The Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area

OSPAR Agreement 2022-07 (Replaces Agreement 2013-08)

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1. Introduction and context

1.1 The OSPAR Commission's vision is a clean, healthy, and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification. To deliver this vision for the North-East Atlantic OSPAR is guided by 12 strategic objectives, grouped under four themes. The first theme concerns the achievement of Clean Seas, and the first objective under this theme is the commitment by OSPAR to "Tackle eutrophication, through limiting inputs of nutrients and organic matter to levels that do not give rise to adverse effects on the marine environment". In order to deliver the objective, OSPAR is guided by the ecosystem approach. This is the comprehensive integrated management of human activities based on the best available scientific knowledge of the ecosystem and its dynamics, to identify and take action on drivers, activities and pressures that adversely affect the health of marine ecosystems. The ecosystem approach thereby achieves the sustainable use of ecosystem goods and services and the maintenance of ecosystem integrity.

1.2 The Common Procedure is the harmonised methodology developed and agreed by OSPAR Contracting Parties for assessing eutrophication in the North-East Atlantic, incorporating the best available scientific knowledge to interpret and assess eutrophication in the North-East Atlantic. In accordance with the ecosystem approach, the Common Procedure is part of a continuous cycle of (i) setting and coordinating ecological objectives and associated targets and indicators, (ii) ongoing management and (iii) regular updates of ecosystem knowledge, research, and advice. Monitoring, assessment, and adaptive management are essential elements for implementing the ecosystem approach.

1.3 OSPAR describes eutrophication status in terms of 'Problem' and 'Non-problem' areas. The ultimate aim of the OSPAR eutrophication strategy is to achieve and maintain non-problem status in all parts of the OSPAR maritime area by 2030. This document is the OSPAR Agreement reached by Contracting Parties describing how, when and where the Common Procedure will be applied to deliver an assessment.

1.4 Although the aim is to achieve non-problem status for all areas before 2030 it is important to recognise that there is a time lag from lowering the pressure, i.e. reducing the nutrient inputs, until the state of the marine ecosystems actually improves (Lønborg and Markager 2021).

1.5 This Agreement defines the Fourth Application of the Common Procedure. The first application was applied nationally in 2002 with a joint report published 2003[25]. Subsequent applications resulted in joint reports in 2008[26] and 2017[27] which contributed to the OSPAR Quality Status Report 2010 and the Intermediate Assessment 2017. This fourth application will provide a basis for the OSPAR Quality Status Report 2023. With the third application, OSPARs eutrophication assessments covered the period from 2006 – 2014 and a long-term period with data back to 1990 for trend assessments in addition. The fourth application will extend this, incorporating data from 2015 – 2020. This fourth application reflects the adaptive management of the ecosystem approach, incorporating a major revision in assessment areas and thresholds

[25] OSPAR, 2003, OSPAR Integrated Report 2003 on the Eutrophication Status of the OSPAR Maritime Area Based Upon the First Application of the Comprehensive Procedure, No: 189, online: https://www.ospar.org/documents?d=6962

[26] OSPAR, 2008, Second OSPAR Integrated Report on the Eutrophication Status of the OSPAR Maritime Area, No: 372, online: https://www.ospar.org/documents?d=7107

[27] OSPAR, 2017, Third Integrated Report on the Eutrophication Status of the OSPAR Maritime Area, No: 694, online: https://www.ospar.org/documents?d=37502

based on the best available scientific knowledge from EU projects such as JMP EUNOSAT[28], and further developed in OSPARs own Ecological Modelling group ICG-EMO.

Table 1: OSPAR eutrophication assessments, assessment periods and publication dates

Assessment	Period of assessment	Published
Quality Status Report 2000	Up to 1998	2000
https://qsr2010.ospar.org/media/assessments/QSR_2000.pdf		
Quality Status Report 2010	1998 – 2008	2010
https://qsr2010.ospar.org/en/index.html		
Common Procedure 1	1990 – 2000	2003
https://www.ospar.org/documents?v=6962		
Common Procedure 2	2001 – 2005	2008
https://www.ospar.org/documents?v=7107		
Waterborne and atmospheric inputs nutrients	1990 – 2004	2008
https://www.ospar.org/documents?d=7122		
Common Procedure 3	2006 – 2014	2017
https://www.ospar.org/documents?v=37502		
Intermediate Assessment	2006 – 2014	2017
https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/		
Waterborne and atmospheric inputs nutrients	1990 (1997 in the Bay of Biscay and Iberian Coast) – 2014/15	2017
Winter nutrient concentrations	2006 – 2014. Trends 1990 – 2014	2017
Growing season chlorophyll-a	2006 – 2014. Trends 1990 – 2014	2017
Dissolved oxygen	2006 – 2014. Trends 1990 – 2014	2017
Phaeocystis	2006 – 2014. Belgium (1990–2009), the Netherlands (1990–2014), Germany (2001–2014)	2017
Common Procedure 4	2015 – 2022	2022
Quality Status Report 2023	2010 – 2020	2023
https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/		

[28] Anon., 2017, JMP EUNOSAT: Coherent eutrophication assessments for the North Sea, using satellite data, contract nr. 11.0661/2017/750678/SUBIENV.C2 of DG-Environment part of the "European Maritime and Fisheries Fund" 3rd call: "Implementation of the second cycle of the MSFD"

1.6 The Common Procedure is an approach for the identification and classification of eutrophication status, in order to identify the need for measures to remedy problems, the scale of measures required and to follow-up whether implementation of measures has had the necessary effect. For areas classified as ‘problem areas’ that means reductions in nutrient loadings. However, it is not possible as part of COMP-4 to quantify such reductions, so it is an objective for the future. As such, it reflects OSPAR’s use of both the regional and risk-based approaches. The first application of the Common Procedure was risk-based, in that it included a screening procedure that made use of information on pressures to identify areas that were not at risk from human-induced eutrophication. The screening procedure considered factors such as population changes in the catchment, nutrient inputs (using information from the OSPAR CAMP and RID programmes) and literature studies indicating existing eutrophication or changes in chemical or biological communities. The Comprehensive Procedure – the more in-depth analysis of eutrophication status – was only applied to areas not identified as free from risk of human-induced eutrophication.

1.7 The OSPAR Intermediate Assessment 2017[29] introduced assessments of a suite of Common Indicators. For eutrophication, these common indicators described nutrient inputs, winter nutrient concentrations, chlorophyll-a, nuisance phytoplankton (*Phaeocystis*) and dissolved oxygen covering a limited part of the Convention area. The indicator assessments were carried out independent of the Common Procedure. The OSPAR Common Indicators are now being extended to cover the entire OSPAR Convention Area, rendering the screening procedure redundant. The fourth application of the Common Procedure will fully incorporate the Common Indicators. Information on changing pressures in the catchment, such as trends in loads, that was previously used in the screening process, will now provide supporting information on the observed eutrophication status, guiding OSPAR Contracting Parties in developing national and OSPAR Programmes of Measures.

1.8 The European Union has introduced several directives concerned with combatting eutrophication which complement and reinforce the Common Procedure. The Nitrates[30] and Urban Wastewater Treatment directives[31] require Member States regularly to identify coastal waters sensitive to enrichment by nitrogen and/or phosphorus. In addition, the Water Framework and Marine Strategy Framework Directives[32,33] (WFD; MSFD) introduce six-year management cycles requiring eutrophication status assessments and programmes of measures to remedy eutrophication. The Common Procedure provides a common eutrophication assessment for OSPAR Contracting Parties that are also EU Member States to use in their Article work 8 (Initial Assessment) under the Marine Strategy Framework Directive. Implementing EU Directives has demanded comprehensive work from Member States in developing and agreeing standards and

[29] OSPAR, 2017, Intermediate Assessment 2017, online: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/

[30] Anon., 1991, Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, online: https://eur-lex.europa.eu/eli/dir/1991/676/oj

[31] Anon., 1991, Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment, online: https://eur-lex.europa.eu/eli/dir/1991/271/oj

[32] Anon., 2000, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, online: https://eur-lex.europa.eu/eli/dir/2000/60/oj

[33] Anon., 2008, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) (Text with EEA relevance), online: http://data.europa.eu/eli/dir/2008/56/oj

methodologies to assess eutrophication. This has resulted in guidance documents[34] and decisions[35,36] where the previous iterations of the Common Procedure have been incorporated.

1.9 The 2010 Commission Decision largely followed the existing structure of the Common Procedure, requiring assessment of nutrient levels (concentrations and ratios), direct effects of nutrient enrichment (chlorophyll-a; transparency; opportunistic macroalgae; shifts in other primary producers) and indirect effects (seaweed depth limitation; dissolved oxygen). The 2017 decision removed aggregation guidance and introduced eight Criteria with accompanying methodological standards. Of the eight Criteria, three are obligatory: nutrient concentrations (D5C1; covering dissolved inorganic and total concentrations of nitrogen and phosphorus), chlorophyll-a (D5C2) and dissolved oxygen (D5C5). The OSPAR Common Indicators provide the analysis of essential features and characteristics for these obligatory criteria, while the Common Procedure assessment describes the current environmental status with respect to eutrophication using an assessment methodology that is consistent across the marine region. The remaining five voluntary criteria under the Decision describe harmful algal blooms (D5C3), transparency/photic limits (D5C4), opportunistic macroalgae (D5C6), macrophyte community structure (D5C7) and benthic macrofaunal communities (D5C8). Where oxygen assessment data are missing, benthic macrofaunal community assessment becomes obligatory. Assessment (threshold) levels are defined as those set under the WFD in coastal waters and established through regional or sub-regional cooperation to be consistent. This OSPAR Agreement documents the regional and sub-regional thresholds established through OSPAR cooperation in the North-East Atlantic for the three common indicators and national thresholds for additional parameters used in the assessment. In addition, it documents the choice of secondary criteria for each assessment unit.

1.10 The Commission Decision requires assessment scales to be harmonised with the WFD in coastal waters (i.e. using the same water bodies or water body types). Assessment scales are defined in terms of subdivisions of the OSPAR regions and subregions beyond coastal waters, divided as appropriate by national boundaries. Definitions of assessment units build on work by projects such as JMP EUNOSAT[37], expert advice from the OSPAR Intersessional Correspondence Group on Ecological Modelling (ICG-EMO) and directly from MSFD works (i.e., MSFD D7 modelling to refine sub-regions in the English Channel). Assessment unit definitions are part of this Agreement.

1.11 The 2017 Commission Decision does not specify how criteria elements (such as dissolved inorganic nitrogen and phosphorus concentrations) should be integrated to produce an assessment at Criteria level. Nor does it define how the various criteria should be integrated into the overall assessment of eutrophication status. These integration rules are defined in this revised Agreement. Additionally, this Agreement describes the methodology used to report the values achieved for each criterion, and the proportion of offshore areas not subject to eutrophication. To assist Contracting Parties in their MSFD Descriptor 1 (Biodiversity) assessments, this Agreement will consider how the distribution and extent (proportion) of the area subject

[34] Anon., 2009, Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document no. 23: Guidance document on eutrophication assessment in the context of European water policies, Technical Report - 2009 – 030, online: https://circabc.europa.eu/sd/a/9060bdb4-8b66-439e-a9b0-a5cfd8db2217/Guidance_document_23_Eutrophication.pdf

[35] Anon., 2010, 2010/477/EU: Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (notified under document C(2010) 5956) Text with EEA relevance, online: http://data.europa.eu/eli/dec/2010/477(2)/oj

[36] Anon., 2017, Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU (Text with EEA relevance), online: http://data.europa.eu/eli/dec/2017/848/oj

[37] Anon., 2017, JMP EUNOSAT: Coherent eutrophication assessments for the North Sea, using satellite data, contract nr. 11.0661/2017/750678/SUBIENV.C2 of DG-Environment part of the “European Maritime and Fisheries Fund” 3rd call: “Implementation of the second cycle of the MSFD”

to pelagic eutrophication (Criteria D5C2 - 4) is estimated and reported as soon as EU guidance on this issue becomes available. The assessment methodology to report on benthic eutrophication (Criteria D5C4 - 8) to assist the MSFD Descriptor 1 and Descriptor 6 assessments will then also be defined.

2. Outline of the Common Procedure

2.1 The Common Procedure provides a regionally consistent approach to describe the features and characteristics associated with eutrophication, as well as assessing the eutrophication status of the North-East Atlantic. It aims at characterising maritime areas regarding their eutrophication status as:

a. *Problem Areas* if there is evidence of an undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients;

b. *Non-problem Areas* if there are no grounds for concern that anthropogenic enrichment by nutrients has disturbed the marine ecosystem.

2.2 The Common Procedure makes use of the OSPAR Common Indicators (Winter nutrient concentrations; Concentrations of chlorophyll-a; and Concentrations of Dissolved Oxygen Near the Seafloor[38]) and applies a common assessment tool (COMPEAT) to produce an assessment of eutrophication status for each assessment area within the entire OSPAR Convention area. This assessment meets the basic requirements enshrined in the EU Commission Decision 2017/848[39], covering the primary (obligatory) criteria for eutrophication assessment under the Marine Strategy Framework Directive. Where possible, Contracting Parties include additional Secondary Criteria identified in the Commission Decision as well as other relevant information to identify problem areas regarding eutrophication.

2.3 The assessment and classification are supplemented by common monitoring and reporting arrangements to attain harmonised information on the eutrophication status of maritime areas. OSPAR regularly reviews and adapts the Common Procedure in order to ensure that it is compatible with the needs of EU member states' reporting under Descriptor 5 (Eutrophication) in addition to being an effective tool to guide Contracting Parties in their individual and collective efforts to minimise eutrophication and the adverse effects thereof.

2.4 This revision of the Common Procedure introduces the automated classification tool COMPEAT (Common Procedure Eutrophication Assessment Tool), hosted by ICES through the OSPAR contract and annual work programme. OSPAR eutrophication data are collected through the Joint Assessment and Monitoring Programme and reported annually to ICES, which is responsible for the management and storage of the data. The COMPEAT tool extracts relevant eutrophication data from the ICES databases and assesses eutrophication criteria against agreed threshold levels in ecologically relevant assessment units. Data collected outside of the OSPAR's Joint Assessment & Monitoring Programme (JAMP)[40], or assessed for example under the Water Framework Directive, can be included in the assessment system. The assessment results are reported in terms of an Ecological Quality Ratio (EQR) which allows the relative distance to non-problem status to be visualised. Trends in EQRs can provide estimates of the time needed before non-problem status is reached, on the assumption that measures continue to be implemented.

[38] *Phaeocystis* is no longer an OSPAR common indicator

[39] Anon. 2017, COMMISSION DECISION (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU

[40] OSPAR's Joint Assessment and Monitoring Programme: https://www.ospar.org/work-areas/cross-cutting-issues/jamp

2.5 Based on the results of the Common Procedure, Contracting Parties will develop coordinated Programmes of Measures individually and jointly in order to minimise eutrophication for all Problem Areas in coastal waters and offshore parts of the OSPAR Maritime Area.

The Common Procedure

2.6 The Common Procedure is the process of assessment and subsequent classification as non-problem or problem areas with regard to eutrophication. The assessment areas to which the Common Procedure is applied are listed in this OSPAR Agreement.

2.7 The Common Procedure is applied in regular intervals in accordance with the requirements for assessments in OSPAR and the reporting requirements of the MSFD, while the common indicators are assessed more frequently.

2.8 The Common Procedure consists of a set of qualitative cause-effect related assessment criteria which are linked to form a holistic assessment and area classification with respect to the eutrophication status of a given maritime area. The holistic approach is reflected in the selection and application of such common assessment parameters which reflect, once inter-linked, the main cause/effect relationships in the eutrophication process. These cause/effect linkages form the essence of the classification process as illustrated by a generic conceptual framework for all categories of surface waters (**Figure 1**).

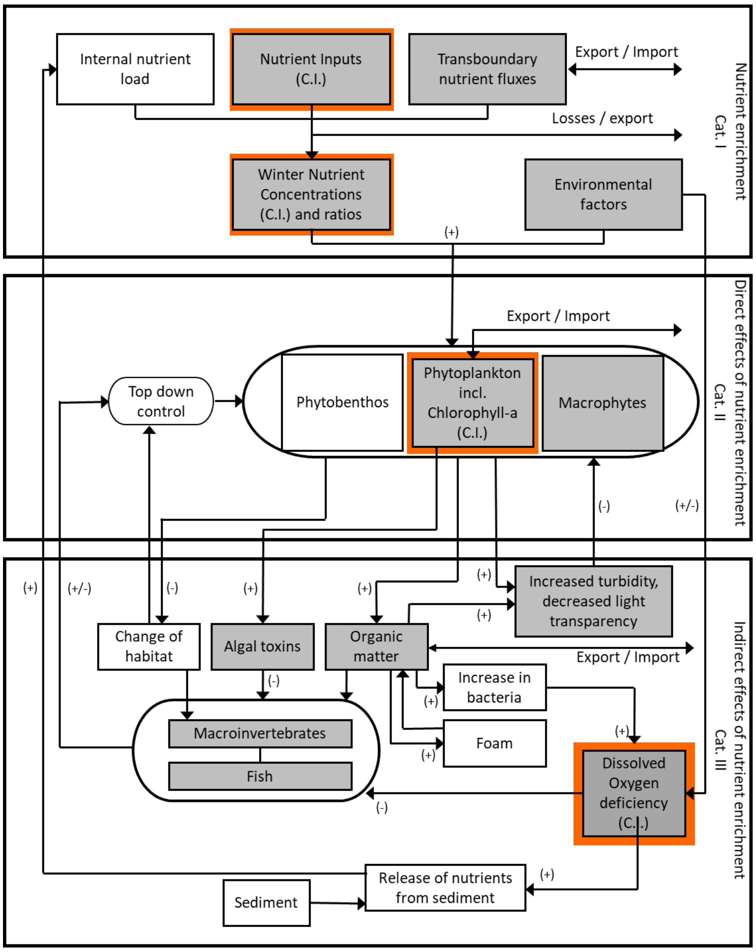

Figure 1: Generic conceptual framework to assess eutrophication in all categories of surface waters illustrating the main cause/effect linkages

Note: Shaded boxes indicate components relevant for the Common Procedure. Coloured boxes indicate OSPAR Common Indicators; '+' indicate enhancement; '-' indicate reduction;

Cat. I = Category I. Degree of nutrient enrichment (causative factors);
Cat. II = Category II. Direct effects of nutrient enrichment;

Cat. III = Category III. Indirect effects of nutrient enrichment.

2.9 Contracting Parties divide the waters of the OSPAR maritime area into suitable assessment units based on the relevant physical and biogeochemical features. This process of characterisation is now undertaken collectively in order to establish ecologically coherent assessment units such that forcing an ecological response can be considered uniform across the assessment unit. As such, common threshold values (levels) and common definitions of an assessment season are agreed for the entire assessment unit. The process of identifying assessment units, threshold values and assessment seasons has been based on best available scientific knowledge. Assessment units, thresholds and seasons have been revised prior to each application of the Common Procedure to reflect improvements in our understanding of the Ecosystem Approach. The Fourth Application of the Common Procedure aims to address issues identified in the Third Application[41] which identified inconsistencies in threshold levels across national marine borders. The OSPAR Intersessional Correspondence Group on Eutrophication Modelling (ICG-EMO) and the EU funded JMP-EUNOSAT project have proposed revised assessment units and thresholds that have been adopted in this Agreement.

2.10 Assessment and area classification in the Common Procedure is a three-step approach based on common methodologies, guidance on which is given in this document.

2.11 In a first step, assessment criteria and their corresponding area-specific assessment levels as set and agreed for the Fourth Application of the Common Procedure are applied for each given area based on a common methodology. The results of the assessment procedure resulting from this application provide the basis for the subsequent integration step.

2.12 In a second step, the results attained in the first step are integrated to give the classification for the given area.

2.13 Steps 1 and 2 are implemented through COMPEAT – the Common Procedure Eutrophication Assessment Tool, hosted by ICES. This provides a harmonised assessment and classification process, including the requirements set out in Section 6, for the parts of the OSPAR maritime area identified in this Agreement. This allows an integrated eutrophication assessment of the entire Convention area as basis for the development of targeted measures and programmes. Using a common assessment tool also enables the previous applications of the Common Procedure to be re-run, providing a more reliable indication of progress in reducing eutrophication than has been possible when comparing previous assessments with varying threshold levels and assessment units.

2.14 A third assessment step involves an expert verification of the COMPEAT results made by the Contracting Parties in whose waters the assessment units occur. Contracting Parties may at this stage agree additional parameters and thresholds to be included in the relevant category in COMPEAT where these reflect particular local characteristics. These adjustments to the assessment will be implemented in COMPEAT and documented in the OSPAR eutrophication assessment report.

2.15 It follows that marine areas shall be monitored with regard to eutrophication in compliance with common minimum monitoring requirements as agreed, for the OSPAR Convention area, in the

[41] OSPAR, 2017, " Third Integrated Report on the Eutrophication Status of the OSPAR Maritime Area", OSPAR Report p000694, https://www.ospar.org/documents?d=37502

Eutrophication Monitoring Programme[42] and CEMP Guidelines for coordinated monitoring of Eutrophication, CAMP and RID[43]. The risk of misinterpretation of the causes of direct and indirect effects should be reduced when all categories (nutrient enrichment, direct effect, and indirect effects) as well as supporting environmental factors are monitored and assessed in coherence/together (see further Section 7). Contracting Parties shall document the relative confidence of their assessment findings as described in Section 8. A confidence assessment is also carried out within the COMPEAT tool.

3. Characterisation of the OSPAR area and assessment units

3.1 The geographic scale of areas for eutrophication assessment have been chosen to balance hydrodynamic and ecosystem considerations with issues such as monitoring design, assessment of direct and indirect effects of nutrient enrichment in the sea and links with nutrient inputs and sources. Areas that are too small are not efficient for monitoring and assessment purposes, and areas that are too large may disguise local problems. The consideration of salinity regimes from the river outflows to offshore helps to identify and quantify cause-effect relationships and to determine assessment scales. The size of geographic assessment scales is expected to increase from smaller inshore waters to bigger offshore areas.

3.2 While assessment areas should be primarily defined based on environmental conditions for those OSPAR Contracting Parties that are also EU Member States, the WFD administrative boundary of 1 nautical mile beyond the baseline separates coastal from offshore waters. Within the coastal waters of the WFD the eutrophication assessment is either done by assessing individual waterbodies, or by aggregating water bodies, for example into units with ecologically coherent coastal water types.

3.3 For the fourth application of the Common Procedure OSPAR has adopted harmonised assessment areas for OSPAR Regions II, III and IV. These were initially developed by JMP EUNOSAT[44] and further refined by ICG-EMO (**Annex 3**). The environmental conditions used in defining assessment areas were physical (depth, salinity, and stratification), chemical (nutrients) and biological factors (phytoplankton dynamics: biomass & primary production) (**Figures 3, 4, 5, 6, 7** and **Table 2**).

[42] The Eutrophication Monitoring Programme (reference number: 2005-4 (as updated in 2013)) supersedes the Nutrient Monitoring Programme adopted by OSPAR 1995 (Reference number 1995-5).
[43] OSPAR Agreement 2016-05, revised 2021: https://www.ospar.org/documents?v=35414
[44] EU project Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data

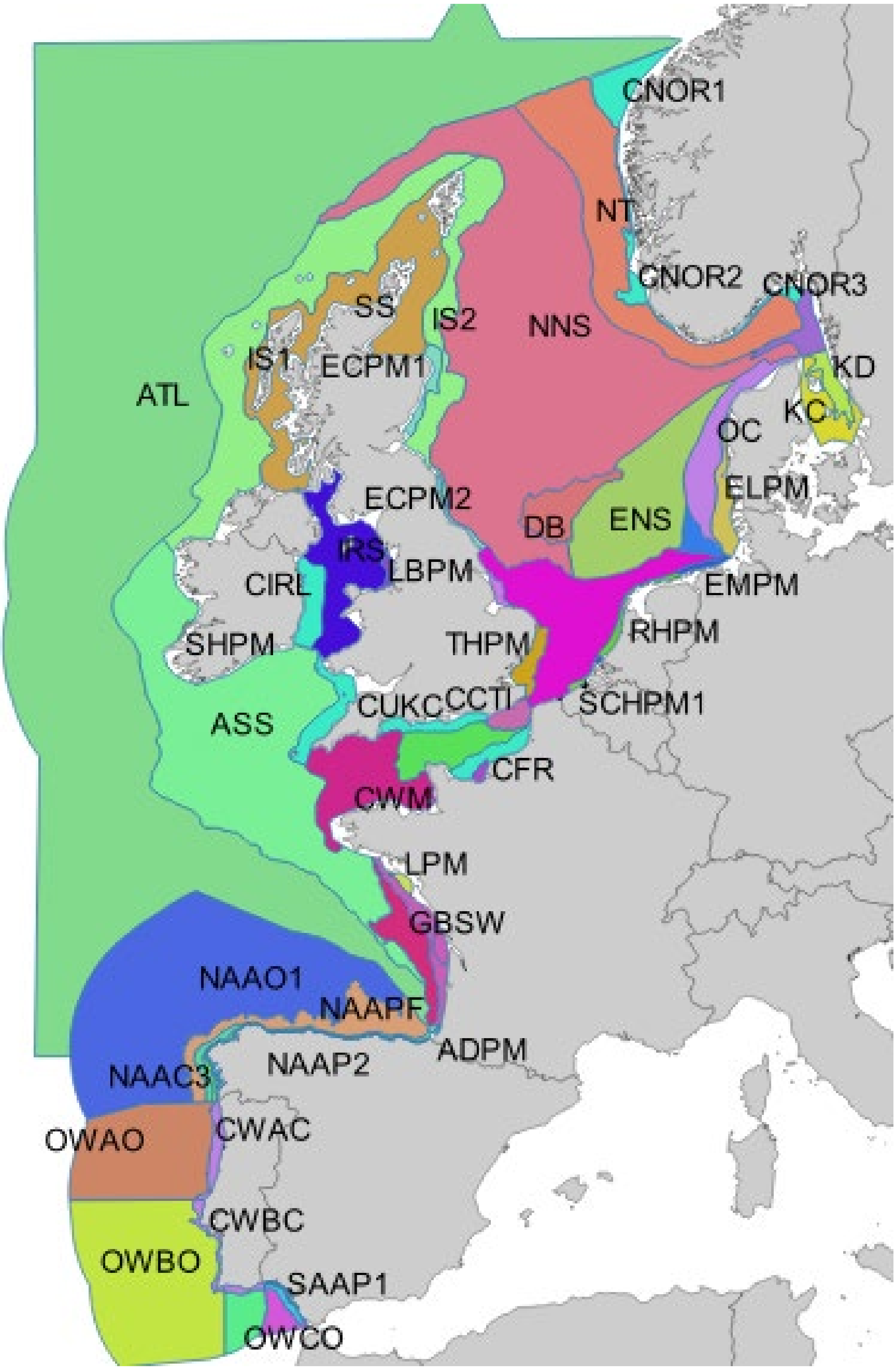

Figure 3: Overview of proposed ecologically relevant assessment areas based on duration of stratification, mean surface salinity, depth, suspended particulate matter and primary production.

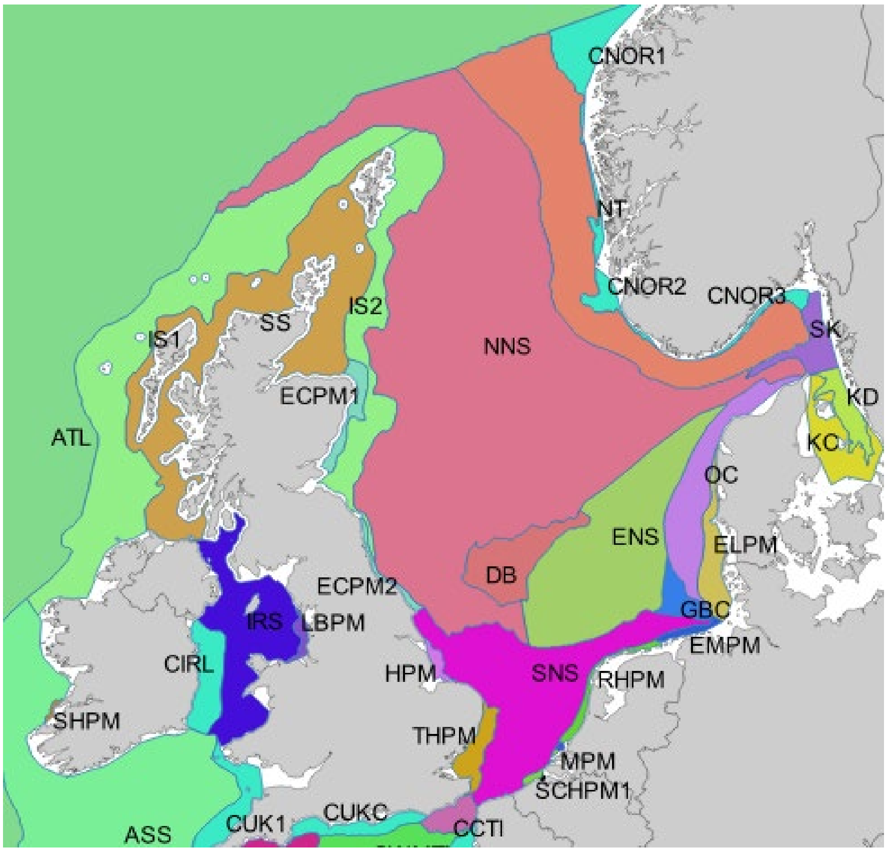

Figure 4: Detailed view of proposed assessment areas in OSPAR region II and III.

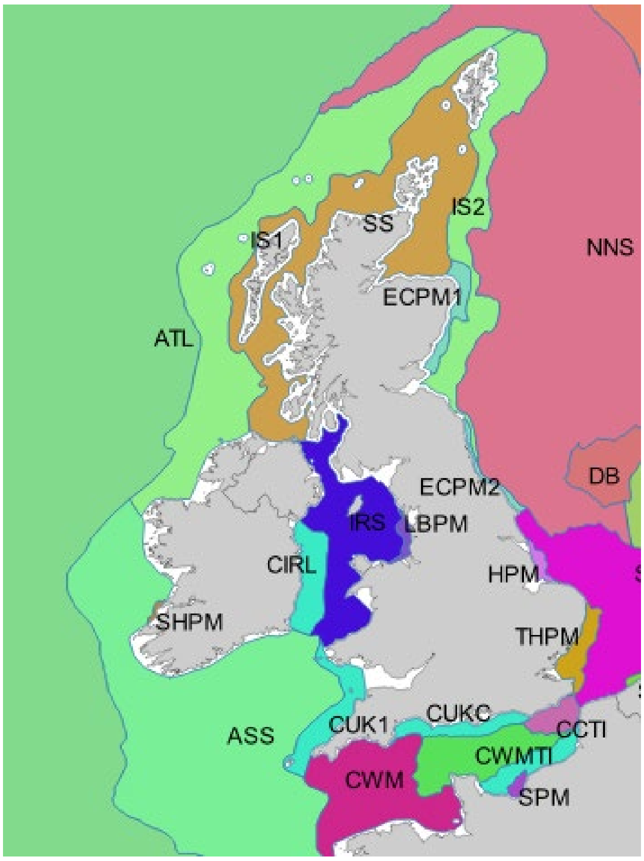

Figure 5: Detailed view of proposed assessment areas in OSPAR region III.

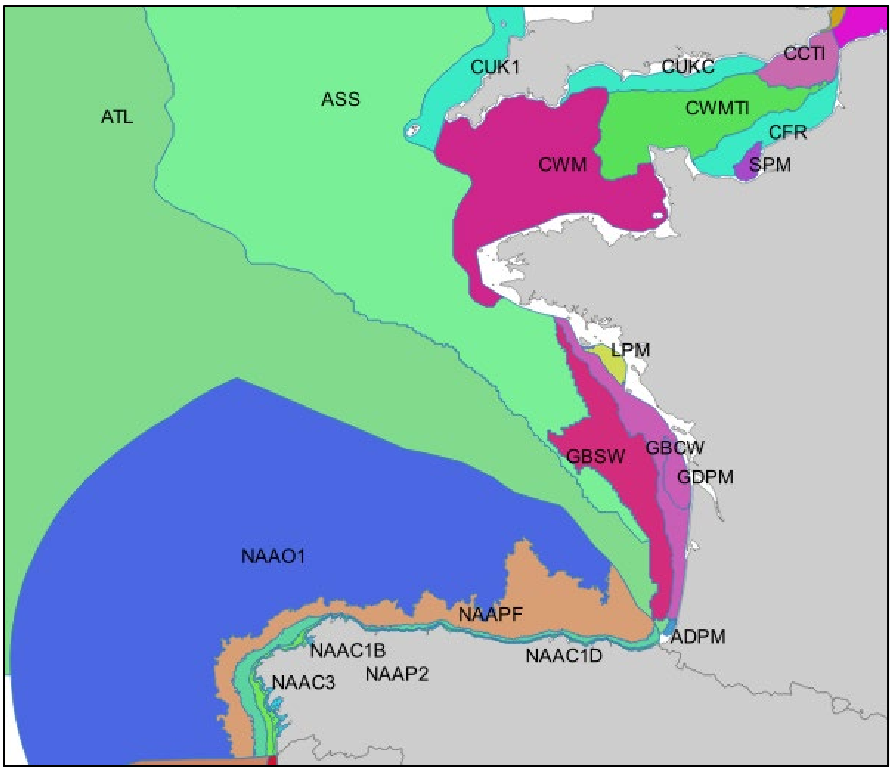

Figure 6: Detailed view of proposed assessment areas in OSPAR region II and IV.

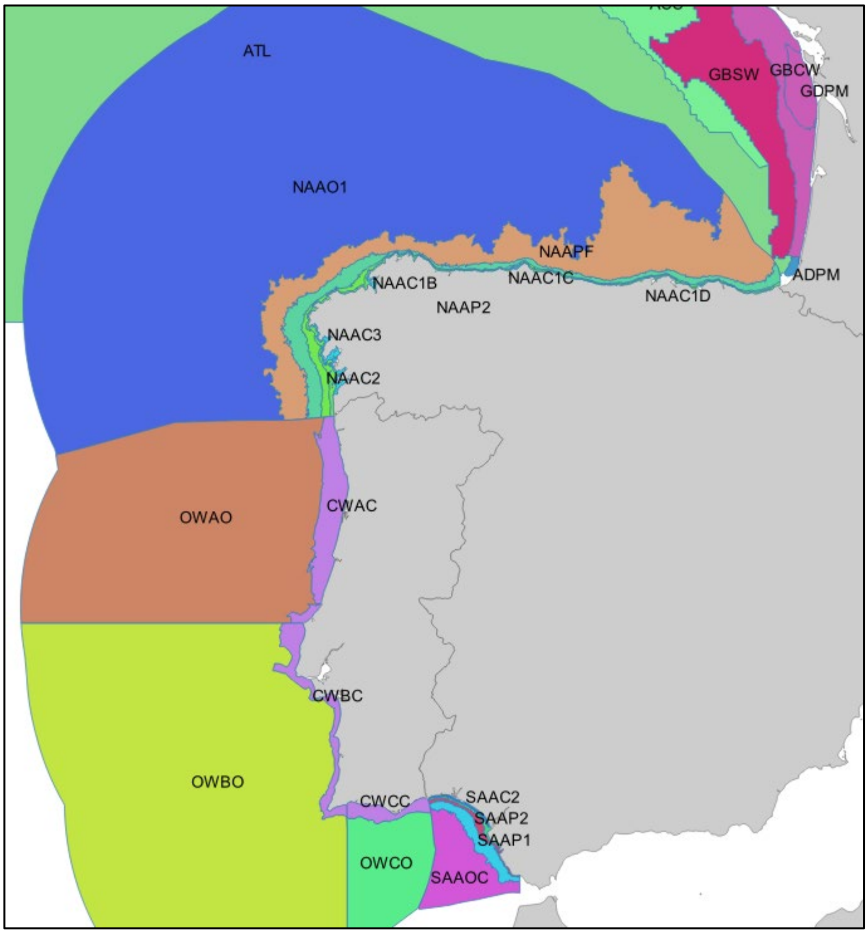

Figure 7: Detailed view of proposed assessment areas in OSPAR region IV.

