.79	10.64	13.50	11.96	22.64	10.05	15.39	15.46	3.69
	Std.dev%	49.6	49.2	36.4	32.5	35.2	35.9	67.0	32.3	36.6	43.9	10.5
	n	36	36	38	37	38	22	31	13	14	265	9
EW34	Mean [µM]	49.87	53.90	31.78	27.64	45.19	51.72	37.69	38.00	29.21	39.55	40.56
	Std.dev [µM]	26.28	30.92	20.35	13.73	15.44	35.68	23.37	17.03	17.04	24.05	9.99
	Std.dev%	52.7	57.4	64.0	49.7	34.2	69.0	62.0	44.8	58.4	60.8	24.6
	n	23	17	30	29	33	34	32	39	37	274	9
EF34	Mean [µM]	49.87	53.90	31.78	27.64	45.19	51.72	37.69	38.00	29.21	47.88	40.56
	Std.dev [µM]	26.28	30.92	20.35	13.73	15.44	35.68	23.37	17.03	17.04	23.00	9.99
	Std.dev%	52.69	57.4	64.0	49.7	34.2	69.0	62.0	44.8	58.4	48.0	24.6
	n	6	21	24	23	22	14	19	19	7	155	9
Elbe	Mean [µM]	153.2	118.5	214.5	72.6	207.1	95.3	71.0	84.7	127.8	131.97	127.19
	Std.dev [µM]	75.7	47.0	172.9	21.9	155.1	37.2	36.6	62.1	116.6	108.62	54.46
	Std.dev%	49.38	39.7	80.6	30.2	74.9	39.1	51.6	73.4	91.2	82.3	42.8
	n	33	36	35	33	21	19	19	18	4	218	9
Weser	Mean [µM]	199.0	283.5	260.9	233.1	161.0	127.3	121.1	118.8		180.42	188.08
	Std.dev [µM]	96.4	335.4	178.8	34.0	37.7	55.1	48.2	41.2		140.79	65.74
	Std.dev%	48.4	118.3	68.5	14.6	23.4	43.3	39.8	34.7		78.0	35.0
	n	8	7	8	6	8	10	12	7	0	66	8
Ems	Mean [µM]	131.0	147.9	165.9	129.8	358.3	170.1	174.9	213.8		180.39	186.46
	Std.dev [µM]	106.2	100.2	173.0	68.6	428.6	130.2	131.7	123.7		184.94	74.51
	Std.dev%	81.1	67.7	104.3	52.9	119.6	76.5	75.3	57.8		102.5	40.0
	n	19	21	19	25	16	21	19	19	0	159	8

Tab. A 29 Chlorophyll-a means [µg/L] during growing seasons 2006-2014, inter-annual means, assessment levels (1880) and deviations [%] within the subareas.

Chl.a means	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Assessment levels	% dev.*	Final
OFFO	Mean [µg/L]		0.24	0.35		0.62	1.11		0.55	0.46	0.48	0.55	1.31	58	
	Std.dev [µg/L]		0.08						0.31	0.09	0.29	0.30			
	Std.dev%		33.7						56.7	20.2	60.7	54.5			
	n	0	4	1	0	1	1	0	5	2	14	6			
OFFI	Mean [µg/L]	0.37	0.70	0.54	1.83	0.79	0.95	0.94	0.41	1.02	0.67	0.84	1.48	42	
	Std.dev [µg/L]	0.27	0.38	0.16		0.22	0.33		0.20	0.61	0.42	0.44			
	Std.dev%	73.5	54.8	29.6		28.3	35.4		49.0	59.9	62.5	52.4			
	n	2	8	4	1	2	2	1	11	4	35	9			
OCNF	Mean [µg/L]		1.13	2.44		3.12	1.38		1.81	2.60	1.99	2.08	1.79	16	
	Std.dev [µg/L]		0.27	0.03		0.06	0.06		0.96	1.18	0.93	0.77			
	Std.dev%		23.5	1.2		1.8	4.0		52.8	45.2	46.9	36.8			
	n	0	3	2	0	2	2	0	7	3	19	7			
OCEF	Mean [µg/L]	3.39	1.86	2.02	2.23	1.11	1.83	1.11	1.38	2.55	1.81	1.94	1.95	3	
	Std.dev [µg/L]	3.72	0.98	1.62	1.15	0.84	1.31	0.81	1.04	1.52	1.60	0.73			
	Std.dev%	109.7	52.8	80.0	51.5	75.7	71.6	73.0	75.3	59.4	88.6	37.7			
	n	13	20	18	15	14	23	23	31	10	167	9			
ICNF	Mean [µg/L]	7.50	4.83	6.27	7.21	8.89	3.62	5.36	4.86	5.13	5.54	5.96	3.66	63	
	Std.dev [µg/L]	6.90	4.40	5.16	8.45	10.24	3.02	4.96	3.22	3.43	5.39	1.65			
	Std.dev%	91.9	91.2	82.4	117.2	115.1	83.5	92.6	66.2	66.8	97.2	27.6			
	n	36	31	29	19	41	66	83	98	79	482	9			
ICEF	Mean [µg/L]		2.12	3.88		4.26	2.20	1.99	2.92	4.45	2.37	3.12	2.57	21	
	Std.dev [µg/L]		0.71			2.68	2.69	1.73	2.97	1.45	2.41	1.06			
	Std.dev%		33.4			62.9	122.6	87.1	101.7	32.7	101.8	34.2			
	n	0	6	1	0	2	203	222	233	116	783	7			
NF12	Mean [µg/L]	7.63	5.46	6.00	5.98	9.15	7.74	7.89	8.46	4.45	7.54	4.80	3.75	28	
	Std.dev [µg/L]	6.41	3.78	5.40	4.74	11.05	4.59	6.86	8.85	4.24	7.13	1.06			
	Std.dev%	84.0	69.2	90.1	79.3	120.8	59.3	86.9	104.6	95.3	94.6	22.1			
	n	128	122	113	108	204	165	194	159	104	1297	9			
EF12	Mean [µg/L]	4.06	5.02	6.32	5.88	10.42	8.21	5.63	7.79	6.90	6.77	6.69	3.75	78	
	Std.dev [µg/L]	3.64	4.84	6.84	6.00	9.61	4.55	2.90	5.49	4.05	5.86	1.91			
	Std.dev%	89.8	96.3	108.3	102.0	92.2	55.5	51.6	70.4	58.7	86.5	28.5			
	n	52	50	52	35	50	57	45	83	53	477	9			
EW34	Mean [µg/L]	11.38	11.36	13.28	11.16	21.75	12.21	10.63	13.96	11.95	13.20	12.99	5.50	133	
	Std.dev [µg/L]	10.98	10.05	11.41	7.34	19.05	14.40	8.19	15.29	4.53	13.23	3.42			
	Std.dev%	96.5	88.5	85.9	65.8	87.6	117.9	77.0	109.5	37.9	100.2	26.4			
	n	56	47	68	65	99	109	128	116	98	786	9			
EF34	Mean [µg/L]	4.79	4.01	5.36	7.51	8.16	5.01	6.91	4.79	6.01	5.99	5.97	5.50	9**	
	Std.dev [µg/L]	4.82	5.02	4.55	6.03	5.08	2.85	5.87	4.82	3.53	4.99	2.41			
	Std.dev%	100.7	125.3	84.8	80.3	62.3	56.8	84.9	100.7	58.8	83.3	40.4			
	n	33	35	35	35	36	35	36	33	28	306	9			
Elbe	Mean [µg/L]	32.63		11.78	13.05	23.59	16.41	20.94			19.35	19.73	13.00	52	
	Std.dev [µg/L]	31.16		5.14	6.52	26.54	7.86	12.94			18.70	7.77			
	Std.dev%	95.5		43.6	49.9	112.5	47.9	61.8			96.6	39.4			
	n	16	0	18	20	17	16	16	0	0	103	6			
Ems	Mean [µg/L]	9.77	7.69	8.19	8.58	8.77	8.77	6.32	5.10		7.76	7.90	10.15	22**	
	Std.dev [µg/L]	5.71	4.37	4.42	9.16	6.57	3.13	3.03	2.72		5.25	1.51			
	Std.dev%	58.5	56.9	54.0	106.8	74.9	35.6	48.0	53.2		67.6	19.1			
	n	18	22	21	22	27	28	30	28	0	196	8			

* marginal deviations, ** probably light limitation

Tab. A 30 Chlorophyll-a 90th percentiles [µg/L] during growing seasons 2006-2014, inter-annual means, assessment levels (1880) and deviations [%] within the subareas.

Chl. a 90th	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means	Assessment levels	St.dev.%
OFFO	[µg/L]		0.32	0.35		0.62	1.11		0.88	0.51	0.63	2.6	-76
	n	0	4	1	0	1	1	0	5	2	14		
OFFI	[µg/L]	0.52	1.10	0.68	1.83	0.92	1.14	0.94	0.73	1.62	1.05	3.0	-64
	n	2	8	4	1	2	2	1	11	4	35		
OCNF	[µg/L]		1.31	2.45		3.15	2.05		2.95	3.49	2.57	3.6	-24
	n	0	3	2	0	2	2	0	7	3	19		
OCEF	[µg/L]	4.28	2.44	4.00	3.56	1.97	3.31	1.98	2.59	3.45	3.06	4.0	-18
	n	13	20	18	15	14	23	23	31	10	167		
ICNF	[µg/L]	12.85	11.80	9.98	11.27	16.34	7.32	13.16	8.63	9.07	11.16	7.4	54
	n	36	31	29	19	41	66	83	98	79	482		
ICEF	[µg/L]		2.75	3.88		5.78	4.64	3.53	5.93	4.36	4.41	5.0	-11
	n	0	6	1	0	2	203	222	233	116	783		
NF12	[µg/L]		15.49	10.43	11.61	13.38	16.77	13.93	15.68	15.22	14.06	7.5	83
	n	128	122	113	108	204	165	194	159	104	1297		
EF12	[µg/L]	7.18	8.91	13.50	13.47	20.50	14.31	10.02	16.43	10.74	12.78	7.5	83
	n	52	50	52	35	50	57	45	53	53	477		
EW34	[µg/L]	25.65	18.71	26.97	21.79	52.26	25.20	20.45	28.53	26.17	27.30	11.0	145
	n	56	47	68	65	99	109	128	116	84	772		
EF34	[µg/L]		11.53	11.57	11.13	12.62	12.87	8.20	16.26	11.48	11.96	11.0	14*
	n	0	33	35	35	35	36	35	36	28	273		
Elbe-E	[µg/L]	70.50		19.30	19.70	45.80	27.00	37.50			36.63	26.0	38*
	n	16	0	18	20	17	16	16	0	0	103		
Weser-E	[µg/L]											27.0	
	n	0	0	0	0	0	0	0	0	0	0		
Ems-E	[µg/L]	19.40	21.00	24.20	46.60	28.00	17.00	14.00	9.60		12.84	20.3	65*
	n	18	22	21	22	27	28	30	28	0	196		

* light limitation

Tab. A 31 Chlorophyll-a maxima [µg/L] during growing seasons 2006-2014, inter-annual means, assessment levels (1880+50%) and deviations [%] within the subareas.

