Supplementary Material

Coherent assessment of Eutrophication across the North-East Atlantic waters (2015- 2020).

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Supplementary Table S : Development of harmonised assessment areas for application in COMP4.

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 was identifying cross-border assessment areas with similar ecological and physical functioning (Blauw et al., 2019) and described below. This approach has been adopted for the application of the Common Procedure.

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| --- | --- |
| Step 1 | 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. |
| 2 | 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. |
| 3 | 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.    *Areas with similar phytoplankton dynamics in satellite data.* |
| 4 | 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.  See below for 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 |   *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)*  D:\Projects\Noordzee\matlab\figures\DepthClasses_draft5.jpg  D:\Projects\Noordzee\matlab\figures\SalinityClasses_draft5.tif  D:\Projects\Noordzee\matlab\figures\StratificationClasses_draft5_Limit=75.tif |
| 5 | 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 S2).  Figure S2 and S3 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.  *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*    *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.* |

Supplementary Table S : Further development of the OSPAR assessment areas after JMP-EUNOSAT and National modifications\*.

\*The original proposal by the JMP-EUNOSAT project was to carry out assessments at three levels of spatial detail including (i) 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, (ii) 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 and (iii) 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. A lengthy consultation was then carried out where further refinements would be made to the assessment areas proposed by JMP-EUNOSAT, based on requests by OSPAR Contracting Parties. This then enable full agreement on the harmonised assessment areas..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.

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| --- | --- |
| Number | Modification added to the initial assessment area |
| 1 | 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. |
| 2 | 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.  *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.* |
| 3 | 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). |
| 4 | In French coastal waters, 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). |
| 5 | In French coastal waters, 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. |
| 6 | Based on the same SHOM work and discussions between UK and France both CPs agreed on new cross-boundary sub-areas within the Channel. |
| 7 | 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    *The newly proposed sub-area in the German Bight as red area projected on the original JMP-EUNOSAT assessment areas.* |
| 8 | 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 including:   * + 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   + Scottish WFD areas outside 3nm boundary were reinstated to unify Scottish Sea into one assessment area.   + Merged Coastal IRL 1 and Scottish Sea 1     *Illustration of some small edits in Scottish waters,* |
| 9 | In the Spanish North Atlantic waters, six pixel-groups with marked differences in the CSAT annual cycle shape were identified. The most productive waters (i.e., with higher CSAT and CM) 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 CM 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    *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).    *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.* |
| 10 | 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.* |

Supplementary Table S 3: Steps in the data flow sequence within COMPEAT. Note that steps 1 to 3 are carried out within COMPEAT to provide an assessment of the common indicators and a final outcome for each assessment area.

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| **Data flow sequence #** | Description of analysis |
| Step 1: Aggregation  ***Data is aggregated to an assessment per parameter over the assessment period.*** | * Individual parameters are assessed annually, and the annual assessments averaged over the defined assessment period * Individual parameters are then 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 direction of the response of the parameter to changes in nutrient inputs. * EQRs are scaled to a uniform scale (EQRS = scaled EQRs) * Final EQRS value for the assessment period is calculate as the averages of the annual averages (note that the calculation of annual averages is dependent on adequate data availability). |
| Step 2 Integration within indicators.  ***Integrating within the common indicators (categories I, II and III).*** | * The nutrients nitrogen and phosphorus are assessed separately within category I to allow identification of the nutrient that is potentially causing eutrophication effects. * If both dissolved and total nutrient components are assessed, the EQRs for each nutrient will be averaged (DIN & TN or DIP & TP), but nitrogen and phosphorus are kept separate. * The assessment parameters within categories II (Chlorophyll) and III (Dissolved Oxygen) were integrated. |
| Step 3: Integration across the common indicators  ***Integration between the common indicators (categories I, II and III).*** | * 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 indirect effects (Category III, e.g. oxygen deficiency or light attenuation). * Areas showing an increased degree of nutrient enrichment accompanied by direct and/or indirect effects are classified as problem areas; * Areas may show direct effects and/or indirect effects, despite no evidence for increased nutrient enrichment, for example, as a result of transboundary transport. These areas are classified as problem areas * Areas with elevated nutrient concentrations are classified as non-problem areas if there is firm, scientifically based evidence of the absence of (direct, indirect) eutrophication effects (though could be contribution to issues elsewhere and will be flagged) * Areas without nutrient enrichment and related (in)direct effects are classified as non-problem areas |
| Step 4:  **expert verification** | * Expert verification of the COMPEAT results made by the Contracting Parties in whose waters the assessment units occur. * At this stage Contracting Parties may agree to include additional parameters and thresholds in the relevant category in COMPEAT. |

Supplementary Table S : 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.