Table 2: Overview table of ecologically relevant assessment areas

Area ID	Area name	Surface area (km^2)	Area ID	Area name	Surface area (km^2)
ADPM	Adour plume	283	KC	Kattegat Coastal	9632
ASS	Atlantic Seasonally Stratified	217301	KD	Kattegat Deep	4958
ATL	Atlantic	934260	LBPM	Liverpool Bay plume	1361
CCTI	Channel coastal shelf tidal influenced	5081	LPM	Loire plume	1495
CFR	Coastal FR channel	7176	MPM	Meuse plume	206
CIRL	Coastal IRL 3	9583	NAAC1A	Noratlantic Area NOR-NorC1(D5)A	549
CNOR1	Coastal NOR 1	8741	NAAC1B	Noratlantic Area NOR-NorC1(D5)B	88
CNOR2	Coastal NOR 2	2606	NAAC1C	Noratlantic Area NOR-NorC1(D5)C	28
CNOR3	Coastal NOR 3	1733	NAAC1D	Noratlantic Area NOR-NorC1(D5)D	12
CUK1	Coastal UK 1	10697	NAAC2	Noratlantic Area NOR-NorC2(D5)	1662
CUKC	Coastal UK channel	6305	NAAC3	Noratlantic Area NOR-NorC3(D5)	2609
CWAC	Coastal Waters AC (D5)	7395	NAAO1	Noratlantic Area NOR-NorO1(D5)	261727
CWBC	Coastal Waters BC (D5)	4230	NAAP2	Noratlantic Area NOR-NorP2(D5)	8327
CWCC	Coastal Waters CC (D5)	1936	NAAPF	Noratlantic Area NOR-Plataforma	37101
CWM	Channel well mixed	42015	NNS	Northern North Sea	264253
CWMTI	Channel well mixed tidal influenced	20632	NT	Norwegian Trench	59124
DB	Dogger Bank	14750	OC	Outer Coastal Germany/Denmark	18540
ECPM1	East Coast (permanently mixed) 1	3519	OWAO	Ocean Waters AO (D5)	98493
ECPM2	East Coast (permanently mixed) 2	1444	OWBO	Ocean Waters BO (D5)	184458
ELPM	Elbe plume	7837	OWCO	Ocean Waters CO (D5)	18719
EMPM	Ems plume	1445	RHPM	Rhine plume	2279
ENS	Eastern North Sea	60634	SAAC1	Sudatlantic Area SUD-C1(D5)	405
GBC	German Bight (deep)	4554	SAAC2	Sudatlantic Area SUD-C2(D5)	267
GBCW	Gulf of Biscay coastal waters	10846	SAAOC	Sudatlantic Area SUD-OCEAN(D5)	10076
GBSW	Gulf of Biscay shelf waters	21008	SAAP1	Sudatlantic Area SUD-P1(D5)	2467
GDPM	Gironde plume	2828	SAAP2	Sudatlantic Area SUD-P2(D5)	916
HPM	Humber plume	1368	SCHPM1	Scheldt plume 1	582
IRS	Irish Sea	32691	SCHPM2	Scheldt plume 2	95
IS1	Intermittently Stratified 1	73501	SHPM	Shannon plume	380
IS2	Intermittently Stratified 2	26517	SK	Skagerrak	5759
			SNS	Southern North Sea	61758
			SPM	Seine plume	1115
			SS	Scottish Sea	53273
			THPM	Thames plume	5523

4. Area-specific assessment parameters and common indicators

4.1 To enable a harmonised assessment of the eutrophication status of maritime waters throughout the Convention area, the Common Procedure is a conceptual framework consisting of harmonised assessment criteria/parameters that are linked to form a holistic assessment. A subset of the criteria/parameters are OSPAR common indicators. The area-specific assessment parameters and common indicators align with the European Union's Water Framework Directive (WFD) and reflect the needs of the Marine Strategy Framework Directive (MSFD) and are also recommended by other oceanographic monitoring organisations, such as the Global Ocean Observing System (GOOS). OSPAR's biodiversity experts also identified these as essential variables influencing biodiversity.

4.2 A first step in the assessment procedure is the selection and application of parameters that are relevant for the area concerned, because they reflect the cause/effect relationships of the eutrophication process (**Table 3**). These linkages are illustrated in **Figure 1**.

4.3 The results of the assessment of each of the parameters in **Table 3** are reported in a harmonised way using ecological quality ratios (EQR) (**Annex 1**).

Setting and selecting of area-specific assessment parameters and common indicators

4.4 The basic assessment parameters for the assessment of eutrophication of maritime waters are laid down for the OSPAR maritime area in the Eutrophication Monitoring Programme[45]. They are to be applied throughout the whole maritime area.

4.5 Building on this, the following three categories of qualitative assessment criteria for application in the Common Procedure are agreed:

Category I Causative factors: nutrient enrichment, taking into account environmental supporting factors;

Category II Direct effects of nutrient enrichment;

Category III Indirect effects of nutrient enrichment.

4.6 For each category, specified assessment criteria and associated biological and chemical parameters are agreed. They are reproduced in the checklist in **Annex 2**.

4.7 Area differences with respect e.g. to demographic and hydrodynamic conditions and differences in data availability are likely to influence the selection of assessment parameters for the use in the eutrophication assessment.

4.8 Based on this, a set of harmonised assessment parameters was selected relating to nutrient enrichment, direct and indirect effects of nutrient enrichment. These parameters form the basis for the later classification of maritime areas with regard to eutrophication (**Table 3** and **Annex 4**).

4.9 Harmonised assessment parameters including the OSPAR common indicators are aligned with the European Commission Decision (EU/2017/848) criteria for assessing human induced eutrophication, i.e. Descriptor 5 of the MSFD. The Commission Decision sets out eight criteria for assessing eutrophication, of which three are primary and five are secondary. Primary criteria must be used by EU member states and

[45]These are for nutrient enrichment: NH_4-N, NO_2-N, NO_3-N, PO_4-P, SiO_4-Si, salinity and temperature; for direct and indirect effects: phytoplankton chlorophyll-*a*, phytoplankton indicator species and species composition, macrophytes, O_2 concentration (including % saturation) and benthic communities and groups of indicator species.

secondary criteria complement primary criteria where a primary criterion is at risk of not achieving or not maintaining good environmental status. The three OSPAR common indicators that are also MSFD primary criteria are: nutrient concentrations, chlorophyll-a concentrations, and dissolved oxygen concentrations in bottom-water. **Table 3** shows the correspondence of OSPAR's harmonised criteria with MSFD primary and secondary criteria.

4.10 In addition to the common indicators/primary criteria, other parameters may be applied where necessary and agreed by those Contracting Parties sharing an assessment unit to support the assessment process, to harmonise the Common Procedure with the WFD and/or the MSFD, and to increase our current understanding (**Table 3** and **Annex 4**). Assessments can take account of information supplied from in-situ monitoring, ships of opportunity, modelling, and remote sensing.

Table 3 Harmonised assessment parameters. P, primary criterion. S, secondary criterion

Assessment parameters		**MSFD criterion**
Category I Degree of nutrient enrichment		
1	**Nutrient concentrations (area-specific)** Elevated level(s) of winter DIN and/or DIP	D5C1 – P
2	**N/P ratio (area-specific)** Elevated winter N/P ratio	
3	**TN & TP**	
	Total nitrogen and phosphorus	D5C1 – P
Category II Direct effects of nutrient enrichment (during growing season)		
1	**Chlorophyll-*a* concentration (area-specific**) Elevated maximum, mean and/or 90 percentile level (OSPAR PH2)	D5C2 – P
2	**Phytoplankton indicator species (area-specific)** Elevated levels of nuisance/toxic phytoplankton indicator species (and increased duration of blooms) OSPAR PH1[46], PH2[47] and PH3[48]	D5C3 – S D1C6 – P
3	**Macrophytes including macroalgae (area-specific)** Shift from long-lived to short-lived nuisance species (e.g. *Ulva*). Elevated levels (biomass or area covered) especially of opportunistic green macroalgae)	D5C6 – S D5C7 – S
Category III Indirect effects of nutrient enrichment (during growing season)		
1	**Oxygen deficiency**	
	Decreased levels (< 2 mg l^{-1}: acute toxicity; 2 - 6 mg l^{-1}: deficiency) and lowered % oxygen saturation	D5C5 – P
2	**Zoobenthos and fish**	
	Kills (in relation to oxygen deficiency and/or toxic algae) Long-term area-specific changes in zoobenthos biomass and species composition	D5C8 – S
3	**Organic carbon/organic matter (area-specific)** Elevated levels (in relation to III.1) (relevant in sedimentation areas)	(relates to D5C8)
4	**Photic limit (transparency of the water column**	D5C4 – S

Defining and applying area-specific assessment levels

4.11 The levels against which assessment is made are area specific. When setting assessment levels, supporting environmental factors as listed under the causative factors (Category I assessment parameters), and the characteristics distinguishing various types of areas (cf. Section 3), should be considered.

[46] PH1: phytoplankton community based on lifeform pairs
[47] PH2: phytoplankton community biomass
[48] PH3: phytoplankton biodiversity index

4.12 For each parameter listed in **Table 3** area-specific assessment levels have been established based on levels of increased concentrations and trends as well as on shifts, changes, or occurrence. Assessment levels are defined in general terms as a percentage above an area-specific reference condition. This reflects natural variability and allows for a 'slight disturbance' as is also the case for assessment under the Water Framework Directive. In general, the background levels are salinity-related and/or specific to a particular area and have been defined for dissolved nutrients and chlorophyll-a through work by the JMP-EUNOSAT project[49] and modelling by ICG-EMO. Assessment levels in the case of Spain are adopted directly from the levels used in the Marine Strategy Framework Directive and in the Water Framework Directive, both coordinated and consistent at country level in all the national assessment areas. For Portugal assessment areas, the assessment levels were calculated as the deviation of area specific reference conditions and are the same used nationally in MSFD and WFD (**Annex 5**).

4.13 In order to allow for natural variability, and in the absence of more specific information, the assessment level was defined as the concentration 50% above the salinity-related and/or area-specific background concentration in the first application of the Common Procedure (OSPAR 2003). This applied to winter DIN and DIP concentrations, winter N/P-ratio and maximum, mean and 90th percentile growing season chlorophyll-a concentrations. In the first application of the Common Procedure, a 50% acceptable deviation from historical background levels was chosen in the absence of additional knowledge. Since then, experience indicates that 50% above historic levels may not represent a eutrophic state everywhere, nor that a 50% increase in nutrient concentrations also gives a 50% increase in algal biomass or chlorophyll concentration. In this application of the Common Procedure, the deviation of assessment levels from background concentrations is area-specific and have been chosen (**Annex 7**). Spain has provided directly the evaluation values, though the metrics and methods of evaluation of the indicators described in the common procedure are fully applicable. Portugal evaluation values were defined as described on the second application of the Common Procedure (OSPAR 2005)

4.14 Parameters that are found at levels above the assessment levels are at "elevated levels" for the purpose of the Common Procedure. In the assessment procedure, elevated levels can be determined by calculating parameter EQRs (ecological quality ratio) (**Annex 1**).

4.15 The parameter assessment and all subsequent assessment steps, such as the integration of categorised assessment parameters and the overall area classification, are carried out on a five-level scale using EQRs in order to enable an estimate of the distance-to-target to identify improvements, in particular in those areas that have not yet achieved a non-problem area status. This approach also allows better comparability with the assessment results of the WFD, which are based on five assessment classes as well, to overcome differences between the Common Procedure and the WFD.

Description of the area-specific assessment parameters

4.16 In the following, the main characteristics of area-specific assessment parameters that can be used to assess causative factors and direct and indirect effects of eutrophication are described (**Annex 6**). Only a limited set of these parameters is finally applied in the COMPEAT tool, with the set of parameters varying between assessment areas.

[49] https://www.informatiehuismarien.nl/uk/projects/algae-evaluated-from/information/results/

(I) Category I - Degree of nutrient enrichment (causative factors)

(1) Winter nutrient (DIN and/or DIP, and Si) concentrations

4.17 Widely used in comparable assessments are dissolved inorganic nitrogen compounds (NO_3- + NO_2- + NH_4+ (DIN)) and ortho-P (DIP) for winter (when algal activity is lowest), expressed as µM. Silicate (SiO_4^{4-}) is monitored, but not widely used in assessments and is therefore not incorporated in **Table 3**.

4.18 Dissolved inorganic nitrogen, phosphorus and silicate concentrations are measured in winter when biological activity and uptake of nutrients by phytoplankton is low. Waters with high nutrient concentrations are not necessarily considered eutrophic because it is the characteristics of these waters (e.g. currents, turbidity) that affect whether those concentrations lead to eutrophication and associated effects.

(a) Overall guidance for salinity gradient riverine influenced waters

4.19 The widely used uniform assessment procedure with respect to yearly trends and elevated concentrations of winter DIN, DIP, and silicate in waters with a salinity gradient (riverine influenced) is as follows (**Annex 10**):

a. Mixing diagrams and salinity-specific background concentrations:

In marine coastal waters beyond WFD with salinity gradients yearly trends in winter nutrient concentrations are assessed by plotting the winter nutrient concentrations of each year in relation to the respective measured salinity values as "mixing diagrams". In winter, defined as period when algal activity is lowest, DIN and DIP (but also silicate) show a conservative behaviour and, therefore, a good linear relationship with salinity, i.e. decreasing concentration with increasing salinity from coast to offshore;

b. Trends and increased concentrations compared with salinity-specific background concentrations:

In order to compensate for differences in salinity at the various locations and during the various years, nutrient concentrations are normalised for salinity. This is done by calculating the winter nutrient concentration at a given salinity (e.g. 30) from the mixing diagram of a particular year. The salinity normalised nutrient concentration (with 95% confidence interval) is plotted in relation to the respective year to establish trends in the winter nutrient concentrations and the assessment level compared with the background concentration (see **Annex 10)**.

4.20 To undertake the assessment, Contracting Parties should use and report comprehensive data on winter DIN and winter DIP concentrations, and silicate, and associated salinity (report on lowest and highest values with associated salinity from the mixing diagram: see **Annex 10**). COMPEAT normalises winter nutrient concentrations for salinity. The exception is the Kattegat, where high salinity waters have the highest nutrient concentrations and salinity normalisation is not appropriate.

(b) Areas without salinity gradients

4.21 In areas where there is no relationship between salinity and winter nutrient concentrations, nutrient levels can be simply assessed by calculating mean values for the winter period (meaning the less productive period) and compared to area-specific background concentrations.

4.22 When reporting on winter DIN and DIP and on silicate for the various areas under investigation, the relevant mean salinity regime shall be reported.

4.23 The following assessment procedure is used for identifying elevated levels :

a. (salinity-related and/or area-specific) background concentrations; and

b. assessment levels based on a justified area-specific % deviation from background not exceeding 50%.

N/P, N/Si and P/Si ratios

4.24 Increased winter nutrient ratios, and in particular, increased N/P ratios (compared to Redfield ratio = 16, assumed to be optimal for phytoplankton growth), when coupled with absolute excess of nitrate, may cause shifts in species composition, from diatoms to flagellates, some of which are toxic. Since such increased N/P ratios increase the risk of blooms of nuisance algae, winter N/P ratios are used as supporting information in the common assessment (**Table 3**), but not assessed against assessment levels. The N/P ratio can provide supporting information on the development of the two nutrients relative to each other in addition to the assessment of the individual nutrient concentrations of DIN and DIP. Changes in nutrient ratios can be helpful to guide management decisions as to whether to reduce N or P inputs. Where appropriate, ratios of N/Si and P/Si may in addition be considered, although silicate is less influenced by anthropogenic activities.

(2) Total nitrogen and phosphorus

4.25 Total nitrogen (TN), total phosphorus (TP) and organic carbon/organic matter are useful assessment parameters in addition to the winter DIN and DIP since they include all phases of the elements N and P and bridge as all-season-values the time-gap between winter and algal growing season and can be used to explain long-term nutrient enrichment in certain areas, caused by transboundary transport (**Annex 9**). TN and TP are a prerequisite to calculate nutrient budgets. They can be helpful to deduce reference conditions throughout estuarine and coastal waters because data for rivers TN and TP are mostly present. With increasing climate change, TN and TP might prove to be the more robust assessment parameters since winter nutrient concentrations decrease when phytoplankton productivity continues throughout warmer winters. TN and TP are, besides riverine inputs, presently not included in the Eutrophication Monitoring Programme.

(II) Category II – Direct effects of nutrient enrichment

(1) Chlorophyll-*a* concentration

4.26 Chlorophyll-a concentrations, measured as a proxy for the (carbon) biomass of phytoplankton, are the net result of several processes: the production of phytoplankton biomass which is determined by nutrient concentrations but also by light and temperature, and the loss of phytoplankton biomass which is determined by mortality, sinking and grazing. Consequently, the chlorophyll-a concentrations that are observed at monitoring sites are influenced by growth, mortality, and transport processes. Physical factors such as turbidity, depth, vertical and horizontal mixing and stratification, and biological factors such as algal species composition, zooplankton grazing and competition with other primary producers have an impact on growth, mortality, and transport. Due to these many interacting factors, the response of phytoplankton biomass to changes in nutrient input is complex and system specific. While there are examples of water systems within the OSPAR Maritime Area where reduced nutrient inputs have resulted in lowered phytoplankton biomass or production this is not always the case due to the complexity of interacting processes. Nevertheless, this parameter is a useful direct effect assessment parameter of nutrient enrichment, and therefore listed in **Table 3**.

4.27 There is a large fluctuation in chlorophyll-a concentrations between years and seasons as well as spatial differences (in general, higher in nutrient enriched coastal waters, at frontal systems, and in (offshore) stratified waters compared to unstratified offshore waters). The latter difference often reflects the difference in nutrient enrichment levels.

4.28 Environmental data such as phytoplankton chlorophyll-*a* exhibits periodicity and episodic change and, as a result, tends to be asymmetrically distributed with few high values (outliers or spikes) and many low values. That is the background for suggesting the 90th percentile value as the metric for the chlorophyll indicator. However, statistical analysis have shown that the 90th percentile is sensitive to sampling frequency and less stable than using the mean value over the season. Based on this, ICG-Eut recommend the use of the mean value over the growing season as the best metric for the chlorophyll indicator.

4.29 Maximum, mean and 90th percentile chlorophyll-*a* concentrations during the growing season have become available over the last decade. According to the Eutrophication Monitoring Programme and the JAMP Eutrophication Monitoring Guidelines[50], chlorophyll-*a* concentration is measured and expressed as µg chl-*a* l^{-1}. Sometimes chlorophyll concentrations are converted to concentration of phytoplankton carbon, e.g. with a conversion factor of 40 C:Chl. However, such a conversion must be interpreted with care, as the conversion factor vary systematically with nutrient richness. When less nutrients, in particular nitrogen, are available for the phytoplankton cell, they will accumulate more carbon in the cells and the factor will increase. Thus, the chlorophyll concentration is only a proxy for phytoplankton biomass and the trend over time will underestimate the change in carbon-based phytoplankton biomass. In addition, Contracting Parties should be conscious that significant differences may be attributable to different analytical methodologies for chlorophyll.

4.30 Chlorophyll is traditionally measured *in situ*, either from discrete water samples analysed in the laboratory or through continuous observation (e.g. fluorimetry) by sensors mounted on fixed stations/buoys or in ships. A long-standing issue is the limited comparability of different sampling and analytical techniques. Moreover, given the variability in space and time of this indicator, the resolution of *in situ* sampling is often insufficient to detect patterns and trends. Notably in offshore areas *in situ* sampling is very sparse. By using 'ocean colour', satellites can also detect chlorophyll at a much higher temporal and spatial resolution and at relatively low costs per observation. Earlier OSPAR assessments used national *in-situ* chlorophyll monitoring as Contracting Parties were not satisfied that satellite chlorophyll algorithms could deliver high quality concentration estimates. Collaboration between North Sea countries in the EU project JMP EUNOSAT (2017-2019) has resulted in the development of a tool to generate and validate satellite chlorophyll-a products for the purpose of coherent eutrophication assessments for the Greater North Sea. This tool uses (satellite) information on the optical characteristics of waters (water types such as clear oceanic, turbid coastal, with high dissolved organics or high chlorophyll content) to choose the appropriate ocean colour algorithm that translates the satellite signal into chlorophyll-a concentrations. In addition, information from different (overlapping) satellite missions is used to cover the entire assessment period. Much effort was spent in JMP-EUNOSAT and since to calibrate and test the tool with *in situ* chlorophyll-a data from North Sea countries. The tool delivers quality controlled high-resolution maps for chlorophyll, which are reported as daily maps to the ICES COMPEAT data system as a contribution to more coherent eutrophication assessments. The JMP EUNOSAT tool will be used in OSPAR Regions I, II and III where the temporal and spatial variation in optical properties is perhaps greatest. In Regions IV and V, the single ARGANS Telechlor satellite product provides high quality estimates of chlorophyll concentration and will be used. Since the JMP-EUNOSAT tool is multi-mission and multi-algorithm, it can be applied anywhere and therefore can contribute in the future to coherence across European sea regions. The COMP4 assessment in coastal waters will be based on WFD assessments. The overall offshore COMP 4 assessment uses a mix of satellite and *in situ* observations. The use of two high quality regionally harmonised

[50] JAMP Eutrophication Monitoring Guidelines, reference numbers: 1997-2 to 1997-6, Benthos and chlorophyll-*a* monitoring guidelines updated by HASEC 2012 as Agreements 2012-11 and 2012-12; Nutrients and oxygen updated by HASEC 2013 as Agreements 2013-04 and 2013-05.

satellite chlorophyll products is a significant advance compared to the previous COMP assessments in which data aggregation lacked consistency in between different countries and data sets and transparency. Determining the ideal approach to data aggregation will become increasingly more important as we move towards integrating all continuous and autonomous data in future COMP5 (see **Annex 14**).

4.31 The assessment level for chlorophyll-*a* is based on a justified area-specific % deviation from a reference condition not exceeding 50%.

4.32 The full expression of chlorophyll-*a* during the growing season can be restricted by light limiting factors, e.g. in high turbidity areas. Contracting Parties should, therefore, take this possibility into account when undertaking their assessment for chlorophyll-*a*, and make provision for the measurement of the variation in transparency of the water column (light regimes) concurrent with chlorophyll-*a* in the relevant circumstances.

(2) Phytoplankton indicators

4.33 Some OSPAR Contracting Parties use two types of area-specific phytoplankton indicators: nuisance species, forming dense "blooms", and toxin producing species as further evidence for direct eutrophication effects, already toxic at low concentration. There is equivocal evidence from the scientific literature as to whether phytoplankton indicators are useful indicators of eutrophication. Increased knowledge about the ecology of toxin producing species suggests that these are not universal indicators of eutrophication in the OSPAR area and their use as such is limited (see **Annex 12**). Nuisance species (*Phaeocystis*, *Noctiluca)* may still be considered however a previous paper submitted to OSPAR (OSPAR ICG-Eut 18/3/2(L)) showed some uncertainty around the relationship between *Phaeocystis* and nutrient enrichment and there has been little work performed on the relationship between *Noctiluca* and eutrophication in OSPAR waters. An update on the general and physiological information of the various relevant indicator/assessment species is given in **Annex 12**. It should be noted that there is scientific uncertainty in the use of toxic phytoplankton species as indicators of direct eutrophication effects. Pelagic Habitat indicators developed as part of the diversity assessment also have the potential to be used (see section 4.35).

4.34 Shifts in species composition from diatoms to flagellates may indicate a shift in the balance of organisms due to eutrophication. The composition of the phytoplankton community could be compared with area-specific reference conditions and be expressed by the ratio of diatoms to flagellates. This approach can be picked up as part of PH1 (see section 4.35).

4.35 Nutrient enrichment will impact the phytoplankton community as a whole. Assessment results of the pelagic indicators PH1, PH2 and PH3 (in OSPAR regions where PH3 is applied) should be used in the assessment of the phytoplankton community's response to nutrient enrichment pending further development. The pelagic indicators address different components of the phytoplankton community. The individual lifeform pairs of indicator PH1 will detect changes in phytoplankton and zooplankton communities at functional group level (including the relationship between diatoms and flagellates) and will be useful if a relationship to nutrients can be identified. Results of indicator PH2 on phytoplankton biomass and zooplankton abundance at an overarching community level and PH3 (in the OSPAR regions applied) on changes in biodiversity at species level may also be useful where regional assessment results are available. Contrary to the phytoplankton indicator species, no assessment levels are used for the pelagic indicators, because they act as trend indicators. A precondition for the inclusion of assessment results of the pelagic indicators is the use of the same division of assessment areas based on JMP EUNOSAT.

(3) Macrophytes including macroalgae

4.36 Shifts in species (from long-lived species like eelgrass to nuisance short-lived species like opportunist macroalgae) form an important area-specific indicator/assessment parameter in shallow waters, estuaries and embayments. They are commonly applied as an indicator under the WFD.

(III) Category III - Indirect effects of nutrient enrichment

(1) Oxygen deficiency

4.37 The degree of oxygen deficiency is widely used as an indirect assessment parameter for nutrient enrichment. Oxygen deficiency is induced by decaying algal blooms and long-term nutrient and associated organic matter enrichment. It is particularly observed in areas susceptible to eutrophication effects, e.g. in sedimentation areas, in areas with long residence time, but also in (shallow) waters covered with surface algal "blooms" of increased abundance and biomass of nuisance algal species. Oxygen deficiency leads to an undesirable disturbance to the balance of organisms in the marine ecosystem and overall water quality including shifts in the composition and extent of flora and fauna and behavioural changes or death of fish and other species. Although oxygen depletion can be an indirect effect of nutrient enrichment, other pressures often complicate the identification of causal links between disturbances and nutrient enrichment. Factors that influence oxygen concentrations include changes in water temperature and salinity and climate change. Seasonal oxygen depletion can be a natural localised process, particularly where the water column stratifies seasonally.

4.38 Assessment levels of the various degrees of oxygen deficiency show ranges for the various areas in the North Sea: <2 mg l^{-1}: acute toxic (ca. 75 % deficiency); 4 - 5 mg l^{-1} (ca. 50 % deficiency) and >5 - 6 mg l^{-1}: deficient. Oxygen concentrations above 6 mg l^{-1} are considered to cause no problems and therefore this value is used as assessment level to judge whether there is an undesired oxygen deficiency level for that particular area. Attention needs to be given to scale and occurrence of oxygen deficiency by sufficient monitoring with respect to spatial and temporal aspects.

4.39 The assessment of oxygen should also include reporting of % saturation, water temperature and salinity to ensure comparability of assessments and presentation of results within the OSPAR maritime area. This can be essential for the final classification, in cases where oxygen concentrations are close to the assessment level. Furthermore, dissolved oxygen criteria (% saturation) could be used in respect to both deoxygenation and supersaturation (based on 5^{th} percentile and 95^{th} percentile compliance), with values established for tidal freshwaters, intermediate waters, and full salinity waters.

(2a) Changes/kills in zoobenthos

4.40 This parameter is indirectly related to nutrient enrichment. A distinction can be made between acute toxicity kills directly related to oxygen deficiency and/or toxic blooms, and long-term changes in zoobenthos species composition as a result of long-term increased eutrophication. However, the latter can also be caused by other factors like fisheries which may have an overriding effect compared with eutrophication effects. Changes in the zoobenthos species composition can be assessed as an indicator under the WFD. There are also approaches that evaluate changes in the biomass of the zoobenthos related to eutrophication.

4.41 The assessment guidance for "kills in zoobenthos" in relation to eutrophication is a "yes-or-no" assessment parameter and should be based on supporting information on the occurrence of nuisance and/or toxic phytoplankton species and oxygen levels. Assessment guidance for "long-term changes in zoobenthos species composition and biomass" is still lacking.

(2b) Fish kills

4.42 This parameter is a “yes-or-no” assessment parameter and should be based on supporting information on the occurrence of toxic phytoplankton species and oxygen levels.

(3) Organic carbon/organic matter

4.43 Organic carbon/organic matter are not widely used in the assessment up to now. However, this parameter can be an integrating eutrophication indicator. It can serve as a food source for heterotrophic flagellates. Especially in sedimentation areas (like e.g. German Bight, Oyster Ground and Skagerrak) particulate organic matter can be accumulated causing undesirable disturbance. Additional effects in coastal areas are the modification of the light regime and formation of particulate organic matter, a product of enhanced sedimentation through flocculation. It is recommended to include this parameter into the eutrophication assessment, where relevant (e.g. sedimentation areas).

(4) Photic limit (transparency of the water column)

4.44 This parameter is indirectly related to eutrophication and is an important parameter controlling the light regime and thereby the structure of primary production and the associated habitats. For macrophytes light attenuation determines the depth limit and hence the area of the sea floor with vegetation. For pelagic ecosystems, light attenuation governs if phytoplankton can grow at or below the pycnocline, and thereby whether oxygen production takes place below the pycnocline, i.e. the water masses susceptible to low oxygen conditions. Light limitation as estimated by photic limit or secchi depth is dependent on suspended particulate matter, water depths, humic substances and chlorophyll. In eutrophic areas, photic limit is reduced due to accumulation of organic matter, both as dissolved substances and organic particles, and in bloom situation, directly due to the pigments in phytoplankton. Particulate organic matter (mud) is easily stirred up (suspended) due to wind in tidal mixing, which reduce the photic limit. Photic limit should be assessed during the growing season. Photic limit is presently not included in the Eutrophication Monitoring Programme. However, some Contracting Parties routinely monitor photic limit and use it as an assessment parameter.

Description of the common indicators

4.45 The OSPAR common indicators are nutrient inputs, winter nutrient concentrations and concentrations of chlorophyll-a and dissolved oxygen. They have been selected as key parameters describing the cause-effect chain of eutrophication processes.

4.46 Nutrient inputs: nitrogen and phosphorus enter the marine environment from the atmosphere, rivers, land runoff, or by direct discharges into the sea. Human activities can result in large quantities of nutrients entering the sea from sources that include agriculture, combustion processes (road traffic, shipping, power plants), municipal and industrial wastewater treatment and aquaculture. Quantifying nutrient inputs from different sources is fundamental for understanding the causes of eutrophication and to evaluate the success of measures taken to reduce nutrient inputs. One of the main directions in the OSPAR Eutrophication Strategy is to cooperate to set appropriate nutrient reduction targets for problem areas with regard to eutrophication. Nutrient emissions are regulated through OSPAR Recommendations and several EU Directives. Atmospheric emissions are also regulated through the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP).

4.47 Winter nutrient concentrations: nutrient inputs can lead to elevated nutrient concentrations in the marine environment, of which dissolved inorganic winter nitrogen and phosphorus concentrations are a good indicator and a key parameter for describing the causative factors for eutrophication.

4.48 Concentrations of chlorophyll-a: elevated levels of phytoplankton biomass can be a direct effect of nutrient enrichment and are closely linked to a number of other eutrophication effects such as reduced photic limits, toxic or nuisance algae blooms and oxygen deficiency at the bottom. Furthermore, chlorophyll-a concentrations can be determined with high confidence by combining in situ-measurements with satellite and ferrybox data.

4.49 Concentrations of dissolved oxygen: oxygen depletion at the bottom as indicated by low oxygen concentrations is a key parameter of indirect eutrophication effects since it determines the conditions for the zoobenthos and thereby benthic habitat quality.

5. Assessment procedure

5.1 The 2nd step of the assessment process of the Common Procedure is the actual assessment procedure, in which individual assessment parameters are aggregated over the assessment period and the different assessment parameter results are then integrated to an overall assessment of the eutrophication status. The aggregation/integration follows pre-defined rules as specified below.

a. Aggregation rules to arrive at an assessment per parameter over the assessment period

5.2 Individual parameters should be assessed annually, and the annual assessments should then be aggregated over the defined assessment period by averaging. Such an average provides for a robust assessment of the status of individual parameters and an assessment of the distance to the assessment level.

5.3 Individual parameters will be assessed against their area-specific assessment levels by calculating an environmental quality ratio (EQR). EQRs are obtained by dividing the assessment data by the respective background concentration or vice versa depending on the response of the parameter to eutrophication. In a second step, EQRs are scaled to a uniform scale (EQRS = scaled EQRs, **Annex 11**).

a. Annual EQR calculations will be based on averages of each year’s data and will be used to assess trends.

b. Multiple-year EQR calculations over the whole assessment period will be based on the averages of the annual averages (note that the calculation of annual average will be dependent on adequate data availability).

b. Integration rules within categories I, II and III

5.4 The nutrients nitrogen and phosphorus will be assessed separately within category I to allow for an identification of the nutrient that is potentially causing eutrophication effects by exceeding the respective assessment level. If dissolved and total nitrogen/phosphorus are assessed, the EQRs for each parameter will be averaged. If nutrient ratios are assessed, the assessment result will not be integrated with the results for the nutrients but used as supplementary information for the assessment.

5.5 The assessment parameters within categories II and III should be integrated by averaging or weighted averaging. If weighted averaging is chosen, the weighing factor should reflect the appropriateness of a parameter for assessing eutrophication effects (e.g. photic limit could be down-weighted in areas where natural turbidity is high, phytoplankton indicator species could be down-weighted due to a weak correlation with nutrient concentrations), but not issues such as data quality or overall confidence. Weighting could be area-specific and appropriate weighing factors would need to be scrutinised per assessment area.

c. Integration rules between categories I, II and III

5.6 The assessment parameters are strongly interlinked along a cause/effect scheme from nutrient enrichment (Category I) to direct effects (Category II, e.g. chlorophyll-*a* and phytoplankton nuisance and toxic indicator species) and indirect effects (Category III, e.g. oxygen deficiency, photic limit and changes/kills in zoobenthos). Therefore, to reduce the risk of misinterpretation of these cause/effects, all categories (nutrient enrichment, direct effects, and indirect effects) should be assessed together.

5.7 The classification shall be as follows:

a. areas showing an increased degree of nutrient enrichment accompanied by direct and/or indirect are regarded as ‘**problem areas**’;

b. areas may show direct effects and/or indirect effects, when there is no evident increased nutrient enrichment, for example, as a result of transboundary transport of (toxic) algae and/or organic matter arising from adjacent/remote areas. These areas should be classified as ‘**problem areas**’;

c. areas with an increased degree of nutrient enrichment where there is firm, scientifically based evidence of the absence of (direct, indirect) eutrophication effects – these are classified as ‘**non-problem areas**’, although the increased degree of nutrient enrichment in these areas may contribute to eutrophication problems elsewhere and this should be flagged in the assessment;

d. areas without nutrient enrichment and related (in)direct effects are considered to be ‘**non-problem areas**’.

5.8 Despite large anthropogenic nutrient inputs and high nutrient concentrations, an area may exhibit few if any direct and/or indirect effects. However, Contracting Parties should take into account the risk that nutrient inputs may be transferred to adjacent areas where they can cause detrimental environmental effects and Contracting Parties should recognise that they may contribute significantly to so-called “transboundary affected” problem areas with regard to eutrophication outside their national jurisdiction. An overview of the integration rules is shown in **Figure 8**.

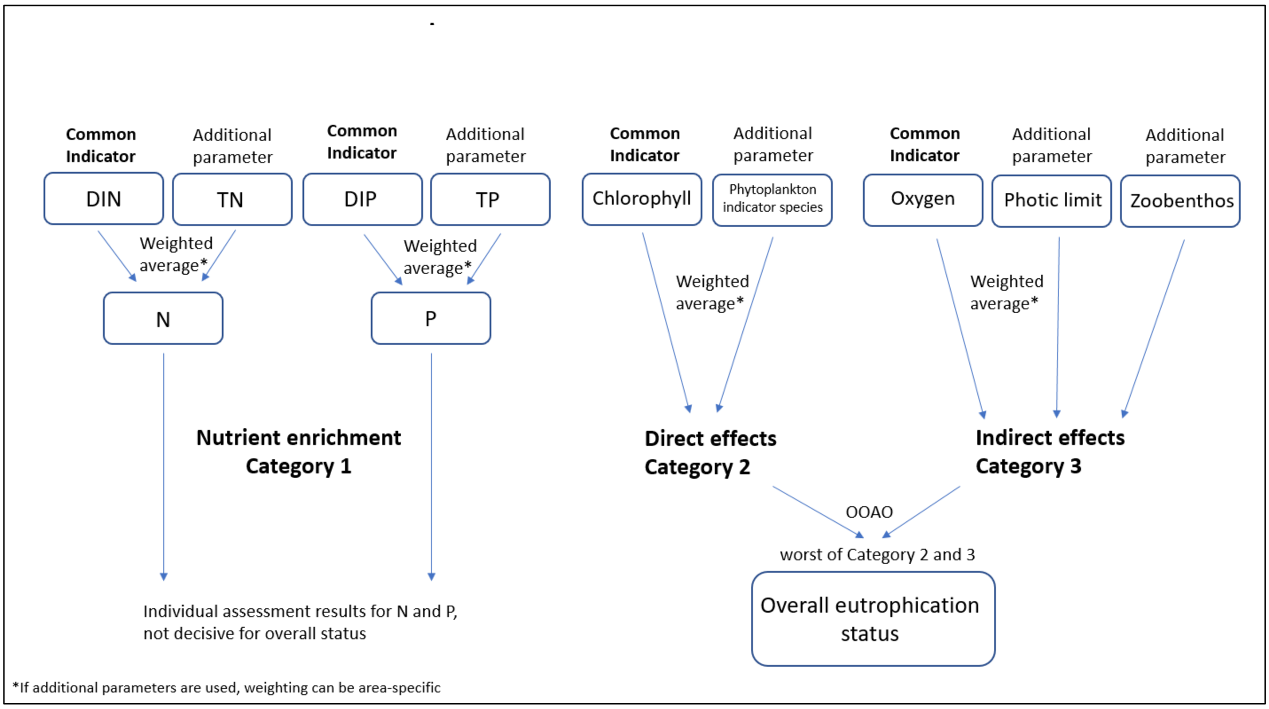

Figure 8: Overview of the integration rules applied in the OSPAR Common Procedure within categories 1,2, and 3 and between the three categories. OOAO – One-out-all-out integration rule.