Chl.a max	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean	Std. dev.%	Assessment levels	Std. dev.%*
OFFO	[µg/L]		0.33	0.35		0.62	1.11		1.06	0.52	0.67	51.6	5.2	-87
	n	0	4	1	0	1	1	0	5	2	14			
OFFI	[µg/L]	0.56	1.22	0.70	1.83	0.95	1.18	0.94	0.79	1.88	1.12	42.0	6.0	-81
	n	2	8	4	1	2	2	1	11	4	35			
OCNF	[µg/L]		1.33	2.46		3.16	1.42		2.96	3.65	2.50	38.0	7.2	-63
	n	0	3	2	0	2	2	0	7	3	19			
	[µg/L]	15.00	5.18	5.96	4.45	3.55	5.94	3.50	4.25	6.49	6.04	58.5	8.0	-20
	n	13	20	18	15	14	23	23	31	10	167			
ICNF	[µg/L]	40.40	16.10	22.21	39.10	48.03	15.15	22.94	15.94	18.00	26.43	47.6	14.8	82
	n	36	31	29	19	41	66	83	98	79	482			
ICEF	[µg/L]		2.80	3.88		6.16	21.76	11.82	20.31	7.60	10.62	72.4	10.0	7*
	n	0	6	1	0	2	203	222	233	116	783			
NF12	[µg/L]	33.16	21.81	45.79	24.17	80.58	28.33	46.64	82.08	20.80	42.60	56.1	15.0	177
	n	128	122	113	108	204	165	194	159	104	1297			
EF12	[µg/L]	21.23	23.16	34.74	28.07	54.62	22.55	14.00	24.76	25.13	27.58	41.9	15.0	98
	n	52	50	52	35	50	57	45	53	53	477			
EW34	[µg/L]	51.70	63.90	54.22	34.26	94.00	114.8	38.49	107.4	47.0	67.31	45.0	22.0	202
	n	56	47	68	65	99	109	128	116	84	772			
EF34	[µg/L]		22.5	19.5	18.9	33.13	21.6	15.36	24.12	12.64	20.97	29.5	22.0	0*
	n	0	33	35	35	35	36	35	36	28	273			
Elbe-E	[µg/L]	115.0		22.00	28.00	112.0	33.00	54.00			60.67	42.3	52.0	4*
	n	16	0	18	20	17	16	16	0	0	103			
Ems-E	[µg/L]	19.40	21.00	24.20	46.60	28.00	17.00	14.00	9.60		22.48		54.0	59*
	n	18	22	21	22	27	28	30	28	0	196			

Std. deviations [%] are related to inter-annual means, * light limitation

Tab. A 32 *Phaeocystis* spec. mean cell numbers/L (V-VIII) 2006-2014 (ass. level 10^6 n/L).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. Inter-annual
OFFO	Mean [n]			0.00		28503					108916	14252	
	Std.dev [n]			0.00		49369					344233	20155	24685
	Std.dev%					173					172	141	173
	n			2		3					5	2	
OFFI	Mean [n]			0.00		15925					3061	7962	
	Std.dev [n]			0.00		21015					11445	11261	10507
	Std.dev%			0		132					200	141	66
	n			2		6					8	2	
OCNF	Mean [n]			484715		5449					101287	245082	
	Std.dev [n]			21015		969430					380387	338892	495222
	Std.dev%			4		17790					181	138	8897
	n			5		8					13	2	
OCEF	Mean [n]	160066	427651	790075	188079	339149	262894	279626	1078083	679819	20411	467271	
	Std.dev [n]	160824	561978	1025644	165075	280858	240911	193740	2384438	1136598	83024	314197	490526
	Std.dev%	100	131	130	88	83	92	69	221	167	180	67	100
	n	100	103	113	102	112	103	104	101	98	936	9	
ICNF	Mean [n]	157322	602312	1642	827	273858	900827	4579565	4231884	1345230	861011	1343719*	
	Std.dev [n]	584290	1546646	5993	2615	1070594	2983610	8631949	6950455	2351958	3308625	1792857	359734
	Std.dev%	371	257	365	316	391	331	188	164	175	129	133	357
	n	18	14	17	10	20	12	12	16	18	137	9	
ICEF	Mean [n]			5885532		0.00					1363617	2942766	
	Std.dev [n]			9888524		0.00					4789867	4161699	4944262
	Std.dev%			168		0					199	141	84
	n			3		3					6	2	
NF12	Mean [n]	82206	1218707	675836	351156	626996	532345	2716284	4991387	1178729	1127713	1374849*	
	Std.dev [n]	269251	3093636	1847659	1454246	2150013	1454651	7229510	11252436	3750802	4512043	1557972	1817306
	Std.dev%	328	254	273	414	343	273	266	225	318	122	113	343
	n	55	56	40	48	61	46	53	64	72	495	9	
EF12	Mean [n]	449366	549760	123123	136490	1172009	34649	1585460	4613765	889610	3158832	1061581*	
	Std.dev [n]	1266093	1448572	263594	526549	3587100	64750	4557582	11674795	4449109	14265334	1430126	1459081
	Std.dev%	282	263	214	386	306	187	287	253	500	168	135	302
	n	40	35	30	30	45	30	34	40	45	329	9	
EW34	Mean [n]	1778515	5955357	17063188	613513	4199743	113778	634395	3583248		1231358	4242717*	
	Std.dev [n]	6773639	11780030	32125118	1017577	10916977	172107	2224432	6918826		6574926	5568353	14686557
	Std.dev%	381	198	188	166	260	151	351	193		125	131	205
	n	22	21	22	25	26	22	24	24	0	186	8	
EF34	Mean [n]		3906779	8187196	153277	3067207	29613	25194	2446667		1781411	2545133	
	Std.dev [n]		10728560	16858825	227582	7012469	88471	64654	6327119		7112545	2954322	8032959
	Std.dev%		275	206	148	229	299	257	259		121	116	194
	n		21	22	21	22	22	22	22		152	7	

* final assessments not according to overall means but to the number of years above thresholds

Tab. A 33 *Dinophysis* spec. mean cell numbers/L (III-X) 2006-2014 (ass. level 100 n/L).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. Inter-annual
OFFO	Mean [n/L]			70	147	0	0				55	54	
	Std.dev [n/L]			140	254	0	0				139	70	99
	Std.dev%			200	173						251	129	187
	n			4	3	3	3				13	4	
OFFI	Mean [n/L]			135	1213	80	1047				647	619	
	Std.dev [n/L]			305	2818	106	1937				1720	595	1292
	Std.dev%			226	137	132	185				266	96	194
	n			8	6	3	6				23	4	
OCNF	Mean [n/L]			2173	1840	24	100				934	1034	
	Std.dev [n/L]			5696	2522	51	136				3016	1131	2101
	Std.dev%			262	137	211	136				323	109	186
	n			7	6	10	6				29	4	
OCEF	Mean [n/L]			30	613	147	22				190	203	
	Std.dev [n/L]			92	1041	382	35				565	279	388
	Std.dev%			307	170	261	159				298	138	224
	n			12	9	9	9				39	4	
ICNF	Mean [n/L]	176	117	277	217	283	61	20	88	378	185	180	
	Std.dev [n/L]	454	287	896	511	861	134	48	188	1386	704	119	530
	Std.dev%	258	246	324	235	304	222	242	214	367	380	66	268
	n	29	24	32	26	36	33	30	33	36	279	9	
ICEF	Mean [n/L]			70	27	13	80				49	48	
	Std.dev [n/L]			140	46	23	139				97	32	87
	Std.dev%			200	173	173	173				197	68	180
	n			4	3	3	3				13	4	
NF12	Mean [n/L]	16	8	22	10	17	12	9	14	4	12	12	
	Std.dev [n/L]	43	32	91	33	107	40	33	38	32	57	5	50
	Std.dev%	267	415	413	326	644	338	372	276	772	468	44	425
	n	80	64	68	66	90	75	80	88	96	707	9	
EF12	Mean [n/L]	15	2530	15	664	0	0	0	0		374	403*	
	Std.dev [n/L]	96	12661	91	2494	0	0	0	0		4393	890	1918
	Std.dev%	621	501	611	376						1174	221	527
	n	50	51	68	56	53	65	57	49		449	8	
EW34	Mean [n/L]	50	8	359	65	81	119	12	41	6	88	82	
	Std.dev [n/L]	218	36	2518	194	265	753	48	104	24	928	110	462
	Std.dev%	437	454	702	299	326	632	396	255	391	1054	134	432
	n	40	38	52	44	59	51	49	44	48	425	9	
EF34	Mean [n/L]		772	4415	589	0	2	0	0		879	826*	
	Std.dev [n/L]		3076	28244	1375	0	15	0	0		11284	215	4673
	Std.dev%		398	640	234		648				1284	26	480
	n		35	42	36	37	42	38	36		266	7	
Elbe-E	Mean [n/L]												
	Std.dev [n/L]												
	Std.dev%												
	n												
Weser-E	Mean [n/L]					0	0	0			0		
	Std.dev [n/L]					0	0	0			0		0
	Std.dev%												
	n					10	13	12			35	3	
Ems-E	Mean [n/L]					0					0	0	
	Std.dev [n/L]					0							
	Std.dev%												
	n					4					4	1	

* final assessments not according to overall means but to the number of years above thresholds

Tab. A 34 *Prorocentrum* spec. mean cell numbers/L (III-X) 2006-2014 (ass. level 10 000 n/L).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. inter-annual
OFFO	Mean [n/L]			944	0	0	0				290	236	
	Std.dev [n/L]			1887	0	0	0				1047	472	472
	Std.dev%			200							361	200	200
	n			4	3	3	3				13	4	
OFFI	Mean [n/L]			315	0	27694	13				3725	7005	
	Std.dev [n/L]			890	0	47864	33				17281	13793	12196
	Std.dev%			283		173	245				464	197	234
	n			8	6	3	6				23	4	
OCNF	Mean [n/L]			15264	13	3499	367				4969	4786	
	Std.dev [n/L]			34197	33	7604	507				17501	7159	10585
	Std.dev%			224	245	217	138				352	150	206
	n			7	6	10	6				29	4	
OCEF	Mean [n/L]			2416	13	18187	3794				5819	6103	
	Std.dev [n/L]			7959	28	30617	11174				17053	8206	12445
	Std.dev%			329	212	168	294				293	134	251
	n			12	9	9	9				39	4	
ICNF	Mean [n/L]	245	1679	15553	258	1210	181	1348	233	1749	2553	2495	
	Std.dev [n/L]	509	3820	34010	560	3285	329	3429	397	6932	12699	4940	5919
	Std.dev%	208	227	219	217	271	182	254	170	396	497	198	238
	n	29	24	32	26	36	33	30	33	36	279	9	
ICEF	Mean [n/L]			1530	0	0	680				628	553	
	Std.dev [n/L]			2981	0	0	1178				1709	726	1040
	Std.dev%			195			173				272	131	184
	n			4	3	3	3				13	4	
NF12	Mean [n/L]	381	402	152377	134	65	89	651	480	284	14743	17207	
	Std.dev [n/L]	2782	841	790584	281	176	136	2965	1488	922	245976	50689	88908
	Std.dev%	729	209	519	209	269	153	456	310	324	1668	295	353
	n	80	64	68	66	90	75	80	88	96	707	9	
EF12	Mean [n/L]	4	107	125	188	81	52	1259	98		243	239	
	Std.dev [n/L]	28	294	427	696	245	247	7455	363		2688	415	1220
	Std.dev%		275	341	370	302		592	370		1108	174	375
	n	50	51	68	56	53	65	57	49		449	8	
EW34	Mean [n/L]	8	301	7995	80	179	45	426	262	313	1156	1067	
	Std.dev [n/L]	27	775	32548	236	539	88	1043	879	521	11589	2601	4073
	Std.dev%	356	257	407	296	301	195	245	336	167	1003	244	284
	n	38	52	44	59	51	49	44	48	98	483	9	
EF34	Mean [n/L]		12	56	490	18	0	447	76		153	157	
	Std.dev [n/L]		59	165	1635	111	0	2245	330		1056	215	649
	Std.dev%		472	294	334	608		502	432		688	137	440
	n		35	42	36	37	42	38	36		266	7	
Elbe-E	Mean [n/L]												
	Std.dev [n/L]												
	Std.dev%												
	n												
Weser-E	Mean [n/L]					67	15	258			113		
	Std.dev [n/L]					213	55	769			465		346
	Std.dev%					316	361	299					325
	n					10	13	12			35	3	
Ems-E	Mean [n/L]					0					0	0	
	Std.dev [n/L]					0							
	Std.dev%												
	n					4					4	1	

* final assessments not according to overall means but to the number of years above thresholds