The COMPEAT tool and final classification

5.9 The COMPEAT tool (Common Procedure Eutrophication Assessment Tool) is an automated classification tool hosted by ICES that produces the eutrophication status assessment based on the aggregation and integration rules outlined in previous sections. The assessment results are reported in terms of an Ecological Quality Ratio (EQR) which allows the relative distance to non-problem status to be visualised. This assessment is the input to the Integrated OSPAR Eutrophication Report. Situations may arise where Contracting Parties have additional information which changes the classification of their part of an assessment unit. Such additional information is included in the Integrated Eutrophication Report to ensure that any changes made to the COMPEAT classification are completely transparent and traceable.

Trends assessments

5.10 Temporal trend assessments of individual indicators at national and regional level could usefully supplement eutrophication status assessments within the Common Procedure. Trend assessment is of particular interest because environmental changes have been sometimes unusual in the past few decades with consequences on the environment in general, including impacts on the eutrophication process, on living resources and fisheries management. Time-series are of importance to studies on the biological influence of anthropogenic effects and climatic changes, both in themselves and in providing a baseline and/or reference conditions for future investigations. They put short assessment periods into long-term perspective. As part of the Common Procedure, temporal trend assessment should allow monitoring whether key environmental parameters of a problem area regarding its eutrophication status are moving in the right direction, indicating that measures taken to combat eutrophication are taking effect.

5.11 Methods for trend assessment should be considered for river discharges, nutrient concentrations in receiving waters and phytoplankton biomass (chlorophyll-a), which together could demonstrate the effectiveness of nutrient reduction. Riverine discharges are assessed through established methods under

OSPAR's working group on inputs to the marine environment (INPUT) (see Guidance on input trend assessment and the adjustment of loads, OSPAR Agreement 2003-9).

5.12 For the other physicochemical and biological parameters and due to the complexity and diversity of statistical tools, a routine procedure (TTAinterfaceTrendAnalysis package) for temporal trend detection has been developed using the R programming software to perform non-parametric trend test analysis (Kendall test family) through an interactive graphical user interface (GUI), easy to handle for non-statistician users. The GUI guides the user through five successive panels which represent the successive steps of the data analysis. The routine trend assessment package is composed of consecutive smaller programmes which interact with each other (data preparation, descriptive statistics, and statistical test either automatically or according to the user's choice (**Annex 8**)).

Assessing eutrophication effects on benthic and pelagic habitats

5.13 The MSFD Commission Decision 2017/848 stipulates that the outcomes of the eutrophication assessments shall also contribute to the assessment of pelagic habitats under Descriptor 1 of the MSFD by assessing the distribution and extent of area that is subject to eutrophication in the water column. In relation to the OSPAR Common Procedure the following assessment parameters, if applied in the respective assessment areas, could be used for such an assessment: chlorophyll-a, phytoplankton indicator species and photic limit. Furthermore, the OSPAR indicators used for the assessment of pelagic habitats (PH1, PH2, PH3) also show linkages to eutrophication and should be considered in such an assessment.

5.14 In addition, the MSFD Commission Decision stipulates that the outcomes of the eutrophication assessments shall also contribute to the assessment of benthic habitats under Descriptor 1 and 6 of the MSFD by assessing the distribution and extent of area that is subject to eutrophication on the seabed. In relation to the OSPAR Common Procedure the following assessment parameters, if applied in the respective assessment areas, could be used for such an assessment: photic limit, macrophytes, oxygen deficiency and changes in zoobenthos.

5.15 It is expected that concrete guidance from the EU will become available on how to conduct assessments of eutrophication effects on pelagic and benthic habitats in the future.

6. Comparison with the Water Framework Directive

6.1 One of the challenges in eutrophication assessment is to arrive at a harmonised and holistic assessment of the eutrophication problem from the catchment to coastal and offshore waters, aligning the requirements of the Water Framework Directive (WFD) and the MSFD in order to provide an unequivocal signal to nutrient management.

6.2 There are similarities between the approach of the WFD and the Common Procedure:

a. pressures: The WFD seeks to assess ecological status resulting from a wide variety of human pressures in coastal and transitional waters including the important pressure due to nutrient input. The Common Procedure seeks identification of where eutrophication problems exist. Each approach seeks to identify measures necessary to achieve good status (WFD) or non-problem area status;

b. geographical area: both the Common Procedure and the WFD include transitional and coastal waters. The WFD assessment area is entirely included in the COMP assessment area and Contracting Parties are either using the WFD water bodies as assessment areas or an aggregation of the water bodies to larger areas for the coastal waters up to 1 nautical mile. Commission Decision 2017/848 of the MSFD stipulates for descriptor 5 “eutrophication” that in coastal waters the assessment scale of the WFD should be used. Seawards, the Common Procedure has a much broader geographical coverage (North-East Atlantic);

c. parameters: Similar parameters are addressed in both assessment approaches, each covers phytoplankton, chlorophyll concentration, nutrients, and dissolved oxygen. The way the parameters are used is different allowing for an assessment of the quality and functioning of the aquatic ecosystem (WFD) or eutrophication status (Common Procedure). Parameters to assess change in the different biological quality elements (e.g. benthic invertebrates and macroalgae) have been further elaborated in the WFD to assess the ecological quality of these elements;

6.3 Concerning the classification, the Commission Decision 2017/848 of the MSFD furthermore stipulates that the criteria shall be used in accordance with the requirements of the WFD to conclude on whether the water body is subject to eutrophication. Hence:

a. the boundary between good/moderate status of the WFD parameters should be the same as the boundary between non-problem/problem area status for parameters used in the Common Procedure. This is illustrated in **Figure 9**;

b. for the classification of the eutrophication status of the coastal waters up to 1 nautical mile Contracting Parties will either use the WFD assessment of ecological status directly or they will use the WFD parameters and will aggregate them following the aggregation rules specified in chapter 5 until further guidance on how to assess MSFD descriptor 5 in coastal waters will become available from EU.

6.4 It is ensured that the assessment levels used under the Common Procedure seawards of the 1 nautical mile boundary are harmonised with the good/moderate boundaries used under WFD in transitional and coastal waters, providing for a plausible gradient from the coast to offshore that takes account of the dilution of the riverine inputs.

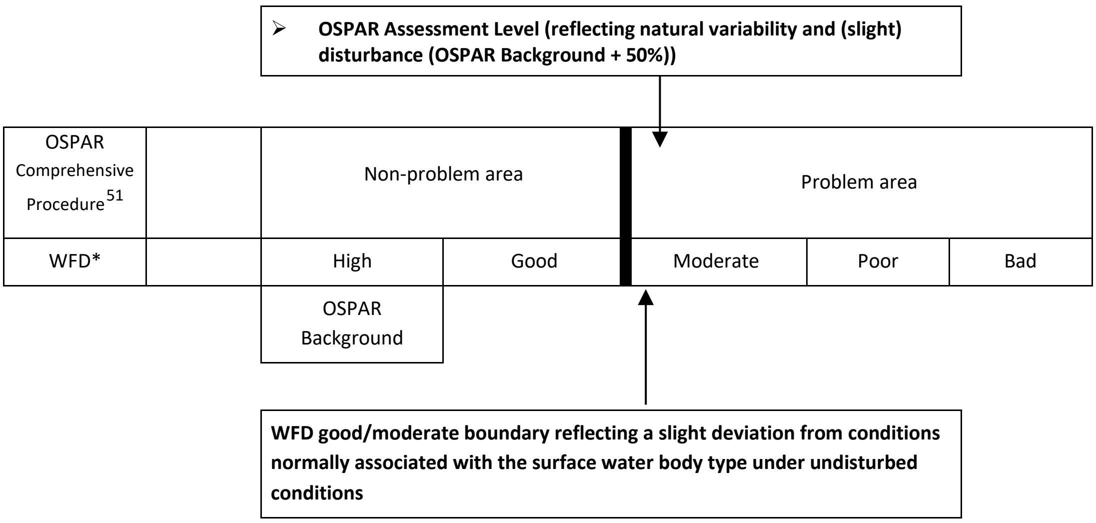

*Figure 9: Relationship between the classification under the Common Procedure and the Water Framework Directive. * when the state under WFD is related to eutrophication.*

[51]Earlier iterations of the COMP (COMP 2 and COMP 3) included a classification ”Potential Problem Area”. This was placed across the boundary of Good/Moderate status, although was in practice applied only when information was insufficient to make a clear classification into Problem or Non-problem area.

7. Confidence rating

7.1 In general, confidence rating of the individual assessment parameters will be applied to indicate the reliability of the data gained from in-situ monitoring, monitoring using novel observation tools (automated buoys, satellite data) and modelling. Confidence rating of novel observation tools and modelling is estimated during the processing of these data and provided together with the data products, while the confidence of in-situ data is calculated directly in the COMPEAT tool. The confidence of the different data types is combined to the parameter confidence by using weighted averaging, similar to the agreed procedure for the combination of different data types to obtain the status assessment result of the respective parameter. Confidence of assessment against area-specific assessment levels in terms of the probability of correct classification considering the uncertainty as well as of representativeness of monitoring stations in space and time will be assessed.

Confidence of assessment against area-specific assessment levels

7.2 Confidence of the assessment against area-specific assessment levels is assigned using either a quantitative (e.g. for the parameters nutrients, chlorophyll-*a*) or a descriptive approach (e.g. for the parameters macrophytes and macrozoobenthos) and is reported per parameter in the column "confidence rating" of the assessment table. For the quantitative approach, a method is proposed that assigns a variable confidence level to estimate the probability of correct classification of being above or below the area-specific assessment level. The calculation of the variable confidence level is included in the COMPEAT tool based on the observed data of the assessment parameter, the standard error, and the respective assessment level. Related confidence class boundaries are documented in **Annex 13**.

Representativeness in space and time

7.3 To estimate the temporal coverage of monitoring data, the number of observations and the frequency of sampling during the parameter-specific assessment seasons are considered in the confidence rating. To document the spatial coverage of monitoring data a gridded approach is used in COMPEAT to assess the proportion of the sampled parts of the different assessment areas related to area-specific predefined grid cell sizes to account for natural variability and gradients. Confidence rating of temporal and spatial coverage of the monitoring data is undertaken to assess whether the underlying database is sufficient for the assessment or needs to be improved. In case the proposed method is not suitable for certain assessment areas exceptional rules with appropriate reasoning can be defined or it should be explicitly described how the monitoring design addresses the particular typology and main hydrographical dynamics in the area, so as to provide evidence on the representativeness of monitoring in space and time. The representativeness in space and time shall be documented in the reporting format.

Confidence rating in COMPEAT

7.4 The confidence approach described above, which includes the assessment of temporal and spatial confidence of in-situ observations, and considers accuracy aspects related to the probability of classifications and uncertainty of the underlying observations, will be used in the automated assessment tool COMPEAT. This will allow for confidence rating on the level of individual assessment parameters (possibly aggregated with confidence rating of novel observation tools and modelling as described in 7.1), which are subsequently integrated to parameter groups, categories, and the overall assessment in the agreed assessment areas. It is intended to supplement the confidence rating with methodological aspects to take into account parameter results based on satellite, ferry box and modelled data and to use an adapted confidence approach for those areas where these data sources are primarily used for assessment as a future prospect.

7.5 Confidence rating results will be classified in the classes high, moderate, and low, where the respective class boundaries of the different confidence aspects take into account parameter-specific needs and different natural variabilities to the extent possible. The class boundaries of the different aspects used for the confidence rating in COMPEAT are documented in **Annex 13**.

7.6 The confidence rating performed in COMPEAT considering the temporal and spatial coverage as well as accuracy, can also be carried out manually outside the automated tool, e.g. when there is a need to include additional parameters.

Implications of the results of confidence rating in space and time

7.7 In cases where parameters of the direct and indirect effect categories or the degree of nutrient enrichment will show low confidence in all confidence aspects used (space and time), this should be flagged in order to emphasise that the quality of the underlying data are not sufficient for the assessment. In such cases, there may be a need to implement monitoring, improve the underlying data and carry out research to enable a reliable assessment of the eutrophication status of the area concerned within five years of its classification as low confidence. In areas where low confidence is based on low monitoring effort, and reduced monitoring has been designed due to the low expectation of eutrophication, the requirements for additional monitoring will not be appropriate (CEMP Guidelines for coordinated monitoring of Eutrophication, CAMP and RID [52]). This is related to all different confidence aspects used for the assessment. At least one of the confidence aspects should reach moderate status in the given time, even if the overall confidence result will remain low. In addition, it calls for preventive measures to be taken in accordance with the precautionary principle.

7.8 Additionally, in the case of a low confidence assessment for the direct and indirect effects and where the degree of nutrient enrichment exceeds the assessment levels the assessment area should be classified as a problem area following the precautionary approach.

Confidence rating of background concentrations and associated assessment levels

7.9 There will be no confidence rating of background concentrations and associated assessment levels in the assessment areas. In case of deviating assessment levels in national areas Contracting Parties will provide a transparent documentation that addresses the following details:

- Detailed account of the method applied to define the background concentrations of all individual assessment parameters (e.g. (i) transfer from undisturbed sites; (ii) historical data; (iii) combination of (i) and (ii) with modelling; (iv) calculation by modelling of undisturbed conditions; (v) expert judgement);
- Detailed account of the method to define assessment levels from background concentrations for those parameters (e.g. indicate whether knowledge on effects or significant correlations between assessment parameters were used or expert judgement).

[52] OSPAR Agreement 2016-05, revised 2021: https://www.ospar.org/documents?v=35414

8. Arrangements for reporting

Reporting in OSPAR

8.1 Reporting for the OSPAR QSR in 2023 consists in general of reporting of the results for the OSPAR common indicators, the results of the OSPAR Common Procedure in a thematic eutrophication assessment and respective reporting templates for Article 8 of the MSFD.

8.2 The results for the OSPAR common indicators winter nutrient concentrations, concentrations of chlorophyll-a and concentrations of dissolved oxygen near the seafloor are generated in COMPEAT, while the results for the OSPAR common indicator nutrient inputs are generated by the INPUT group. All results for the common indicators are reported using the general OSPAR QSR templates for common indicators and its guidance.

8.3 The results of the thematic eutrophication assessment are generally based on the classification produced by COMPEAT and are reported using an adaptation of the general OSPAR QSR template for thematic assessments and its guidance.

8.4 Any national modifications of the results of the eutrophication assessment produced by COMPEAT also need to be considered in the thematic eutrophication assessment, based on information provided by national reporting following the guidance below.

Additional national Reporting

8.5 National reporting is required if OSPAR Contracting Parties chose to undertake one of the following:

a. Assessing additional parameters in their national parts of the OSPAR assessment areas that are not listed in **Annex 4**;

b. Modifying the final assessment results of the COMPEAT tool in their national parts of the OSPAR assessment areas by making use of additional information as outlined under 5.8 and based on the checklist for a holistic assessment (**Annex 2**).

8.6 To ensure harmonised reporting, a reporting format has been developed which is to be used by Contracting Parties making use of such additional information (**Annex 1**).

8.7 The reporting format requests Contracting Parties to provide information on additional assessment parameters used including their assessment results and any modifications of the final classification of COMPEAT applied to national assessment areas.

8.8 The information reported by Contracting Parties according to **Annex 1** will be considered in the OSPAR thematic eutrophication assessment.

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Lønborg, C & S. Markager (2021) Nitrogen in the Baltic Sea: Long-term trends, a budget and decadal time lags in responses to declining inputs. Estuarine, Coastal and Shelf Science, 261.

The Eutrophication Monitoring Programme (reference number: 2005-4 (as updated in 2013)) supersedes the Nutrient Monitoring Programme adopted by OSPAR 1995 (Reference number 1995-5).

EU project Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data

Annexes

Table of Contents

Annex 1: Template for national reporting

Introduction

Description of the area

Description of the assessment areas for which additional assessment parameters were used or results of the classification of COMPEAT were modified.

Monitoring

Information on additional monitoring data that were used in the assessment and description of the monitoring design.

Assessment

Rationale for the use of additional assessment parameters or the modification of COMPEAT assessment results. If additional assessment parameters were considered the results should be provided in **Table A.1.1** (one table per assessment area to be filled in). If the final classification of COMPEAT was modified, reasons and results should be documented using **Table A.1.2**.

Table A.1.1 Results for additional assessment parameters

Category	**Additional assessment parameters**	**Description of the results**	**Classification (EQR)**	**Confidence rating**			
				Temporal	**Spatial**	**Accuracy**	**Overall**
Degree of Nutrient Enrichment (I)	TN / TP concentrations						
	Winter N/P ratio (Redfield N/P = 16)						
Direct Effects (II)	Area-specific phytoplankton indicator species						
	Macrophytes including macroalgae						
Indirect Effects (III)	Photic limit						
	Changes/kills in zoobenthos and fish kills						
	Organic carbon/organic matter						

Table A.1.2 Results for the final classification

Area	Initial classification provided by COMPEAT	Rationale for using additional information	Detailed description of the additional information used	Confidence rating of the additional information (where applicable)	Final classification

Discussion

Explanation of the modification of COMPEAT assessment results

Other relevant information

Any other information relevant for the national assessment.

Conclusions

References

Annex 2: Checklist for a holistic assessment

Eutrophication is the result of excessive enrichment of water with nutrients, which may accelerate the growth of algae (phytoplankton) in the water column. This may result in a range of undesirable disturbances in the marine ecosystem, including a shift in the composition of the flora and fauna, which in turn affects habitats and biodiversity, depletion of oxygen, changes in water clarity, and behavioural changes or even death of fish and other species.

Eutrophication can be considered as a series of steps, with cause (nutrient enrichment), direct effects and indirect effects. The list below considers the different parameters that could be part of a eutrophication assessment. It provides for each category specified assessment criteria (equivalent to the OSPAR common indicators and MSFD primary and secondary criteria) as well as associated biological and chemical parameters that could be used to interpret the assessment outcome in terms of a more holistic approach.

Category I the causative factors:

The degree of nutrient enrichment

- with regard to inorganic/organic nitrogen
- with regard to inorganic/organic phosphorus
- with regard to silicate

Taking account of:

- sources (differentiating between anthropogenic and natural sources)
- increased/upward trends in concentration
- elevated concentrations
- increased N/P, N/Si, P/Si ratios
- fluxes and nutrient cycles (including across boundary fluxes, recycling within environmental compartments and riverine, direct and atmospheric inputs)
- the supporting environmental factors, including:
    - light availability (irradiance, turbidity, suspended load)
    - hydrodynamic conditions (stratification, flushing, retention time, upwelling, salinity, gradients, deposition)
    - climatic/weather conditions (wind, temperature)
    - zooplankton grazing (which may be influenced by other anthropogenic activities);

Category II the direct effects of nutrient enrichment:

i. Phytoplankton:

- increased biomass (e.g. chlorophyll a, organic carbon and cell numbers)
- increased frequency and duration of blooms
- increased annual primary production
- phytoplankton indicator species, including shifts in species composition (e.g. from diatoms to flagellates, some of which are nuisance or toxic species)

ii. Macrophytes, including macroalgae:

- increased biomass
- shifts in species composition (from long-lived species to short-lived species, some of which are nuisance species)
- reduced depth distribution

Category III. the indirect effects of nutrient enrichment:

i. Organic carbon/organic matter:

- increased dissolved/particulate organic carbon concentrations
- occurrence of foam and/or slime
- increased concentration of organic carbon in sediments (due to increased sedimentation rate)

ii. Oxygen:

- decreased concentrations and saturation percentage
- increased frequency of low oxygen concentrations
- increased consumption rate
- occurrence of anoxic zones at the sediment surface (“black spots”)

iii. Zoobenthos and fish:

- mortalities resulting from low oxygen concentrations

iv. Benthic community structure:

- changes in abundance
- changes in species composition
- changes in biomass

v. Ecosystem structure:

- structural changes

vi Photic limit:

- transparency of the water column

Annex 3: Methods for delineation of assessment units

Method for delineation of assessment units in the North Sea (and adjacent waters)

Overview

The EU project Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data (JMP-EUNOSAT) developed an assessment framework for the Greater North Sea based on the eutrophication indicator *chlorophyll a*. Part of this work is identifying cross-border assessment areas with similar ecological and physical functioning (Blauw et al., 2019). This approach has been adopted for the application of the Common Procedure. However, during a joint workshop of ICG-EMO and TG-COMP in Hamburg (Sept. 2019) it was decided that further refinements would be made to the assessment areas proposed by JMP-EUNOSAT, based on requests by OSPAR Contracting Parties.

JMP-EUNOSAT proposal for assessment areas

The assessment framework for the Greater North Sea is based on the eutrophication indicator *chlorophyll a*; identifying cross-border assessment areas with similar ecological and physical functioning. Relevant environmental conditions for defining assessment areas include physical (depth, salinity and stratification), chemical and biological factors and anthropogenic pressures.

In JMP-EUNOSAT the areas with similar phytoplankton dynamics were derived from cluster analysis of satellite data of chlorophyll-a and primary production. Boundaries between the areas found in the cluster analysis could often be related to physical variables in the JMP-EUNOSAT oceanographic model. Therefore, boundaries between assessment areas were defined using the physical variables best explaining the clusters found in the phytoplankton data. For example, areas were subdivided along 32 psu salinity and 35 m depth contours. Additionally, geographical areas were distinguished, such as the Channel, Irish Sea and Kattegat.

For the cluster analysis the chlorophyll signal from satellite data was decomposed into an interannual signal, a seasonal signal and a residual signal. The interannual signal can indicate long-term trends or regime shifts. The seasonal signal is an indication whether the blooms occur each year systematically in the same season or not. The residual signal gives an indication of the remaining variability and can give an indication of strongly varying conditions between years and seasons. With a statistical analysis using the various signals, areas with similar patterns can be identified and merged (**Figure A.3.1**). Largely similar areas appeared in an analysis of patterns in primary production derived from satellite data.

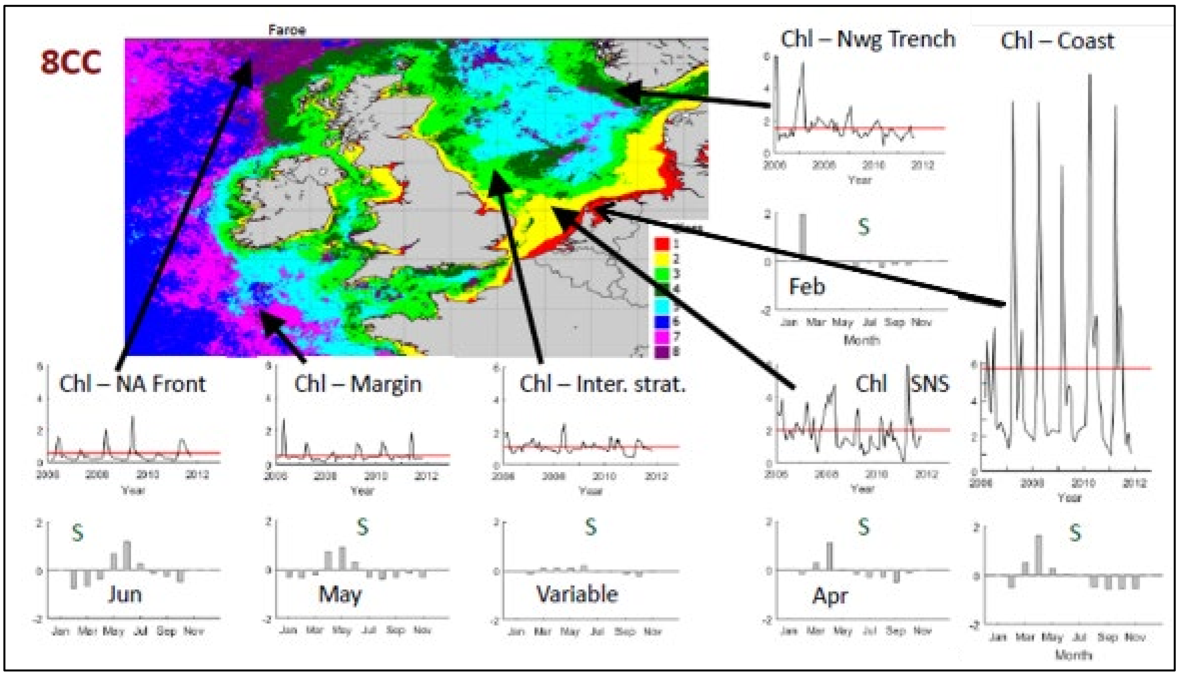

Figure A.3.1 Areas with similar phytoplankton dynamics in satellite data.

In JMP-EUNOSAT Deltares used the hydrodynamic model DCSMv6 FM (Dutch Continental Shelf model version 6) to model stratification and salinity and those results were combined with data on bathymetry. The DCSMv6 FM model has a spatial resolution (model grid size) of 1 nautical mile for all areas that are less than 100 m deep and covers the Greater North Sea and part of the NE Atlantic Ocean and Baltic Sea. Satellite data, in-situ data and FerryBox data were used for the model validation. Stratification was determined based on the modelled monthly averaged density difference between the top and bottom layer in the model. A grid cell was classified as stratified when the density difference was larger than 0.75 kg m^{-3} similar to van Leeuwen et al. (2015). Areas that are almost always stratified are the Norwegian Trench and the waters off the French Atlantic coast. The Northern North Sea is only stratified in summer and mixed in winter. The shallow areas of the Dogger Bank and the Southern North Sea are always mixed. The Atlantic Ocean seems never to be stratified in the model, although in reality the ocean is permanently stratified. To differentiate the type of stratification (permanently, seasonally or intermittently) the number of consecutive months, in which grid cells are either mixed or stratified is calculated. The areas are then classified as shown in **Figure A.3.2** and **Table A.3.1.**

Table A.3.1 Stratification classes

Stratification class	**Number of consecutive months stratified**	**Number of consecutive months mixed**
Permanently stratified	≥ 8	<8
Seasonally stratified	≥ 3 and <8	≥ 6
Intermittently stratified	≥ 1 and <3	≥ 6
Permanently mixed	= 0	≥ 10

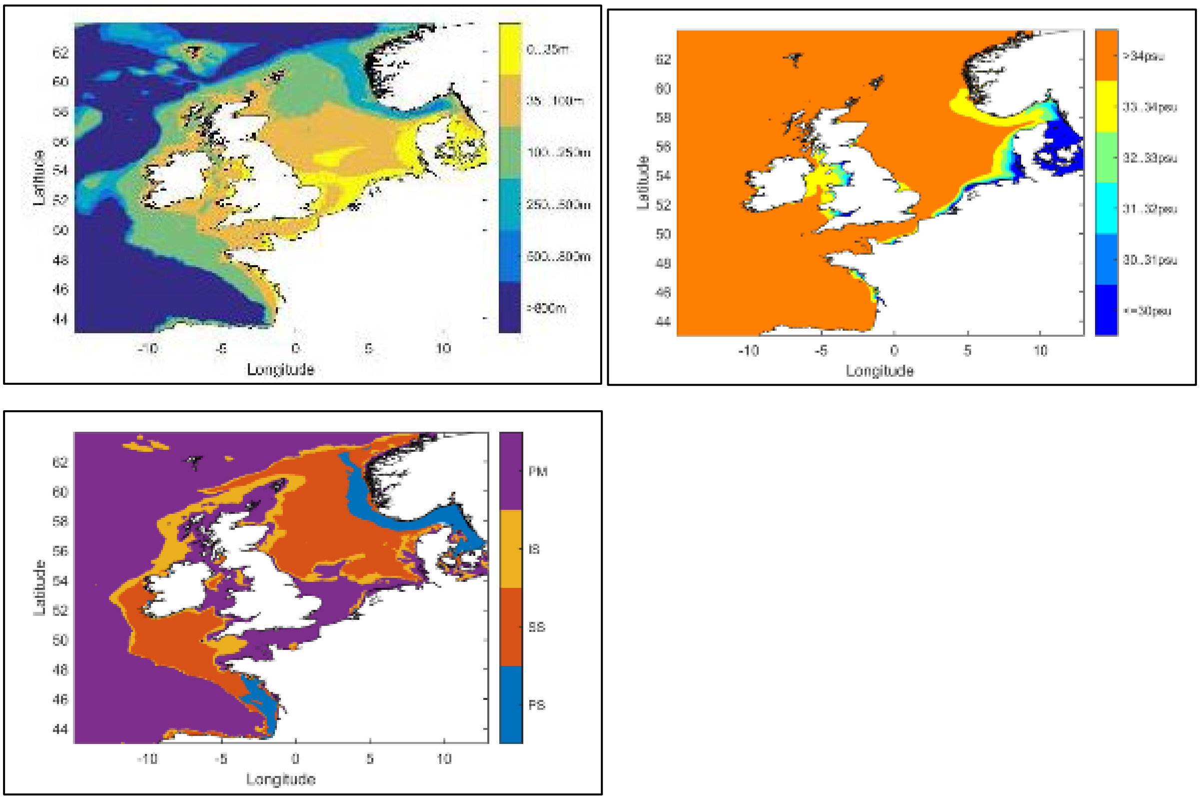

Figure A.3.2 Physical conditions used to determine ecologically coherent assessment areas. Top left (a): Depth contours; top right (b): Salinity contours of the modelled salinity in the top layer; bottom (c): Stratification classes: Permanently stratified (PS), seasonally stratified (SS), and intermittently stratified (IS) or permanently mixed (PM)

Some of the features in the spatial chlorophyll patterns are consistent with the bathymetry of the North Sea, namely the Dogger Bank, the Southern North Sea and the Norwegian Trench. Those features are best depictured by the 35 m (Dogger Bank and Southern North Sea) and the 250m depth contour (Norwegian Trench, **Figure A.3.2**). The deep Atlantic is also separated by the 250 m depth contour. A salinity threshold of 32 psu was chosen to best approximate the coastal water type (**Figure A.3.2**).

Figure A.3.3 and A.3.4 show the resulting assessment areas proposed by JMP-EUNOSAT. When comparing these assessment areas with the assessment areas used for the previous OSPAR assessment report (**Figure A.3.3**) the main difference is that different water types in the North Sea stand out clearly in the new approach and different water types (for example 'coastal waters' or 'Dogger Bank') are defined in the same way across national borders and form a coherent sub-area.

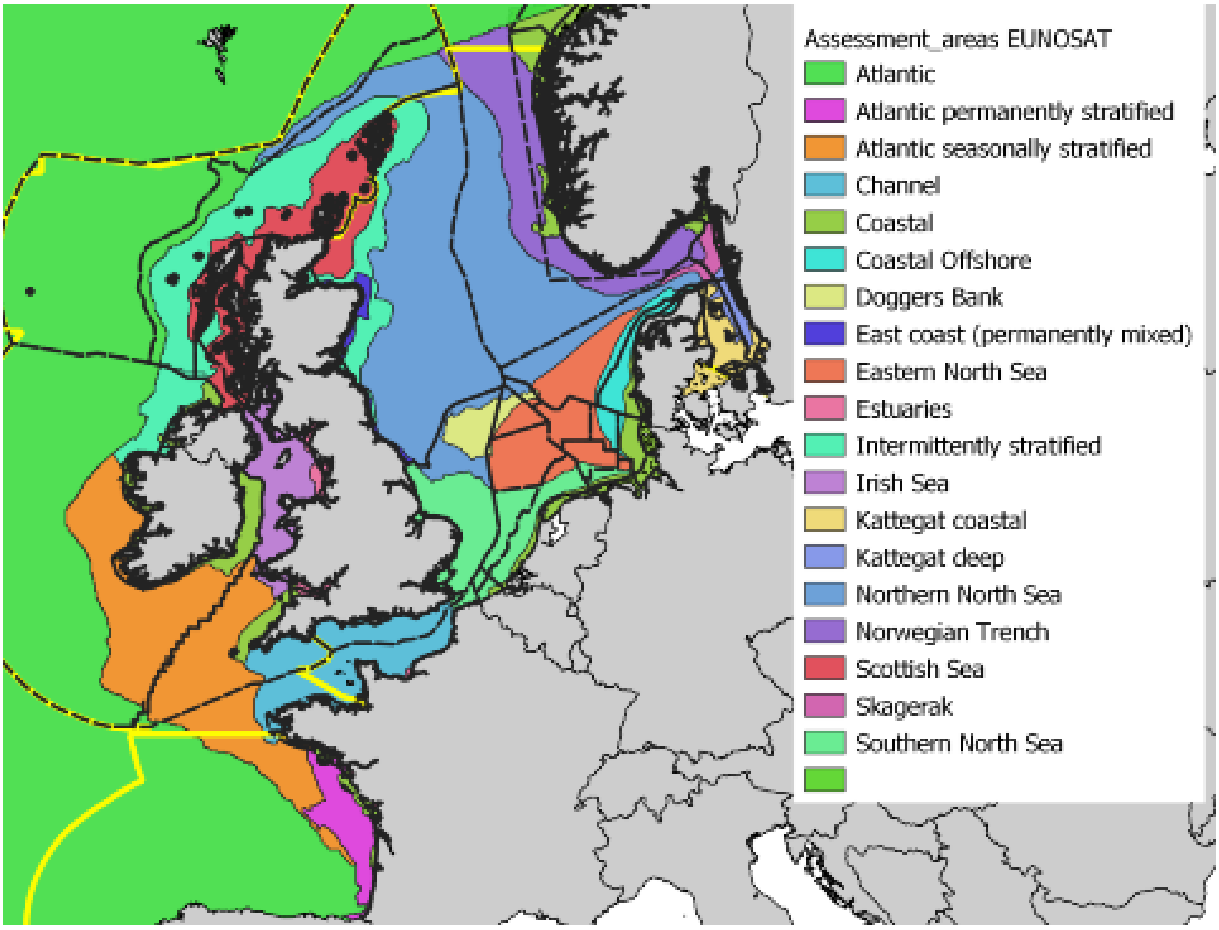

Figure A.3.3 Comparison of 'new' assessment areas developed by JMP Eunosat with COMP3 assessment areas (indicated with black broken lines). Borders between MSFD subregions are shown by yellow lines.

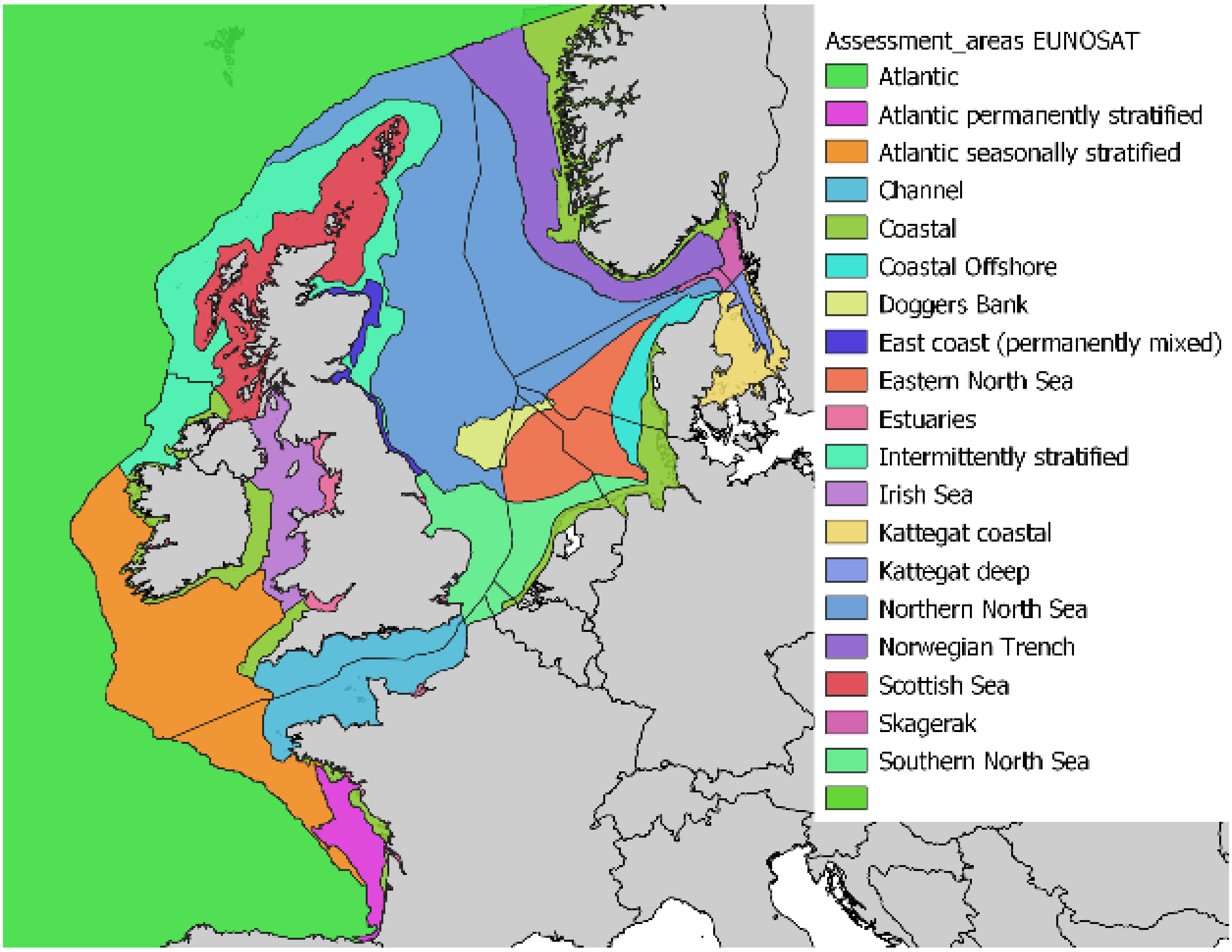

Figure A.3.4 JMP-EUNOSAT proposal for ecologically relevant assessment areas based on phytoplankton dynamics, duration of stratification, mean surface salinity and depth, with borders between EEZs projected on the assessment areas as black lines.

Further development of the OSPAR assessment areas after JMP-EUNOSAT

The original proposal by the JMP-EUNOSAT project was to carry out assessments at three levels of spatial detail:

1. Areas defined based on similar ecological and physical functioning throughout the North Sea, based on spatial and seasonal patterns of chlorophyll and primary production in satellite data;

2. Subdivision of cross-border coherent areas into national sub-areas, so countries can take responsibility for their own part of the cross-border assessment areas;

3. National sub-areas further subdivided into smaller areas, depending on preferences and practical considerations of countries. This would allow e.g., to assess changes in areas that are affected by specific river catchments.

For practical reasons, such as easy implementation of the assessment procedure in the COMPEAT tool, it was decided at the September 2019 TG COMP/ICG EMO meeting in Hamburg that OSPAR will only perform assessments at one level of spatial detail. There was no need to separate assessment areas along country boundaries. But it was considered important that individual large river catchments would be represented as distinct assessment areas. Furthermore, it was decided that the OSPAR assessment areas should not overlap with the WFD assessment areas. Therefore, the WFD assessment areas were cropped out of the OSPAR assessment areas.

Based on requests by Contracting Parties the following changes were made to the assessment areas as originally proposed by the JMP-EUNOSAT project:

- The area 'coastal waters' along the Belgian, Dutch, German and Danish coasts has been split up along river catchments, following the same delineations as used by the WFD. So, the boundaries perpendicular to the coast that split up the 1 nautical mile area (WFD water bodies) along the coast have been extended further offshore. This resulted in the following areas, representing major river inflows: Scheldt plume, Meuse plume, Rhine plume, Ems plume and Elbe plume (all the way up along the Danish coast). We have considered to include the Weser as separate river plume but abandoned this idea to avoid a very small assessment area. We also considered changing the boundaries between the Scheldt, Meuse and Rhine plumes to better represent that, in reality, the coastal waters are dominated by fresh water inputs from the Rhine and, to a lesser extent, Meuse rivers (already mixed in the Dutch delta area) rather than the Scheldt (that has a relatively small discharge and nutrient load). For coherence with the WFD we have so far used the WFD boundaries between the Scheldt, Meuse and Rhine catchments (**Figure A.3.5**).

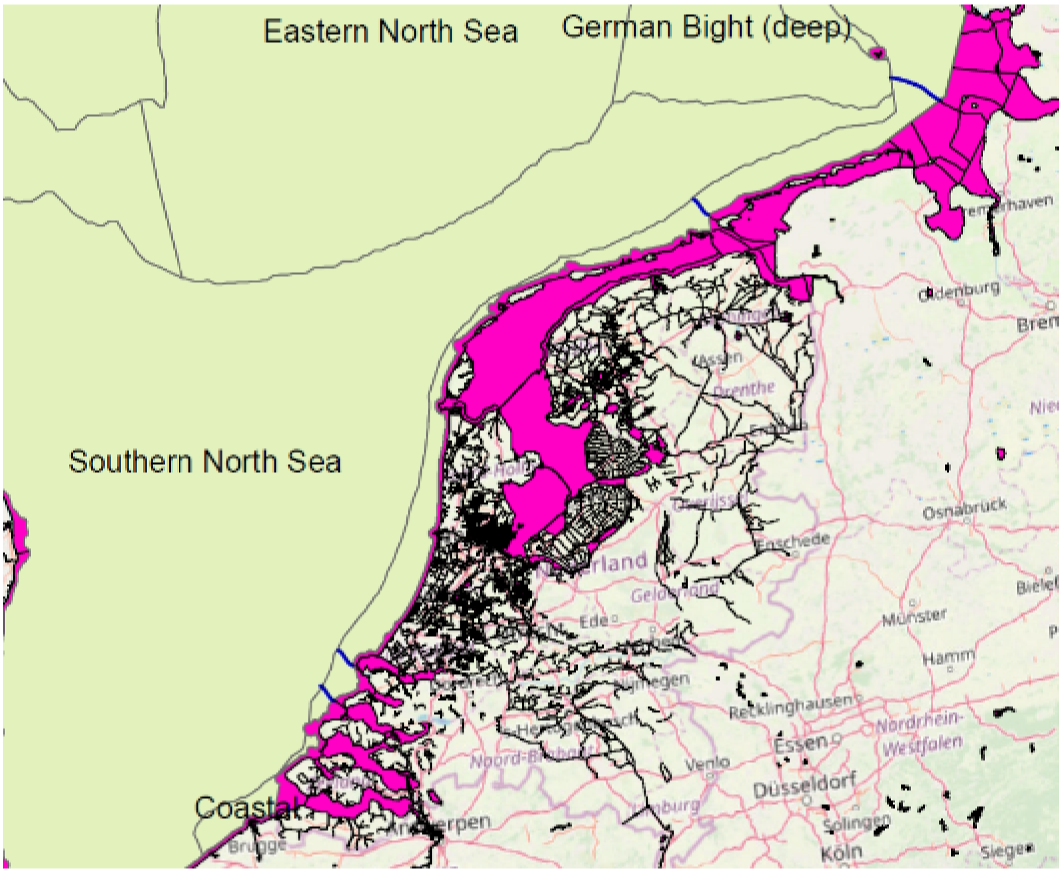

Figure A.3.5 WFD assessment areas (pink), JMP-EUNOSAT assessment areas (green with grey borders) and the proposed cut-up of the coastal water assessment area into river catchments (dark blue) by extending WFD boundaries further offshore.

- In UK coastal waters river plumes of the Humber, Thames and Liverpool Bay were defined as separate assessment areas. After some discussion with the Environment Agency, it was decided to include some of the outer WFD areas in the Thames and Liverpool Bay areas as the areas extend quite a bit into the plume and it was preferred to assess it as one area. The Thames plume follows the 25mg/l SPM contour, Liverpool Bay follows 10 mg/l SPM and Humber follows 11 mg/l SPM, based on a 10-year average (Greenwood et al., 2019).
- In French coastal waters also major river plumes were used as assessment areas: Adour plume, Gironde plume, Loire plume and Seine plume. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019 and Tew-Kai et al., 2020).
- In French coastal waters also new area boundary definitions have been defined based on the same work by SHOM: Bay of Biscay shelf waters, Bay of Biscay coastal waters and Channel coastal waters.
- Based on the same SHOM work and discussions between UK and France both CPs agreed on new cross-boundary sub-areas within the Channel.
- Germany proposed a new subarea in the eastern North Sea for a better representation of the salinity gradient. This has been implemented as German Bight central (**Figure A.3.6**).

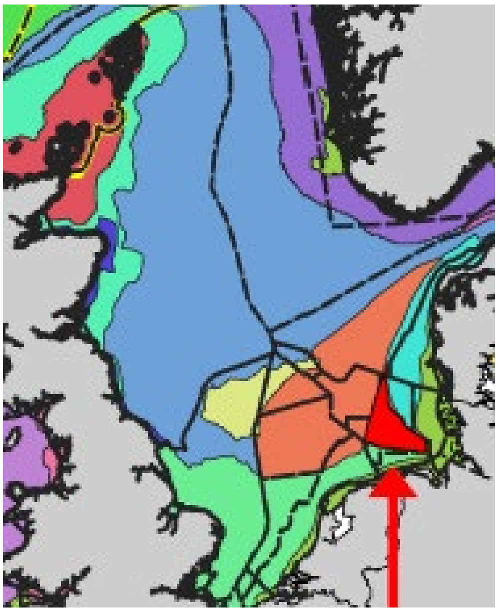

Figure A.3.6 The newly proposed sub-area in the German Bight as red area projected on the original JMP-EUNOSAT assessment areas.

Furthermore, some smaller polishing edits were made such as: removing small leftover polygons after cropping out WFD areas and splitting up some assessment areas into separate areas:

- Removed Outer Coastal area splitting up Skagerrak
- Moved boundary between Eastern North Sea and German Bight to align with 34psu salinity contour.
- Moved boundary between Coastal UK1 and Irish Sea to align with old OSPAR boundary.

- ○ Extended outer boundaries to encompass all of UK and Irish EEZs.
- ○ Removed a fragment polygon in Outer Coastal region (merged with German Bight)
- ○ Split the intermittently stratified region into two along the boundary between the Celtic Seas and Greater North Sea (purple dashed line in **Figure A.3.7**).
- ○ Scottish WFD areas outside 3nm boundary were reinstated to unify Scottish Sea into one assessment area.
- ○ Merged Coastal IRL 1 and Scottish Sea 1 (highlighted in pink in **Figure A.3.7**)

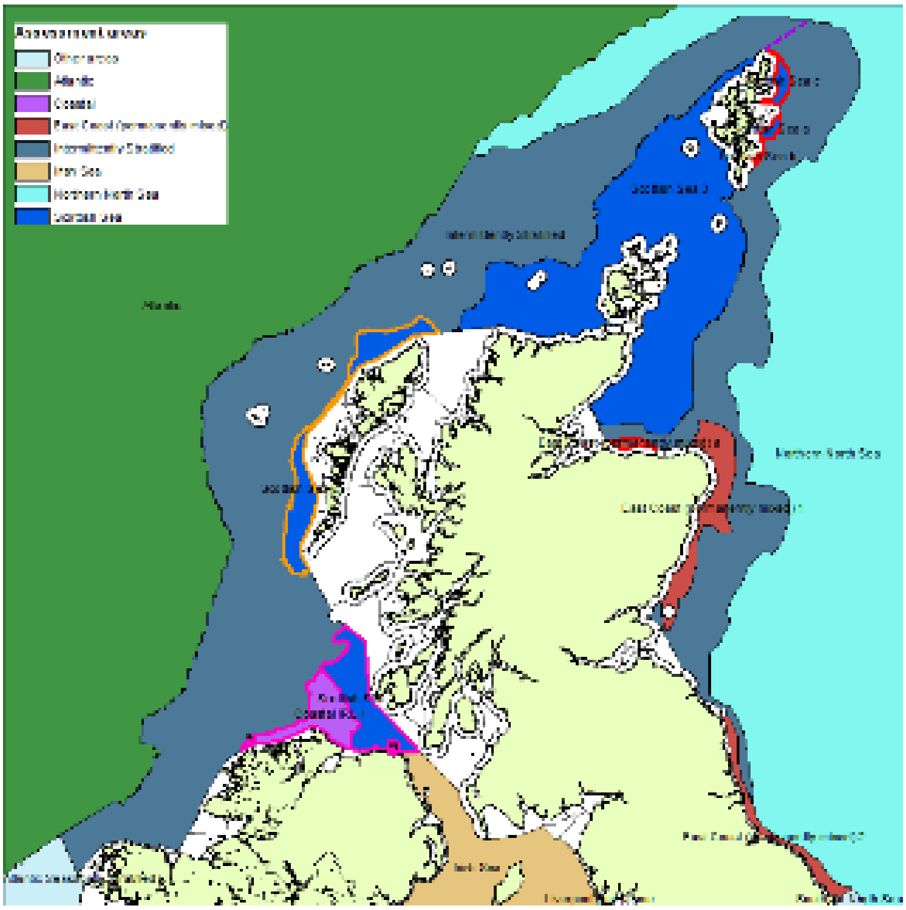

Figure A.3.7 Illustration of some small edits in Scottish waters.

The resulting new proposal for assessment areas for OSPAR eutrophication assessments is shown in **Figure A.3.8.**

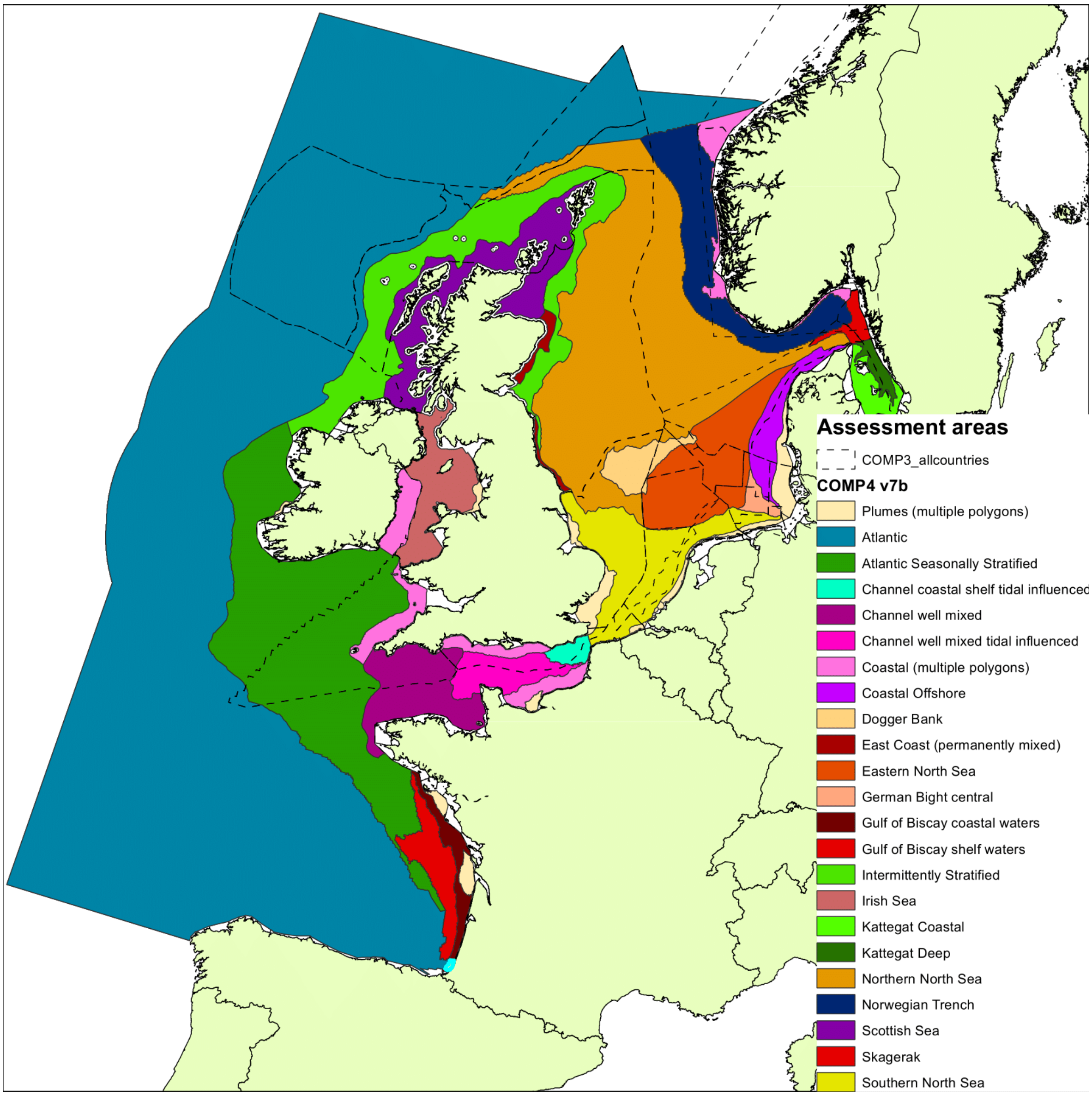

Figure A.3.8 Proposal for ecologically relevant assessment areas based on duration of stratification, mean surface salinity and depth

After the ICG-EUT meeting in January 2020 in Dublin, countries within the OSPAR area but outside the EUNOSAT project area were contacted to ask if they had assessment regions they would like to be included. Portugal and Spain both responded, and their areas were added. The definition of these areas was based on salinity dynamics (Portugal) and phytoplankton dynamics (Spain).

Method for delineation of assessment units in the Spanish waters

Rationale

The conceptual model of coastal eutrophication proposed by Cloern (2001) suggests that the effects of nutrient pollution on phytoplankton productivity (direct effects) in a given marine area are conditioned by its physical and/or biological characteristics including optical properties of the water column and/or horizontal transport processes that depend on several factors like wind, bathymetry, basin geography and river flow. These attributes that vary among marine systems act as filters that modulate (i.e., do amplify or mitigate) the impacts of nutrient enrichment. Consequently, the response to changing signals in nutrient load within a given marine region might spatially differ depending on the operation of these *filters* (following the Cloern's terminology) which additionally would act at different time scales, i.e., seasonal, decadal, or inter-annual; Li et al. 2010). This theoretical framework guided the objective of delimiting relevant areas in eutrophication assessment for the Spanish Atlantic marine waters.

Available dataset about physical variables, nutrients and chlorophyll a in the water column coming from *in situ* samplings is fairly reduced for wide areas of the Atlantic Spanish waters. In contrast, satellite provides with information at high temporal and spatial resolution, which is suitable to identify spatial distribution patterns of the chlorophyll attributable to hydrological variability and/or anthropogenic impact (Gohin et al. 2008) as well as to detect algal blooms and shifts in dominance patterns of some phytoplankton taxonomic groups (Hu et al. 2005, Ahn and Shanmugam 2006, Carvalho et al. 2011, Shanmugam et al. 2008, Jackson et al. 2011). If this satellite information is appropriately analysed for a given marine region, areas distinguishable according to the particular mechanisms that control the nutrient-driven chlorophyll dynamics would be identified (for instance, upwelling areas, anticyclonic gyres or zones affected by river discharge; Klemas 2011). Consequently, Spain based its task of delimiting relevant areas regarding to eutrophication on the analysis of satellite chlorophyll a time series.

Procedure

MODIS-Aqua Level-2 images covering the Spanish waters of the Cantabrian Sea and Galician coast (Spanish Northern-Atlantic waters) and the Gulf of Cadiz (Southern-Atlantic waters) for 2002-2013 were downloaded from the NASA website (http://oceancolor.gsfc.nasa.gov/) in June 2014 (MODIS-Aqua reprocessing 2013.1). The supplier provides a daily scene of chlorophyll for the study area with a spatial resolution of 1.1x1.1 Km^2. Satellite chlorophyll *a* (C_{SAT}) was calculated from reflectance values by using the global algorithm OC3M v.6 based on NOMAD v.2 database (O'Reilly et al. 2000, Werdell and Bailey 2005). Daily data of satellite surface temperature were also retrieved from the images of MODIS-Aqua. The time series of C_{SAT} for each pixel were processed to compose climatological monthly maps.

The monthly means of C_{SAT} were used for identifying contrasting areas with respect to their chlorophyll *a* annual cycle. For this objective, all pixels were grouped by means of the statistical technique of non-hierarchical clustering analysis (*k-means* clustering analysis). *k-means* clustering analysis classifies objects (pixels) into a pre-defined number of clusters unrelated hierarchically. In our analysis, each pixel was assigned to a particular group according to the features of its annual cycle of C_{SAT} as determined by the climatological monthly means. Note that this procedure classified the pixels mainly according to pixel-to-pixel relative differences more than based on the absolute values of C_{SAT}. Independent analyses were performed for the Spanish Northern- and Southern-Atlantic sub-areas. The clustering analyses were performed with monthly means calculated for different duration time periods within 2002-2013. For each assayed time period, the analyses were carried out for pre-defined different number of clusters (*k*, ranging from 2 to 10). The optimal number of clusters for each assayed time period was determined by using the RS index (R-squared; Halkidi et al. 2001). The clustering algorithms were run 100 times for each combination of time interval and *k* values.

The outcomes of the clustering analyses were validated by comparing the pixel grouping patterns with the spatial structure expected according to available data of *in situ* chlorophyll *a* (C_M) and nutrients in the two sub-areas. For this purpose, *in situ* data obtained from multiple research cruises performed by the Spanish Institute of Oceanography from 1992 to 2012 were gathered. Most data were obtained during quarterly or monthly samplings carried out in several fixed stations (http://www.ieo-santander.net/seriestemporales/). Only data obtained in the upper 20 m depth layer were used. The sampling stations were projected onto the clustering map to assign them to one particular pixel grouping area (or assessment area). Afterwards, monthly, and yearly means of nutrients (nitrate and phosphate) and C_M were calculated for each pixel grouping area and the statistical significance of the differences among areas was tested.

A complete description of the methodology for analysis of satellite images, clustering and validation can be found in Mercado et al. (2016).

Spanish assessment areas

In the Spanish North Atlantic waters, six pixel-groups with marked differences in the C_{SAT} annual cycle shape were identified. The most productive waters (i.e., with higher C_{SAT} and C_M) were located in the Galician Rias (NorC1/NAAC1) and the surrounding environments (NorC2/NAAC2). The Iberian Peninsula northwest coast, which is frequently affected by intensive upwelling, was also discriminated (NorC3/NAAC3). For the rest of Spanish northern-Atlantic waters, the pixels were grouped following the gradient from coast (NorP2/NAAP2) to open sea (NorO1/NAAO1). These differences among grouping areas were also obtained when C_M and nutrients concentrations are compared. Consequently, the grouping of pixels based on satellite data reflected reasonably the underlying mechanisms that control the phytoplankton biomass in the study area (**Figure A.3.9**).

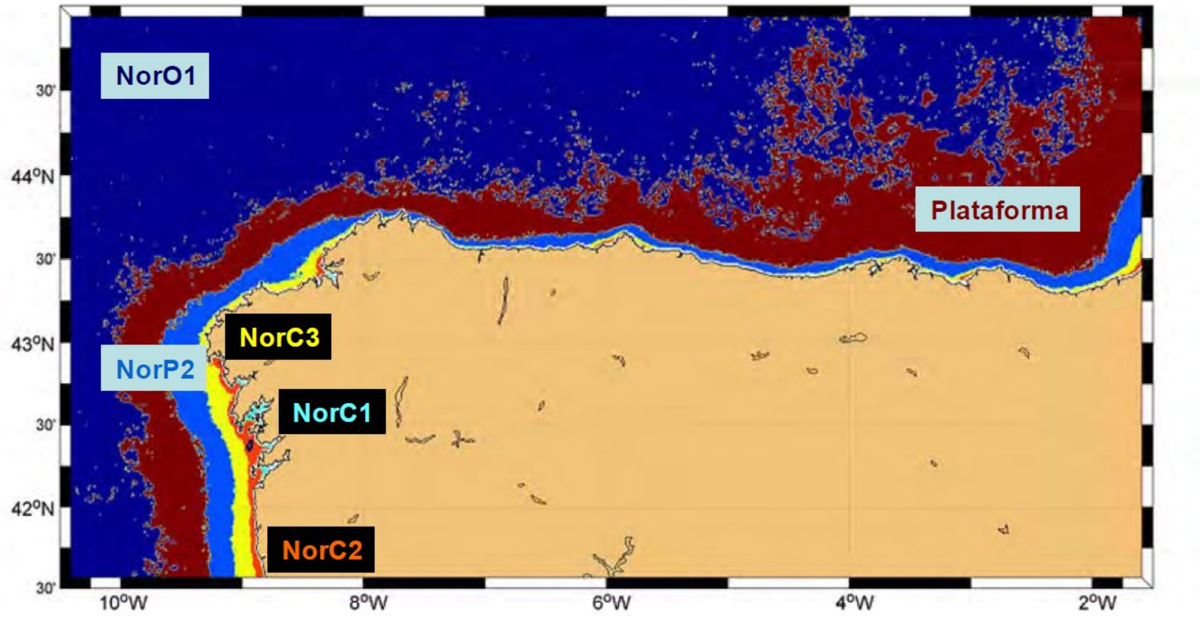

Figure A.3.9 Resulting assessment areas in the North Atlantic Spanish waters.

The South Atlantic waters we found also different areas. The most coastal SUR-C1(SAAC1) and SUR-C2 (SAAC2) with the highest chlorophyll concentrations, and very influenced by the river discharges. We also find 2 areas of transition between the coastal and the open ocean (SUR-OCEAN/SAAOC), one of them also very influence by the rivers (Guadalquivir and Guadiana, Tinto-Odiel, Guadalete) SUR-P1 (SAAP1), and another more external SUR-P2 (SAAP2) (**Figure A.3.10**).

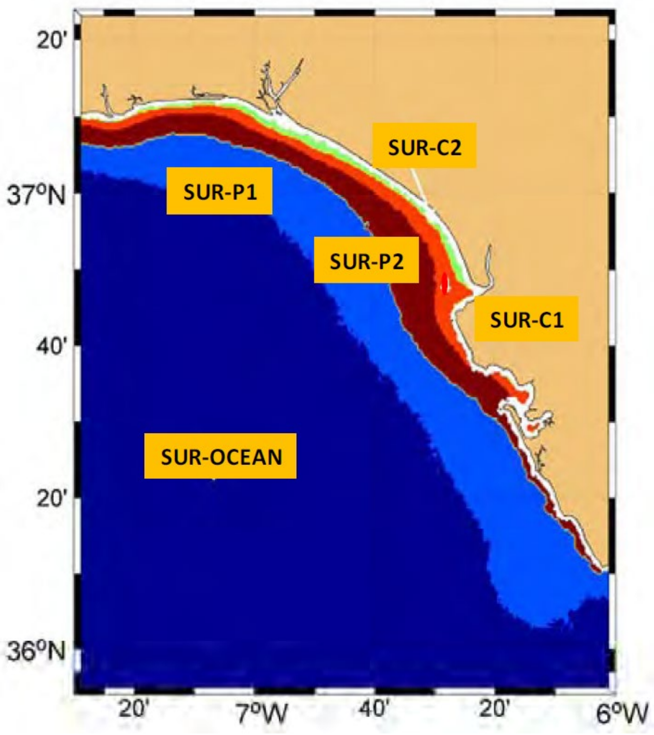

Figure A.3.10 Resulting assessment areas in the South Atlantic Spanish waters.

These units can be used for spatial aggregation of eutrophication indicators, e.g., data collected from *in situ* samplings, as well as for calculating robust reference values and time trends (see Mercado et al. 2016). Furthermore, the pixel grouping is useful for optimising the pre-existing monitoring programs as it facilitates the aggregation, selection, and location of sampling stations in order to avoid collection of redundant and/or pointless information. Also, this method is useful to decide when is preferable to sample as the centroides of each cluster are the characteristic annual cycle of surface chlorophyll *a* concentration in the corresponding assessment area (**Figure A.3.11**).

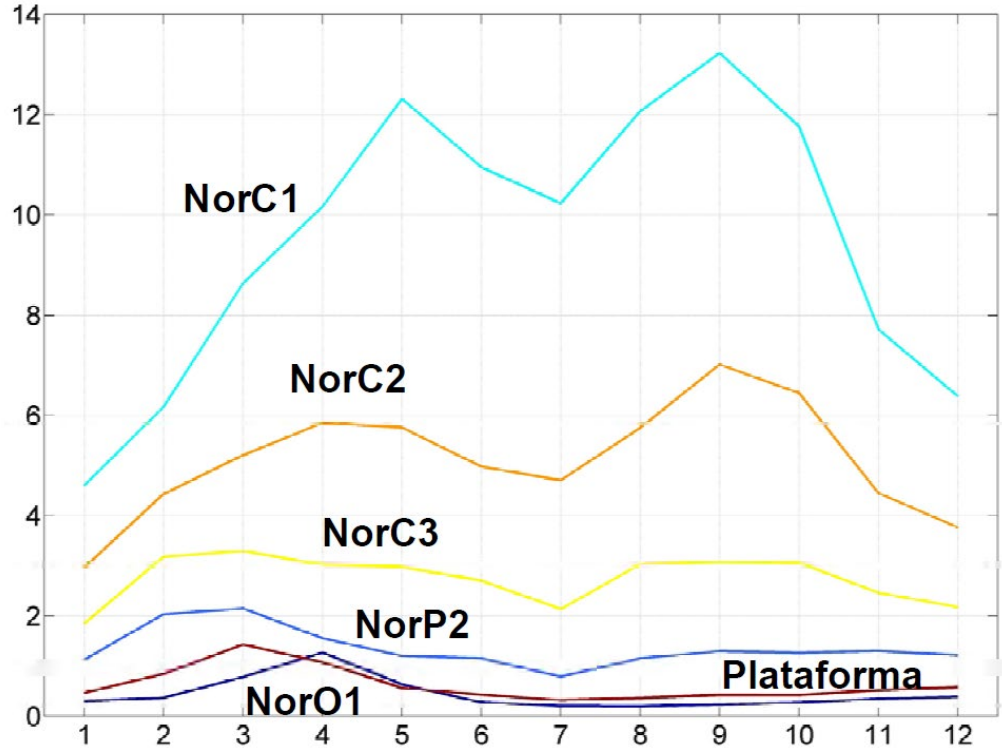

Figure A.3.11 Resulting centroides in the North Atlantic Spanish waters.

Method for delineation of assessment units in Portuguese waters

The Portuguese continental EEZ was divided into smaller sub-areas due to the geographic and oceanographic spatial heterogeneity of this wide region. The limits of the assessment areas were adopted from the Water Framework Directive (WFD) for coastal waters (Bettencourt et al., 2004) and were lengthen up to the EEZ boundaries, resulting in three major areas, designated as A, B and C, from north to south (**Figure A.3.12**).

WFD Coastal waters were assessed by using two main tools: a top-down approach, based on expert knowledge, and a bottom-up approach developed as a follow up to the LoiczView clustering tool developed by LOICZ, and entitled “Deluxe Integrated System for Clustering Operations” (DISCO). Three different coastal types were identified for coastal waters: Exposed Atlantic Coast (A), Moderately Exposed Atlantic Coast (B) and Sheltered Atlantic Coast (C). Of these three, B area, mesotidal moderately exposed Atlantic coast, is unique because combines colder north-east Atlantic and warmer Mediterranean influences with the dynamics of a narrow shelf.

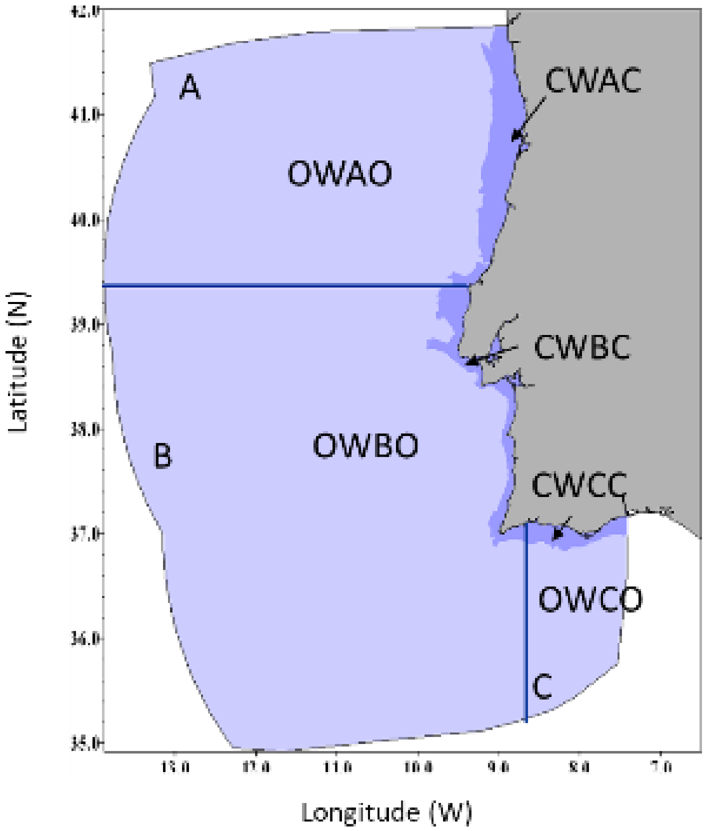

Figure A.3.12 Map of the Portuguese continental EEZ showing bathymetry, the 100 m isobath, assessment areas (CWAC, OWAO, CWCB, OWBO, CWCC, OWCO)

The three main areas (A, B and C lengthen up to the EEZ boundaries,) included zones of coastal water under the influence of both river and upwelling plumes, and offshore areas, either well mixed or seasonally stratified. Assuming that eutrophication is mostly associated with nutrient enriched freshwater inputs and to ensure that any eutrophication problems were not overlooked, the assessment areas A, B and C were further divided longitudinally on the basis of salinity gradients that resulted from the mixing of freshwater and seawater, in order to separate the coastal plume influenced strip (CWAC, CWBC and CWCC, Figure A.3.12) from the offshore area (OWAO, OWBO and OWCO, Fig A.3.12). The salinity regimes adopted were 30.0–34.5 for coastal waters and >34.5 for offshore waters. The adopted criteria separate the coastal plume influenced waters strip (CWAC, CWBC and CWCC, Fig. A12) from the offshore area (OWAO, OWBO and OWCO, Figure A.3.12) at an average depth of 81 m. However, given the observed large intra- and inter-annual variability, denoted by the high standard deviation (Cabrita et al., 2015)., the 100 m isobath was cautiously selected and used to separate coastal from offshore waters so that any eutrophication problems were not overlooked. This decision was made taking into account the spatial variation of the 90th percentile of Chl a concentration (**Figure A.3.13**).

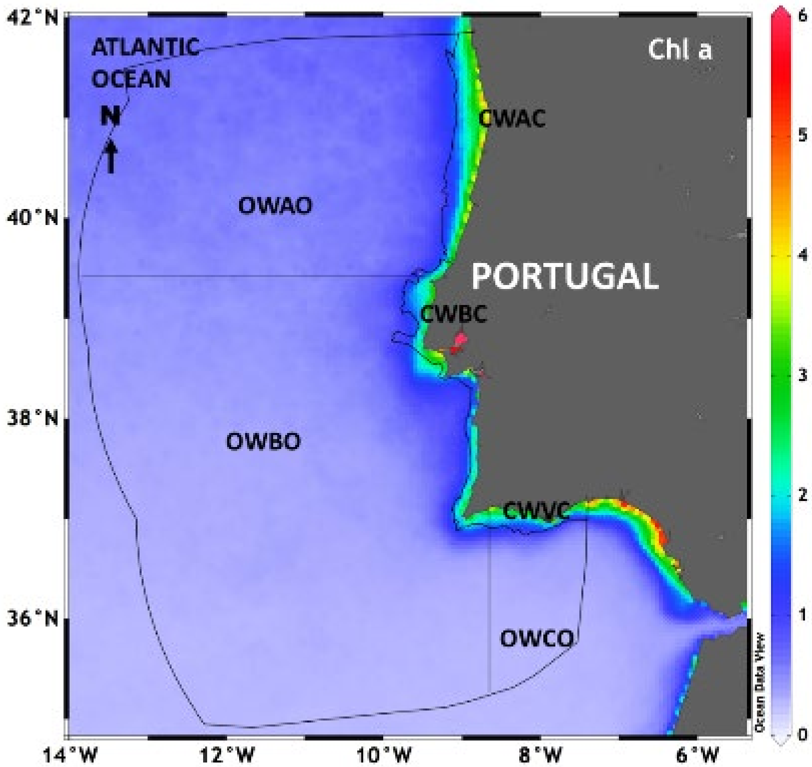

Figure A.3.13 Spatial variation of 90th percentile values (P90) of Chl a concentration (µM) in the water column, in the assessment areas (CWAC, OWAO, CWCB, OWBO, CWCC, OWCO) within the Portuguese continental EEZ. The 100 m isobath line is also indicated.

Additional edits

Additional edits were:

- Aligning boundaries in French waters
- Removing self-intersections and slivers from polygons
- Aligning Spanish and Portuguese assessment areas to ensure no gaps
- Simplifying Spanish assessment polygons and removing isolated fragments.

For a full history of edits to the shapefiles for the assessment areas, visit the COMPEAT github repository (https://github.com/ices-tools-dev/COMPEAT) and view the commit history.