Tab. A 35 *Pseudo-nitzschia* spec. mean cell numbers/L (III-X) 2006-2014 (ass. level 10^6 n/L).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. inter-annual
OFFO	Mean [n/L]			21150	187	2307	440				7184	6021	
	Std.dev [n/L]			41793	323	3372	440				23090	11482	11482
	Std.dev%			198	173	146	100				321	191	154
	n			4	3	3	3				13	4	
OFFI	Mean [n/L]			4725	72390	13075	1940				22739	23032	
	Std.dev [n/L]			8563	109183	21991	4461				60845	36049	36049
	Std.dev%			181	151	168	230				268	157	183
	n			8	6	3	6				23	4	
OCNF	Mean [n/L]			3120	1147669	7591	3107				241462	290372	
	Std.dev [n/L]			3236	1992583	14812	5020				964862	503913	503913
	Std.dev%			103.7	173.6	195.1	161.6				400	174	159
	n			7	6	10	6				29	4	
OCEF	Mean [n/L]			8544	146869	4630	9376				39754	42355	
	Std.dev [n/L]			19103	343174	11029	25975				169122	99820	99820
	Std.dev%			224	234	238	277				425	236	243
	n			12	9	9	9				39	4	
ICNF	Mean [n/L]	69811	36184	11418	5725	12652	18562	303702	176810	15001	71545	72207	
	Std.dev [n/L]	171624	58250	23161	10214	31716	98872	860791	384263	43970	329182	186985	186985
	Std.dev%	246	161	203	178	251	533	283	217	293	460	259	263
	n	29	24	32	26	36	33	30	33	36	279	9	
ICEF	Mean [n/L]			138166	3267	25445	61062				63229	56985	
	Std.dev [n/L]			163233	2762	32765	105762				108787	76131	76131
	Std.dev%			118	85	129	173				172	134	126
	n			4	3	3	3				13	4	
NF12	Mean [n/L]	12433	193312	30003	9808	49177	5205	318707	335049	17110	109610	107867	
	Std.dev [n/L]	39970	667002	98321	20530	161716	24699	775495	899696	60612	478598	305338	305338
	Std.dev%	321	345	328	209	329	474	243	269	354	437	283	319
	n	80	64	68	66	90	75	80	88	96	707	9	
EF12	Mean [n/L]	19298	31686	2110176	22033	308404	2914	11879	127880		380367	329284	
	Std.dev [n/L]	41576	88305	7317878	58141	1224000	5861	42146	509780		2959119	1160961	1160961
	Std.dev%	215	279	347	264	397	201	355	399		778	353	307
	n	50	51	68	56	53	65	57	49		449	8	
EW34	Mean [n/L]	224296	50698	53054	14888	18650	1911	80313	507386	5773	98935	106330	
	Std.dev [n/L]	574129	84317	193414	20067	106969	4760	407465	1685089	11947	605704	343128	343128
	Std.dev%	256	166	365	135	574	249	507	332	207	612	323	310
	n	40	38	52	44	59	51	49	44	48	425	9	
EF34	Mean [n/L]		47918	1335444	17261	199579	2409	11645	40794		254826	236436	
	Std.dev [n/L]		154598	3748309	49059	716161	3788	36496	104823		1572281	687605	687605
	Std.dev%		323	281	284	359	157	313	257		617	291	282
	n		35	42	36	37	42	38	36		266	7	
Elbe-E	Mean [n/L]												
	Std.dev [n/L]												
	Std.dev%												
	n												
Weser-E	Mean [n/L]					967	238	487			532	564	
	Std.dev [n/L]					1786	415	1148			1192	1117	1117
	Std.dev%					185	174	236			224	198	198
	n					10	13	12			35	3	
Ems-E	Mean [n/L]					3027					3027	3027	
	Std.dev [n/L]					4120					4120	4120	4120
	Std.dev%					136					136	136	136
	n					4					4	1	

Tab. A 36 Secchi depth [m] during growing seasons 2006-2014, inter-annual means, assessment levels (1880+50%) and deviations [%].

Secchi depth	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Annual means	Ass. levels	% dev.	Final
OFFO	Mean [m]		12.57	12.00	13.50	9.60	11.17		10.00	12.63	11.74	11.64	10.6	11	
	Std.dev [m]		2.49	4.89	3.59	0.74	2.57		4.83	2.84	3.32	1.44			
	Std.dev%		19.8	40.7	26.6	7.7	23.0		48.3	22.5	28.3	12.4			
	n	0	7	5	5	5	3	0	4	4	33	7			
OFFI	Mean [m]	11.50	7.42	4.86	6.67	7.96	5.78	5.83	10.04	9.17	7.73	7.69	9.4	18	
	Std.dev [m]		3.18	2.25	2.48	3.21	1.94	0.58	3.79	3.27	3.31	2.20			
	Std.dev%		42.9	46.3	37.2	40.3	33.5	9.9	37.8	35.7	42.8	28.5			
	n	1	12	7	6	22	9	3	12	12	84	9			
OCNF	Mean [m]		6.67	4.88	6.33	6.04	6.17	5.67	7.40	6.83	6.15	6.25	7.9	21	
	Std.dev [m]		1.26	0.85	0.29	1.66	1.53	1.04	3.78	1.26	1.78	0.77			
	Std.dev%		18.9	17.5	4.6	27.5	24.8	18.4	51.1	18.4	29.0	12.3			
	n	0	3	4	3	34	3	3	5	3	58	8			
OCEF	Mean [m]	7.41	6.50	5.59	6.33	5.28	5.77	7.24	5.83	5.88	6.16	6.20	7.3	15	
	Std.dev [m]	1.02	1.66	2.37	1.85	1.12	0.90	1.65	1.89	0.77	1.66	0.73			
	Std.dev%	13.8	25.5	42.4	29.3	21.2	15.7	22.8	32.5	13.1	26.9	11.8			
	n	11	9	12	12	9	13	10	18	12	106	9			
ICNF	Mean [m]	3.23	3.82	3.00	3.13	3.08	3.08	2.70	2.64	3.26	3.04	3.10	4.1	25	
	Std.dev [m]	1.49	2.12	1.81	1.81	1.66	2.09	1.84	1.27	1.49	1.72	0.34			
	Std.dev%	46.0	55.5	60.5	57.9	53.9	68.0	68.3	48.0	45.7	56.7	11.1			
	n	48	26	53	49	79	52	50	71	37	465	9			
ICEF	Mean [m]	5.04	3.90	3.90	4.64	3.99	4.32	4.66	4.29	4.39	4.36	4.35	5.7	23	
	Std.dev [m]	1.41	1.44	1.53	1.66	1.55	1.91	2.05	1.48	1.70	1.69	0.39			
	Std.dev%	28.0	37.0	39.2	35.7	38.7	44.3	44.0	34.6	38.8	38.7	8.9			
	n	213	164	213	208	195	204	205	216	182	1800	9			
NF12	Mean [m]		3.32	2.44	2.23	3.25	2.40	2.69	3.26	2.50	2.84	2.76	4.1	32	
	Std.dev [m]		1.77	1.31	1.08	0.35	1.18	1.87	1.45		1.46	0.44			
	Std.dev%		53.5	53.7	48.3	10.9	49.3	69.5	44.5		51.4	16.1			
	n	0	6	5	3	2	6	10	11	1	44	8			
EF12	Mean [m]					0.64	0.76	0.81		0.70	0.70	0.69	4.6	85	
	Std.dev [m]					0.22	0.39	0.35		0.32	0.32	0.12			
	Std.dev%					34.2	51.8	43.5		46.4	180.7	17.9			
	n	0	0	0	0	32	36	35	0	28	131	4			
EW34	Mean [m]	1.40	0.80	1.08	1.12	1.16	0.85	1.00	1.10	1.15	1.09	1.07	2.8	62	
	Std.dev [m]	1.11	0.45	0.95	1.18	1.02	0.98	0.79	0.75	0.89	0.93	0.18			
	Std.dev%	78.9	55.5	88.5	104.7	87.4	115.5	79.1	67.7	77.6	85.7	16.6			
	n	52	33	45	47	59	50	63	68	64	481	9			
EF34	Mean [m]					0.70	0.63	0.71	0.70	0.66	0.66	0.66	3.2	78	
	Std.dev [m]					0.27	0.26	0.21	0.19	0.24	0.24	0.07			
	Std.dev%					39.1	40.9	29.2	27.0	35.6	35.6	10.4			
	n	0	0	0	0	32	36	35	35	28	166	5			
Elbe-E	Mean [m]							0.25	0.50		0.42	0.42	1.1	-47	
	Std.dev [m]														
	Std.dev%														
	n	0	0	0	0	0	0	1	1	0	2	2			

Tab. A 37 Mean seasonal oxygen concentrations near the bottom VII-X 2006-2014 (ass. level 6 mg/L).

O_2 conc.	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std.dev. inter-annual
OFFO	Mean [mg/L]	7.65	7.55	8.34	6.83	7.05	7.65	6.97	7.79	7.63	7.56	7.49	
	Std.dev [mg/L]	0.30	0.53	0.41	0.86	0.12	0.63	0.58	0.03	0.77	0.72	0.47	0.47
	Std.dev%	4.0	7.1	5.0	12.6	1.8	8.2	8.3	0.4	10.1	9.5	6.3	6.39
	n	6	4	5	6	4	4	4	2	4	39	9	
OFFI	Mean [mg/L]	7.50	7.17	7.30	7.27	6.80	7.13	7.34	6.50	6.96	7.14	7.11	
	Std.dev [mg/L]	0.83	0.38	1.11	0.42	0.89	1.08	0.57	0.81	0.94	0.84	0.31	0.78
	Std.dev%	11.0	5.4	15.1	5.7	13.0	15.1	7.8	12.4	13.5	11.8	4.3	12.23
	n	14	8	18	20	12	11	11	10	12	116	9	
OCNF	Mean [mg/L]	6.52	7.12	7.84	7.37	7.21	7.72	6.73	6.51	7.67	7.21	7.19	
	Std.dev [mg/L]	1.32	0.12	0.54	0.36	0.19	0.09	0.52	0.40	0.26	0.77	0.51	0.42
	Std.dev%	20.3	1.7	6.8	4.9	2.6	1.2	7,8	6.1	3.4	10.6	7.1	3.66
	n	6	3	6	6	3	3	3	3	4	37	9	
OCEF	Mean [mg/L]	7.30	7.54	7.65	7.27	6.99	7.51	7.41	7.33	7.65	7.42	7.41	
	Std.dev [mg/L]	0.36	0.32	0.97	0.25	0.33	0.19	0.12	0.28	0.18	0.49	0.21	0.33
	Std.dev%	4.9	4.2	12.7	3.5	4.7	2.5	1.6	3.9	2.3	6.6	2.8	4.48
	n	10	7	11	8	6	6	6	6	6	66	9	
ICNF	Mean [mg/L]	7.38	7.80	8.02	7.40	7.09	7.64	7.69	7.42	7.51	7.56	7.55	
	Std.dev [mg/L]	1.01	0.88	0.52	0.75	0.61	0.50	0.22	0.60	0.90	0.76	0.27	0.67
	Std.dev%	13.7	11.2	6.5	10.2	8.6	6.6	2.9	8.1	12.0	10.1	3.6	8.87
	n	28	21	23	22	15	16	15	14	14	168	9	
ICEF	Mean [mg/L]	7.47	7.02	7.92	7.47	6.69	7.48	7.38	6.97	7.73	7.41	7.35	
	Std.dev [mg/L]	0.21	0.63	0.60	0.51	0.49	0.27	0.30	0.63	0.38	0.57	0.39	0.45
	Std.dev%	2.8	8.9	7.5	6.8	7.3	3.6	4.0	9.1	4.9	7.6	5.3	6.31
	n	12	6	11	7	6	6	6	5	6	65	9	
NF12	Mean [mg/L]	7.18	8.40	8.25		7.84	8.06	7.76	8.38	7.93	7.88	7.97	
	Std.dev [mg/L]	1.17	0.10	0.27		0.50	0.30	0.34	0.17	0.21	0.67	0.40	0.38
	Std.dev%	16.3	1.2	3.3		6.4	3.8	4.4	2.0	2.7	8.5	5.0	5.01
	n	10	3	4	0	9	5	10	8	8	57	8	
EF12	Mean [mg/L]	5.09	8.30	8.16	7.57	8.63	8.53	8.43	8.10	7.43	7.86	7.80	
	Std.dev [mg/L]	2.13	1.43	0.97	2.62	1.01	0.96	0.59	0.73	0.85	1.40	1.10	1.26
	Std.dev%	41.8	17.3	11.9	34.6	11.8	11.3	7.0			17.9	14.1	19.38
	n	7	7	9	7	7	17	15	14	31	114	9	
EW34	Mean [mg/L]	5.67	8.27	7.50	7.73	7.77	7.82	8.23	8.10	8.02	7.92	7.68	
	Std.dev [mg/L]	0.49	0.67	1.05	0.03	0.57	0.64	0.60	0.62	0.83	0.79	0.79	0.61
	Std.dev%	8.6	8.2	14.1	0.4	7.3	8.2	7.3	7.7	10.3	9.9	10.3	8.02
	n	3	7	4	2	12	20	17	16	18	99	9	
EF34	Mean [mg/L]						8.38	8.50	7.62	7.12	7.78	7.91	
	Std.dev [mg/L]						0.95	0.30	0.52	1.29	1.13	7.17	0.76
	Std.dev%						11.3	3.5	6.9	18.1	14.5	90.6	9.94
	n	0	0	0	0	0	6	3	3	8	20	4	
Elbe-E	Mean [mg/L]					5.91	6.80	6.60	6.28		6.50	6.40	
	Std.dev [mg/L]					0.89	1.49	1.12	0.78		18.70	0.39	1.07
	Std.dev%					15.0	21.8	17.0	12.5		1.2	6.1	16.58
	n	0	0	0	0	17	34	34	17	0	102	4	
Weser-E	Mean [mg/L]					8.51	7.54				7.89	8.02	
	Std.dev [mg/L]					3.06	0.87				1.95	0.69	1.96
	Std.dev%					36.0	11.5				24.8	8.6	23.73
	n	0	0	0	0	8	14	0	0	0	22	2	
Ems-E	Mean [mg/L]	7.57	8.26	7.90	8.02	6.30	7.19	7.56	7.24		7.35	7.51	
	Std.dev [mg/L]	0.83	1.05	0.97	0.85	1.57	2.41	0.63	0.72		1.52	0.61	1.13
	Std.dev%	11.0	12.7	12.3	10.6	24.9	33.5	8.3	10.0		20.7	8.1	15.42
	n	13	10	10	13	23	22	12	14	0	117	8	

Tab. A 38 Mean seasonal oxygen saturation near the bottom VII-X 2006-2014 (ass. level 85 %).