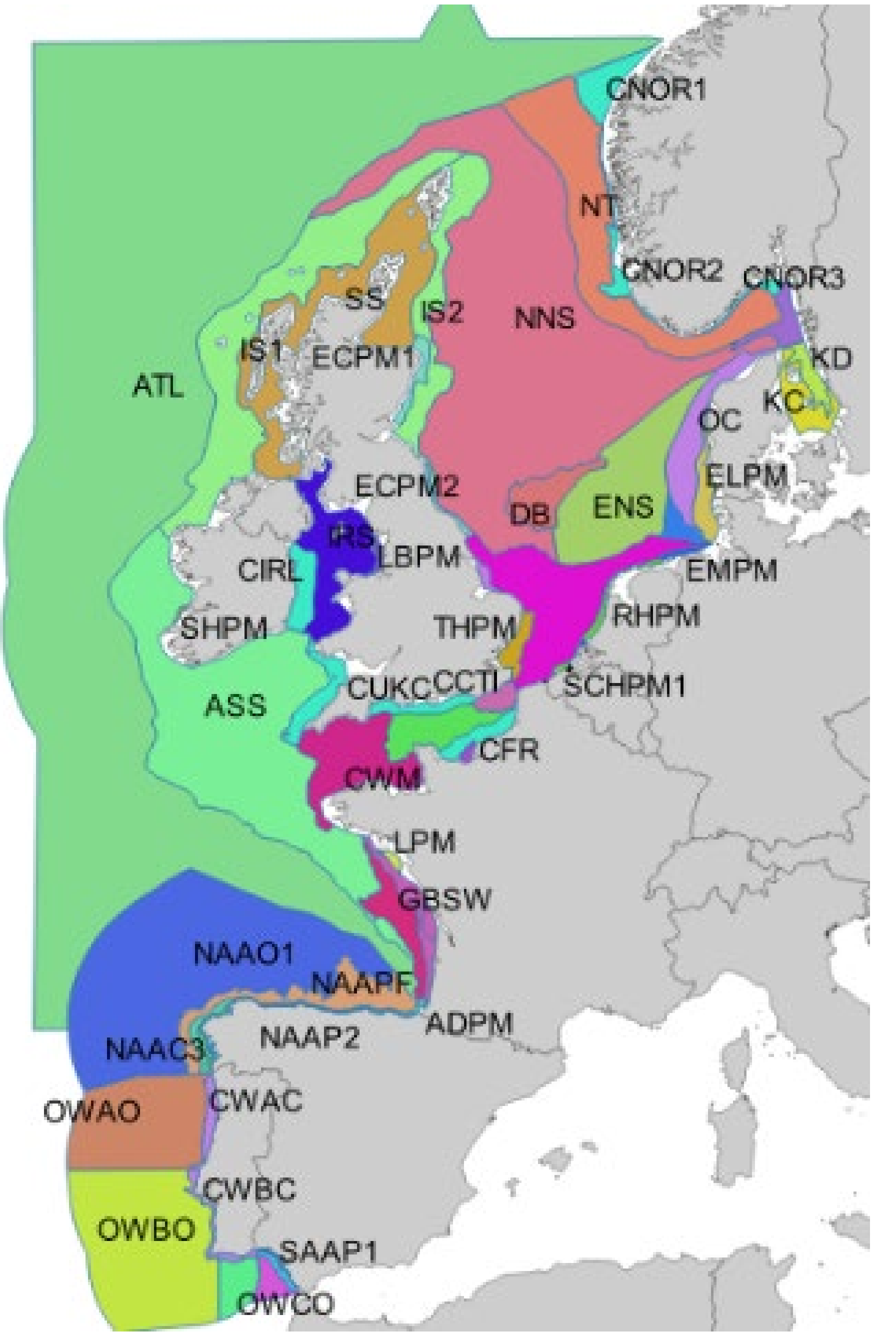

Figure A.3.14 The current version of proposed assessment areas.

Table A.3.2 Description of the assessment areas. WFD areas are excluded and the COMP4 assessment areas are only relevant to open waters beyond WFD

Area code	Area name	CPs involved	Description	Area (km^2)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
ADPM	Adour plume	FR	Plume of the Adour River (SW France). The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019)	283	34	33	35	87	37	174
ATL	Atlantic	ES, FR, IE, UK, NO	All areas west of 250 m depth line, separating deeper Atlantic Ocean from shallower areas in Bay of Biscay, Celtic Seas, Greater North Sea. Outer boundary undefined (outside of model domain)	934260	35	35	36	2291	320	4827
ASS	Atlantic Seasonally Stratified	FR, IE, UK	Area between 100-250 m dept line, seasonally stratified. NW part of Region IV, SW part of region III.	217301	35	35	35	134	90	174
CCTI	Channel coastal shelf tidal influenced	FR, UK	Eastern part of Channel. Not stratified, influenced by tidal mixing. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019) and discussions between FR and UK.	5081	35	35	35	40	26	55
CWM	Channel well mixed	FR, UK	Western part of Channel, extending into Bay of Biscay. Not stratified. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019) and discussions between FR and UK.	42015	35	35	35	77	43	106
CWMTI	Channel well mixed tidal influenced	FR, UK	Central part of Channel. Not stratified, influenced by tidal mixing. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019) and discussions between FR and UK.	20632	35	35	35	59	43	74
CFR	Coastal FR channel	FR, UK	Coastal waters with freshwater influence along the French coast in the E part of the Channel. The landward boundaries are the WFD water bodies and the Seine plume, the outer boundaries are the well mixed central waters of the Channel. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019).	7176	34	33	35	33	22	42

Area code	Area name	CPs involved	Description	Area (km^2)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
CIRL	Coastal IRL 3	IE	Coastal waters on E coast of Ireland (Irish Sea). The landward boundaries are the WFD water bodies, the outer boundary is the Irish Sea assessment area.	9583	34	34	34	65	25	99
CNOR1	Coastal NOR 1	NO	The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour.	8741	34	34	34	190	123	238
CNOR2	Coastal NOR 2	NO	The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour.	2606	34	34	34	217	131	250
CNOR3	Coastal NOR 3	NO	The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour	1733	32	32	33	171	113	233
CUK1	Coastal UK 1	UK	Coastal waters SW of England, permanently mixed (Nr of consecutive months stratified = 0, Nr of consecutive months mixed >= 10) and intermittently stratified (Nr of consecutive months stratified >=1 and < 3, Nr of consecutive months mixed >= 6). The landward boundary is the WFD water bodies, the outer boundary are the seasonally stratified waters in the Celtic Seas.	10697	35	34	35	60	40	80
CUKC	Coastal UK channel	UK	Coastal waters with freshwater influence along the English coast in the E part of the Channel. The landward boundaries are the WFD water bodies, the outer boundaries are the 50 m depth contour.	6305	35	35	35	37	23	51
DB	Dogger Bank	NL, DE, DK, UK	Permanently mixed waters less than 35 m deep in the Dogger Bank area.	14750	35	35	35	28	20	34
ECPM1	East Coast (permanently mixed) 1	UK	Permanently mixed coastal waters. The outer boundary are the intermittently stratified waters	3519	35	35	35	73	45	94

Area code	Area name	CPs involved	Description	Area (km²)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
ECPM2	East Coast (permanently mixed) 2	UK	Permanently mixed coastal waters. The outer boundary are the intermittently stratified waters	1444	34	34	35	43	30	53
ENS	Eastern North Sea	NL, DE, DK	Seasonally stratified, east of the Dogger Bank, West of the 35m depth contour and the 34 psu contour	60634	35	34	35	43	37	49
ELPM	Elbe plume	DE, DK	Plume of the Elbe river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32 psu salinity contour.	7837	31	29	32	18	12	23
EMPM	Ems plume	DE	Plume of the Ems river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32 psu salinity contour.	1445	31	31	32	19	11	25
GBC	German Bight central	DE	Seasonally stratified	4554	33	33	34	39	36	41
GDPM	Gironde plume	FR	Plume of the Gironde river (SW France). The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019)	2828	33	32	34	34	17	51
GBCW	Gulf of Biscay coastal waters	FR	Coastal waters along the French coast (SW France). The landward boundaries are the WFD water bodies and the river plumes of Adour, Gironde and Loire. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019).	10846	35	34	35	53	30	73
GBSW	Gulf of Biscay shelf waters	FR	Permanently stratified shelf waters in Gulf of Biscay. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019).	21008	35	35	35	106	77	133

Area code	Area name	CPs involved	Description	Area (km²)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
HPM	Humber plume	UK	Plume of the Humber river. The outer boundary follows the 11 mg/l contour, based on a 10-year average (Greenwood et al., 2019).	1368	33	33	34	16	10	24
IS1	Intermittentlychec Stratified 1	UK		73501	35	35	35	138	88	177
IS2	Intermittently Stratified 2	IE, UK		26517	35	35	35	102	57	141
IRS	Irish Sea	IE, UK	Permanently mixed central part of the Irish Sea. Landward boundaries are the WFD water bodies and coastal waters of Ireland.	32691	34	33	34	65	27	119
KC	Kattegat Coastal	DK, SE	Kattegat shallower than 35m	9632	26	23	28	21	11	32
KD	Kattegat Deep	DK, SE	Kattegat deeper than 35m	4958	28	26	29	50	36	69
LBPM	Liverpool Bay plume	UK	Plume of Liverpool Bay. The outer boundary follows the 10 mg/l contour, based on a 10-year average (Greenwood et al., 2019).	1361	31	29	32	15	8	22
LPM	Loire plume	FR	Plume of the Loire river. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019)	1495	34	33	34	38	23	50
MPM	Meuse plume	NL	Plume of the Meuse river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32 psu salinity contour. The boundary between the Rhine and the Meuse plume is based on an extension of the WFD water body boundaries.	206	29	27	31	16	10	22
NNS	Northern North Sea	UK, DK, SE, NO, DE	Seasonally stratified waters deeper than 35 m	264253	35	35	35	121	57	170

Area code	Area name	CPs involved	Description	Area (km²)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
NT	Norwegian Trench	NO, SE, DK	Deeper than 100 m, permanently stratified	59124	34	33	35	349	269	453
OC	Outer Coastal DEDK	DE, DK	Coastal waters along the coast of DE and DK. The landward boundary is formed by WFD water bodies and the 32 psu salinity level. The outer boundary is formed by the 34 psu salinity level.	18540	33	33	34	27	21	33
RHPM	Rhine plume	NL	Plume of the Rhine river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32(?) psu salinity contour. The boundary between the Rhine and the Meuse plume is based on an extension of the WFD water body boundaries.	2279	31	30	32	17	12	22
SCHPM1	Scheldt plume 1	BE, NL	Southern part of the plume of the Scheldt river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32 psu salinity contour.	582	31	31	32	13	8	18
SCHPM2	Scheldt plume 2	NL	Northern part of the plume of the Scheldt river. The landward boundary is the WFD water bodies, the outer boundaries are defined by the 32(?) psu salinity contour. The boundary between the Scheldt and the Meuse plume is based on an extension of the WFD water body boundaries.	95	31	30	32	15	8	22
SS	Scottish Sea	UK	Waters surrounding Scotland. Landward boundary defined by the 3nm WFD boundaries. Outer boundaries defined by stratification and old OSPAR boundary	53273	35	35	35	89	55	124
SPM	Seine plume	FR	Plume of the Seine river. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019)	1115	32	30	33	25	15	35
SHPM	Shannon plume	IE	Plume of the Shannon river.	380	34	34	34	61	38	83
SK	Skagerrak	DK, SE	Salinity and geography	5759	32	30	33	134	63	215

Area code	Area name	CPs involved	Description	Area (km²)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
SNS	Southern North Sea	FR, BE, NL, UK, DE	Mostly less than 35 m deep, permanently mixed	61758	34	33	35	32	23	44
THPM	Thames plume	UK	Plume of the Thames river. The outer boundary follows the 25 mg/l SPM contour, based on a 10-year average (Greenwood et al., 2019).	5523	34	34	35	22	9	34
OWAO	Ocean Waters AO	PT	Oceanic waters form 100m contour out to 200 nautical miles for the area from the northern border with Spain to Cape Carvoeiro (A area)	98493	tbd	tbd	tbd	tbd	tbd	tbd
CWAC	Coastal Waters AC	PT	Coastal waters up to 100m contour for the area from the northern border with Spain to Cape Carvoeiro (A area)	7395	tbd	tbd	tbd	tbd	tbd	tbd
OWBO	Ocean Waters BO	PT	Oceanic waters form 100m contour out to 200 nautical miles for the area from Cape Carvoeiro to Ponta da Piedade (B area)	184458	tbd	tbd	tbd	tbd	tbd	tbd
CWBC	Coastal Waters BC	PT	Coastal waters up to 100m contour for the area from Cape Carvoeiro to Ponta da Piedade (B area)	4230	tbd	tbd	tbd	tbd	tbd	tbd
OWCO	Ocean Waters CO	PT	Oceanic waters form 100m contour out to 200 nautical miles for the area from Ponta da Piedade in the western part of the Algarve to the Guadiana estuary, on the Southeastern border with Spain (C area)	18719	tbd	tbd	tbd	tbd	tbd	tbd
CWCC	Coastal Waters CC	PT	Coastal waters up to 100m contour for the area from Ponta da Piedade in the western part of the Algarve to the Guadiana estuary, on the Southeastern border with Spain (C area)	1936	tbd	tbd	tbd	tbd	tbd	tbd

Area code	Area name	CPs involved	Description	Area (km^2)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
NAAC1A	Noratlantic Area NOR-NorC1A	ES	Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body A.	549	tbd	tbd	tbd	tbd	tbd	tbd
NAAC1B	Noratlantic Area NOR-NorC1B	ES	Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body B.	88	tbd	tbd	tbd	tbd	tbd	tbd
NAAC1C	Noratlantic Area NOR-NorC1C	ES	Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body C.	28	tbd	tbd	tbd	tbd	tbd	tbd
NAAC1D	Noratlantic Area NOR-NorC1D	ES	Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body D.	12	tbd	tbd	tbd	tbd	tbd	tbd
NAAC2	Noratlantic Area NOR-NorC2	ES	Assessment area based on phytoplankton productivity: Coastal waters surrounding the Galician Estuaries (Rías Gallegas).	1662	tbd	tbd	tbd	tbd	tbd	tbd
NAAC3	Noratlantic Area NOR-NorC3	ES	Assessment area based on phytoplankton productivity: NW Iberian Peninsula waters most strongly affected by upwelling that are especially intensive in spring and summer.	2609	tbd	tbd	tbd	tbd	tbd	tbd
NAAO1	Noratlantic Area NOR-NorO1	ES	Assessment area based on phytoplankton productivity: Oceanic area.	261727	tbd	tbd	tbd	tbd	tbd	tbd

Area code	Area name	CPs involved	Description	Area (km^2)	Salinity mean	Salinity 10 %ile	Salinity 90 %ile	Depth mean	Depth 10 %ile	Depth 90 %ile
NAAP2	Noratlantic Area NOR-NorP2	ES	Assessment area based on phytoplankton productivity: Transition area between the coast and open ocean, internal.	8327	tbd	tbd	tbd	tbd	tbd	tbd
NAAPF	Noratlantic Area NOR-Plataforma	ES	Assessment area based on phytoplankton productivity: Transition area between the coast and open ocean, external.	37101	tbd	tbd	tbd	tbd	tbd	tbd
SAAC1	Sudatlantic Area SUD-C1	ES	Assessment area based on phytoplankton productivity: Coastal area influenced by river discharges, internal.	405	tbd	tbd	tbd	tbd	tbd	tbd
SAAC2	Sudatlantic Area SUD-C2	ES	Assessment area based on phytoplankton productivity: Coastal area influenced by river discharges, external.	267	tbd	tbd	tbd	tbd	tbd	tbd
SAAOC	Sudatlantic Area SUD-OCEAN	ES	Assessment area based on phytoplankton productivity: Oceanic area	10076	tbd	tbd	tbd	tbd	tbd	tbd
SAAP1	Sudatlantic Area SUD-P1	ES	Assessment area based on phytoplankton productivity: Transition area between coast and open sea, river influenced.	2467	tbd	tbd	tbd	tbd	tbd	tbd
SAAP2	Sudatlantic Area SUD-P2	ES	Assessment area based on phytoplankton productivity: Transition area between coast and open sea, external.	916	tbd	tbd	tbd	tbd	tbd	tbd

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Annex 4: Setting and selecting of area-specific assessment parameters for the application of COMP4

Overview

This Annex is related to Chapter 4 of the Assessment procedure, setting, and selecting of area-specific assessment parameters.

In addition to the common indicators of nutrient concentrations, chlorophyll-a concentrations and oxygen concentrations that are also MSFD primary criteria, other parameters may be applied where necessary and agreed by those Contracting Parties sharing an assessment unit to support the assessment process, to harmonise the Comprehensive Procedure with the WFD and/or the MSFD, and to increase our current understanding as laid down in paragraph 4.18 of the Common Procedure.

Table A.4.1 provides an overview of all assessment parameters intended to be used by individual Contracting Parties (based on COMP3 assessments and updated information provided by the Contracting Parties taking into account the relevance of parameters in national areas.

Table A.4.1 Common Indicators (shaded) and assessment parameters (additional voluntary parameters) by Contracting Parties*

Parameter	BE	DE	DK	ES	FR	IE	NL	NO	PT	SE	UK
Winter DIN and DIP concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chlorophyll-a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Decreased oxygen concentration (and saturation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Phytoplankton indicator species[1]		✓								✓	✓
Macrophytes											
Zoobenthos[1]		✓								✓	
Photic limit		✓	✓	✓	✓					✓	
Total nitrogen, total phosphorus		✓	✓							✓	
N/P ratio*		✓								✓	

1) DE assessment of phytoplankton indicator species depends on available data and assessment of zoobenthos depends on a suitable indicator

The set of parameters per Contracting Party as shown in **Table A.4.1** was not fully implemented in COMP4 due to one or more of the following reasons:

a. Lack of data;
b. Lack of suitable common thresholds;
c. Lack of agreement between CPs for the shared assessment area;
d. Inclusion of suitable assessment parameters still under development, e.g. pelagic habitat indicators PH1, PH2, PH3 and benthic indicators.

For the implementation of COMP4 in COMPEAT mainly the Common Indicators Dissolved nutrient concentrations, Chlorophyll-a concentrations and Oxygen deficiency have been used. An exception to this rule is the Portuguese oceanic assessment areas (OWAO, OWBO and OWCO), where oxygen deficiency is not assessed, mainly due to the fact that, to a great extent, in these areas, depth is over 1000m. In selected assessment areas additional assessment parameters for total nutrients (TN, TP) and Photic limit/Secchi depth have been used in COMPEAT as listed below:

a. Elbe plume (ELPM)
b. Ems plume (EMPM)
c. German Bight central (GBC)
d. Kattegat Coastal (KC)
e. Kattegat Deep (KD)
f. Outer coastal DEDK (OC)
g. Skagerrak (SK)

Annex 5: Area-specific assessment seasons

Assessment seasons are specific for the different assessment parameters. Furthermore, since the OSPAR regions span a wide and climatically variable area, there is generally a need to vary assessment seasons for the same parameter between areas.

In COMPEAT, such variation has not yet been implemented for the 4th application of the Common Procedure and the same seasons per parameter are used for all areas. The reason is that the threshold values have been modelled for specific assessment seasons and the monitoring data that are used in the assessment need to match these. An overview of what is used in COMPEAT is shown in **Table A.5.1**. below:

Table A.5.1 Assessment seasons as used in COMPEAT for COMP4. Only assessment parameters that are used in COMPEAT are shown.

Assessment parameter	**Depth range**	**Assessment season used in COMPEAT**[1]
Inorganic nutrients	0-10m	December-February
Total nutrients	0-10m	January - December
Chlorophyll-a	0-10m	March - September
Dissolved oxygen	Bottom 10m	July - October
Secchi Depth	Surface	March - September

[1] The period starts on the first day of the month in which the season starts and ends on the last day of the month in which the season ends.

Annex 6: OSPAR area-specific assessment parameters

Overview

This Annex lists the area-specific assessment parameters agreed for the 4th application of the COMP. **Table A.6.2** presents all three categories, with columns for the indicator thresholds. Thresholds for Winter DIN and DIP and chlorophyll a are calculated according to the method used by ICG-EMO, which is described in Annex 7, historic scenario 2. In a number of assessment units' deviations from historic scenario 2 were considered necessary, for several reasons. This is explained in the last column of the Table and the values are presented in bold. Thresholds for Winter DIN and DIP and chlorophyll a in Spanish and Portuguese waters are derived using national methods, which is also indicated in the last column. Thresholds for oxygen depletion near the seafloor are the same in all assessment units and have not been changed since COMP3.

In some areas thresholds for Total N and P and for the photic limit (Secchi depth) have been added. The latter methods for threshold setting have been agreed between DE, DK and SE.

Table A.6.1 Area-specific assessment parameters for use in COMP4

Key to the table			Country codes	
Category I Degree of nutrient enrichment	**DI**	winter nutrient conc. DIN, DIP	BE	Belgium
	NP	N/P ratio	DE	Germany
	TN	annual total nutrients TN, TP	DK	Denmark
Category II Direct effects	**Ca**	chl-a conc.	ES	Spain
	Ps	phytoplankton indicator species/ PH1, PH2, PH3	FR IE	France Ireland
	Mp	Macrophytes	NL	Netherlands
Category III Indirect effects	**O2**	5 percentile oxygen deficiency (summer-early autumn)	NO	Norway
	Ck	zoobenthos,fish kills	PT	Portugal
	Oc	organic carbon/organic matter	SE	Sweden
	Pl	photic limit	UK	United Kingdom

Table A.6.2 *Area-specific assessment levels for use in COMP4*				Category 1 - nutrient enrichment				Category II – Direct effects	Category III – Indirect effects		
UnitID	**Code**	**Assessment unit full name**	**Contracting Parties involved**	**Mean Winter DIN (µM)**	**Mean Winter DIP (µM)**	**Mean Annual Total N (µM)**	**Mean Annual Total P (µM)**	**Mean growing season Chl-a (µ/l)**	**Oxygen deficiency near the seafloor (mg/l)**	**Secchi depth (m)**	**Explanation of deviation from Historic Scenario 2**
1	ADPM	Adour plume	FR	8.9	0.67			1.7	6.0		ICG-EMO HS2 thresholds
2	ASS	Atlantic Seasonally Stratified	FR, IE, UK	11.7	0.84			**1.8**	6.0		Chl-a changed from 1.379 to 1.8 for consistency with adjacent waters, sensible gradient with WFD (and poor model coverage ASS, ATL)
3	ATL	Atlantic	ES, FR, IE, UK, NO	15.4	0.98			1.8	6.0		ICG-EMO HS2 thresholds
4	CCTI	Channel coastal shelf tidal influenced	FR, UK	12.0	0.64			2.3	6.0		ICG-EMO HS2 thresholds
5	CFR	Coastal FR channel	FR, UK	15.8	0.60			2.8	6.0		ICG-EMO HS2 thresholds
6	CIRL	Coastal IRL 3	IE	11.4	0.77			1.8	6.0		ICG-EMO HS2 thresholds
7	CNOR1	Coastal NOR 1	NO	12.5	0.87			2.7	6.0		ICG-EMO HS2 thresholds
8	CNOR2	Coastal NOR 2	NO	10.3	0.77			1.9	6.0		ICG-EMO HS2 thresholds
9	CNOR3	Coastal NOR 3	NO	9.2	0.68			2.4	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
10	OC DE/DK	Outer Coastal DEDK	DE, DK	**9.3**	**0.59**	13.7	0.85	**1.6**	6.0	7.0	Correction factor applied to HS2 TV (DIN: 0.7*13.34; DIP: 0.9*0.66; Chl a: 0.6*2.73) to ensure plausible gradient to WFD areas and thresholds for the Danish area part; to align gradient to adjacent areas. Ref: HASEC 22/10/03 Add.2-Rev.2. For TN and TP Danish and German threshold proposals were averaged since the threshold estimates were quite similar. German thresholds are based on the MONERIS nutrient input modelling approach and extrapolation of the riverine nutrient inputs along the salinity gradient into the sea which was used in the previous COMP3 assessment. The Danish thresholds are based on a model approach extrapolating the results from adjacent WFD areas. For Secchi the approach described for total nutrients resulted in significant differences between Danish and German threshold proposals. Therefore, it was decided to use the higher thresholds for Secchi/photic limit to follow the precautionary principle and because mechanistic modelling of light attenuation is highly turbid waters like the Elbe plume is uncertain and remains difficult.
11	CUK1	Coastal UK 1	UK	11.7	0.82			1.7	6.0		ICG-EMO HS2 thresholds
12	CUKC	Coastal UK channel	UK	12.8	0.73			2.3	6.0		ICG-EMO HS2 thresholds
13	CWAC	Coastal Waters AC (D5)	PT	12.0	0.80			12.0	6.0		National thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
14	CWBC	Coastal Waters BC (D5)	PT	12.0	0.80			8.2	6.0		National thresholds
15	CWCC	Coastal Waters CC (D5)	PT	12.0	0.80			8.2	6.0		National thresholds
16	CWM	Channel well mixed	FR, UK	8.3	0.66			1.3	6.0		ICG-EMO HS2 thresholds
17	CWMTI	Channel well mixed tidal influenced	FR, UK	9.2	0.69			1.5	6.0		ICG-EMO HS2 thresholds
18	DB	Dogger Bank	NL, DE, DK, UK	7.2	0.76			1.3	6.0		ICG-EMO HS2 thresholds
19	ECPM1	East Coast (permanently mixed) 1	UK	11.0	0.78			2.1	6.0		ICG-EMO HS2 thresholds
20	ECPM2	East Coast (permanently mixed) 2	UK	10.9	0.86			3.5	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
21	ELPM	Elbe plume	DE, DK	**18.2**	**0.72**	21.4	0.95	**3.7**	6.0	4.1	correction factor applied to HS2 TV (DIN: 0.7*26.06; DIP: 0.9*0.80; Chl a: 0.7*5.25) to ensure plausible gradient to WFD areas and thresholds. Ref: HASEC 22/10/03 Add.2-Rev.2. For TN and TP Danish and German threshold proposals were averaged since the threshold estimates were quite similar. German thresholds are based on the MONERIS nutrient input modelling approach and extrapolation of the riverine nutrient inputs along the salinity gradient into the sea which was used in the previous COMP3 assessment. The Danish thresholds are based on a model approach extrapolating the results from adjacent WFD areas. For Secchi the approach described for total nutrients resulted in significant differences between Danish and German threshold proposals. Therefore, it was decided to use the higher thresholds for Secchi/photic limit to follow the precautionary principle and because mechanistic modelling of light attenuation is highly turbid waters like the Elbe plume is uncertain and remains difficult.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
22	EMPM	Ems plume	DE	**15.1**	**0.61**	16.1	0.68	**3.7**	6.0	5.7	correction factor applied to HS2 TV (DIN: 1.4*10.80; DIP: 0.9*0.68; Chl a: 0.7*5.30). Unrealistically low values for DIN have been increased to reduce sharp differences to neighbouring areas and to ensure plausible coastal-offshore gradient. Correction to align gradient to adjacent areas (DIP) and to ensure plausible gradient to WFD areas and thresholds (Chl a). Ref: HASEC 22/10/03 Add.2-Rev.2. German thresholds for TN and TP are based on the MONERIS nutrient input modelling approach and extrapolation of the riverine nutrient inputs along the salinity gradient into the sea, which was used in the previous COMP3 assessment. German thresholds for photic limit are based on correlations with summer TN concentrations.
23	ENS	Eastern North Sea	NL, DE, DK	**7.3**	**0.6**			**1.2**	6.0		correction factor applied to HS2 TV (DIN: 0.9*8.07; DIP: 0.9*0.67; Chl a: 0.7*1.73) to align gradient to adjacent areas (DIN, DIP), and to prevent EQR values >1 (better than reference conditions) for Chl a. Ref: HASEC 22/10/03 Add.2-Rev.2.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
24	GBC	German Bight Central	DE	**10.1**	**0.62**	13.1	0.82	**1.9**	6.0		correction factor applied to HS2 TV (DIN: 1.4*7.25; DIP: 0.9*0.69; Chl a: 0.7*2.69). Unrealistically low values for DIN have been increased to reduce sharp differences to neighbouring areas and to ensure plausible coastal-offshore gradient. Correction to align gradient to adjacent areas (DIP and Chl a). Ref: HASEC 22/10/03 Add.2-Rev.2. German thresholds for TN and TP are based on the MONERIS nutrient input modelling approach and extrapolation of the riverine nutrient inputs along the salinity gradient into the sea, which was used in the previous COMP3 assessment. German thresholds for photic limit are based on correlations with summer TN concentrations.
25	GBCW	Gulf of Biscay coastal waters	FR	11.8	0.75			2.7	6.0		ICG-EMO HS2 thresholds
26	GBSW	Gulf of Biscay shelf waters	FR	8.7	0.69			**2.0**	6.0		Chl a: too low compared to adjacent area (gradient). Correction applied to HS1 values (0.863 becomes 2.02). Computed with ICG-EMO data. Ref: ICG-Eut(1) 2022 p03_france_thresholdtests
27	GDPM	Gironde plume	FR	12.7	0.68			5.4	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
28	HPM	Humber plume	UK	**26.3**	**1.16**			**10.6**	6.0		Correction factor based on relative method. The UK broadly accepts the thresholds from the weighted ensemble modelling as they have a scientific evidence base. This evidence base stems from the agreed assumption of setting the best /high condition as year 1900. The nutrient reduction scenarios as defined by the e-hype project. The ensemble modelling used the best available modelling which then produced estimates of the best condition. There are a few specific regions, the plume areas, where the weighted modelling work produces very different estimates from the relative method. Furthermore, for the Thames, Humber and Liverpool Bay regions the relative method produces thresholds which are more consistent with similar type environments, along the Netherlands and German coasts. In these regions the relative method is used. In all other regions the weighted ensemble method is accepted. For the UK there is no distinction between the HS1 or HS2 scenarios, therefore which ever has the greatest scientific evidence should be used. The use of 50% as a suitable anthropogenic impact (AD), is accepted on the basis of reaching consensus with contracting parties. The UK would like to see more discussion and implementation of a process that calculates AD based on the natural variability from in-situ and modelled data.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
29	IRS	Irish Sea	IE, UK	9.9	0.78			2.0	6.0		ICG-EMO HS2 thresholds
30	IS1	Intermittently Stratified 1	UK	13.7	0.90			**1.8**	6.0		Chl a changed from 1.65 to 1.8 as per ASS
31	IS2	Intermittently Stratified 2	IE, UK	11.3	0.86			1.7	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
32	KC	Kattegat Coastal	DK, SE	**4.5**	**0.45**	14.6	0.82	**1.2**	6.0	8.5	Correction factor applied to HS2 TV (DIN: 0.6*7.55; DIP: 0.7*0.64; Chl a: 0.5*2.37). Reasoning: DIN: Kattegat is close to boundary of model domain and conditions are strongly influenced by imposed boundary conditions. HELCOM TARGREV (data driven) suggests 4.1 µM. SE regulations propose 3.5 in the south and 5.6 µM in the North. A factor of 0.6 takes us closer to these. Also ensures reasonable coastal - offshore gradients considering the WFD. Unlikely that either Kattegat coastal or deep are in good status for DIN at present. DIP: TARGREV proposed 0,49 µM. Current SE regulations use 0.6 µM (value from 1990s). Given the large scale anoxia and resultant high P concentrations in Baltic outflows it seems unlikely that we have good status for P here. Proposed factor gives plausible gradients to coastal waters and is close to TARGREV value. Chl a: We note boundary issues with EMO modelling in the Kattegat + concerns about the light climate modelling concentrating algal production to the near surface, which likely results in an overestimate of chlorophyll concentrations. TARGREV proposed 1.22 µg/l threshold in the Kattegat. SE regulations suggest 1.5 µg/l. The proposed factors adjust the thresholds to this zone. It ensures plausible gradients to WFD areas and thresholds. Ref: HASEC 22/10/03 Add.2-Rev.2. Awaiting confirmation from Sweden regarding TN, TP and Secchi values.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
33	KD	Kattegat Deep	DK, SE	**4**	**0.48**	14.4	0.78	**1.4**	6	9	correction factor applied to HS2 TV (DIN: 0.6*6.64; DIP: 0.7*0.69; Chl a: 0.5*2.76). Reasoning: DIN: Note that Kattegat is close to boundary of the model domain and conditions are strongly influenced by imposed boundary conditions. HELCOM TARGREV (data driven) suggests 4.1 µM. SE regulations propose 3.5 in the south and 5.6 µM in the North. A factor of 0.6 takes us closer to these. Also ensures reasonable coastal - offshore gradients considering the WFD. Unlikely that either Kattegat coastal or deep are in good status for DIN at present. DIP: TARGREV proposed 0,49 µM. Current SE regulations use 0.6 µM (value from 1990s). Given the large-scale anoxia and resultant high P concentrations in Baltic outflows it seems unlikely that we have good status for P here). Proposed factor gives plausible gradients to coastal waters and is close to TARGREV value. Chl a: to prevent EQR values >1 (better than reference conditions) which appears particularly unlikely in the Kattegat, where hypoxia regularly occurs. Factor arrives at the same level as HELCOM target values. Ref: HASEC 22/10/03 Add.2-Rev.2. Awaiting confirmation from Sweden regarding TN, TP and Secchi values.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
34	LBPM	Liverpool Bay plume	UK	**22.2**	**1.35**			**9.0**	6.0		correction factor based on relative method. The UK broadly accepts the thresholds from the weighted ensemble modelling as they have a scientific evidence base. This evidence base stems from the agreed assumption of setting the best /high condition as yeaar 1900. The nutrient reduction scenarios as defined by the e-hype project. The ensemble modelling used the best avialable modelling which then produced estimates of the best condition. There are a few specific regions, the plume areas, where the weighted modelling work produces very different estimates from the relative method. Furthermore, for the Thames, Humber and Liverpool Bay regions the relative method produces thresholds which are more consistent with similar type environments, along the Netherlands and German coasts. In these regions the relative method is used. In all other regions the weighted ensemble method is accepted. For the UK there is no distinction between the HS1 or HS2 scenarios, therefore which ever has the greatest scientific evidence should be used. The use of 50% as a suitable anthropogenic impact (AD), is accepted on the basis of reaching consensus with contracting parties. The UK would like to see more discussion and implementation of a process that calculates AD based on the natural variability from in-situ and modelled data.
35	LPM	Loire plume	FR	19.3	0.79			3.3	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
36	MPM	Meuse plume	NL	**40.7**	**1.35**			**8.0**	6.0		ICG-EMO HS1 thresholds. HS2 DIP reference values too low, comparable to pristine state rather than concentrations around 1900. Ref: ICG-Eut 21/5/2 Add.5
37	NAAC1A	Noratlantic Area NOR-NorC1(D5)A	ES	22.0	1.00			13.5	6.0		National thresholds
38	NAAC1B	Noratlantic Area NOR-NorC1(D5)B	ES	22.0	1.00			13.5	6.0		National thresholds
39	NAAC1C	Noratlantic Area NOR-NorC1(D5)C	ES	22.0	1.00			13.5	6.0		National thresholds
40	NAAC1D	Noratlantic Area NOR-NorC1(D5)D	ES	22.0	1.00			13.5	6.0		National thresholds
41	NAAC2	Noratlantic Area NOR-NorC2(D5)	ES	15.5	0.97			12.0	6.0		National thresholds
42	NAAC3	Noratlantic Area NOR-NorC3(D5)	ES	15.5	0.97			12.0	6.0		National thresholds
43	NAAO1	Noratlantic Area NOR-NorO1(D5)	ES	9.4				6.0	6.0		National thresholds
44	NAAP2	Noratlantic Area NOR-NorP2(D5)	ES	15.0	0.70			7.7	6.0		National thresholds
45	NAAPF	Noratlantic Area NOR-Plataforma	ES	9.4				6.0	6.0		National thresholds
46	NNS	Northern North Sea	UK, DK, NO, DE	**10.3**	**0.71**			**1.1**	6		correction factor applied to HS2 TV (DIN: 0.9*10.91; DIP: 0.8*0.89; Chl a: 0.7*1.58). Reasoning: to prevent EQR values >1 (better than reference conditions). Ref: HASEC 22/10/03 Add.2-Rev.2.

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
47	NT	Norwegian Trench	NO, SE, DK	**6.55**	**0.60**			1.68	6.0		correction factor applied to HS2 DIN and DIP TV (DIN: 0.6*10.91; DIP: 0.7*0.86). Reasoning: to prevent EQR values >1 (better than reference conditions). Ref: HASEC 22/10/03 Add.2-Rev.2.
48	OWAO	Ocean Waters AO (D5)	PT	**10.5**	**0.60**			**2.3**	6.0		National thresholds. One of the main reasons why there is no data in these areas is because of their depths greater than 1000m in more than 75% of this area (OWAO).
49	OWBO	Ocean Waters BO (D5)	PT	**10.0**	**0.60**			**2.0**	6.0		National thresholds. One of the main reasons why there is no data in these areas is because of their depths greater than 1000m in more than 90% of this area (OWBO).
50	OWCO	Ocean Waters CO (D5)	PT	**10.0**	**0.50**			**1.5**	6.0		National thresholds. One of the main reasons why there is no data in these areas is because of their depths greater than 1000m in more than 75% of this area (OWCO).
51	RHPM	Rhine plume	NL	**29.7**	**1.15**			**6.8**	6.0		ICG-EMO HS1 thresholds. HS2 DIP reference values too low, comparable to pristine state rather than concentrations around 1900. Ref: ICG-Eut 21/5/2 Add.5
52	SAAC1	Sudatlantic Area SUD-C1(D5)	ES	**21.9**				**15.1**	6.0		National thresholds
53	SAAC2	Sudatlantic Area SUD-C2(D5)	ES	**28.9**				**20.3**	6.0		National thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
54	SAAOC	Sudatlantic Area SUD-OCEAN(D5)	ES	**3.4**	**0.40**			**1.4**	6.0		National thresholds
55	SAAP1	Sudatlantic Area SUD-P1(D5)	ES	**4.8**	**0.60**			**3.9**	6.0		National thresholds
56	SAAP2	Sudatlantic Area SUD-P2(D5)	ES	**13.3**	**1.40**			**8.8**	6.0		National thresholds
57	SCHPM1	Scheldt plume 1	BE, NL	**25.9**	**1.31**			**5.0**	6.0		ICG-EMO HS1 thresholds. HS2 DIP reference values too low, comparable to pristine state rather than concentrations around 1900. Ref: ICG-Eut 21/5/2 Add.5 Rev.1
58	SCHPM2	Scheldt plume 2	NL	**33.3**	**1.02**			**8.9**	6.0		ICG-EMO HS1 thresholds. HS2 DIP reference values too low, comparable to pristine state rather than concentrations around 1900. Ref: ICG-Eut 21/5/2 Add.5
59	SHPM	Shannon plume	IE	**11.7**	**0.84**			**1.8**	6.0		Values changed from Chl a 1.84, DIN 11.07, DIP 0.79 for consistency with adjacent waters, sensible gradient with WFD (and poor model coverage ASS, ATL)

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
60	SK	Skagerrak	DK, SE	**4.7**	**0.64**	11.7	0.81	**1.7**	6.0	8.3	Correction factor applied to HS2 TV (DIN: 0.7*6.71; DIP: 0.9*0.71; Chl a: 0.9*1.93). Reasoning: DIN: This estimate gives a reasonable gradient between the Kattegat and outer North Sea waters. The existing threshold in Swedish regulations (9 µM) puts Skagerrak waters in equal to or better than reference condition for DIN, which is unlikely given the adjacent waterbodies and coastal water. DIP: Factor ensures a reasonable gradient between Kattegat and outer North Sea. A factor of 0.9 = almost complete acceptance of the EMO proposal. Chl a: The factor gives a minor adjustment to EMO values and gives a plausible gradient from Kattegat to offshore - noting the greater need for adjustment in the Norwegian trench to avoid "better than reference" conditions. Current SE regulations propose 1.8 µg/l, so this value is a minor adjustment. Ref: HASEC 22/10/03 Add.2-Rev.2. Awaiting confirmation from Sweden regarding TN, TP and Secchi values.
61	SNS	Southern North Sea	FR, BE, DE, NL, UK	13.0	0.70			3.8	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
62	SPM	Seine plume	FR	**27.3**	0.91			5.1	6.0		DIN: too high compared to existing French thresholds (WFD CWM: 29 and 33; MSFD Inshore 24.65, MSFD Offshore 20.3). Correction applied to HS1 values (38.52 becomes 27.3). Computed (HS1) with ECOMARS3D data only. Ref: ICG-Eut(1) 2022 p03_france_thresholdtests
63	SS	Scottish Sea	UK	9.7	0.80			1.5	6.0		ICG-EMO HS2 thresholds

UnitID	Code	Assessment unit full name	Contracting Parties involved	Mean Winter DIN (µM)	Mean Winter DIP (µM)	Mean Annual Total N (µM)	Mean Annual Total P (µM)	Mean growing season Chl-a (µ/l)	Oxygen deficiency near the seafloor (mg/l)	Secchi depth (m)	Explanation of deviation from Historic Scenario 2
64	THPM	Thames plume	UK	**16.9**	**1.04**			**7.4**	6.0		correction factor based on relative method. The UK broadly accepts the thresholds from the weighted ensemble modelling as they have a scientific evidence base. This evidence base stems from the agreed assumption of setting the best /high condition as year 1900. The nutrient reduction scenarios as defined by the e-hype project. The ensemble modelling used the best available modelling which then produced estimates of the best condition. There are a few specific regions, the plume areas, where the weighted modelling work produces very different estimates from the relative method. Furthermore, for the Thames, Humber and Liverpool Bay regions the relative method produce thresholds which are more consistent with similar type environments, along the Netherlands and German coasts. In these regions the relative method is used. In all other regions the weighted ensemble method is accepted. For the UK there is no distinction between the HS1 or HS2 scenarios, therefore which ever has the greatest scientific evidence should be used. The use of 50% as a suitable anthropogenic impact (AD), is accepted on the basis of reaching consensus with contracting parties. The UK would like to see more discussion and implementation of a process that calculates AD based on the natural variability from in-situ and modelled data.

Annex 7: Coherent background concentrations and assessment levels for nutrients and chlorophyll-a

Introduction

In the third application of the Common Procedure OSPAR Contracting Parties evaluated the eutrophication status of their marine waters using their own set of assessment levels for concentrations of nutrients and chlorophyll a. Coherence between CPs was restricted to the acceptable deviation relative to the background concentrations (mostly +50%), but the background concentrations had been set in the past using different approaches, leading to different assessment levels (cf. **Figure A.7.1**) and different outcomes of the eutrophication assessment across national borders.

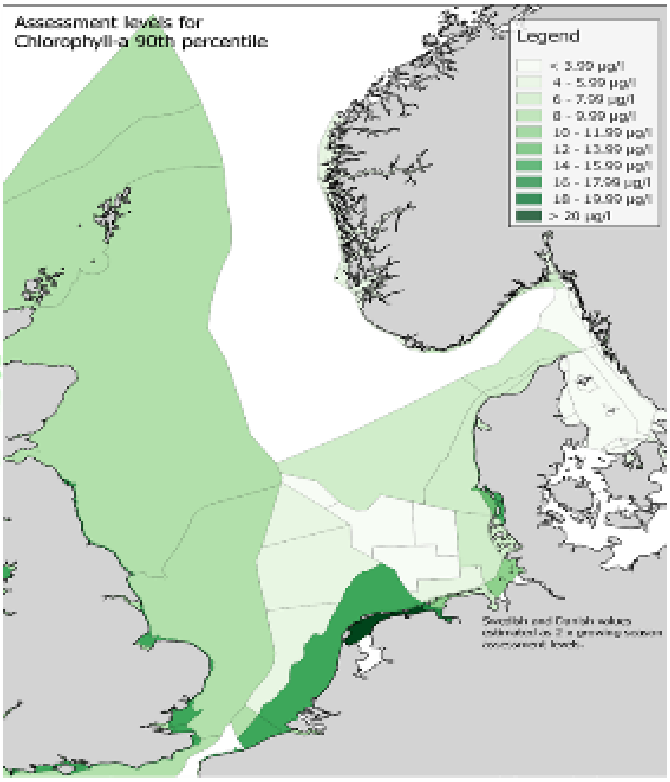


Figure A.7.1 National chlorophyll a assessment levels as used in the COMP3 assessment (OSPAR, 2017). Nutrient assessment levels showed comparable incoherencies across national borders.

Strategic Objective 1 on tackling eutrophication in OSPAR's North-East Environmental Strategy requires '…harmonised and transparent assessments for OSPAR and the Marine Strategy Framework Directive and to provide support for the development of the SDG 14.1.1 Index of Coastal Eutrophication in 2025.' Gathering the OSPAR COMP reports, which are based on national assessment reports, the EU Commission (Dos Santos Fernandes De Araujo *et al.*, 2021) critically remarked the use of national threshold for the eutrophication indicators and demanded a change towards a coherent assessment. In a first step this requires a re-structuring of the assessment units towards a more ecological-relevant subdivision of the EU waters and in a second step the development of a consistent set of reference levels and threshold values for nutrient and chlorophyll a levels for each of these assessment units. For this purpose, OSPAR built on a model study within the EU project JMP EUNOSAT, (2017-2019) which aimed to provide a common, area specific, method in order to develop a coherent assessment framework across CPs (Blauw et al., 2019). The assessment units proposed by the project and further modified by OSPAR are described in Annex 3, while the present Annex summarizes the development of coherent threshold values.

The novel proposed eutrophication threshold values for the North Sea should be coherent in different ways:

1. Between countries around the North Sea;
2. Between the eutrophication indicators for dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP) and chlorophyll-a (chl-a).

JMP EUNOSAT approach

The main causes of eutrophication in marine waters are nutrient inputs from land, through rivers and atmospheric deposition. The nutrient inputs from rivers are diluted with marine waters, resulting in elevated concentrations of nutrients and chlorophyll near the outflow of major rivers and near the coast.

Within OSPAR environmental thresholds for eutrophication are traditionally determined as 50% above the estimated concentration of nutrients and chlorophyll under natural reference conditions. Countries have earlier used different reference years representing "natural background conditions", ranging from 1880 to 1930. Therefore, the project consortium first agreed to use a common reference year representing natural background conditions: the period around 1900. For a derivation of coherent environmental thresholds, the same stepwise approach was used (as illustrated in Figure A.7.2) for all North Sea waters:

1. estimate nutrient loads to the North Sea from rivers under natural reference conditions, using the European model E-HYPE and observed data;
2. estimate nutrient concentrations in the North Sea under natural reference conditions, by combining the nutrient loads from E-HYPE with the Deltares D-FLOW-FM transport model, assuming conservative transport;
3. estimate chlorophyll concentrations, corresponding to the estimated nutrient concentrations under natural reference conditions, using modelling;
4. estimate coherent environmental thresholds based on the above modelling.

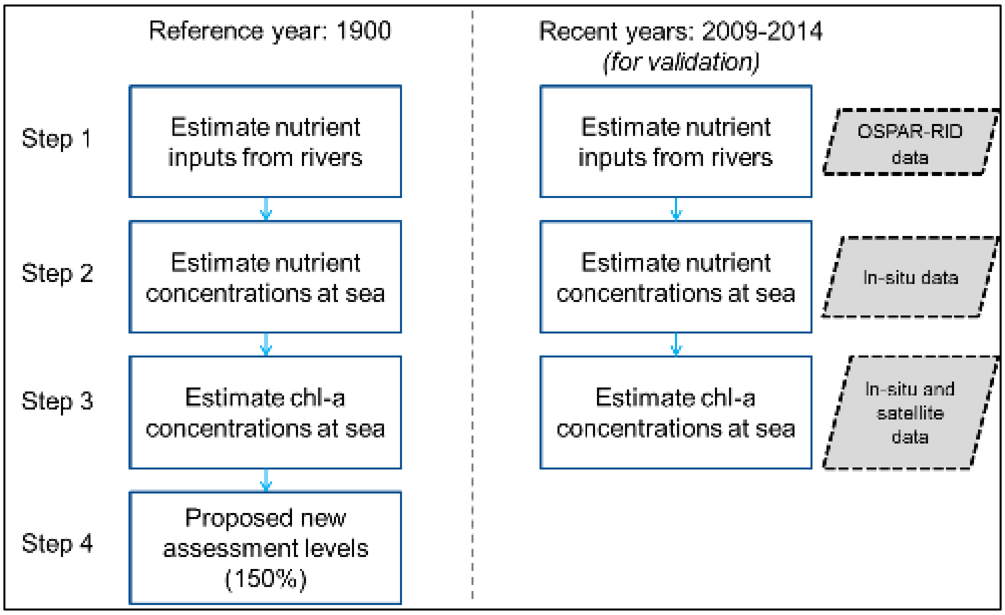


Figure A.7.2 Schematised representation of the workflow used to estimate chlorophyll concentrations under reference conditions and validate with present conditions. Grey boxes indicate validation data used.

Since observed data for model validation were lacking for the period around 1900 the project ran the same series of models for recent years. These were validated and compared with recent observations on nutrient inputs from rivers (from OSPAR-RID database), marine in-situ data and satellite data. Observed data were collected from all countries around the North Sea, on nutrients, chlorophyll, salinity and light climate for validation of the models in this study. Satellite data on chlorophyll-a and suspended particulate matter were provided by RBINS as part of the project.

JMP EUNOSAT delivered an initial proposal for a coherent assessment of DIN, DIP and chlorophyll a, using the newly developed assessment areas and area-specific assessment levels[2].

ICG-EMO follow-up approach

After the finalisation of the JMP EUNOSAT project, ICG-EMO tried to validate and improve the procedure used in JMP EUNOSAT with a more complete in situ database, more and improved hydrodynamic models and a better ‘narrative’ for a joint ‘historic, pre-eutrophication’ scenario to establish the background concentrations. The new assessment levels can be obtained by adding an allowable deviation of max. 50% to these reference conditions, which reflects the common practice for most countries under OSPAR and the Water Framework Directive (WFD).

As first major step the proposed assessment units from the JMP EUNOSAT project were further refined by the OSPAR Contracting Parties and the actual version v7e (cf. Annex 3) forms now the basis for the COMP4 assessment areas and the ICG-EMO exercise.

ICG-EMO initiated the collaboration between the eight participating modelling groups: CEFAS (UK), JRC (EC), Deltares (NL), UHH-HZG (DE), IFREMER (FR), University of Oldenburg (DE), RBINS (BE) and SMHI (SE). The

[2] All results are available on the JMP EUNOSAT project website: www.informatiehuismarien.nl/uk/projects/algae-evaluated-from/

results of the model exercise, the derived thresholds as well as the basic information of the scenario definition and a wide variety of interpretation of the model results can be found in the ICG-EMO report (HASEC HOD (2) 21/2/1) and the related Annexes (HASEC HOD (2) 21/2/1 Add.1 to Add.5) .

From the ICG-EMO modelling partners listed above, the first four model domains cover OSPAR Region II, III and the northern part of Region IV, the other models applied subregional domains. In general, OSPAR Region II is the best covered area (as illustrated in Fig A.7.2). All models describe physical transport and the biogeochemical processes that are relevant to quantify concentrations of nutrients and chlorophyll-a and include the riverine and atmospheric inputs of nutrients to the marine environment. In addition to nutrients and chlorophyll-a, the models provide results for several other assessment indicators, like oxygen and transparency. The models have been validated against observations during earlier studies.

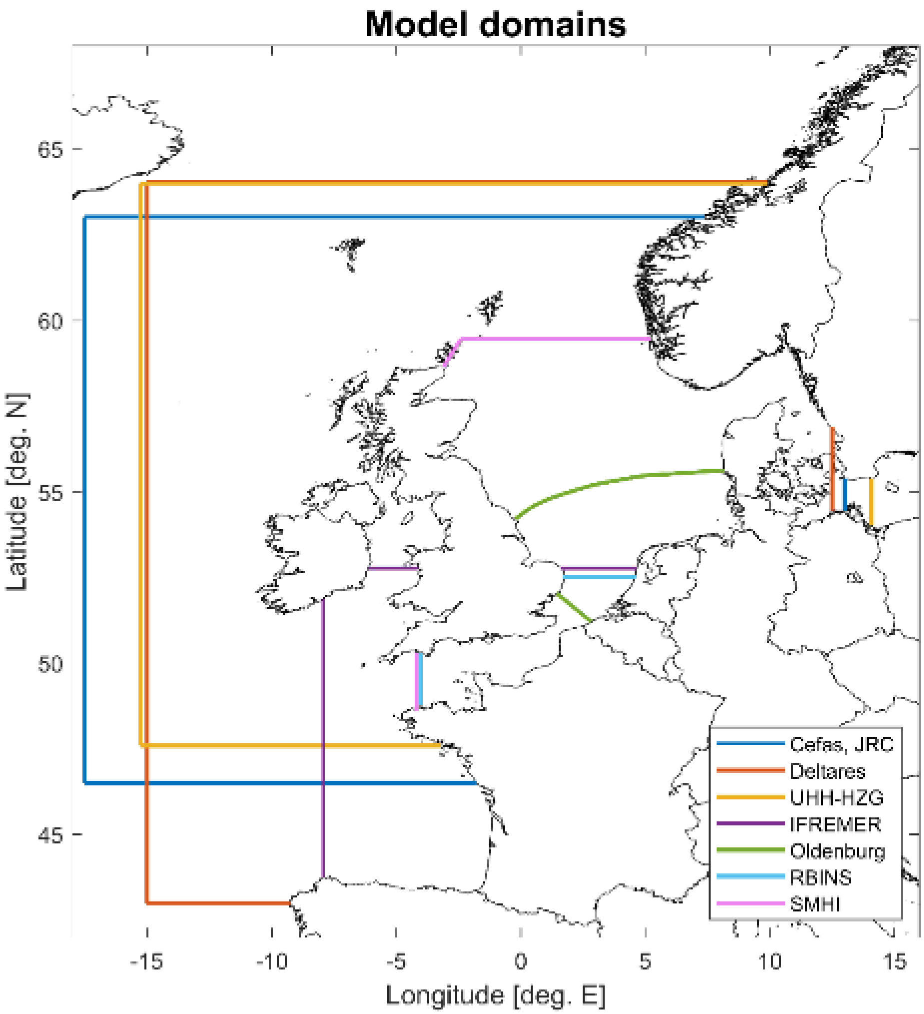


Figure A.7.3 Overview of the eight model domains of the ecosystem models that run the historic scenarios

All models simulated the years 2009-2014 under current conditions, for validation purposes. The simulations representing the reference level were defined as the same period but with historic input levels according to the defined reference scenario. This allows for quantification of the effect of nutrient input reduction as all other conditions, such as coastal protection infrastructure, reflect the present-day situation.

The historic scenario definition was drawn by an expert group (members from ICG-EMO and TG-COMP) as pre-eutrophic conditions (conditions when anthropogenic nutrient enrichment of the marine environment was limited) around 1900. This represents a period before industrialization and agricultural intensification and before the establishment of the Haber-Bosch process (industrial production of inorganic nitrogen fertilizer, 1913).

Nutrient riverine input data for N and P was available for OSPAR areas II-IV from the JMP-EUNOSAT project (E-HYPE simulation of 1900 conditions). These data were used to determine the relative difference between current and pre-eutrophic nutrient loads, which defined Historic Scenario 1. National studies from Germany and Denmark, indicating lower historic P loads, defined a hybrid Historic Scenario 2, affecting Danish, German and Dutch rivers. The reductions obtained from the JMP-EUNOSAT project were then applied to the observation-based riverine loads in the ICG-EMO riverine database (for details see **Table A.7.1** and the illustration in Fig. A7.3). Atmospheric N deposition and exchange between the Baltic Sea and the North Sea were adopted to historic values as well.

Table A.7.1: Estimates of pre-eutrophic annual loads for a selection of individual rivers for scenario 1 (TN and TP) and the 2nd scenario (TP only). When changes in the 2nd scenario occur compared to the 1st scenario the TP loads are highlighted in bold numbers. Loads are expressed in percentage of current (2009-2014) mean loads.

Contracting Party	**River**	**TN load (%)** Scenario1	**TP load (%)** Scenario 1	**TP load (%) Scenario 2**
Belgium	IJzer	23	61	61
Belgium	GentOostendeCanal	17	76	76
Belgium	SchipdonkCanal	25	49	49
Belgium	LeopoldCanal	25	49	49
Denmark	Omme	30	38	**36**
Denmark	Skjern	30	38	**36**
Denmark	Stora	32	44	**36**
Denmark	Vida	30	30	**36**
France	Seine	45	71	71
France	Loire	50	92	92
France	Garonne	70	74	74
France	Dordogne	57	82	82
Germany	Elbe	51	95	**26**
Germany	Ems	26	60	**17**

Contracting Party	**River**	**TN load (%)** Scenario1	**TP load (%)** Scenario 1	**TP load (%)** **Scenario 2**
Germany	Weser	37	74	**24**
Germany	Eider	23	73	**8**
Ireland	Blackwater	35	55	55
Ireland	Suir	34	57	57
Ireland	Barrow	34	57	57
Ireland	Boyne	31	50	50
The Netherlands	Meuse	38	44	**32**
The Netherlands	Rhine	43	72	**32**
The Netherlands	Lake IJssel East	22	34	**33**
The Netherlands	Lake IJssel West	21	21	**33**
The Netherlands	North Sea Canal	30	27	27
The Netherlands	Schelde	46	81	81
Norway	Glomma	44	50	50
Norway	Skien	47	76	76
Norway	Otra	48	91	91
Norway	Kvina	37	80	80
Spain	Deba	44	34	34
Spain	Oiartzun	31	21	21
Spain	Urola	44	34	34
Spain	Urumea	31	21	21
Sweden	Gota alv	56	62	62
Sweden	Lagan	48	57	57
Sweden	Nissan	48	45	45
Sweden	Atran	48	66	66
United Kingdom	TWEED	56	83	83
United Kingdom	HUMBER	34	33	33
United Kingdom	THAMES	35	38	38
United Kingdom	TAY	63	100	100

* Estimates of historic percentage (with current values as 100%) by riverine **loads in tonnes**

The historic levels in percent of current day load for the individual rivers related to these two scenarios are displayed in **Figure A.7.4**.

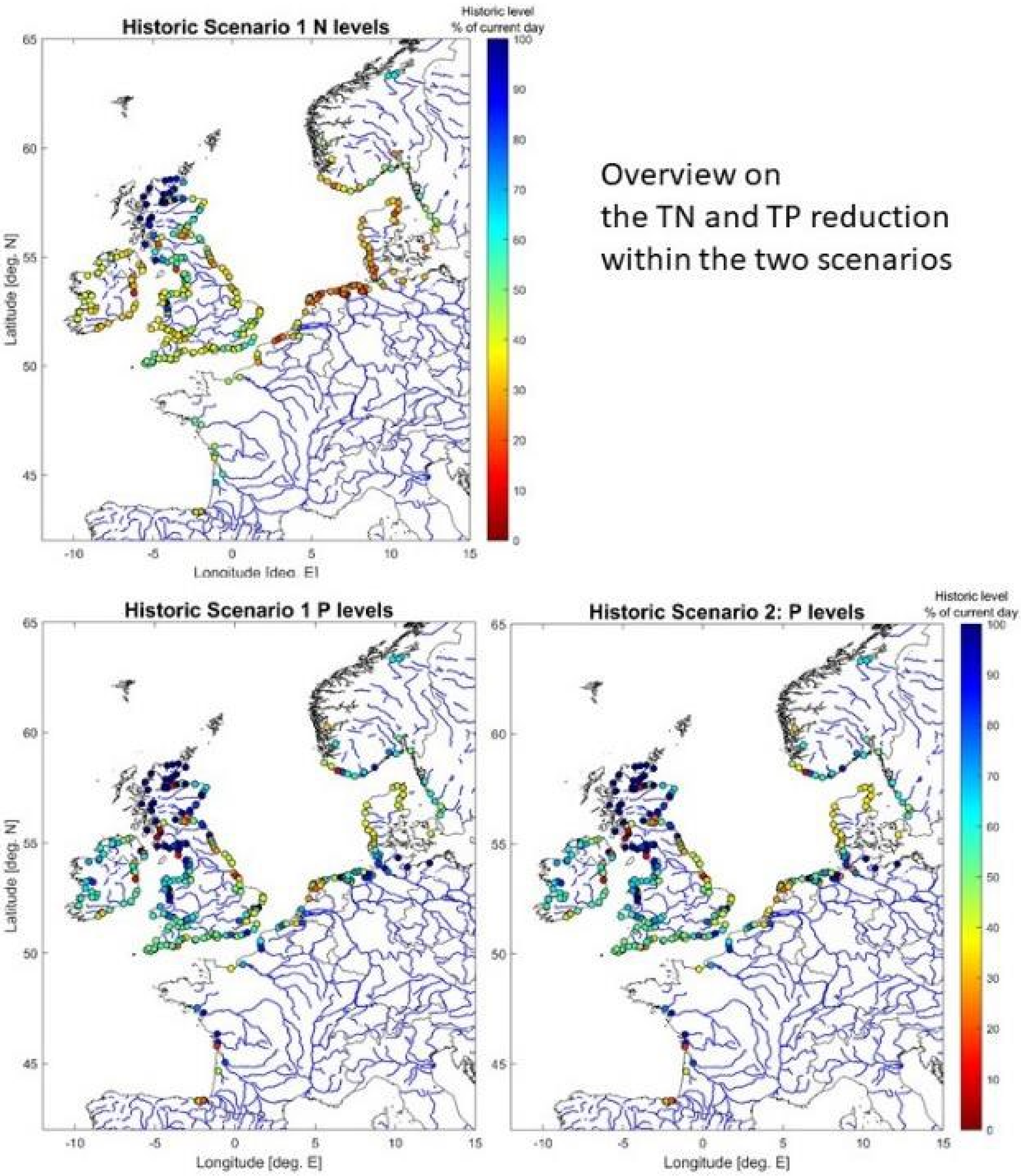


Figure A.7.4 Overview of the two historic reduction scenarios. Since only the P levels are reduced for the 2nd hybrid scenario, the N load reduction are the same for both scenario runs.

Derivation of new threshold values

Following a common practice in earlier definitions of threshold levels in OSPAR and one that is also commonly used in the Water Framework Directive (WFD), threshold levels are based on an acceptable deviation from the reference of 50%, i.e. the threshold levels are 50% higher than the reference. Based on the results from the two reference scenarios, two sets of threshold values are proposed for dissolved inorganic nitrogen, dissolved inorganic phosphorous and chlorophyll a.

In this study multiple models are applied, instead of relying on a single one, which is commonly recognized as the 'ensemble modelling' approach. For obtaining unified estimates based on an ensemble of model results their contribution to the ensemble mean can be considered equal. Alternatively, the relative contribution of each model to the mean can be based on their performance i.e. resemblance with observations. We used the approach of Almroth & Skogen (2010), where weighing factors for ensemble members are determined separately for each assessment variable based on their skill in each COMP4 area. By calculating the reference values as the weighed mean of an ensemble of model outputs in this report, we reduce the uncertainty in the reference values. In addition, we link the model results to the national *in situ* data held in the ICES database and used within the COMPEAT tool. The effect of a broader data coverage could be demonstrated when the former sparse Chl-a data from *in-situ* observations were complemented by satellite data, which improved the quality of the weighted ensemble mean considerably. The satellite data (2009-2014) were provided by RBINS using the multi-algorithm multi-mission tool developed in JMP EUNOSAT (Lavigne et al. 2021).

However, the calculation of the weighted ensemble mean is just one aspect of the stepwise approach that result in the ICG-EMO threshold estimates (see **Figure A.7.4**):

1. Estimate nutrient inputs to the NE Atlantic under pre-eutrophic reference conditions.
2. Estimate marine nutrient and chlorophyll-a concentrations under reference conditions, with an ensemble of models using nutrient inputs from step 1.
3. Estimate average concentrations per assessment area under reference conditions.
4. Calculate the cost function and normalised weights associated with each model and assessment area. This is done on the basis of combined *in-situ* and satellite observation data held in the ICES database compared to the model results from the Current State simulation.
5. Multiply averaged pre-eutrophic concentration per model with their weights and aggregate the final weighted ensemble means per parameter and assessment area.
6. Derive threshold values as 150% of nutrient and chlorophyll-a concentrations under reference conditions from the weighted ensemble mean.

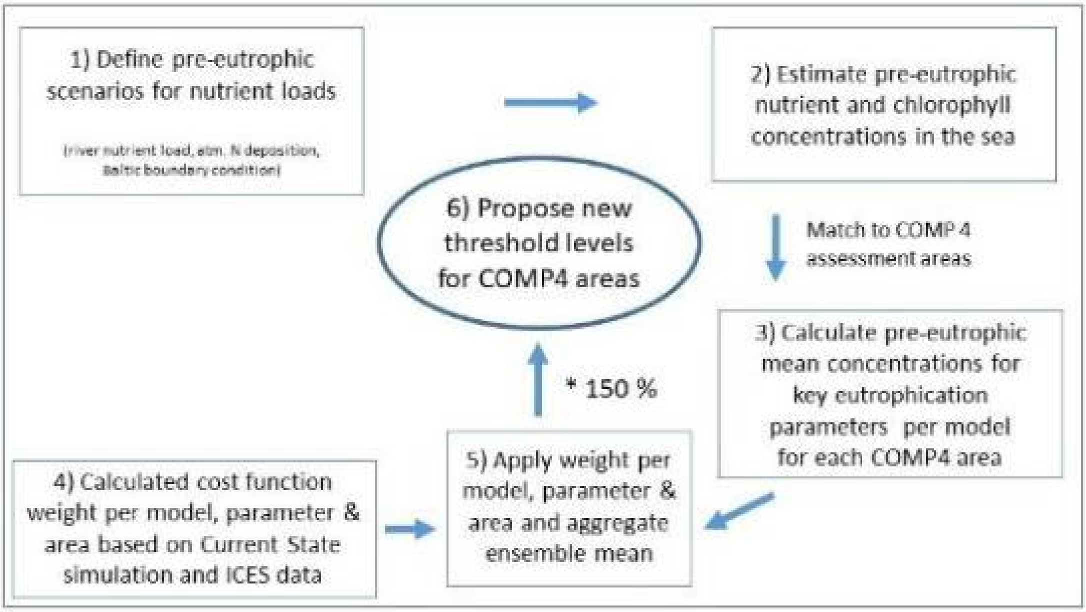


Figure A.7.5 Conceptual diagram to achieve new threshold levels for the COMP4 assessment units.

As a first step it is interesting to analyse the reduction accomplished in the historic scenario. One has to note, that the first scenario HS1 achieves overall very similar concentrations for DIN and only small deviations for DIP and Chlorophyll along the coast of the Netherlands, Germany and Denmark in comparison to the HS2 scenario. Therefore only the comparison of the concentration from the current state simulation against the hybrid scenario HS2 is displayed. The weighted ensemble mean concentration, presented in their horizontal distribution for the COMP4 assessment areas, are displayed in the following **Figure A.7.6** for DIN, **Figure A.7.7** for DIP and **Figure A.7.8** for Chlorophyll-a.

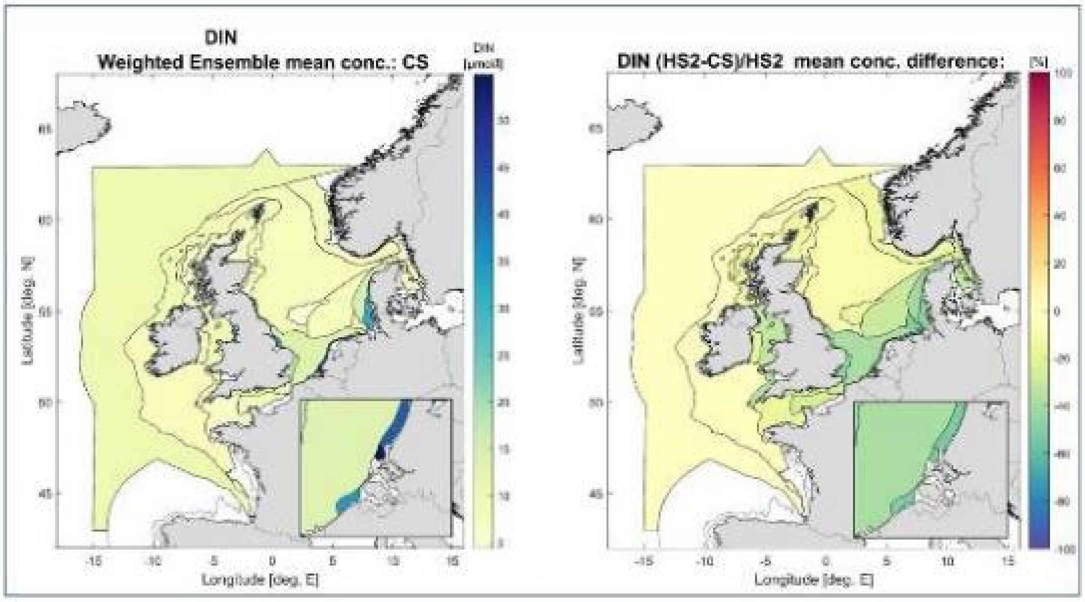


Figure A.7.6 Horizontal distribution of the weighted mean DIN concentration from the Current State simulation (left) and the percent difference in comparison to the HS2 scenario (right).

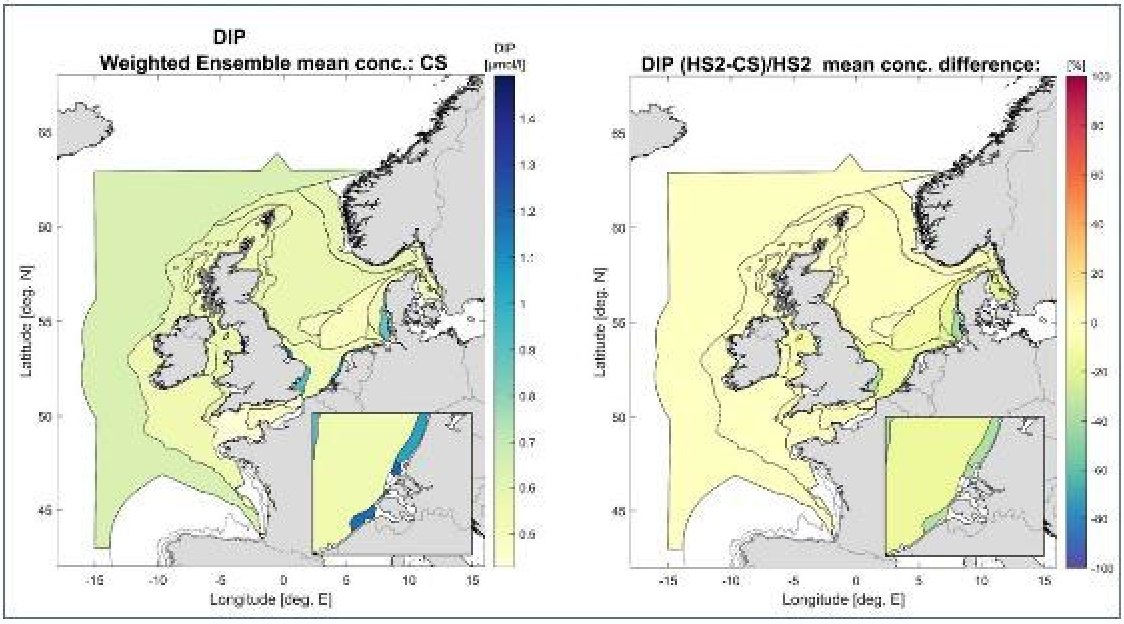


Figure A.7.7 Horizontal distribution of the weighted mean DIP concentration from the Current State simulation (left) and the percent difference in comparison to the HS2 scenario (right).

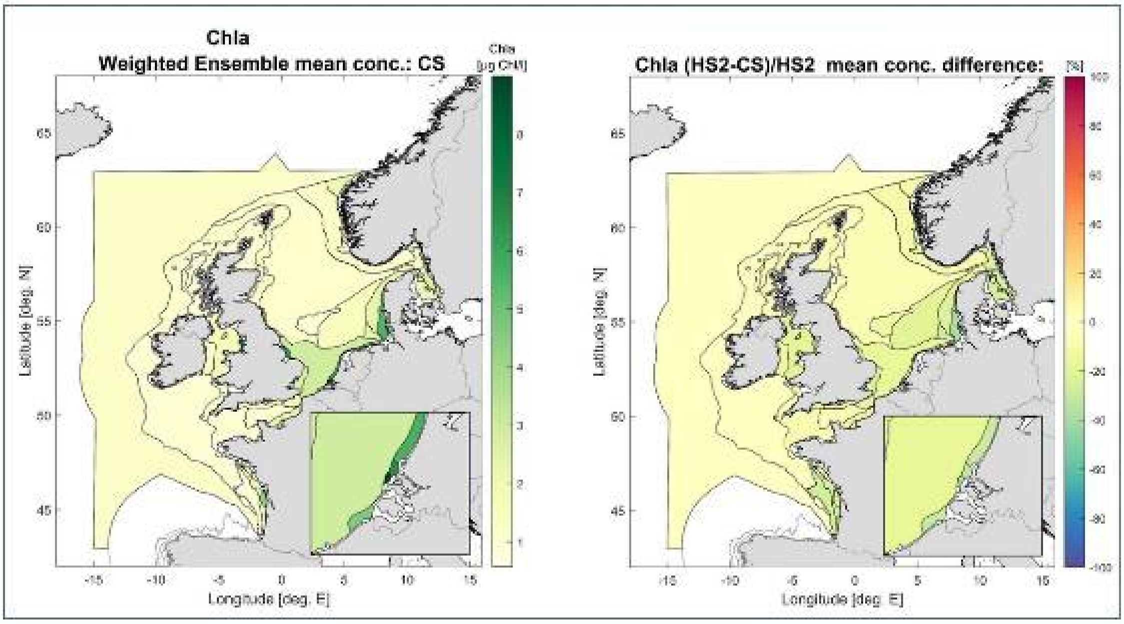


Figure A.7.8 Horizontal distribution of the weighted mean Chlorophyll-a concentration from the Current State simulation (left) and the percent difference in comparison to the HS2 scenario (right).