O_2 sat%	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. inter-annual
.	Mean [%]	86.57	87.50	91.84	78.85	77.33	84.85	79.12	89.99	86.41	94.53	84.72	
OFFO	Std.dev	15.36	11.61	7.58	14.35	5.37	11.57	10.22	11.20	12.41	10.88	5.16	11.07
	Std.dev%	17.7	153.8	90.9	210.2	76.1	151.3	12.9	143.9	14.4	12.9	6.1	13.08
	n	6	4	5	6	4	4	4	2	4	39	9	
	Mean [%]	89.91	89.42	86.67	91.96	79.71	87.25	90.36	73.34	84.69	86.61	85.92	
OFFI	Std.dev	10.07	6.35	12.15	6.45	5.77	16.27	6.94	7.72	13.74	11.20	5.97	9.50
	Std.dev%	11.2	7.1	14.0	7.0	7.2	18.6	7.7	10.5	16.2	12.9	6.9	11.07
	n	14	8	18	20	12	11	11	10	12	116	9	
	Mean [%]	82.45	91.53	98.64	94.48	91.67	97.84	86.38	81.53	98.48	91.54	91.44	
OCNF	Std.dev	18.39	1.40	2.14	4.40	1.76	1.17	7.03	5.47	2.75	9.99	6.67	4.94
	Std.dev%	22.3	1.5	2.2	4.7	1.9	1.2	8.1	6.7	2.8	10.9	7.3	5.71
	n	6	3	6	6	3	3	3	3	4	37	9	
	Mean [%]	94.34	96.83	95.05	94.52	89.97	95.48	96.22	94.07	99.56	95.07	95.11	
OCEF	Std.dev	5.06	3.88	10.15	2.99	4.64	2.38	1.68	3.97	1.69	5.51	2.56	4.05
	Std.dev%	5.4	4.0	10.7	3.2	5.2	2.5	1.7	4.2	1.7	5.8	2.7	4.28
	n	10	7	11	8	6	6	6	6	6	66	9	
	Mean [%]	93.93	97.30	98.94	93.53	87.58	95.58	97.77	93.75	95.92	95.16	94.92	
ICNF	Std.dev	13.46	8.16	1.86	8.65	6.53	6.02	3.02	8.25	11.65	8.92	3.35	7.51
	Std.dev%	14.3	8.4	1.9	9.2	7.5	6.3	3.1	8.8	12.1	9.4	3.5	7.96
	n	28	21	23	22	15	16	15	14	14	168	9	
	Mean [%]	96.27	90.36	97.71	95.07	85.46	95.04	95.62	89.17	99.26	94.40	93.77	
ICEF	Std.dev	2.66	8.20	2.85	6.35	6.04	3.26	4.50	8.96	4.76	6.30	4.48	5.29
	Std.dev%	2.8	9.1	2.9	6.7	7.1	3.4	4.7	10.0	4.8	6.7	4.8	5.72
	n	12	6	11	7	6	6	6	5	6	65	9	
	Mean [%]	93.53	109.08	103.25		101.26	101.01	100.19	107.54	104.62	101.60	102.56	
NF12	Std.dev	15.43	1.48	4.07		3.50	4.75	3.87	2.31	3.31	8.28	4.83	4.84
	Std.dev%	16.5	1.4	3.9		3.5	4.7	3.9	2.1	3.2	8.2	4.7	4.89
	n	10	3	4	0	9	5	10	8	8	57	8	
	Mean [%]	65.7	100.7	105.0		109.4	102.6	106.7	103.9	95.8	99.10	98.25	
EF12	Std.dev	24.0	13.5	5.7		5.2	8.9	12.8	9.3	8.4	15.49	13.13	12.74
	Std.dev%	36.6	13.4	5.5		4.8	8.6	12.0	9.0	8.8	15.6	13.4	8.54
	n	7	7	9	0	7	17	15	14	31	114	8	
	Mean [%]	72.10	101.02	94.91	97.86	95.83	93.64	103.85	103.27	101.92	98.72	96.04	
EW34	Std.dev	2.87	6.77	11.82	0.42	5.41	6.90	7.78	8.73	10.93	10.04	9.72	6.85
	Std.dev%	4.0	6.7	12.5	0.40	5.6	7.4	7.5	8.5	10.7	10.2	10.1	7.85
	n	3	7	4	2	12	20	17	16	18	99	9	
	Mean [%]						96.6	109.6	98.0	91.4	96.68	98.91	
EF34	Std.dev						2.2	4.9	6.4	13.5	10.66	7.70	6.76
	Std.dev%						2.3	4.5	6.6	14.7	11.0	7.8	7.02
	n	0	0	0	0	0	6	3	3	8	20	4	
	Mean [%]					68.05	72.62	73.31	74.85		72.46	72.21	
Elbe-E	Std.dev					11.07	16.35	12.76	9.82		2.10	2.92	1.07
	Std.dev%					16.3	22.5	17.4	13.1		13.3	4.0	15.46
	n	0	0	0	0	17	34	34	17	0	102	4	
	Mean [%]					89.82	79.03				83.14	84.43	
Weser-	Std.dev					26.43	5.52				17.08	7.63	15.98
E	Std.dev%					29.4	7.0				20.5	9.0	18.21
	n	0	0	0	0	8	14	0	0	0	22	2	
	Mean [%]	91.22	89.98	91.80	96.28	70.62	80.50	89.50	86.10		84.87	87.00	
Ems-E	Std.dev	4.62	5.36	4.45	5.53	17.55	28.68	2.00	4.47		17.06	8.05	1.17
	Std.dev%	5.1	6.0	4.8	5.7	24.9	35.6	2.2	5.2		20.1	9.3	15.66
	n	13	10	10	13	23	22	12	14	0	117	8	

Tab. A 39 Mean seasonal oxygen depletion near the bottom VII-X 2006-2014.

O_2 depl.	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. inter-annual
OFFO	Mean [mg/L]	1.23	1.14	0.76	1.90	2.09	1.41	1.88	0.93	1.24	1.42	1.40	
	Std.dev [mg/L]	1.47	1.06	0.71	1.30	0.59	1.09	0.95	1.07	1.12	1.00	0.27	1.04
	Std.dev%	119.3	93.6	93.8	68.1	28.2	77.2	50.6	115.0	90.4	70.3	19.2	81.80
	n	6	4	5	6	4	4	4	2	4	39	9	
OFFI	Mean [mg/L]	0.86	0.87	1.12	0.65	1.70	1.11	0.79	2.36	1.31	1.13	1.20	
	Std.dev [mg/L]	0.85	0.52	0.99	0.53	0.53	1.44	0.57	0.69	1.19	0.97	0.34	0.81
	Std.dev%	99.0	60.6	88.6	80.8	31.0	130.0	71.5	29.1	91.4	85.3	28.0	75.79
	n	14	8	18	20	12	11	11	10	12	116	9	
OCNF	Mean [mg/L]	1.43	0.67	0.11	0.44	0.67	0.18	1.07	1.49	0.13	0.68	0.69	
	Std.dev [mg/L]	1.51	0.11	0.17	0.34	0.14	0.09	0.55	0.45	0.21	0.81	0.45	0.40
	Std.dev%	105.2	16.2	150.9	77.6	20.4	51.4	51.6	30.1	165.8	118.9	64.8	74.34
	n	6	3	6	6	3	3	3	3	4	37	9	
OCEF	Mean [mg/L]	0.45	0.26	0.39	0.43	0.79	0.37	0.30	0.47	0.05	0.39	0.39	
	Std.dev [mg/L]	0.40	0.30	0.79	0.23	0.36	0.19	0.13	0.31	0.13	0.43	0.20	0.32
	Std.dev%	88.5	117.5	201.0	53.3	45.5	51.3	43.0	65.7	286.3	109.1	51.5	105.79
	n	10	7	11	8	6	6	6	6	6	66	9	
ICNF	Mean [mg/L]	0.50	0.22	0.09	0.52	1.00	0.36	0.19	0.51	0.34	0.39	0.41	
	Std.dev [mg/L]	1.07	0.64	0.15	0.67	0.51	0.48	0.24	0.65	0.93	0.70	0.30	0.59
	Std.dev%	213.7	294.0	156.9	129.4	51.2	132.3	126.6	127.8	276.8	178.7	71.4	167.63
	n	28	21	23	22	15	16	15	14	14	168	9	
ICEF	Mean [mg/L]	0.30	0.76	0.19	0.40	1.15	0.40	0.35	0.86	0.07	0.45	0.50	
	Std.dev [mg/L]	0.21	0.64	0.22	0.50	0.47	0.26	0.35	0.71	0.37	0.49	0.18	0.41
	Std.dev%	67.9	83.9	117.3	125.1	40.8	63.7	99.4	82.5	534.9	109.8	36.3	135.05
	n	12	6	11	7	6	6	6	5	6	65	9	
NF12	Mean [mg/L]	0.51	-0.69	-0.24		-0.09	-0.07	0.00	-0.57	-0.33	-0.11	-0.18	
	Std.dev [mg/L]	1.17	0.11	0.32		0.28	0.38	0.30	0.18	0.25	0.63	0.33	0.37
	Std.dev%	226.4	-16.4	-134.2		-315	-569	-11873	-31	-74	-575.2	-179.8	-1598.35
	n	10	3	4	0	9	5	10	8	8	57	8	
EF12	Mean [mg/L]	2.54	-0.09	-0.40	0.37	-0.75	-0.20	-0.47	-0.29	0.33	0.06	0.12	
	Std.dev [mg/L]	1.74	1.09	0.47	2.10	0.47	0.72	1.06	0.71	0.63	1.18	0.57	1.00
	Std.dev%	68.4	-1187	-117.2	573.9	-62.6	-361.5	-227.6	-247.0		1845.9	493.1	-152.13
	n	7	7	9	7	7	17	15	14	31	114	9	
EW34	Mean [mg/L]	2.20	-0.08	0.40	0.18	0.35	0.54	-0.29	-0.23	-0.13	0.12	0.33	
	Std.dev [mg/L]	0.13	0.54	0.91	0.03	0.43	0.56	0.62	0.68	0.84	0.79	0.29	0.53
	Std.dev%	5.8	-720.8	226.3	18.4	125.1	104.1	-212.2	-290.4	-642.7	651.3	90.0	-175.60
	n	3	7	4	2	12	20	17	16	18	99	9	
EF34	Mean [mg/L]						0.3	-0.7	0.2	0.65	0.26	0.09	
	Std.dev [mg/L]						0.2	0.4	0.5	1.0	0.80	0.35	0.51
	Std.dev%						61.9	-51.2	298.1	153.8	302.4	367.6	115.67
	n	0	0	0	0	0	6	3	3	8	20	4	
Elbe-E	Mean [mg/L]					2.81	2.56	2.43	2.13		2.48	2.48	
	Std.dev [mg/L]					1.00	1.53	1.17	0.82		6.35	0.30	1.07
	Std.dev%					35.5	59.7	48.3	38.7		1.2	12.1	15.46
	n	0	0	0	0	17	34	34	17	0	102	4	
Weser-E	Mean [mg/L]					0.87	1.99				0.28	1.43	
	Std.dev [mg/L]					2.58	0.48				5.89	1.49	1.53
	Std.dev%					296.8	23.9				2101.3	104.3	160.34
	n	0	0	0	0	8	14	0	0	0	22	2	
Ems-E	Mean [mg/L]	0.73	0.92	0.70	0.32	2.67	1.86	0.89	1.17		1.36	1.16	
	Std.dev [mg/L]	0.36	0.51	0.38	0.47	1.60	2.66	0.16	0.37		1.58	0.87	1.19
	Std.dev%	49.8	55.2	53.7	144.2	60.1	142.8	17.5	31.1		115.8	74.9	16.08
	n	13	10	10	13	23	22	12	14	0	117	8	

Tab. A 40 Minimum annual oxygen saturation [%] VII-X 2006-2014 (ass. level 85 %).

Min O_2 sat %	year	2006	2007	2008	2009	2010	2011	2012	2013	2014		Means inter-annual
OFFO	Min [%]	71.81	76.45	83.02	65.62	71.85	73.52	69.94	82.07	71.76		74.01
	Std.dev											5.63
	Std.dev%											7.6
	n	6	4	5	6	4	4	4	2	4		9
OFFI	Min [%]	69.88	80.46	64.35	76.88	68.52	58.55	74.46	61.80	61.35		68.47
	Std.dev											7.61
	Std.dev%											11.1
	n	14	8	18	20	12	11	11	10	12		9
OCNF	Min [%]	60.80	90.12	95.93	88.17	90.38	96.72	78.36	75.75	94.49		85.64
	Std.dev											11.85
	Std.dev%											13.8
	n	6	3	6	6	3	3	3	3	4		9
OCEF	Min [%]	81.85	90.89	68.32	89.95	85.42	93.02	93.47	87.56	97.73		87.58
	Std.dev											8.60
	Std.dev%											9.8
	n	10	7	11	8	6	6	6	6	6		9
ICNF	Min [%]	56.94	68.63	93.92	69.40	73.17	84.43	92.46	80.89	60.74		75.62
	Std.dev [%]											13.17
	Std.dev%											17.4
	n	28	21	23	22	15	16	15	14	14		9
ICEF	Min [%]	92.37	77.33	91.76	85.97	74.47	89.00	89.30	75.44	91.82		85.27
	Std.dev											7.43
	Std.dev%											8.7
	n	12	6	11	7	6	6	6	5	6		9
NF12	Min [%]	68.48	107.74	98.09		96.89	95.33	95.94	103.82	100.12		95.80
	Std.dev [%]											11.82
	Std.dev%											12.3
	n	10	3	4	0	9	5	10	8	8		8
EF12	Min [%]	41.52	83.42	96.80	59.94	101.13	90.05	80.77	86.45	71.22		79.03
	Std.dev											18.83
	Std.dev%											23.8
	n	7	7	9	7	7	17	15	14	31		9
EW34	Min [%]	69.33	93.37	77.22	97.56	84.63	79.75	92.67	78.32	72.97		82.87
	Std.dev											9.80
	Std.dev%											11.8
	n	3	7	4	2	12	20	17	16	18		8
EF34	Min [%]						94.02	104.55	91.31	61.74		87.90
	Std.dev											18.35
	Std.dev%											20.9
	n	0	0	0	0	0	6	3	3	8		4
Elbe-E	Min [%]					44.26	42.90	40.68	60.99			47.21
	Std.dev											9.31
	Std.dev%											19.7
	n	0	0	0	0	17	34	34	17	0		4
Weser-E	Min [%]					62.05	66.69					64.37
	Std.dev											3.28
	Std.dev%											5.1
	n	0	0	0	0	8	14	0	0	0		2
Ems-E	Min [%]	84.66	79.05	85.60	89.19	40.27	30.72	86.29	78.53			71.79
	Std.dev											22.83
	Std.dev%											31.8
	n	13	10	10	13	12	12	12	14	0		8

Tab. A 41 Minimum oxygen concentrations VII-X 2006-2014 (ass. level 6mg/L).

O_2 min mg/L	year	2006	2007	2008	2009	2010	2011	2012	2013	2014		Means Inter-annual
OFFO	Min [mg/L]	6.51	6.86	7.73	5.76	6.90	6.83	6.27	7.76	6.50		6.79
	Std.dev [mg/L]											0.65
	Std.dev%											9.5
	n	6	4	5	6	4	4	4	2	4		9
OFFI	Min [mg/L]	5.67	6.63	5.20	6.43	5.73	5.23	6.04	5.19	5.34		5.72
	Std.dev [mg/L]											0.54
	Std.dev%											9.5
	n	14	8	18	20	12	11	11	10	12		9
OCNF	Min [mg/L]	5.00	7.01	7.11	6.86	7.05	7.66	6.14	6.11	7.31		6.69
	Std.dev [mg/L]											0.81
	Std.dev%											12.1
	n	6	3	6	6	3	3	3	3	4		9
OCEF	Min [mg/L]	6.50	7.09	5.28	6.93	6.62	7.33	7.25	6.87	7.35		6.80
	Std.dev [mg/L]											0.65
	Std.dev%											9.5
	n	10	7	11	8	6	6	6	6	6		9
ICNF	Min [mg/L]	4.57	5.36	7.27	5.33	5.70	6.71	7.29	6.45	4.91		5.95
	Std.dev [mg/L]											1.01
	Std.dev%											17.0
	n	28	21	23	22	15	16	15	14	14		9
ICEF	Min [mg/L]	7.10	6.03	7.11	6.76	5.81	6.99	6.95	5.99	7.12		6.65
	Std.dev [mg/L]											0.55
	Std.dev%											8.2
	n	12	6	11	7	6	6	6	5	6		9
NF12	Min [mg/L]	5.25	8.30	8.00		7.30	7.70	7.40	8.10	7.70		7.47
	Std.dev [mg/L]											0.96
	Std.dev%											12.8
	n	10	3	4	0	9	5	10	8	8		8
EF12	Min [mg/L]	3.11	6.39	6.54	4.40	7.70	7.20	7.30	6.80	5.32		6.08
	Std.dev [mg/L]											1.52
	Std.dev%											24.9
	n	7	7	9	7	7	17	15	14	31		9
EW34	Min [mg/L]	5.18	7.26	5.96	7.71	6.60	6.60	7.50	6.18	5.69		6.52
	Std.dev [mg/L]											0.86
	Std.dev%											13.1
	n	3	7	4	2	12	20	17	16	18		8
EF34	Min [mg/L]						7.70	8.20	7.06	4.60		6.89
	Std.dev [mg/L]											6.99
	Std.dev%											101.5
	n	0	0	0	0	0	6	3	3	8		4
Elbe	Min [mg/L]					3.90	4.00	3.70	5.10			4.18
	Std.dev [mg/L]											0.63
	Std.dev%											15.1
	n	0	0	0	0	17	34	34	17	0		4
Weser	Min [mg/L]					5.40	6.00					5.70
	Std.dev [mg/L]											0.42
	Std.dev%											7.4
	n	0	0	0	0	8	14	0	0	0		2
Ems	Min [mg/L]	6.51	7.29	6.54	7.10	3.50	2.80	6.87	6.20			5.85
	Std.dev [mg/L]											1.71
	Std.dev%											29.3
	n	13	10	10	13	12	12	12	14	0		8

Tab. A 42 Maximum oxygen depletion VII-X 2006-2014.

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means Inter-annual
OFFO	Max [mg/L]	2.55	2.11	1.57	3.01	2.69	2.45	2.69	1.69	2.55	2.37
	Std.dev [mg/L]										0.48
	Std.dev%										20.3
	n	6	4	5	6	4	4	4	2	4	9
OFFI	Max [mg/L]	2.45	1.62	2.89	1.94	2.64	3.70	2.08	3.21	3.36	2.65
	Std.dev [mg/L]										0.70
	Std.dev%										26.4
	n	14	8	18	20	12	11	11	10	11	9
OCNF	Mean [mg/L]	3.28	0.78	0.33	0.93	0.76	0.27	1.71	1.96	0.44	1.16
	Std.dev [mg/L]										0.99
	Std.dev%										84.9
	n	6	3	6	6	3	3	3	3	4	9
OCEF	Max [mg/L]	1.45	0.72	2.46	0.79	1.14	0.56	0.52	0.99	0.19	0.98
	Std.dev [mg/L]										0.67
	Std.dev%										68.1
	n	10	7	11	8	6	6	6	6	6	9
ICNF	Max [mg/L]	3.47	2.46	0.48	2.36	2.10	1.25	0.61	1.53	3.18	1.94
	Std.dev [mg/L]										1.05
	Std.dev%										54.4
	n	28	21	23	22	15	16	15	14	14	9
ICEF	Max [mg/L]	0.60	1.78	0.65	1.11	2.00	0.87	0.84	1.96	0.65	1.16
	Std.dev [mg/L]										0.59
	Std.dev%										50.4
	n	12	6	11	7	6	6	6	5	6	9
NF12	Max [mg/L]	2.43	-0.58	0.17		0.25	0.39	0.33	-0.28	0.00	0.34
	Std.dev [mg/L]										0.91
	Std.dev%										269.0
	n	10	3	4	0	9	5	10	8	8	8
EF12	Max [mg/L]	4.44	1.34	0.26	2.96	-0.07	0.83	1.74	1.08	2.16	1.64
	Std.dev [mg/L]										1.40
	Std.dev%										85.8
	n	7	7	9	7	7	17	15	14	31	9
EW34	Max [mg/L]	2.31	0.53	1.77	0.20	1.21	1.69	0.61	1.72	2.12	1.35
	Std.dev [mg/L]										0.75
	Std.dev%										55.6
	n	3	7	4	2	12	20	17	16	18	8
EF34	Max [mg/L]						0.51	-0.34	0.68	2.87	0.93
	Std.dev [mg/L]										1.37
	Std.dev%										147.3
	n	0	0	0	0	0	6	3	3	8	4
Elbe	Max [mg/L]					4.93	5.34	5.41	3.28		4.74
	Std.dev [mg/L]										1.00
	Std.dev%										21.0
	n	0	0	0	0	17	34	34	17	0	4
Weser	Max [mg/L]					3.32	3.01				3.16
	Std.dev [mg/L]										0.22
	Std.dev%										6.9
	n	0	0	0	0	8	14	0	0	0	2
Ems	Max [mg/L]	1.29	2.04	1.12	0.89	5.21	6.33	0	1.92		2.50
	Std.dev [mg/L]										2.08
	Std.dev%										83.3
	n	13	10	10	13	12	12	12	14	0	8

Tab. A 43 Mean concentrations of macrozoobenthos [AFD g/m²] in the GEEZ 2006-2014 and assessment levels