The results that are presented in the ICG-EMO report, including the distribution maps for the individual models, suggest that, overall, there is a reasonably good similarity between the models, both in reproducing a realistic spatial distribution of nutrients and chlorophyll in the OSPAR area and in reproducing comparable responses to nutrient reduction.

The threshold estimates from the ICG-EMO model exercise, presented in their horizontal distribution for the COMP4 assessment areas, are displayed in the following **Figure A.7.9** for DIN, **Figure A.7.10** for DIP and **Figure A.7.11** for Chlorophyll-a.

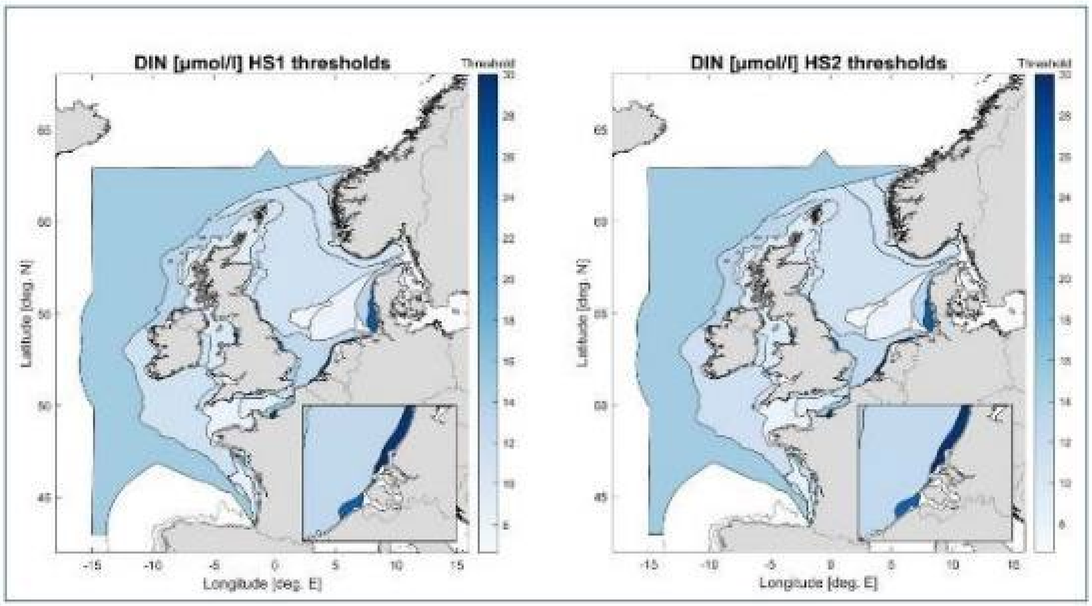


Figure A.7.9 Horizontal distribution of DIN threshold values for the assessment units for the two scenarios.

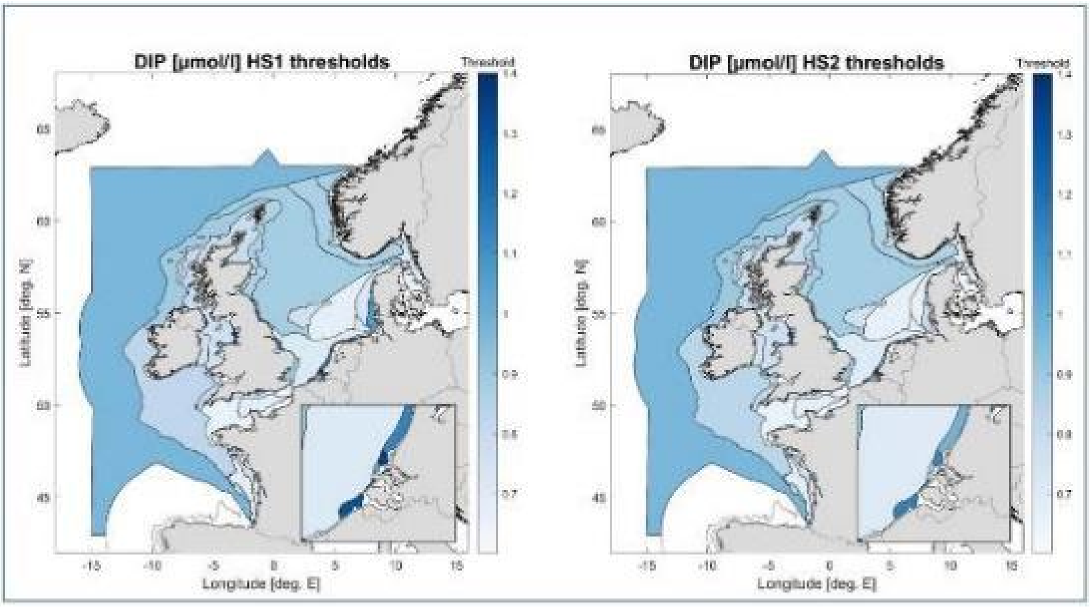


Figure A.7.10 Horizontal distribution of DIP threshold values for the assessment units for the two scenarios.

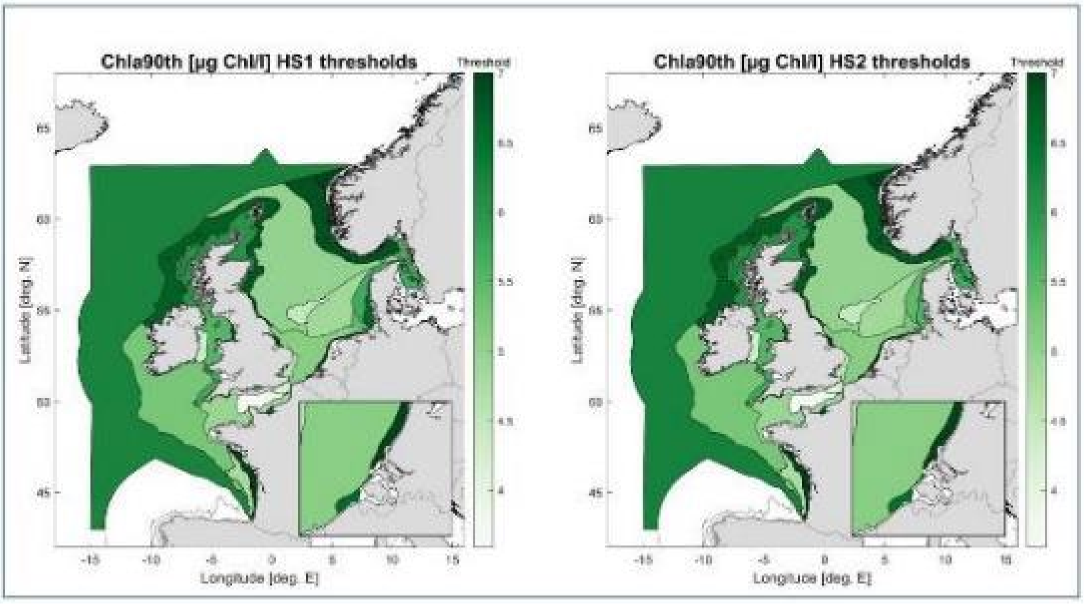


Figure A.7.11 Horizontal distribution of Chl mean threshold values for the assessment units for the two scenarios.

The complete overview on the model exercise, the pre-eutrophic condition as well as a number of interpretations of the model results towards the final threshold estimates can be found in the ICG-EMO report on model comparison for historical scenarios as basis to derive new threshold values[3] (HASEC HOD (2) 21/2/1) and the 5 Annexes (HASEC HOD (2) 21/2/1 Add.1 to Add.5).

References

Almroth, E., Skogen, M.D. A North Sea and Baltic Sea Model Ensemble Eutrophication Assessment. AMBIO 39, 59–69 (2010). https://doi.org/10.1007/s13280-009-0006-7

Blauw, A., et al. (2019). Coherence in assessment framework of chlorophyll a and nutrients as part of the EU project 'Joint monitoring programme of the eutrophication of the North Sea with satellite data (Ref: DG ENV/MSFD Second Cycle/2016). Activity 1 Report. 76 pp.)

Dos Santos Fernandes De Araujo, R. and Boschetti, S., Marine Strategy Framework Directive Review and analysis of EU Member States' 2018 reports - Descriptor 5: Eutrophication, EUR 30677 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-36246-3, doi:10.2760/180642, JRC124915. https://publications.jrc.ec.europa.eu/repository/handle/JRC124915

Lavigne H. & Van der Zande D. & Ruddick K. & Cardoso Dos Santos J. & Gohin F. & Brotas V. & Kratzer S. Quality-control tests for OC4, OC5 and NIR-red satellite chlorophyll-a algorithms applied to coastal waters (2021) *Remote Sensing of Environment*, Vol. 255 p. 112237. https://odnature.naturalsciences.be/downloads/publications/lavigne_rse_2021.pdf

[3] ICG-EMO Report. OSPAR Publication Number: 895/2022 https://www.ospar.org/documents?v=48846

Annex 8: Technical annex on trend assessment

In a number of studies on water quality data many parametric and non-parametric tests have been applied for trend detection in environmental parameters to explain change in water quality and consequently in ecosystem functioning. Both parametric and non-parametric tests are commonly used. Parametric trend tests are more powerful than non-parametric ones, but they require data to be independent and normally distributed. On the other hand, non-parametric trend tests require only that the data be independent and can tolerate outliers (that can be due to a detection limit of measurement method) and missing values in the data. The TTAinterfaceTrendAnalysis package was developed in R to perform non-parametric trend test analysis (based on Kendall test family) through an interactive GUI, easy to handle for non-statistician users.

How to download and use the TTAinterfaceTrendAnalysis package:

The **TTAinterfaceTrendAnalysis** package (Devreker & Lefebvre, 2014) needs the basic R console to be installed and launched. It was written with R version 3.00+ and is compatible with the most recent version. R software (at least v3.00+) comes with basic packages and a command console which can be downloaded from the CRAN website http://cran.r-project.org/.

The **TTAinterfaceTrendAnalysis** package was created with the Tcl/Tk toolkit included in the tcltk package which is a part of the standard R installation for Windows, Linux and Unix platforms. For Mac OS X compatibility it is necessary to install an X Windows version of Tcl/Tk (http://cran.r-project.org/bin/macosx/tools/).

Once R is installed, the package is available on the CRAN mirror (an internet connection is obviously needed). Open the R console and click on "Install package(s)" in the 'Packages' menu of the console (step 1), select your mirror (your country), and follow the instructions to find the **TTAinterfaceTrendAnalysis** package. It will automatically install all the package that the **TTAinterfaceTrendAnalysis** package depend on.

When everything is installed, click on 'Packages/Load package…' in the 'Packages' menu of the console and select **TTAinterfaceTrendAnalysis** from the list (step 2). A small panel appears inviting you to start the interface. The first step needs to be done only once to install the package, skip it and go directly to step **2** every time you need to load the interface. The GUI can be directly re-launched using the start panel.

A user guide is available in the folder where the user installed R (example: C:\Program Files\R\R-4.00\library\TTAinterfaceTrendAnalysis\help). The user guide is also directly available from the interface (User Guide button). This user guide and some step-by-step helps are also available directly from the GUI.

Examples of applications of the **TTAinterfaceTrendAnalysis** package are available in the following references.

References

Devreker D and Lefebvre A (2014) TTAinterfaceTrendAnalysis: An R GUI for routine temporal trend analysis and diagnostics. J. Oceanogr. Res. Data, 1 (7), 1-18.

Nı´ Longphuirt S., Mockler E.M., O'Boyle S., Wynne C., Stengel D.B., 2016. Linking changes in nutrient source load to estuarine responses: an Irish perspective Biology and Environment: Proceedings of the Royal

Irish Academy, Vol. 116B, No.3 (2016), pp. 295-311. http://www.jstor.org/stable/10.3318/bioe.2016.21

Ní Longphuirt S., O'Boyle S., Stengel D.B., 2015. Environmental response of an Irish estuary to changing land management practices. Science of the Total Environment, 521-522: 388-399. http://dx.doi.org/10.1016/j.scitotenv.2015.03.076

Annex 9: Transboundary nutrient inputs

Transboundary nutrient inputs, the movement of waterborne nutrients and airborne nitrogen in coastal and marine waters across national borders, are a major characteristic in OSPAR waters and need to be taken into account when addressing nutrient inputs and assessing the eutrophication status. In addressing nutrient inputs, Contracting Parties can refer to the results of transboundary nutrient transport modelling work undertaken under OSPAR by the Intersessional Correspondence Group on Eutrophication Modelling.

As it is stated in the OSPAR 3rd Integrated Report on the Eutrophication Status, Transboundary Nutrient Transports (TBNT) are an important source of nutrient inputs that need to be taken into account when setting nutrient reduction targets. Essentially, this means that the nutrient reduction requirements of Contracting Parties are not only driven by the eutrophication status in their national waters but in addition should consider nutrients exported to the waters of other Contracting Parties. In order to quantify transboundary nutrient transports work has been ongoing in ICG-EMO to model this process. Marine ecosystem models provide information on the distribution of ecosystem parameters in space and time by calculating their biogeochemical dynamics and transport. The TBNT (Trans-Boundary Nutrient Transport) tool constitutes an extension allowing for the tracing of nutrients from specific sources, like rivers or atmospheric nitrogen deposition. This implies that all nutrient fluxes, both physical and biogeochemical, are related to the input from these selected sources. The result is a budget of the contribution from different input sources to the overall amount of the selected nutrient (e.g. TN or TP) within a certain region of the ecosystem. Therefore, this tool underpins the source-oriented approach by OSPAR as it allows quantification of the contribution from selected sources to the overall nutrient cycle within one defined maritime area.

During the OSPAR TBNT workshop in 2009 in Brussels an overview was provided on the percentage contributions from the different national river groups to total nitrogen in maritime areas and specific water bodies averaged over the relevant models. For the executive summary reported to the OSPAR 2010 meeting (document OSPAR 10/6/2-Add.1) from this model exercise were derived as aggregated information as presented in **Figure A.9.1**.

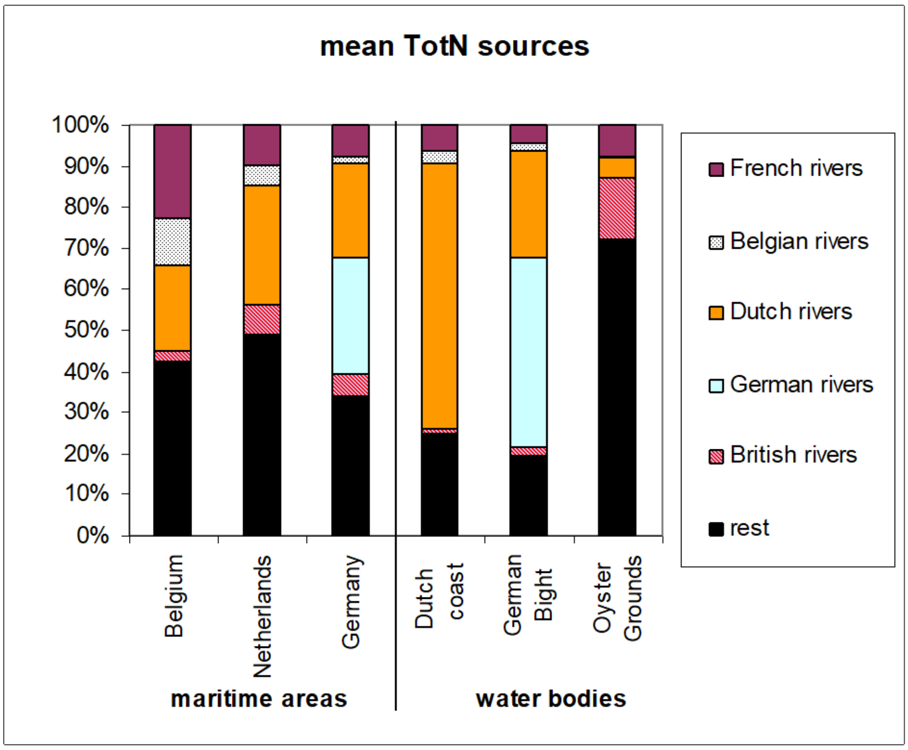


Figure A.9.1 The percentage contributions from the different national river groups to total nitrogen in maritime areas and specific water bodies averaged over the relevant models. Because the category 'rest' is different for each model used in calculating the mean the contribution of Atlantic Ocean, Channel, atmospheric deposition and the 'rest' are taken together.

Transboundary transport must be taken into account because national measures in some areas are not or only partly capable to improve the eutrophication status of the area under consideration. Therefore, Contracting Parties whose waters are affected by transboundary transports (Belgium, France, Germany and the Netherlands) have addressed these in their national reports as an important source for nutrient inputs.

The United Kingdom carried out an evaluation of the risks of its nutrient enriched waters scoring "+--" to eutrophication problems elsewhere in the second application of the Common Procedure. The evaluation was not updated since the eutrophication status of the different United Kingdom areas has not changed since the last Common Procedure and the level of nutrient input was found to be decreasing. Belgium used the model MIRO&CO to undertake an assessment of transboundary nutrient transports in Belgium waters, including atmospheric deposition while the Netherlands used a model study from 2006. France reported the ICG-EMO results from 2009, while Germany reported new results that have been produced with the model ECOHAM in 2015. These results for the German waters show that the contribution of the German riverine input of total nitrogen quickly diminishes from coastal to offshore waters (**Figure A.9.2**). In inner coastal waters the German contribution is 54% and it is reduced to 9% in outer coastal waters and to only 2% in offshore waters. At the same time, the contribution of the Netherlands (which contains contributions from Germany for the River Rhine) increases from 12% in inner coastal waters to 21% in outer coastal waters and the contribution of the United Kingdom increases from 6% in inner coastal waters to 13% in outer coastal waters. In offshore waters the main contribution comes from the open Atlantic Ocean.

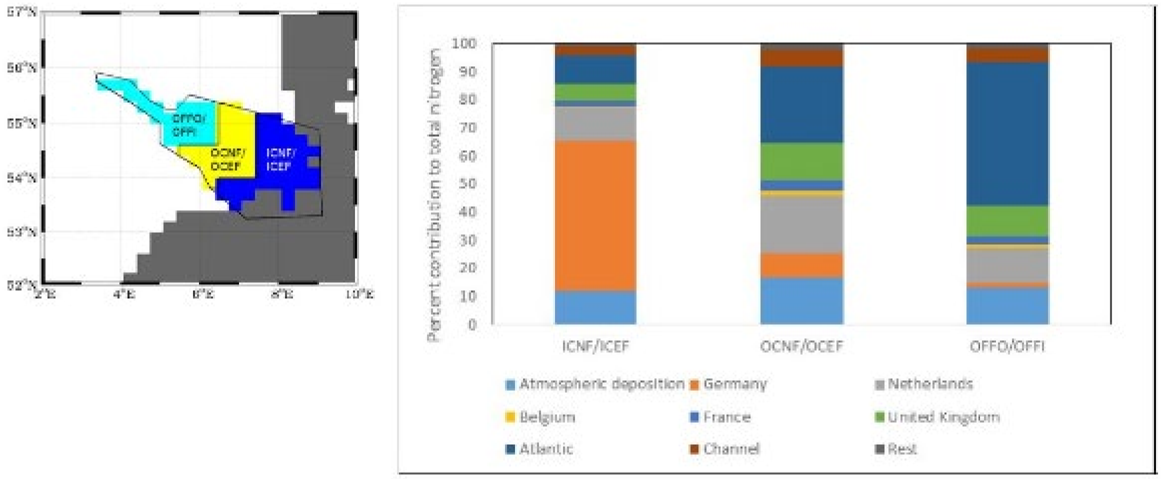


Figure A.9.2 Analysis of transboundary nutrient transport (TBNT) for German inner coastal (IC), outer coastal (OC) and offshore (OF) waters. Left: three model areas for which TBNT was analysed. Right: percent contributions to total nitrogen in the three areas. Source: Lenhart & Große (2018)

In addition to the quantitative analysis of the current state of TBNT for the German EEZ, Lenhart & Große (2018) also provided the first representation of a WFD-compliant riverine nitrogen reduction scenario for the North Sea, which provides a consistent approach based on the combined national measures from OSPAR Contracting Parties under WFD. The applied reduction levels are presented in **Table A.9.1**.

Table A.9.1 DIN and PON reduction levels for the WFD reduction scenario

Country	**River(s)**	**DIN reduction (%)**	**PON reduction (%)**
France	Authie, Canche, Seine, Somme	50	50
Belgium	Scheldt	37	37
Netherlands	Meuse, Rhine, North Sea Canal, Lake Ijssel	5	5
United Kingdom	All	0	0
Germany	Ems	50	37
Germany	Weser	35	15
Germany	Elbe	29	9

The results of the percent distribution of TN in relation to the sources for the reference run and WFD reduction scenario is displayed in **Table A.9.2**. One can clearly see the effects of the higher WFD reduction efforts from France, Belgium, and Germany in a reduction of the TN contributions in all three subareas. In contrast, the low or zero reduction by the Netherlands and the United Kingdom is reflected in an increase in the TN contribution in subarea IC and OC from the Netherlands and in all three subareas for the United Kingdom contribution. However, it needs to be pointed out that the contribution by the Atlantic and the atmospheric nitrogen deposition were also increased in the WFD reduction scenario (due to the fact that no reductions for these sources were assumed), while the Channel contribution is increased only for the subarea IC.

Table A.9.2 Percentage of mean TN contribution by different sources within the sub-regions of the German EEZ for the Current State for the years 2006 – 2014, comparing Current State vs. WFD reduction scenario according to Table 1.

Region	**IC**	**IC**	**OC**	**OC**	**OF**	**OF**
Simulation/ Source	Current State	WFD Red.	Current State	WFD Red.	Current State	WFD Red.
Atmos. N Dep.	11.9	14.9	16.9	18.4	13.3	13.7
Germany	53.6	45.1	8.5	5.7	1.5	1.0
The Netherlands	11.6	13.7	20.8	21.2	12.7	12.3
Belgium	0.7	0.5	1.5	1.0	1.0	0.6
France	1.9	0.9	3.8	1.6	2.8	1.1
United Kingdom	6.1	7.5	13.3	14.3	11.2	11.6
Atlantic	10.3	12.8	26.9	29.5	51.1	53.6
Channel	2.9	3.4	6.1	6.1	4.5	4.3
Rest	1.0	1.2	2.2	2.2	1.9	1.8

The overall conclusion from Lenhart & Große (2018) was that sufficiently long assessment periods need to be evaluated due to the high natural year-to-year variability in riverine nitrogen loads strongly affecting the relative contributions of the different nitrogen sources. Multi-model studies are required in order to obtain more reliable assessments of TBNT and the TBNT method is already available for a number of North Sea ecosystem models. However, for the application in management and decision making an assessment framework is needed, either within OSPAR, or in the context of WFD or MSFD.

References:

Lenhart H & F. Große, 2018: Assessing the Effects of WFD Nutrient Reductions Within an OSPAR Frame Using Transboundary Nutrient Modelling, *Frontiers in Marine Science*, Series: 5, pp. 447.

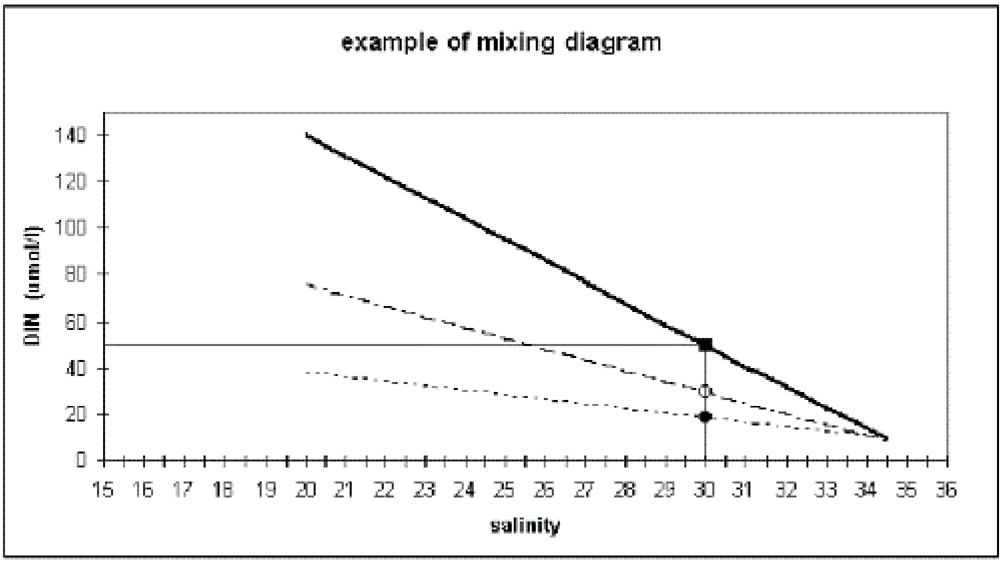
Annex 10: Mixing diagrams and salinity normalisation

This Annex contains the following parts:

1. Theoretical example of a mixing diagram
2. Examples of trends in salinity-related winter concentrations of DIP and DIN in Dutch coastal waters
3. Calculation method for salinity normalisation in COMPEAT

Theoretical example of a mixing diagram

In coastal marine waters with salinity gradients, yearly trends in nutrient concentrations are assessed by plotting each year winter nutrient concentrations against the measured salinity values to produce nutrient-salinity plots. This procedure, often called mixing diagrams (**Figure A.10.1**), was adopted by NUT in 1989. In winter, when algae activity is lowest, nutrients show more or less conservative behaviour and a clear linear relationship with salinity: i.e. decreasing concentrations with increasing salinity from coast to offshore.



Black top line: linear relation between measured winter DIN concentrations and salinity.
Dotted middle line: 50% elevation of winter DIN contrations above background concentrations, all related to salinity
Dotted lower line: winter DIN background concentration related to salinity

Closed square: DIN concentration at a salinity of 30 psu
Open circle: 50 % elevation of DIN concentration above the background concentration at 30 psu
Closed circle: DIN background concentration at 30 psu

Figure A.10.1 Example of mixing diagram illustrating the linear relation between winter DIN concentrations and salinity.

Examples of trends in salinity-related winter concentrations of DIP and DIN (Dutch coastal waters)

An example of mixing diagrams and trends in nutrient concentrations after salinity normalisation, comes from monitoring data in the Dutch part of the North Sea. For this analysis, a number of fixed monitoring stations was selected, that cover a gradient from 2 km off the coast, near the main discharge points of the river Rhine (winter salinity ranging between 17-32), to 70 km off the coast (winter salinity ranging between 34.4-35.4).

Mixing diagrams for winter means of phosphate and DIN for a selection of years are shown in **Figure A.10.2**.

In the case of significant linear correlations between winter nutrient concentrations and salinity, the regression line of phosphate or DIN against salinity in the mixing diagrams was used to calculate nutrient concentrations at salinity 30. These normalised concentrations are shown in **Figure A.10.3**. The normalised concentrations clearly illustrate the >50% reduction in phosphate concentrations and the >30% reduction in DIN concentrations.

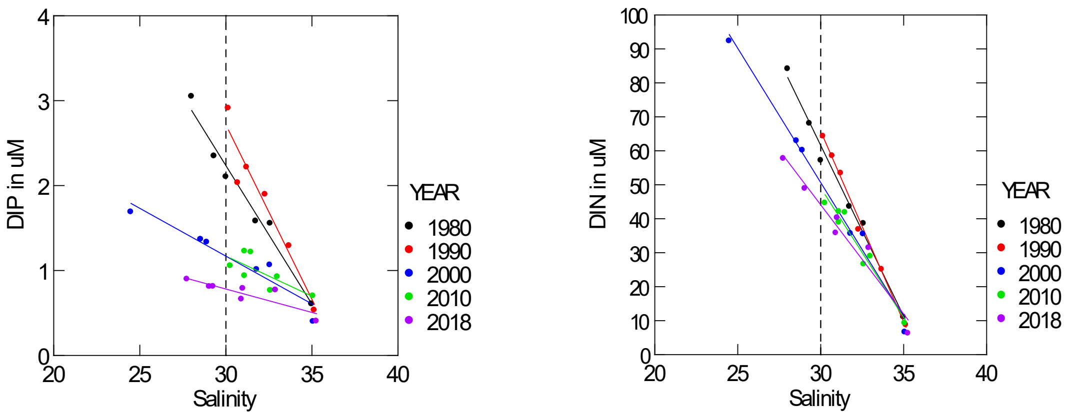


Figure A.10.2 Concentrations of winter means of phosphate (left) and DIN (right) plotted against winter mean salinity on the transect from river Rhine mouth to offshore, for the years 1980, 1990, 2000, 2010, 2018. The broken vertical line indicates salinity 30.

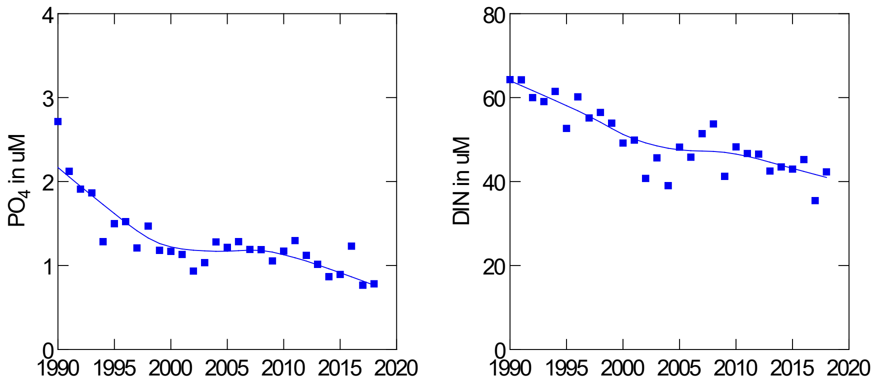


Figure A.10.3 Winter concentrations of phosphate (left) and DIN (right) at the transect from river Rhine mouth to offshore, normalised to salinity 30. The line represents the curve fitted by LOESS smoothing.

Calculation method for salinity normalisation in COMPEAT

In general, nutrient data should be normalised if there is a significant relation between nutrients and salinity. To normalise the data, area specific relations from mixing diagrams should be used which are performed with data from the agreed assessment period or available data from a longer period.

In the assessment procedure of COMPEAT the linear regression coefficients of nutrient indicators and related salinities are calculated (see link for available script on GitHub: GitHub-COMPEAT). If the indicator has a significant relation to salinity above the 95% confidence interval ($p < 0.05$), the indicator concentration is normalised according to the formula below.

ES_normalised = ES_observed + A * (S_reference - S_observed)

Where ES_normalised is the normalised nutrient concentration and ES_observed is the observed/measured nutrient concentration. A is the regression slope of the nutrient/salinity relation, S_reference is the mean salinity of the whole assessment period, whereas S_observed is the salinity related to the measured nutrient concentration. The observed value is only replaced with a normalised value if the relation is significant ($p<0.05$) as indicated above.

The calculation in COMPEAT is based on the procedure as used e. g. in Sweden, but also in other Contracting Parties in a similar way.

Annex 11: Calculation procedure in COMPEAT including aggregation and integration rules

This Annex is related to the assessment procedure described in Chapter 5 and illustrates the calculation process as implemented in the automated tool COMPEAT including aggregation rules on parameter level as well as integration rules within and between categories I, II and III.

Aggregation rules per parameter over the assessment period

Annual assessment of individual parameters is based on annual measured values for each common indicator. Annual Ecological Quality Ratio values (EQR) are calculated from reference conditions and measured values. Final multi-year EQR is based on the 'average of annual EQR values'. Calculation of the annual EQR is dependent on adequate data availability. All results will be converted to an EQR value scaled (EQRS) to a uniform range between 0-1 (worst case to best case). The EQR is calculated by dividing the reference value by the measured value for nutrients and chlorophyll and vice versa for oxygen and Secchi depth. The calculations for this are undertaken in COMPEAT in a stepwise manner detailed in **Figure A.11.1** and an example is presented.

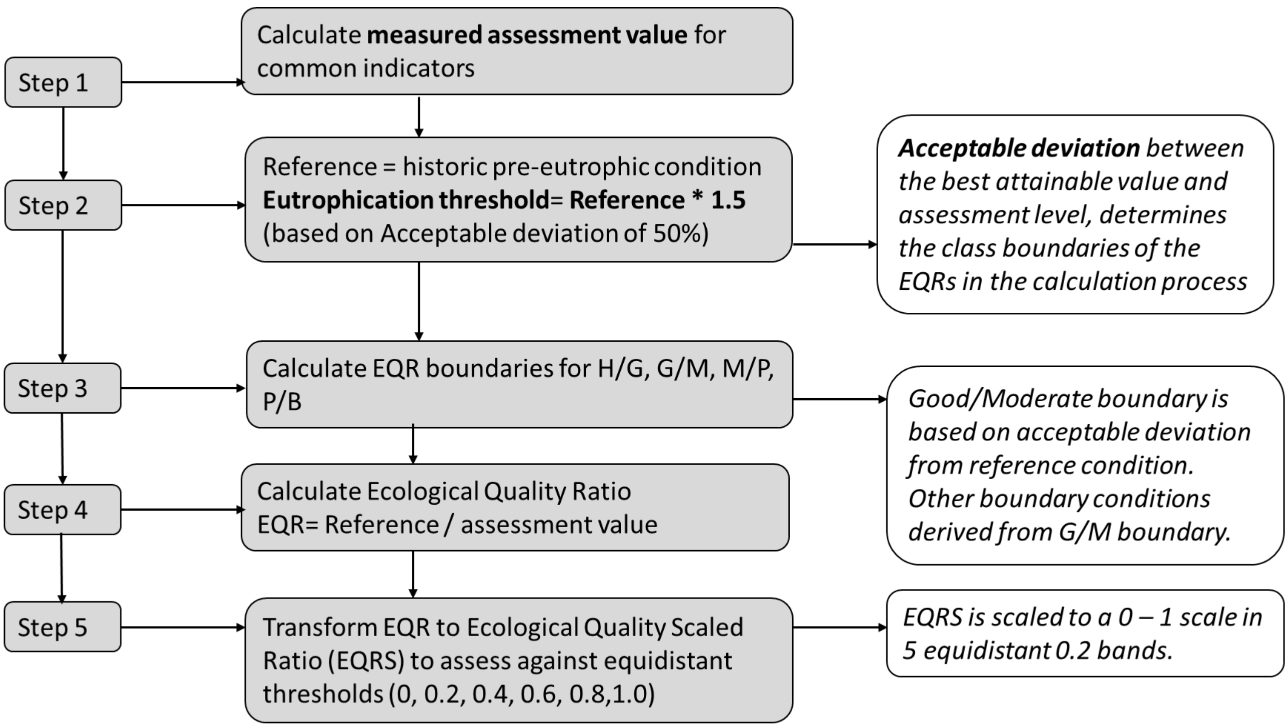


Figure A.11.1 Step wise calculation of the EQR and EQRS values.

Example of how to calculate the EQR value for assessment and threshold level for nutrients and chlorophyll.

Eutrophication target (assessment level derived from pre-eutrophic reference * 1.5) equals Good/Moderate Boundary = **10.68**

Step 1: Measured assessment value = **16.61**

Step 2: Reference concentration = **7.12**

Step 3: EQR boundaries: High/Good: **0.808**; Good/Moderate: **0.666**; Moderate/Poor: **0.525**; Poor/Bad: **0.383;** all based on acceptable deviation set to 50 % of the pre-eutrophic reference (as applied for nutrients and chlorophyll-a)

Step 4: Calculate EQR value = 7.12/16.61 = **0.428** (Reference/Threshold); EQR value falls between moderate/poor (MP) and poor/bad (PB) boundaries.

Step 5: Scaled EQR = (EQR - EQR_PB) * (0.4 - 0.2) / (EQR_MP - EQR_PB) + 0.2

EQRS= (**0.428**-**0.383**)*(0.4-0.2)/**0.525**-**0.383**)+0.2 = **0.263**

EQRS boundaries are 0.8 (H/G); 0.6 (G/M); 0.4 (M/P); 0.2 (P/B)

Scaled EQR (EQRS) result of **0.263** lies within the fourth class, indicating 'poor' status

Integration rules within categories I, II and III

Each annual EQR value for each parameter will be averaged to give an EQR for the respective criterion. For example, to assess Nitrogen in category I, the EQR values of DIN and TN will be used to calculate a Nitrogen EQR based on the average of the two EQRs. Note that the second EQR for TN will only be calculated where data is available and Contracting Parties sharing an assessment area have agreed on the use of TN. There are two assessment results for category I, differentiated into Nitrogen and Phosphorus, which are not integrated further.