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means Single data	Means Inter annual	Assessment levels g/m²	Dev% of 1880
MZB AFDW	mean g/m²			5.03	6.65	9.30					14.82	6.99	2.62	167
OFFO	Std.dev			1.31	30.75	5.15					19.51	2.15		
1	Std.dev%			25.9	462.6	55.3					131.7	30.8		
	n Stations	0	0	2	3	3	0	0	0	0	8	3		
MZB AFDW	mean g/m²			4.75	7.70	3.62					5.41	5.36	2.56	109
OFFI	Std.dev			2.54	6.86	1.65					4.4	2.11		
2	Std.dev%			53.4	89.2	45.5					82.1	39.3		
	n Stations	0	0	3	4	4	0	0	0	0	11	3	3	
MZB AFDW	mean g/m²			7.11	8.20	2.54					12.17	5.95	3.10	92
ONCF	Std.dev			7.02	7.52	33.10					22.02	3.00		
3	Std.dev%			98.7	91.8	1304.8					181.0	50.5		
	n Stations	0	0	2	4	5	0	0	0	0	11.0	3		
MZB AFDW	mean g/m²			8.67	6.27	5.27					6.77	6.74	3.38	99
OCEF	Std.dev			3.77	4.80	1.92					3.69	1.75		
4	Std.dev%			43.5	76.5	36.4					54.6	25.9		
	n Stations	0	0	6	5	6	0	0	0	0	17	3		
MZB AFDW	mean g/m²	29.67	50.08	21.44	41.31	13.40	37.75	19.55	33.63		28.50	30.85	6.33	387
ICNF	Std.dev	11.70	27.75	25.12	89.63	9.66	20.81	13.76	11.17		42.71	12.29		
5	Std.dev%	39.4	55.4	117.2	217.0	72.1	55.1	70.4	33.2		149.8	39.8		
	n Stations	4	4	10	10	10	4	4	4	0	50	8		
MZB AFDW	mean g/m²			15.13	43.11	11.79					23.34	23.34	4.44	426
ICEF	Std.dev			7.98	21.38	11.01					19.10	17.20		
6	Std.dev%			52.8	49.6	93.3					81.8	73.7		
	n Stations	0	0	2	2	2	0	0	0	0	6	3		
MZB AFDW	mean g/m²	40.64	22.68	11.62	11.70	10.67	16.92	14.93	13.18		15.93	17.79	6.49	174
NF12	Std.dev	9.13	22.49	2.09	6.57	4.20	21.68	15.47	12.59		14.23	10.01		
7	Std.dev%	22.5	99.2	18.0	56.1	39.3	128.2	103.6	95.5		89.3	56.3		
	n Stations	2	2	3	3	5	5	5	4	0	29	8		
MZB AFDW	mean g/m²	20.77	33.61	27.98	5.46	9.20	15.19	9.23	22.77	24.44	28.90	19.81	6.49	205
EF12	Std.dev	9.72	70.83	67.67	3.99	9.04	22.58	8.82	22.52	17.00	51.25	9.55		
8	Std.dev%	46.8	210.8	241.9	73.1	98.3	148.7	95.6	98.9	69.6	177.3	48.2		
	n Stations	2	23	11	4	6	6	7	6	5	70	9		
MZB AFDW	mean g/m²	5.42	39.05	11.52	11.26	15.86	9.21	12.65	17.51	6.63	15.13	14.35	9.51	51
EW34	Std.dev	7.05	42.79	21.03	12.44	11.23	7.11	6.76	24.99	2.18	22.02	10.05		
9	Std.dev%	130.1	109.6	182.6	110.5	70.8	77.1	53.4	142.7	32.9	145.6	70.1		
	n Stations	7	8	20	8	8	8	8	8	2	77	9		
MZB AFDW	mean g/m²	0.70	7.86	7.25	6.18	8.86	6.33	8.48	5.26	21.61	7.97	8.06	9.51	-15
EF34*	Std.dev	0.95	7.39	7.33	6.64	7.80	3.88	3.05	6.02	27.43	9.53	5.63		
10	Std.dev%	135.8	94.0	101.1	107.4	88.1	61.3	36.0	114.5	126.9	119.6	69.9		
	n Stations	2	10	10	9	7	5	5	6	4	58	9		
MZB AFDW	mean g/m²		1.63	9.95	5.05	5.79	2.52	4.08	2.80	3.51	4.73	4.42	28.22	-84
Weser	Std.dev		2.08	16.65	3.36	3.80	1.68	5.62	2.18	4.55	7.77	2.61		
12	Std.dev%		128	167	67	66	67	138	78	130	164.2	59.2		
	n Stations	0	17	11	11	11	4	4	2	2	62	8		
MZB AFDW	mean g/m²	20.58	0.63	0.90	0.65	1.10	2.95	22.95	2.71	14.31	6.39	7.42	20.11	-63
Ems	Std.dev	45.02	0.21	1.20	0.55	1.16	3.20	43.72	2.66	14.83	21.05	9.21		
13	Std.dev%	218.8	32.9	132.9	84.7	105.2	108.4	190.5	98.5	103.6	329.5	124.1		
	n Stations	5	5	8	8	6	4	6	6	2	50	9		

* sublittoral

Data: LLUR (2006-2013 Mar, Apr, Aug, Sept, Oct), NLWKN (2006-2014, monthly. w/o Feb and June), BSH (2008-2011, March and Oct/Nov)

Tab. A 44 Annual means of analysed TOC concentrations in the GEEZ during growing season 2006-2014 and assessment levels.

TOC µM	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	St. dev. inter-annual	Assessment levels µM	St. Dev. %
ICNF	Mean µM							216.7		167.7	188.7	192.2		109.9	75
	Std.dev µM							53.49		38.69	50.4	34.6	46.09		
	Std.dev%							24.7		23.1	26.7	18.0	23.88		
	n							6	0	8	14	2			
ICEF	Mean [µM]							158.3		187.5	175.00	172.9		77.1	125
	Std.dev [µM]							38.19		58.33	49.30	20.6	48.26		
	Std.dev%							24.1		31.1	28.2	11.9	27.61		
	n							3	0	4	7	2			
EF12	Mean [µM]	439.3	429.4	402.4	325.5	301.1	375.3	325.7	314.3	305.9	349.1	357.7		97.5	267
	Std.dev [µM]	120.1	109.4	41.3	64.7	84.2	121.7	116.9	81.1	76.9	106.5	54.7	90.71		
	Std.dev%	27.3	25.5	10.3	19.9	28.0	32.4	35.9	25.8	25.2	30.5	15.3	25.58		
	n	17	15	17	16	15	32	37	14	47	210	9			
EW34	Mean [µM]	324.5		347.2	373.3	2057.3	390.7	370.8		339.6	580.7	600.5		163.5	268
	Std.dev [µM]	42.3		37.6	61.6	66.1	98.5	163.9		119.0	577.9	642.8	84.14		
	Std.dev%	13.0		10.8	16.5	3.2	25.2	44.2		35.1	99.5	107.0	21.15		
	n	16	0	3	20	16	26	28	0	16	125	7			
EF34	Mean [µM]						572.5	405.6		364.6	455.2	447.5		141.9	215
	Std.dev [µM]						269.0	177.6		122.0	217.8	110.1	189.54		
	Std.dev%						47.0	43.8		33.5	47.8	24.6	41.41		
	n						10	9	0	8	27	3			
Elbe-E	Mean [µM]	726.2	828.1	769.0	847.1	2042.9	821.3	645.3			963.9	954.3		472.2	102
	Std.dev [µM]	155.0	238.5	219.3	336.6	171.9	256.0	95.4			502.9	485.1	210.36		
	Std.dev%	21.3	28.8	28.5	39.7	8.4	31.2	14.8			52.2	50.8	24.68		
	n	68	68	67	85	68	68	48	0	0	472	7			
Weser-E	Mean [µM]	1406.9	898.6	1216.2	1248.1	752.6	1165.7				1124.3	1114.7		490.2	128
	Std.dev [µM]	496.5	170.2	413.1	315.0	232.4	577.2				454.3	242.5	367.39		
	Std.dev%	35.3	18.9	34.0	25.2	30.9	49.5				40.4	21.8	32.30		
	n	18	18	18	18	16	24	0	0	0	113	6			
Ems-E	Mean [µM]	3936.3	3421.9	2458.3		3503.5	4461.8				3630.6	3556.4		349.2	919
	Std.dev [µM]	1594.9	1871.2	676.3		2320.4	2376.9				2028.7	740.1	1767.96		
	Std.dev%	40.5	54.7	27.5		66.2	53.3				55.9	20.8	48.44		
	n	17	16	16	0	24	24	0	0	0	97	5			

Tab. A 45 Annual means and assessment levels of TN.

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Std. dev. inter-annual	Assessment levels µM	% dev.*	Final
OFFO	Mean [µM]	9.00	7.95	9.83	8.47	9.84	8.83	10.39	8.83	8.37	8.87	9.05		8.59	9	
	Std.dev [µM]	1.41	2.12	1.29	1.80	2.22	1.31	0.59	2.42	1.39	1.86	0.80	1.62			
	Std.dev%	15.7	26.7	13.1	21.3	22.6	14.9	5.7	27.4	16.7	8.8	8.84	18.23			
	n	11	12	4	9	5	8	6	8	8	71	9				
OFFI	Mean [µM]	10.74	9.62	11.23	9.28	11.13	8.76	10.11	11.52	10.50	10.34	10.32		9.47	8	
	Std.dev [µM]	2.53	2.44	3.39	1.83	2.00	2.25	2.00	3.70	4.08	2.88	0.95	2.69			
	Std.dev%	23.6	25.4	30.2	19.8	18.0	25.7	19.8	32.1	38.8	9.2	9.2	25.93			
	n	27	15	16	12	14	19	21	17	19	160	9				
OCNF	Mean [µM]	15.64	13.70	16.78	11.58	13.98	11.97	12.14	15.09	12.17	13.81	13.67		11.13	23	
	Std.dev [µM]	3.83	3.36	1.15	1.26	2.59	3.37	3.28	5.56	2.47	3.72	1.85	2.98			
	Std.dev%	24.5	24.5	6.8	10.9	18.5	28.2	27.0	36.8	20.3	13.6	13.6	21.95			
	n	22	7	5	6	8	11	11	9	9	88	9				
OCEF	Mean [µM]	16.05	14.64	14.70	13.35	17.95	16.21	15.88	16.88	15.91	15.74	15.73		12.25	28	
	Std.dev [µM]	4.89	5.83	9.25	3.10	5.13	6.33	8.81	3.93	6.77	6.24	1.35	6.00			
	Std.dev%	30.5	39.9	62.9	23.2	28.6	39.0	55.5	23.3	42.5	8.6	8.6	38.38			
	n	40	32	23	23	23	31	29	26	12	239	9				
ICNF	Mean [µM]	34.80	42.01	47.80	35.32	41.06	48.56	36.72	40.12	29.25	39.17	39.51		23.66	67	
	Std.dev [µM]	18.50	24.39	26.93	16.62	19.75	29.86	22.08	16.19	11.72	21.82	6.25	20.67			
	Std.dev%	53.2	58.1	56.3	47.1	48.1	61.5	60.1	40.4	40.1	15.8	15.8	51.64			
	n	92	56	33	27	38	42	48	45	33	414	9				
ICEF	Mean [µM]	22.12	31.62	37.41	22.26	28.36	27.54	25.82	29.80	25.15	27.52	27.79		16.12	72	
	Std.dev [µM]	7.76	17.11	17.51	7.28	9.21	13.62	10.76	10.13	10.45	12.24	4.81	11.54			
	Std.dev%	35.1	54.1	46.8	32.7	32.5	49.4	41.7	34.0	41.6	17.3	17.3	40.87			
	n	26	24	14	13	17	19	41	33	20	207	9				
NF12	Mean [µM]	39.66	47.28	62.89	47.71	47.71	62.42	47.92	48.93	26.77	49.17	47.92		25.05	91	
	Std.dev [µM]	19.23	23.46	23.54	31.50	24.26	31.87	29.28	21.94	3.46	25.83	10.91	24.35			
	Std.dev%	48.5	49.6	37.4	66.0	50.9	51.1	61.1	44.8	12.9	22.8	22.8	50.13			
	n	28	13	8	6	23	27	26	34	2	167	9				
EF12	Mean [µM]	66.74	77.39	79.20	55.09	57.61	57.50	50.68	50.71	53.68	61.28	60.96		22.75	168	
	Std.dev [µM]	30.02	34.64	32.74	17.98	25.10	22.79	25.57	21.33	22.07	28.53	10.94	25.95			
	Std.dev%	45.0	44.8	41.3	32.6	43.6	39.6	50.5	42.1	41.1	17.9	17.9	42.57			
	n	87	84	90	87	87	89	103	48	101	776	9				
EW34	Mean [µM]	69.26	63.54	45.89	57.76	102.80	72.15	53.28	65.13	60.56	64.33	65.60		36.38	80	
	Std.dev [µM]	36.41	55.69	38.73	33.82	90.95	53.22	35.56	36.87	30.92	48.17	16.09	45.80			
	Std.dev%	52.6	87.6	84.4	58.5	88.5	73.8	66.7	56.6	51.1	24.5	24.5	68.87			
	n	62	41	58	67	37	82	75	81	17	520	9				
EF34	Mean [µM]	82.26	80.32	78.15	63.76	70.39	75.33	67.37	70.59	68.56	71.94	72.97		34.28	113	
	Std.dev [µM]	31.66	39.54	34.76	23.23	36.97	32.94	33.32	31.59	34.31	33.67	6.33	33.15			
	Std.dev%	38.5	49.2	44.5	36.4	52.5	43.7	49.5	44.8	50.0	8.7	8.7	45.46			
	n	6	55	59	58	57	60	62	61	49	467	9				
Elbe-E	Mean [µM]	265.2	229.3	213.8	214.4	249.3	267.7	217.7	264.5	170.3	238.46	232.46		102.69	126	
	Std.dev [µM]	88.0	89.1	72.8	77.6	67.1	89.9	63.3	69.7	98.7	81.81	32.39	79.58			
	Std.dev%	33.2	38.9	34.1	36.2	26.9	33.6	29.1	26.3	58.0	13.9	13.9	35.13			
	n	109	104	101	118	84	86	74	70	5	751	9				
Weser-E	Mean [µM]	368.1	390.3	332.0	342.3	304.3	268.6	273.3	293.2		318.06	321.51		107.13	200	
	Std.dev [µM]	96.4	71.5	64.8	73.8	84.7	79.7	78.4	88.6		89.50	44.18	79.72			
	Std.dev%	26.2	18.3	19.5	21.6	27.8	29.7	28.7	30.2		13.7	13.7	25.24			
	n	26	25	25	24	23	33	35	21	0	212	8				
Ems-E	Mean [µM]	396.0	444.7	347.5	447.2	432.6	385.6	380.5	515.1		421.00	418.66		78.80	431	
	Std.dev [µM]	254.9	216.2	207.8	360.7	269.0	254.6	299.5	466.4		311.42	52.25	291.16			
	Std.dev%	64.4	48.6	59.8	80.7	62.2	66.0	78.7	90.5		12.5	12.5	68.87			
	n	53	51	53	65	67	72	69	73	0	503	8				

Tab. A 46 Annual means and assessment levels of TP.