Where multiple category parameters are available, e.g. for Category II, there may be chlorophyll-a together with phytoplankton indicator species and HABs or for Category III, with dissolved oxygen and photic depth, these will be averaged or integrated using weighted averaging if agreed on an area-specific basis. The final set of parameters within each category will be agreed for each assessment area depending on the data available.

The assessment of the Common Indicators (DIN, DIP, CHL and DO) will be included in COMPEAT. National data on additional parameters can be provided by CPs using a standard template for submission to ICES.

Integration rules between categories I, II and III

For the assessment, there will be (up to) four EQRs for each assessment area including Category I (Nitrogen), Category I (Phosphorus), Category II (direct effects), Category III (indirect effects). The final classification will depend on the type of categories that have fallen below an EQR value of 0.6. The final EQR will be the lower of Categories II and III (**Table A.11.1**). Category I (Nitrogen and Phosphorus) failures do not drive the final assessment if they fail, but individual parameter failures will be indicated in the final assessment outcome.

*Table A.11.1 Final classification based on the aggregation of Categories I, II and III. Additional supporting information and outcomes of trend analysis may also be used in the final classification. *Failure of Nitrogen or Phosphorus will be flagged in the assessment outcome e.g. by hatching on the final maps.*

Category I - N	**Category I - P**	**Category II**	**Categories III**	**COMPEAT outcomes**	**Classification**
<0.6	<0.6	<0.6	<0.6	Moderate Status or worse	Problem Area
<0.6	<0.6	<0.6	>0.6	Moderate Status or worse	Problem Area
<0.6	<0.6	>0.6	<0.6	Moderate Status or worse	Problem Area
>0.6	>0.6	<0.6	<0.6	Moderate Status or worse	Problem Area
>0.6	>0.6	<0.6	>0.6	Moderate Status or worse	Problem Area
>0.6	>0.6	>0.6	<0.6	Moderate Status or worse	Problem Area
<0.6	>0.6	>0.6	>0.6	Good status but failing nutrient(s)*	Non Problem Area but failing nutrients*
>0.6	>0.6	>0.6	>0.6	Good or High Status	Non Problem Area

Annex 12: Phytoplankton indicator species

Overview

This Annex is related to Chapter 4 of the Assessment procedure, Category II – Direct effects of nutrient enrichment.

Anthropogenic nutrient enrichment can increase the potential for phytoplankton growth resulting in elevated concentrations of chlorophyll 'a', high and sustained densities of phytoplankton, and can potentially influence the composition of different phytoplankton life forms. Attempts have been made to identify 'indicator species' of eutrophication. This is a challenging task as phytoplankton abundance is not driven by nutrients alone. Climate change, weather, wind driven advection, changes in water circulation, grazing and viral infection all play a role in governing cell abundances. Considerable variability exists in the diversity of phytoplankton communities within the OSPAR area and thus assigning 'indictor species' of anthropogenic nutrient enrichment presents difficulties.

Some phytoplankton species form blooms that can negatively impact the marine ecosystem and/or the goods and services it produces. These have been termed Harmful Algal Blooms (HABs) and thus there is an incentive to try and mitigate impacts from these blooms. There are two types of HABs. 'Nuisance' HABs have a negative impact through high biomass such as blooms that cause water discolorations, scums and foams, or mortalities of the benthos or farmed fish due to anoxia during bloom decay. 'Toxin producing HABs' produce toxins that can render shellfish unfit for human consumption or result in mortalities of fish, shellfish and benthos. A review of the use of both types of HABs as indicators of anthropogenic nutrient enrichment including examples from OSPAR waters is given in Gowen et al., 2012. This review concludes that in some areas of the world there is clear support for the hypothesis that nutrient enrichment promotes the development of HABs in some water bodies but not in others, and that '*The occurrence of HABs and the abundance of HAB species should not be used to diagnose eutrophication unless a link to anthropogenic nutrient enrichment can be demonstrated*'.

OSPAR has identified a suite of species that are still used as 'indicator' species for eutrophication by some Contracting Parties. As knowledge on the ecology and lifecycles of these species has increased over the years, their link with anthropogenic nutrient enrichment has become increasingly tenuous.

Notes on these indicator species are below.

General and physiological information of various phytoplankton species suggested as indicators of eutrophication by OSPAR.

Phaeocystis species

* *Phaeocystis* spp. has been considered as an indicator for the OSPAR Intermediate Assessment in 2017 to investigate trends in *Phaeocystis* blooms based on data from three countries (Belgium, The Netherlands, Germany), where blooms of *Phaeocystis* frequently occur in coastal areas.
* Foam-forming nuisance species in colonial form; occurrence during spring-summer. *Phaeocystis* blooms are recorded sporadically in many countries within the OSPAR area where they are not associated with

anthropogenic nutrient enrichment. *Phaeocystis* is considered by some Contracting Parties to be an indicator of anthropogenic nutrient enrichment in the southern North Sea and is also used under the WFD to assess the biological quality element phytoplankton.

* Some studies have established a clear relationship between eutrophic conditions and the occurrence of *Phaeocystis* blooms (Cadeé 1986, Lefebvre & Dezécache 2020). In particular shifts in N/P ratios were found to trigger the onset of blooms (Riegmann et al. 1992).
  A review of 25 years of data to assess the applicability of using *Phaeocystis* as an indicator of anthropogenic nutrient enrichment in the Dutch Wadden Sea revealed that the *Phaeocystis* metrics (cell densities, bloom frequency) previously used in OSPAR COMP showed a lack of response to nutrient enrichment. As a result, the use of *Phaeocystis* metrics as an indicator to inform management might be limited and the occurrence of *Phaeocystis* blooms alone is not sufficient to judge on the eutrophication status of an area but should only be used and interpreted in combination with other indicators. (Anon 2018).

Noctiluca scintillans

* This large (0.3 mm) non-toxic heterotrophic (hence oxygen consuming) dinoflagellate forms 'tomato soup' coloured surface accumulations in spring under calm weather conditions (<3-5 Bft) (nuisance species).

* Its high abundance (above 10^3 cells/l) can lead to low oxygen concentrations below the top layer and to high ammonium concentrations which may be harmful to fish or cause irritation to divers. Oxygen deficiency induced by *Noctiluca* blooms caused a mass kill of cockles in the Dutch Wadden Sea.

* Its high abundance may be due to its increased food resources, in some areas as result of increased eutrophication. As an example, from other Regional Conventions, *Noctiluca* is used in the eutrophication assessment in the Black Sea (Lazar, 2019).

* There have been little recent investigations in OSPAR waters into the link between *Noctiluca* and eutrophication.

Prymnesium polylepis (previously Chrysochromulina polylepis)

* Fish and benthos killing species; toxic above 10^6 cells/l; blooms, when they occur are usually in Spring.

* The causes behind the exceptional bloom in May 1988 in Kattegat and Skagerrak waters are unresolved but are likely due to a combination of unique hydrological and meteorological conditions (2nd lowest wind speed recorded, higher than average irradiance). See review by Gjosaeter et al., 2000 and references therein.

Karenia mikimotoi (former name is Gymnodinium mikimotoi, Gyrodinium aureolum)

* Fish-killing species when cell density exceeds 10^5 - 10^6 cells/l; in the Channel, west UK, Danish, Norwegian and Swedish waters these blooms have caused fish kills.

* Bloom occurrence: late summer-autumn; first observation in 1966 along south-west Norwegian coast; optimal growth at 20 ^{0}C.

* Blooms of *Karenia mikimotoi* can form along the shelf edge and be advected into coastal currents where they can have negative impacts on the ecosystem and aquaculture industries (Gilibrand et al., 2016). There is currently no association of *Karenia mikimotoi* with anthropogenic nutrient enrichment in European waters.
* Records of impacts from *K. mikimotoi* are regionally restricted with no records of impact from the Atlantic coasts of Spain or Portugal. The majority of records of impacts along the Atlantic coast of France, Norway, Sweden and Denmark come from the 1970s to the 1990s with frequency of harmful algal events subsequently reducing (Bresnan et al., 2021, Karlson et al., 2021). In Ireland and the UK events associated with *K. mikimotoi* have been recorded over the last two decades. These blooms are associated with transport from the shelf edge and offshore fronts (Silke et al, 2005, Davidson et al., 2009, Gillibrand et al., 2016) with the last major extensive bloom events recorded in 2012 and 2006 respectively.
* Molecular studies suggest that *Karenia mikimotoi* is not an introduced species in the OSPAR area (Al-Kandari et al., 2011).

Alexandrium species

* Several species of *Alexandrium* (e.g. *A. catenella. A. minutum, A. ostenfeldii*) are confirmed producers of paralytic shellfish toxins (PSTs) in OSPAR waters. There is a strong regional distribution with *A. catenella* causing problems in Scotland and Scandinavia, *A. minutum* in Ireland, SW England, France, Spain and Portugal. The incidence of PSTs in shellfish in the Netherlands, Germany and Denmark is rare however there was an incidence of canine mortality in an enclosed creek in the Netherlands in 2012 due to high concentrations of *A. ostenfeldii* (Burson et al., 2014)
* The distribution and annual cycle of *Alexandrium* is strongly influenced by its lifecycle strategy, with resting cysts playing a very important role as seed beds of blooms (Anderson et al., 2012).
* *Alexandrium* spp. and closure of shellfish harvesting areas due to PSTs are also recorded in areas where anthropogenic nutrient enrichment is not a problem, thus its use as a standalone indicator of anthropogenic nutrient enrichment is limited, particularly at low cell densities.

Dinophysis species

* *Dinophysis acuminata, D. acuta, D. norvegica, D. caudata, D. fortii* and *D. sacculus,* produce diarrhetic shellfish toxins which result in annual closures of shellfish harvesting areas in many countries within the OSPAR area.
* A threshold of 10^2 cells/l is used as a threshold to ensure that shellfish are tested for the presence of DSTs. This threshold is not associated with anthropogenic nutrient enrichment.
* *Dinophysis* has a very complex mixotrophic feeding cycle; feeding on a ciliate that feeds on a cryptophyte (Park et al., 2006). A relationship with anthropogenic nutrient enrichment has not been established, with local hydrography, weather, transport in coastal currents and wind driven advection identified as important influences on cell densities in coastal waters.

Prorocentrum species

Prorocentrum species are routinely recorded in the OSPAR area. More than 50 species exist, at least six of which can form high biomass blooms (Glibert et al., 2012) and at currently thirteen have been found to produce toxins (Hoppenrath, 2021). Some species such e.g. *P. minimum, P. donghaiense* have formed massive blooms in Asia and elsewhere related to nutrient enrichment (Glibert et al., 2012). *Prorcentrum minimum* is considered invasive in the Baltic (Telesh et al., 2016). High biomass blooms of all phytoplankton species and life forms will be picked up by the Pelagic Habitat diversity tool PH1 (McQuatters Gallop et al., 2019, Bedford et al., 2020).

Other species

The dictyophyte *Pseudochattonella* has formed blooms in Scandinavian waters since the 1990s (Karlson et al., 2021). Two species *P. farcimen* and *P. verruculosa* have caused problems in the waters of the Kattegat and Skagerrak. They are seldom recorded elsewhere in the OSPAR area. Impacts from *Fibrocapsa japonica* are infrequently recorded in the OSPAR area (Bresnan et al., 2021, Karlson et al., 2021).

The plankton community is composed of many different lifeforms. Plankton lifeforms have already been successfully used in European waters to identify changes in the plankton community (Bedford et al., 2020) and in Asia it has been used to describe recovery of the plankton community during improved water quality (Lei et al., 2018). This approach has been used in the development of PH1 for the assessment of diversity in the OSPAR area. Nutrient enrichment will impact the phytoplankton community as a whole. Assessment results of the pelagic indicators PH1, PH2 and PH3 (in the OSPAR regions where PH3 is applied) may be used in the assessment of the phytoplankton community's response to nutrient enrichment pending further development. The pelagic indicators address different components of the phytoplankton community. The individual lifeform pairs of indicators PH1 will detect changes in phytoplankton and zooplankton communities at functional group level (including the relationship between diatoms and flagellates) and will provide evidence of community shifts ifa relationship to nutrients can be identified. Results of indicator PH2 on phytoplankton biomass and zooplankton abundance at an overarching community level and PH3 (in the OSPAR regions applied) on changes in biodiversity at species level may also be useful where regional assessment results are available. Contrary to the phytoplankton indicator species, no assessment levels are currently used for the pelagic indicators related to the good environmental status, because they act as trend indicators (McQuattors-Gollop et al., 2019, Bedford et al., 2020).

Recommendation

'Indicator phytoplankton species' should only be used when a clear link with anthropogenic nutrient enrichment has been established in the area investigated as the role of anthropogenic nutrients in promoting harmful algal blooms is mainly site-specific and not widespread (Davidson et al. 2014). Only those phytoplankton indicator species that are relevant in certain areas occurrence in (high quantities with negative effects) should be used in the assessment and not necessarily the entire list of indicator species in all areas, provided that a link to nutrients exists (Gowen et al., 2012). The application of pelagic habitat indicators PH1, PH2 and PH3 should be considered where appropriate. The use of these indicators in the eutrophication assessment should also be dependent on clear links with anthropogenic nutrient enrichment, as required for phytoplankton indicator species. The pelagic indicators PH1, PH2 and PH3 have been established as state indicators to assess pelagic habitats and to identify changes in plankton communities due to different drivers (climate change, hydrodynamic processes, eutrophication and other pressures) (McQuatters Gollop et al., 2019). The Pelagic Habitat assessment results or parts of them could be used as supporting information in the eutrophication assessment if applicable.

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Annex 13: Confidence rating in COMPEAT

Based on the general confidence rating procedure described in Chapter 7, this Annex refers to the confidence assessment applied in COMPEAT. Detailed confidence class boundaries for temporal, spatial and accuracy confidence aspects as applied in the assessment procedure of COMPEAT are given in the following tables. In general, the different confidence aspects are classified either high (100), moderate (50) or low (0).

Temporal confidence

The aspect of temporal coverage of monitoring data considers the confidence of the parameter in terms of its year-to-year variation and the continuity of observations during the parameter-specific assessment seasons (winter, growing season). The general temporal confidence is assessed based on the number of annual observations during the assessment period, whereas for the specific temporal confidence the number of missing months in the respective assessment periods of the different parameters determines the classification. The different natural variability of winter nutrients and chlorophyll in the growing season, as well as the different length of the assessment season, is reflected in the confidence class boundaries with different requirements.

Table A.13.1 gives an overview of the confidence class boundaries for general temporal confidence for winter nutrients and chlorophyll in the growing season.

Table A.13.1 Confidence class boundaries for general temporal confidence aspects

Score	Evaluation criteria for general temporal confidence of winter nutrients (XII-II)	Evaluation criteria for general temporal confidence of chlorophyll (III-IX)
HIGH	> 12 annual observations	> 26 annual observations
MODERATE	6-12 annual observations	14-26 annual observations
LOW	< 6 annual observations	< 14 annual observations

In **Table A.13.2** the confidence class boundaries for specific temporal confidence for winter nutrients and chlorophyll in the growing season are given on an annual basis.

Table A.13.2 Confidence class boundaries for specific temporal confidence aspects

Score	Evaluation criteria for specific temporal confidence of winter nutrients (XII-II) - annually	Evaluation criteria for specific temporal confidence of chlorophyll in growing season (III-IX) - annually
HIGH	0 missing months (in total a maximum of half of the number of years of the whole assessment period is acceptable)	1 missing month
MODERATE	1 missing month	2 missing months
LOW	≥ 2 missing months	≥ 3 missing months

Spatial confidence

The aspect of spatial representability in the confidence assessment is considered by a general and a specific spatial confidence aspect and both are based on a gridded approach. The number of observations in the assessment period is related to a predefined grid cell size in different assessment areas depending on the total area size. The resulting number per grid for the respective area is the general spatial confidence. The distribution of observations within the area is considered by counting the number of sampled and not sampled grid cells in the area and calculating the percentage of sampled grid cells in relation to the total number of grid cells in the respective area as specific spatial confidence. The class boundaries for general and specific spatial confidence listed in **Table A.13.3** are separated for winter nutrients and chlorophyll to account for different natural variabilities and associated different requirements. In case the proposed method is not suitable for certain assessment areas, exceptional rules with appropriate reasoning can be defined, in particular for very large or very small assessment areas.

Table A.13.3 Confidence class boundaries for general and specific spatial confidence aspects

Score	Evaluation criteria for general spatial confidence - n/grid annually		Evaluation criteria for specific spatial confidence - % of sampled grid cells	
Parameter	Winter nutrients	Chlorophyll	Winter nutrients	Chlorophyll
HIGH	> 0.8	> 1	> 70 %	> 80 %
MODERATE	0.4 - 0.8	0.6 - 1	50 – 70 %	60 – 80 %
LOW	< 0.4	< 0.6	< 50 %	< 60 %

For other parameters, the class boundaries for temporal and spatial confidence aspects can also be used, e.g., in case of using total nutrients or photic limit in the eutrophication assessment the same confidence class boundaries as for chlorophyll should be used, while for oxygen the class boundaries of the winter nutrients can be applied based on the comparable length of the assessment season.

Accuracy confidence

The accuracy of the parameter result indicates how certain the assessment is in relation to the variability of the data. The accuracy aspect of the confidence assessment is considered by calculating variable confidence level per assessment parameter to estimate the probability or certainty of the classification of being below or above the area-specific assessment level (depending on the response of the parameter to eutrophication) and thus the classification as problem or non-problem area. In contrast to temporal and spatial confidence, the accuracy will be assessed over the entire assessment period and not on annual basis, because it is a matter of estimating the probability of correct classification for the overall result. It is also possible to use the bootstrapping method of the Monte Carlo simulation for the accuracy confidence aspect when implemented in the COMPEAT tool.

The variable confidence level is calculated in the assessment procedure of COMPEAT based on the observed value, the standard error, and the assessment level of the respective assessment parameter per assessment area. The calculated confidence level is directly used as the probability of correct classification as a non-problem area or a problem area. The class boundaries for the accuracy confidence are listed in **Table A.13.4** below. In case of missing information on standard deviation and standard error, no calculation of variable confidence levels and thus no quantitative accuracy estimates will be possible. Alternatively, a qualitative estimate based on expert judgement for the respective parameter and area can be used.

Table A.13.4 Confidence class boundaries for accuracy confidence aspect

Score	Evaluation criteria for accuracy confidence (confidence level of being above or below area-specific assessment level)
HIGH	Assessment result is considered correct with at least 90 % probability
MODERATE	Assessment result is considered correct with a probability between 70 % and 90 %
LOW	Assessment result is considered correct with less than 70 % probability

Aggregation/Integration of parameter confidence

On parameter level the different confidence aspects are aggregated in the following way:

1. Averaging annual confidence results over the assessment period for temporal and spatial confidence aspects separately
2. Averaging or weighted averaging of temporal, spatial and accuracy confidence (and potential further methodological confidence in particular when using different data types) to a parameter confidence result.

The different parameter confidence results are combined to category results according to the integration principle of the status assessment:

1. DIN and DIP are assessed separately in category I and not averaged. If TN and TP are used in addition, their confidence results are averaged with the respective dissolved inorganic nutrient component (averaging of DIN and TN as well as DIP and TP) unless otherwise agreed.
2. Chlorophyll *a* and phytoplankton indicator species or results of pelagic indicators, where used, are aggregated by averaging or weighted averaging in category II
3. oxygen and photic limit or zoobenthos, where used, are averaged or calculated as weighted average in category III.

The nutrient confidence results for nitrogen and phosphorus and the confidence results of category II and III are averaged to the overall confidence and no one-out-all-out principle will be applied in the final step in contrast to the status assessment where the worst assessment result of category II or III determines the final assessment result.

For combined confidence aspects the following ranges are used for the classification:

High > 75

Moderate 50-75

low < 50

In case a national eutrophication assessment for COMP4 is carried out outside the automated tool of COMPEAT, the procedure for assessing the confidence as described above can also be applied manually. Alternatively, the different confidence rating methodologies outlined in OSPAR Agreement 13-08[4] can still be used.

[4] https://www.ospar.org/documents?d=32957

Annex 14: Improving and harmonizing methods for data aggregation in space, time and between data types

In addition to traditional discrete observations of parameters used for Eutrophication, data from remote sensing, models, and autonomous/semi-autonomous sampling platforms (buoys, ferryboxes) are available for use in the 4th application of the Common Procedure. Simple averaging of data across data types is not appropriate as it would bias the assessment statistics towards higher spatial and temporal resolution observations, consequently, a transparent and consistent approach to data aggregation must be agreed.

As higher spatial and temporal resolution datasets for eutrophication assessment parameters become available (see summary in **Table A.14.1**), it has become increasingly important to properly integrate various datasets and obtain assessment statistics. In previous COMP applications, data aggregation lacked consistency (across countries and datasets) and transparency.

Simple averaging of higher resolution data sets introduces a bias towards data types which sample at highest spatial and temporal resolution, which may not be those which the highest confidence, precision, and accuracy. It also biases towards locations and times sampled most intensely, and therefore does not provide a representative picture of the assessment area or time period.

There are a multitude of potential more complex and thus more computationally involved approaches to combining data types in space and time to avoid biases. The HELCOM HEAT tool (Example 1) provides an example of one approach. Research and development exploring more complex methods is ongoing. Determining the ideal approach to data aggregation will become increasingly more important as we move towards integrating all continuous and autonomous data in future COMPS. Development of a moving target may be more appropriate given the continuous nature of method development and improved observations.

Based on current knowledge and best practices, a common approach should be agreed for future COMP5, which is as simple as possible, yet sufficiently addresses the issues highlighted above to produce a valid assessment. The approach should be transparent and accompanied by a clear description of its limitations and outstanding issues. This annex does not recommend a preferred method for data aggregation but describes some examples of what has been done in other evaluations (HELCOM) or possible statistical processes. It is a first attempt to address a complex issue and aims to stimulate further discussion on what kind of data should be included in future COMP assessments, and the most appropriate aggregation of such data.

Table A.14.1: Summary of relevant data sources and types.

Source	Type	Relevant parameters	Spatial resolution	Temporal resolution	Issues
Discrete samples	Points	all	Variable, dependent on sampling strategy	Variable, dependent on sampling strategy	May miss bloom or other events, difficult to calculate statistics with confidence, especially percentiles. Often spatially biased to coastal areas.
Profiles	Points but continuous or binned in depth dimension	all	Variable, dependent on sampling strategy	Variable, dependent on sampling strategy	Need to take a section of the profile (e.g. surface or bottom waters) or average.
Moorings	Fixed points	chlorophyll, nutrients, potentially oxygen if lander attached.	Single point or network of points	High, from 10 minutes	Autonomous sensors require calibration with discrete data. Not representative of large assessment areas; can bias results due to high temporal frequency, issues with autocorrelation.
FerryBoxes on ferries (ships of opportunity) and research vessels	Points along transects or more random routes	Chlorophyll, nutrients in future?	High along repeated transects, low elsewhere. Resolution varies with ship speed.	High, usually 1-3 minutes	Autonomous sensors require calibration with discrete data.

Source	Type	Relevant parameters	Spatial resolution	Temporal resolution	Issues
Remote sensing	Gridded data	chlorophyll	Medium-high	High	Limited by cloud cover, need to use appropriate algorithms Less reliable in near-shore areas In situ datasets used for validation so may not be truly independent
Ecosystem models	Gridded data	all	Medium	High	Not based on in situ observations, may not reflect reality.

Example 1: HELCOM Heat Tool Approach

HEAT uses data drawn from the ICES database into a separate HELCOM assessment database (also in ICES). Additional data products, such as validated and pre-aggregated EO and ship-of-opportunity data, are submitted by the provider directly to the HELCOM assessment database

Discrete data are defined as any data which result from a single collection of water with a specific and identifiable time, position and depth (e.g. single bottle of a rosette, water drawn from non-toxic flow).

EO data (reflectance, chlorophyll-a) must be validated based on in-situ monitoring data (from ICES). Two aggregation sales: (1) large scale (HELCOM assessment unit, annual assessment period (summer months), (2) small scale: 20 km grid, daily. Submitted data included arithmetic and geometric mean value, standard deviation, percentiles, and number of observations used to derive statistics. Note that these grids and assessment units exclude coastal areas.

Ferrybox data (ships of opportunity), validated against in-situ monitoring data. Similarly to EO, aggregated at either large and small scale, in this case raw data are also accepted.

Information in the HEAT manual addresses only aggregation of different components of a single indicator (e.g. dissolved nitrogen and phosphorous), aggregation of different data sources is not mentioned.

A more detailed description of aggregation of different data types was presented at the JMP-EUNOSAT final meeting.

- To compensate for "systematic spatial bias in monitoring" (e.g. a ferrybox samples only one part of an assessment region), "each 20 km^2 gird cell average value is weighted in relation to the long-term average".
- Each data type is first used to produce a single value for every assessment area in which it is available, and these layers are then aggregated.
- Aggregation of layers is done by weighted average, based on data availability and methodological certainty – factors are agreed by expert network.
- Highest methodological certainty is given to in-situ data as a conservative approach.
- Timeline shows that this approach was not used in the last application of the HEAT tool.
- EO data is not applied in coastal areas.
- To emphasize that current approach does not represent final/best/optimal solution.

References:

HELCOM Eutrophication Assessment Manual. Updated 31.12.2015. Accessed online at http://www.helcom.fi/Documents/Eutrophication%20assessment%20manual.pdf

Presentation at JMP EUNOSAT Final meeting by Vivi Fleming-Lehtinen, Jenni Attila, Vesa Keto, and Seppo Kaitala (Finnish Environment Institute), "Introducing information from multiple platforms in the update of the Chlorophyll-a indicator for HELCOM HOLAS II. February 2019

Example 2: Optimising Monitoring Programs in the United Kingdom

Recent work which has recalculated OSPAR Eutrophication indicators in specific regions of UK waters by including non-traditional high resolution data sets clearly demonstrates that inclusion of these data can change the assessment outcomes. This is due to a combination of improved spatial and temporal data coverage (i.e. exposing the limitations of assessments relying on spatially and temporally sparse discrete observations, generally biased towards coastal locations) and yet-unresolved biasing of simple statistics towards data sets with the most observations (**Figure A.14.1**).

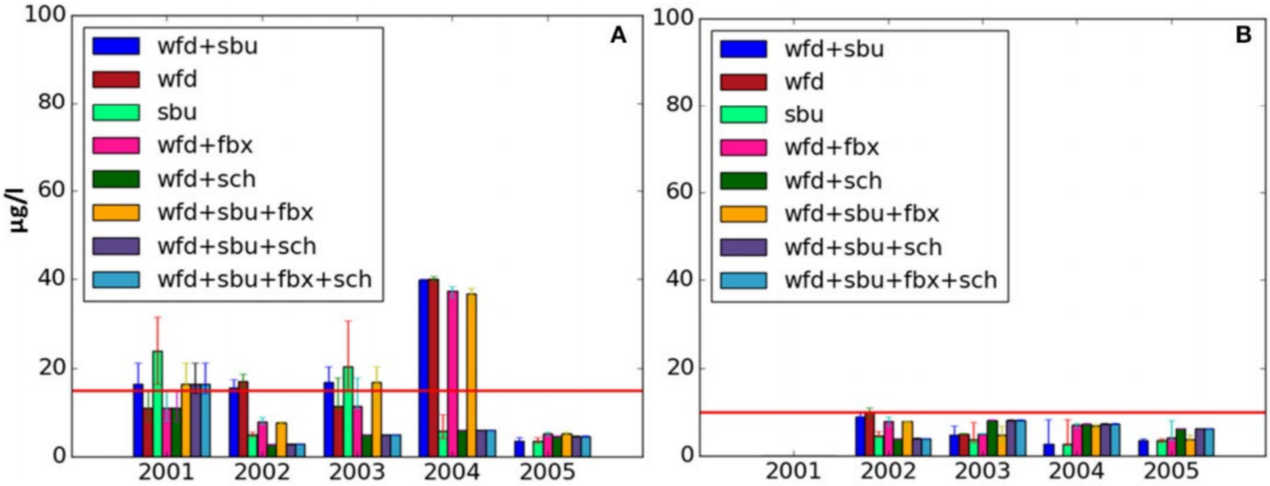

Figure A.14.1 from Garcia-Garcia et al 2019. COMP2 assessment for chlorophyll in (A) coastal and (B) offshore waters of the UK East Anglia region based on different combinations of data. wfd: water framework directive monitoring programme, sbu: Smartbuoy mooring, fbx: Cuxhaven-Harwich FerryBox, sch: MODIS daily chlorophyll satellite product.

Outstanding issues include the need to improve the calculation of the representativeness of data in space and time from the method of Brockmann and Topcu (2014) by assigning appropriate confidence to different data types and that high spatial and temporal resolution data should be averaged before combining with other data types not only to avoid biasing aggregate data towards higher resolution sampling, but also to properly account for and remove bias due to autocorrelation.

References:

Garcia-Garcia, L *et al*. (2019) Optimizing Monitoring Programs: A Case Study Based on the OSPAR Eutrophication Assessment for UK Waters. Frontiers in marine Science 5:203.

Greenwood, N *et al*. (2019) Utlizing Eutrophciation Assessment Directives from Transitional to Marine Systems in the Thames Estuary and Liverpool Bay, UK. Frontiers in Marine Science 6:116.

Example 3: Ongoing data type integration work: gridded data product approach

An assessment needs to make use of all of these available data types, but since they are so different, they cannot all be thrown in together. We are trialling a gridded approach which incorporates different kinds of uncertainty.

Data are split into different types:

- Ferrybox transects;
- *In situ* discrete data from moorings;
- ship-based discrete samples and profiles (averaged per station);
- Remote sensing data (Copernicus product 067 or EUNOSAT/RBINS product (once this is available);
- Model data from GETM-ERSEM model.

All data types are first aggregated onto the same spatial grid and at the same temporal scale. For example, the grid of the model, at approx. 5.5 km by 5.5 km, and monthly temporal resolution (other time periods also being trialled. Average and standard error products are calculated for each data type and this results in four chlorophyll data products, with associated uncertainty layers (standard error), are in the same format.

The next step is to combine the four data products into a merged product. This process needs to incorporate two types of uncertainty:

1. The uncertainty of each grid cell for each product. This is determined from the standard error, which accounts for the variability of the data throughout the time period (month) and the number of data points available.

    - The model produces data for every day, so the number of data points available is always equal to the number of days in a month. The standard error calculation therefore has constant *n*, so standard error only reflects variation in the value in through the time period (not in sampling intensity) and will be lower than for other methods.

2. Uncertainty of the product overall – product weighting.

    - Similarly, to the HEAT approach, weighting factors should be agreed for each product. These should be based on comparison of different data types (e.g. model compared against in situ data) and expert judgement.

    - The simplest approach is to have one weighting factor per data product which does not vary through space and time. However, there may be variation in reliability of a product, e.g. remote sensing data is less reliable close to the coast, which should be incorporated.

A weighted mean can then be calculated, taking into account both types of uncertainty.

$$\bar{x} = \frac{\sum_{i=1}^{n}(w_i x_i \sigma_i^{-2})}{\sum_{i=1}^{n}(w_i \sigma_i^{-2})}$$

where w_i is the product weight, x_i is the product value for the grid cell, and σ_i is the standard error for the grid cell.

Example 4: Ongoing data type integration work 2: statistical modelling

This work involves the same four chlorophyll data types described above in Annex 4, considered during the growing season (March-October inclusive) of 2011. The spatial extent of each data type is shown in **Figure A.14.2**.

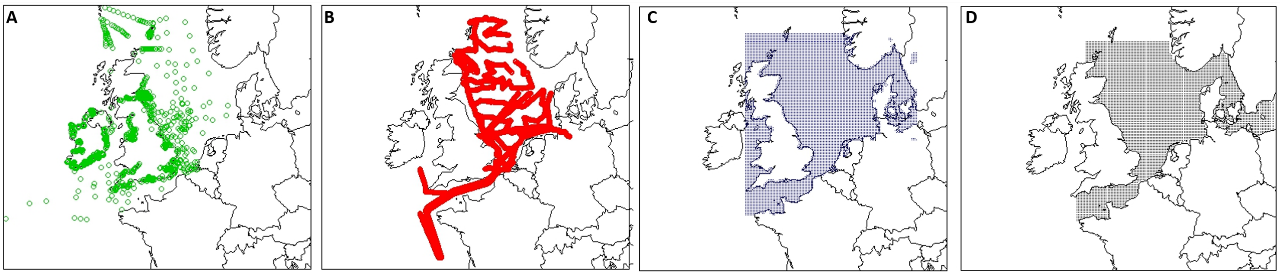

Figure A.14.2 Spatial extent of each data type, A: in situ, B: ferrybox, C: remote sensing, D: model.

A Generalised Additive Model (Wood, 2017) to chlorophyll (ln(x+0.1) transformed) of the form:

Ln(chlorophyll+0.1) = *a* + *M_j* + *f(X,Y)* + *f(D)* + *E*

where *f(X,Y)* is some smooth function of *X* and *Y*, *f(D)* is a smooth function of days since January 1st 2011, *M_j* is the effect of the *j*th method, and *E* is an error term. The data were log-transformed to obtain a Gaussian distribution. The smoothing method used thin plate splines – however, soap film splines may be more appropriate because we do not want to smooth over land masses; these may be applied in future work.

The application of the model is based on the assumptions (1) that the mean chlorophyll concentration varies smoothly in space and time and (2) the different data types have some additive effect on chlorophyll. For example, one data type gives readings X units higher (or lower) than another. This second assumption is likely to be a simplistic approached and will be examined and refined in future.

The fitted model is used to predict a spatial grid of chlorophyll values for a standardized data type (combining knowledge from all available data types) a particular date (or set of dates).

For example, **Figure A.14.3** shows standardized chlorophyll concentration map representing 1st June and 1st March 2011 which incorporates information from all data types, but accounts for their differences from the in-situ data (in other words, standardized to the in-situ data). Standardization to the in-situ data was chosen as this is traditionally deemed to best represent “true” status.

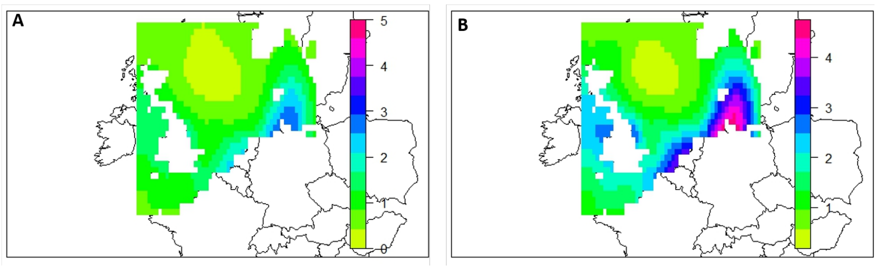

Figure A.14.3 Statistical model-predicted chlorophyll concentrations for (A) 1st March, and (B) 1st June which combine information from the 4 different types.

Outstanding issues

Table A.14.2: Outstanding issues for consideration

Which data types will be considered in future COMPS? **In which areas/to which indicators are they relevant?**	Non-traditional data types which need to be considered/accounted for include: <u>Remote sensing/Earth Observation; chlorophyll-a; sea surface</u> • Temporal and spatial data coverage limited by clouds; • Better confidence away from coastal areas; • Different algorithms available to derive chlorophyll from observed reflectance; • Data require calibration/validation against traditional discrete samples. <u>Ferrybox/Ship-of-opportunity; chlorophyll-a; near surface</u> • Variable temporal and spatial coverage between lines; • Observed fluorescence relies on co-measured discrete samples to derive chlorophyll, or manufacturer provided calibrations; Recommend this be considered in greater detail prior to the next COMP; • May not be truly independent from ship based samples if these are used to calibrate (potentially an issue for other data types also). <u>Fixed moorings; chlorophyll-a and nitrate; near surface</u> • High temporal resolution at limited spatial points; • Observed fluorescence relies on co-measured discrete samples to derive chlorophyll, or lab calibrations.

	<u>Biogeochemical model outputs; nutrients, chlorophyll-a, oxygen; several water depths</u> • Models available only for some areas; • Model outputs typically validated against in situ observations. • Models estimates may be unreliable. <u>Gliders/ASVs</u> • Similar issues to ferrybox.
How to account for temporal autocorrelation?	• The HEAT method of daily averages may be too high-temporal resolution to avoid autocorrelation; • An appropriate timescale is required for each data type.
Percentile-based statistics create an additional level of computational complexity for combining data types.	• Use of mean instead of 90th percentile chlorophyll could significantly simplify the problem.
How can we assign confidence to the different data types and to the assessment itself?	•
How can we incorporate uncertainty?	•
How to improve the current method for deriving representativeness of assessment data in space and time? *(Brockmann and Topcu, 2014).*	•
How to avoid/account for 'double counting' if discreate measurements are used to validate/calibrate higher resolution sampling and also included as an independent data source? *(e.g. chlorophyll by fluorescence from ferryboxes) and buoys, chlorophyll from EO.*	•