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual	Assessment levels µM	St. dev. %*	Final
OFFO	Mean [µM]	0.46	0.46	0.62	0.62	0.55	0.53	0.65	0.64	0.54	0.55	0.56	0.78	-28	
	Std.dev [µM]	0.23	0.22	0.14	0.08	0.18	0.13	0.19	0.32	0.16	0.20	0.07			
	Std.dev%	50.2	47.3	22.4	12.1	32.0	24.3	29.8	50.0	29.7	36.2	13.2			
	n	11	12	5	10	5	7	8	7	7	72	9			
OFFI	Mean [µM]	0.61	0.63	0.83	0.70	0.68	0.62	0.88	0.75	0.65	0.70	0.70	0.79	-11	
	Std.dev [µM]	0.27	0.21	0.45	0.08	0.13	0.09	0.26	0.30	0.19	0.26	0.10			
	Std.dev%	45.4	32.9	54.4	12.2	19.8	14.0	29.3	40.0	28.9	36.9	13.7			
	n	29	16	15	13	16	21	20	17	19	166	9			
OCNF	Mean [µM]	0.73	0.73	1.17	0.72	0.65	0.67	0.81	0.65	0.75	0.74	0.76	0.81	-6	
	Std.dev [µM]	0.17	0.26	0.67	0.13	0.09	0.06	0.22	0.23	0.16	0.25	0.16			
	Std.dev%	23.8	35.6	57.8	17.7	14.3	8.4	26.9	35.3	21.6	33.4	20.9			
	n	23	7	5	6	8	10	10	10	9	88	9			
OCEF	Mean [µM]	0.79	0.79	0.71	0.53	0.63	0.75	0.74	0.71	0.80	0.72	0.72	0.82	-12	
	Std.dev [µM]	0.43	0.21	0.45	0.15	0.16	0.30	0.31	0.22	0.14	0.31	0.09			
	Std.dev%	54.2	27.0	63.4	27.9	25.6	39.6	42.0	31.2	17.5	42.5	12.5			
	n	40	33	22	21	22	30	29	25	11	233	9			
ICNF	Mean [µM]	1.57	1.79	1.83	1.57	1.43	1.73	1.90	1.57	1.42	1.65	1.65	0.93	77	
	Std.dev [µM]	0.78	0.89	0.90	0.88	0.52	1.04	1.36	0.74	0.64	0.90	0.17			
	Std.dev%	49.5	50.0	49.3	56.2	36.5	60.0	71.2	47.3	45.3	54.5	10.5			
	n	91	58	34	29	37	43	48	42	34	416	9			
ICEF	Mean [µM]	1.08	1.24	1.11	0.82	1.18	1.12	1.01	1.09	1.16	1.09	1.09	0.86	27	
	Std.dev [µM]	0.34	0.43	0.44	0.20	0.45	0.62	0.33	0.77	0.43	0.49	0.12			
	Std.dev%	31.6	34.9	39.9	24.2	37.7	55.1	32.7	70.9	37.3	44.7	10.9			
	n	26	25	14	14	15	20	41	32	20	207	9			
NF12	Mean [µM]	1.89	1.90	3.12	1.99	2.23	2.54	1.97	1.80	1.44	2.08	2.10	0.95	121	
	Std.dev [µM]	0.79	0.85	1.30	1.60	1.02	1.51	0.95	0.93	0.37	1.10	0.48			
	Std.dev%	42.0	45.0	41.9	80.7	45.9	59.6	48.3	52.0	25.7	53.1	23.1			
	n	28	14	9	6	23	26	26	35	6	173	9			
EF12	Mean [µM]	5.19	2.66	3.88	2.49	2.85	3.08	2.98	2.69	3.17	3.30	3.22	0.92	250	
	Std.dev [µM]	3.35	1.02	1.99	0.82	0.92	0.95	1.57	1.41	1.13	1.91	0.84			
	Std.dev%	64.5	38.2	51.2	33.0	32.3	30.9	52.6	52.2	35.8	57.7	26.1			
	n	87	84	91	70	88	37	47	48	97	649	9			
EW34	Mean [µM]	2.70	2.99	3.17	2.44	3.08	3.24	2.77	2.68	3.30	2.89	2.93	1.06	176	
	Std.dev [µM]	1.58	1.20	2.05	1.42	1.76	2.34	1.63	1.83	1.81	1.81	0.30			
	Std.dev%	58.6	40.0	64.9	58.4	57.3	72.4	58.9	68.3	54.9	62.8	10.1			
	n	64	41	56	55	46	84	76	83	16	521	9			
EF34	Mean [µM]	4.10	3.38	3.53	2.83	3.30	4.37	2.47	3.30	3.62	3.34	3.43	1.04	230	
	Std.dev [µM]	1.47	1.71	1.44	0.83	1.19	2.49	1.45	1.42	1.47	1.45	0.58			
	Std.dev%	35.9	50.7	40.7	29.3	36.2	57.0	58.6	43.1	40.5	43.3	16.9			
	n	6	55	59	58	57	12	11	61	49	368	9			
Elbe-E	Mean [µM]	6.84	7.07	6.53	6.76	7.24	6.21	7.89	6.03	7.36	6.83	6.88	1.73	298	
	Std.dev [µM]	4.31	3.71	3.02	3.93	3.16	3.23	4.02	3.32	4.43	3.65	0.58			
	Std.dev%	63.1	52.5	46.3	58.2	43.6	52.0	51.0	55.1	60.2	53.4	8.5			
	n	107	104	103	118	104	89	75	71	5	776	9			
Weser-E	Mean [µM]	15.32	7.92	11.13	14.23	6.75	14.98	15.12	7.98		12.04	11.68	1.78	556	
	Std.dev [µM]	6.07	2.06	5.20	5.50	2.99	10.52	9.22	6.49		7.66	3.68			
	Std.dev%	39.6	25.9	46.7	38.6	44.2	70.3	61.0	81.2		63.6	31.5			
	n	26	25	26	24	24	35	36	24	0	220	8			
Ems-E	Mean [µM]	29.95	22.22	20.04	36.40	31.46	35.45	35.05	43.27		32.60	31.73	1.49	2030	
	Std.dev [µM]	25.31	17.51	16.98	37.48	29.35	36.84	43.73	44.55		34.75	7.66			
	Std.dev%	84.5	78.8	84.7	103.0	93.3	103.9	124.8	103.0		106.6	24.1			
	n	54	51	51	65	67	70	72	72	0	502	8			

SD = standard deviation

Tab. A 47 Silicate concentrations (Si) [µM] during winter 2006-2014, inter-annual means.

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means Inter-annual
	Mean [µM]	2.51	1.30	3.20	2.38	2.30	2.10	2.64	2.89	2.76	2.43	2.45
OFFO	Std.dev [µM]	1.01	0.50	0.14	0.66	1.15	1.01	0.74	0.92	0.51	0.84	0.54
	Std.dev%	40.3	38.2	4.4	27.9	50.1	48.1	27.9	31.8	18.3	34.8	22.2
	n	5	4	2	6	3	5	7	3	6	41	9
	Mean [µM]	5.37	3.95	4.67	3.27	4.99	3.58	3.76	5.06	4.13	4.24	4.31
OFFI	Std.dev [µM]	1.22	2.47	1.26	1.14	1.27	1.18	1.03	0.67	2.11	1.54	0.74
	Std.dev%	22.7	62.5	27.1	35.0	25.5	33.1	27.3	13.2	51.1	36.4	17.2
	n	9	6	6	8	9	14	14	9	15	90	9
	Mean [µM]	7.54	8.27	4.45	4.78	6.17	4.43	4.20	5.00	4.21	6.08	5.45
OCNF	Std.dev [µM]	1.63	4.26	0.35	0.34	0.15	1.36	1.78	0.10	2.28	2.64	1.53
	Std.dev%	21.7	51.6	7.9	7.1	2.5	30.6	42.4	1.9	54.0	43.4	28.0
	n	17	8	2	3	3	6	6	3	6	54	9
	Mean [µM]	6.78	7.80	5.88	3.40	5.93	4.64	6.07	7.62	6.11	6.12	6.02
OCEF	Std.dev [µM]	2.13	3.73	2.06	0.88	2.75	2.07	3.67	1.70	3.51	2.88	1.38
	Std.dev%	31.4	47.8	35.0	25.9	46.5	44.6	60.6	22.3	57.4	47.1	22.8
	n	21	14	9	10	7	14	14	10	9	108	9
	Mean [µM]	18.70	20.97	18.30	14.92	19.09	24.71	19.69	20.63	14.74	19.05	19.08
ICNF	Std.dev [µM]	11.43	13.35	9.61	8.72	8.50	18.16	10.57	8.14	11.56	12.04	3.06
	Std.dev%	61.1	63.7	52.5	58.5	44.5	73.5	53.7	39.4	78.4	63.2	16.0
	n	55	41	39	34	27	44	39	34	51	364	9
	Mean [µM]	4.45	6.91	9.19	8.61	10.32	7.86	7.43	7.75	7.75	9.35	2.45
ICEF	Std.dev [µM]	5.79	5.30	4.02	1.99	4.30	4.71	6.16	6.85	4.30	5.85	0.54
	Std.dev%	130.1	76.7	43.8	23.1	41.7	59.9	82.9	88.4	55.5	62.5	22.2
	n	91	87	111	108	94	112	125	110	110	948	9
	Mean [µM]	24.75	24.42	27.93	22.07	23.96	27.94	27.95	26.31	29.13	25.86	26.05
NF12	Std.dev [µM]	9.21	11.47	7.00	9.06	8.67	11.24	9.11	8.28	17.19	10.02	2.37
	Std.dev%	37.2	47.0	25.0	41.1	36.2	40.2	32.6	31.5	59.0	38.7	9.1
	n	60	58	58	48	45	52	48	50	21	440	9
	Mean [µM]	49.14	33.61	24.93	24.76	28.87	28.41	27.44	24.42	39.36	31.70	31.22
EF12	Std.dev [µM]	26.13	12.00	9.70	12.62	8.35	12.66	8.30	10.76	10.19	16.22	8.28
	Std.dev%	53.2	35.7	38.9	51.0	28.9	44.6	30.2	44.1	25.9	51.2	26.5
	n	38	36	38	37	38	22	24	6	14	253	9
	Mean [µM]	51.73	66.83	47.15	33.24	48.95	44.76	59.53	52.14	34.41	47.50	48.75
EW34	Std.dev [µM]	33.98	23.20	27.55	22.85	21.52	27.22	32.09	32.16	21.95	28.50	10.77
	Std.dev%	65.7	34.7	58.4	68.7	44.0	60.8	53.9	61.7	63.8	60.0	22.1
	n	35	22	35	29	38	36	25	37	44	301	9
	Mean [µM]	113.2	44.41	37.68	30.16	36.75	34.25	38.42	47.69	54.08	42.09	48.52
EF34	Std.dev [µM]	52.68	23.19	16.54	13.33	15.15	7.57	9.31	13.67	9.32	23.61	25.32
	Std.dev%	46.5	52.2	43.9	44.2	41.2	22.1	24.2	28.7	17.2	56.1	52.2
	n	6	21	24	23	22	13	17	17	7	150	9
	Mean [µM]	158.7	167.8	163.3	109.7	176.32	106.08	129.0	146.1	124.16	147.73	142.35
Elbe-E	Std.dev [µM]	42.00	34.53	31.53	50.29	28.01	46.04	40.06	38.43	75.25	46.04	26.01
	Std.dev%	26.5	20.6	19.3	45.8	15.9	43.4	31.1	26.3	60.6	31.2	18.3
	n	20	20	19	17	19	11	13	11	4	134	9
	Mean [µM]	89.39	114.5	95.40	123.5	123.40	116.31	103.3	127.7		109.29	111.69
Ems-E	Std.dev [µM]	26.93	26.64	29.08	28.31	19.59	24.02	27.34	26.95		28.53	14.11
	Std.dev%	30.1	23.3	30.5	22.9	15.9	20.7	26.5	21.1		26.1	12.6
	n	11	13	11	5	5	9	8	8	0	70	8

Tab. A 48 Ratios of DIN/Si [M/M] during winter 2006-2014, inter-annual means (1:1 M/M ass. level).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual
OFFO	Mean [µM]	1.92	1.39	1.06	2.33	1.95	2.28	1.53	1.66	0.87	1.77	1.67
	Std.dev [µM]		0.33	0.17	0.58	0.28	1.86	0.50	0.27	0.11	0.88	0.51
	Std.dev%	0.0	23.7	16.5	24.9	14.3	81.4	32.9	16.3	13.1	49.7	30.5
	n	1	4	2	6	3	5	7	3	2	33	9
OFFI	Mean [µM]	0.74	0.74	1.09	1.30	1.00	0.85	1.03	1.41	0.59	1.00	0.97
	Std.dev [µM]	0.01	0.41	0.23	0.44	0.18	0.34	0.48	0.23	0.65	0.43	0.27
	Std.dev%	0.9	55.1	20.7	33.8	17.9	39.7	46.4	16.3	110.7	43.2	27.8
	n	3	6	6	8	9	14	14	9	6	75	9
OCNF	Mean [µM]	1.38	1.48	1.54	0.97	1.04	0.96	0.94	1.44	0.81	1.22	1.17
	Std.dev [µM]	0.34	0.53	0.07	0.04	0.18	0.47	0.49	0.12	0.11	0.43	0.28
	Std.dev%	24.7	36.0	4.9	4.1	17.1	49.0	52.4	8.5	14.1	35.6	24.0
	n	14	8	2	3	3	6	6	3	3	48	9
OCEF	Mean [µM]	2.13	1.37	1.00	1.99	1.55	1.59	1.17	1.45	1.46	1.54	1.52
	Std.dev [µM]	2.84	0.45	0.70	1.28	0.29	0.64	0.30	0.19	0.70	1.26	0.36
	Std.dev%	133.6	32.5	69.8	64.0	18.7	40.1	25.4	13.2	47.7	81.8	23.4
	n	15	14	9	9	7	14	14	9	8	99	9
ICNF	Mean [µM]	1.86	1.35	1.55	1.38	1.56	1.47	1.33	1.46	1.41	1.48	1.49
	Std.dev [µM]	1.15	0.50	0.48	0.49	0.31	0.32	0.35	0.30	0.58	0.57	0.16
	Std.dev%	62.0	37.3	31.1	35.9	19.9	22.0	26.6	20.5	41.1	38.6	10.9
	n	35	40	39	34	27	43	39	34	51	342	9
ICEF	Mean [µM]	3.77	1.29	1.25	1.57	1.62	1.54	1.44	1.27	1.41	1.64	1.68
	Std.dev [µM]	3.39	0.49	0.59	0.70	0.46	0.50	0.55	0.47	0.53	1.33	0.79
	Std.dev%	89.9	37.7	47.5	44.5	28.3	32.2	38.2	36.9	37.5	81.1	47.0
	n	85	86	111	107	94	112	125	110	109	939	9
NF12	Mean [µM]	0.50	0.58	0.59	0.58	1.68	1.77	1.66	2.26	2.10	1.00	1.30
	Std.dev [µM]	0.32	0.50	0.60	0.52	0.22	0.41	0.30	0.83	1.06	0.82	0.73
	Std.dev%	63.1	87.0	101.8	89.8	13.3	23.0	18.3	37.0	50.4	81.9	55.9
	n	54	58	57	47	44	20	11	16	21	328	9
EF12	Mean [µM]	0.89	1.32	1.84	1.71	1.46	1.35	1.51	1.34	1.33	1.44	1.42
	Std.dev [µM]	0.51	0.71	0.91	0.64	0.47	0.37	0.50	0.33	0.24	0.67	0.27
	Std.dev%	56.8	54.0	49.4	37.6	32.3	27.7	33.2	24.2	18.2	46.6	19.0
	n	37	36	38	37	38	20	24	6	14	250	9
EW34	Mean [µM]	1.43	1.16	1.24	1.51	1.38	1.55	1.29	1.33	1.24	1.35	1.67
	Std.dev [µM]	1.13	0.33	0.46	0.89	0.20	0.36	0.25	0.45	0.40	0.57	0.51
	Std.dev%	38.6	15.7	46.8	12.5	20.1	19.2	21.8	19.3	16.6	41.9	30.5
	n	25	17	30	29	33	32	24	35	37	262	9
EF34	Mean [µM]	0.46	1.62	1.63	1.97	1.70	1.47	1.57	1.31	1.41	1.58	1.46
	Std.dev [µM]	0.08	0.41	0.62	1.45	0.91	0.38	0.32	0.28	0.15	0.79	0.42
	Std.dev%	17.1	25.4	38.0	73.2	53.7	26.2	20.2	21.5	10.6	50.3	28.8
	n	6	21	24	23	22	14	19	19	7	155	9
Elbe-E	Mean [µM]	1.56	1.44	1.35	1.61	1.44	2.17	1.26	0.99	1.28	1.47	1.45
	Std.dev [µM]	0.13	0.23	0.29	0.33	0.25	2.25	0.23	0.53	0.11	0.76	0.33
	Std.dev%	8.7	15.9	21.5	20.8	17.6	103.4	18.2	53.7	8.5	51.3	22.4
	n	18	20	19	17	10	11	11	10	4	120	9
Ems-E	Mean [µM]	1.60	2.11	1.58	1.26	1.82	1.70	1.64	1.73		1.71	1.68
	Std.dev [µM]	0.30	0.55	0.44	0.38	0.34	0.62	0.69	0.46		0.52	0.24
	Std.dev%	19.1	25.9	27.8	30.3	18.5	36.4	42.1	26.5		30.5	14.3
	n	11	13	11	5	5	9	8	8	0	70	8

Tab. A 49 DIP/Si [M/M] ratios during winter 2006- 2014 (0.06 M/M as ass. level).

	year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Means single data	Means inter-annual
OFFO	Mean [µM]	0.23	0.18	0.12	0.20	0.21	0.21	0.15	0.16	0.14	0.18	0.18
	Std.dev [µM]	0.10	0.03	0.01	0.04	0.04	0.18	0.04	0.02	0.04	0.08	0.05
	Std.dev%	44.3	15.9	8.1	18.3	19.3	86.2	26.4	10.5	28.2	44.2	30.8
	n	4	4	2	6	3	5	7	3	6	40	9
OFFI	Mean [µM]	0.14	0.11	0.12	0.11	0.11	0.11	0.09	0.09	0.10	0.12	0.11
	Std.dev [µM]	0.05			0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.01
	Std.dev%	35.3			23.4	29.2	32.7	38.1	29.2	29.8	31.8	7.8
	n	2	1	1	6	6	65	7	22	13	123	9
OCNF	Mean [µM]	0.08	0.09	0.09	0.09	0.08	0.10	0.08	0.10	0.11	0.09	0.09
	Std.dev [µM]	0.02	0.03	0.01	0.05	0.01	0.02	0.02	0.00	0.04	0.03	0.02
	Std.dev%	23.7	35.1	6.6	61.3	14.6	17.8	29.0	2.1	39.5	30.6	18.8
	n	17	8	2	4	3	6	6	3	6	55	9
OCEF	Mean [µM]	0.11	0.09	0.10	0.10	0.11	0.11	0.09	0.08	0.09	0.10	0.10
	Std.dev [µM]	0.08	0.03	0.03	0.01	0.06	0.07	0.04	0.02	0.03	0.05	0.02
	Std.dev%	79.4	34.7	32.2	13.9	60.2	64.2	41.6	30.0	37.2	54.1	24.6
	n	21	14	9	10	7	14	14	10	9	108	9
ICNF	Mean [µM]	0.06	0.05	0.07	0.08	0.06	0.06	0.06	0.06	0.08	0.07	0.07*
	Std.dev [µM]	0.04	0.02	0.03	0.04	0.02	0.03	0.03	0.02	0.05	0.03	0.01
	Std.dev%	56.8	45.1	45.9	52.9	39.1	50.9	44.9	36.1	57.7	52.7	13.9
	n	53	40	38	34	27	44	39	34	51	360	9
ICEF	Mean [µM]	0.11	0.06	0.10	0.10	0.09	0.09	0.11	0.09	0.10	0.09	0.09
	Std.dev [µM]	0.06	0.04	0.04	0.04	0.06	0.05	0.09	0.09	0.06	0.06	0.02
	Std.dev%	58.5	57.9	44.7	36.6	72.6	53.3	80.3	100.3	54.3	65.9	20.3
	n	90	85	111	108	94	110	124	105	110	439	9
NF12	Mean [µM]	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.07	0.04	0.04
	Std.dev [µM]	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.06	0.02	0.02
	Std.dev%	31.7	37.3	40.7	25.4	42.2	53.7	43.0	45.9	88.6	54.9	40.1
	n	60	58	58	48	45	51	48	50	21	252	9
EF12	Mean [µM]	0.03	0.04	0.05	0.07	0.04	1.33	0.04	0.05	0.04	0.15	0.19
	Std.dev [µM]	0.01	0.02	0.02	0.05	0.01	5.90	0.02	0.02	0.02	1.70	1.96
	Std.dev%	52.7	52.4	33.5	80.8	32.9	442.9	42.3	52.7	44.6	1123.9	1048.1
	n	38	36	38	37	38	21	24	6	14	297	9
EW34	Mean [µM]	0.04	0.03	0.04	0.07	0.03	1.59	0.03	0.04	0.05	0.23	0.21
	Std.dev [µM]	0.03	0.01	0.02	0.05	0.01	6.49	0.01	0.02	0.03	2.29	2.15
	Std.dev%	87.2	42.7	50.5	69.6	45.1	406.9	39.6	60.8	49.2	991.1	1004.5
	n	33	21	35	29	37	36	25	37	44	297	9
EF34	Mean [µM]	0.01	0.03	0.04	0.07	0.03	0.04	0.04	0.03	0.03	0.04	0.04
	Std.dev [µM]	0.00	0.02	0.02	0.09	0.01	0.02	0.02	0.01	0.00	0.04	0.03
	Std.dev%	16.2	55.6	41.7	135.3	22.7	38.0	41.7	38.7	18.6	101.4	76.8
	n	6	21	24	23	22	12	17	17	7	149	9
Elbe-E	Mean [µM]	0.01	0.01	0.01	0.03	0.01	0.03	0.02	0.02	0.02	0.02	0.02
	Std.dev [µM]	0.01	0.01	0.01	0.03	0.00	0.04	0.01	0.01	0.02	0.02	0.01
	Std.dev%	51.3	56.7	58.4	88.4	40.5	124.9	57.0	57.6	85.0	104.9	64.8
	n	20	20	19	17	18	11	11	11	4	131	9
Ems-E	Mean [µM]	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01		0.02	0.02
	Std.dev [µM]	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.00		0.01	0.00
	Std.dev%	24.2	56.9	28.4	63.9	26.9	43.5	43.5	28.9		45.9	19.9
	n	11	13	11	5	5	9	8	7	0	69	8