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| **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 |

Supplementary Table S : *Description of the COMP 4 assessment areas. WFD areas are excluded and the COMP4 assessment area are only relevant to open waters beyond WFD.* Overview of ecologically relevant assessment areas based on duration of stratification, mean surface salinity, depth, suspended particulate matter and primary production.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Type** | **Area code** | **Area name** | **Description** | **Area (km2)** | **Depth mean** | **mean Salinity** | **OSPAR Region** | **CPs involved** |
| River plumes | ADPM | Adour plume | 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 | 87 | 34.4 | IV | FR |
| River plumes | GDPM | Gironde plume | 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 | 34 | 33.5 | IV | FR |
| River plumes | GBCW | Gulf of Biscay coastal waters | 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 | 53 | 34.6 | IV | FR |
| River plumes | HPM | Humber plume | 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 | 16 | 33.5 | II | UK |
| River plumes | IRS | Irish Sea | Permanently mixed central part of the Irish Sea. Landward boundaries are the WFD water bodies and coastal waters of Ireland. | 32691 | 65 | 33.7 | III | IE, UK |
| River plumes | NAAC1A | Noratlantic Area NOR-NorC1A | Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body A | 549 | tbd | - | IV | ES |
| River plumes | NAAC1B | Noratlantic Area NOR-NorC1B | Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body B. | 88 | tbd | - | IV | ES |
| River plumes | NAAC1C | Noratlantic Area NOR-NorC1C | Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body C. | 28 | tbd | - | IV | ES |
| River plumes | NAAC2 | Noratlantic Area NOR-NorC2 | Assessment area based on phytoplankton productivity: Coastal waters surrounding the Galician Estuaries (Rías Gallegas). | 1662 | tbd | - | IV | ES |
| River plumes | NAAC3 | Noratlantic Area NOR-NorC3 | 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 | - | IV | ES |
| River plumes | NNS | Northern North Sea | Seasonally stratified waters deeper than 35 m | 264253 | 121 | 35 | II | UK, DK, SE, NO, DE |
| River plumes | NT | Norwegian Trench | Deeper than 100 m, permanently stratified | 59124 | 349 | 34.1 | II | NO, SE, DK |
| River plumes | OC | Outer Coastal DEDK | 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 | 27 | - | II | DE, DK |
| River plumes | SAAP2 | Sudatlantic Area SUD-P2 | Assessment area based on phytoplankton productivity: Transition area between coast and open sea, external. | 916 | tbd | - | IV | ES |
| Coastal | CFR | Coastal FR channel | 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 | 33 | 34.2 | II | FR |
| Coastal | CIRL | Coastal IRL 3 | 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 | 65 | 34 | III | IE |
| Coastal | CNOR1 | Coastal NOR 1 | The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour. | 8741 | 190 | 34.3 | II | NO |
| Coastal | CNOR2 | Coastal NOR 2 | The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour. | 2606 | 217 | 34 | II | NO |
| Coastal | CNOR3 | Coastal NOR 3 | The landward boundary is the WFD water bodies. Seasonally stratified coastal waters, outer boundary is the 250m depth contour | 1733 | 171 | 32.4 | II | NO |
| Coastal | CUK1 | Coastal UK 1 | 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 | 60 | 34.5 | III | UK |
| Coastal | CUKC | Coastal UK channel | 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 | 37 | 34.8 | II | UK |
| Coastal | CWCC | Coastal Waters CC | 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 | - | IV | PT |
| Coastal | DB | Dogger Bank | Permanently mixed waters less than 35 m deep in the Dogger Bank area. | 14750 | 28 | 35.1 | II | NL, DE, DK, UK |
| Coastal | ECPM1 | East Coast (permanently mixed) 1 | Permanently mixed coastal waters. The outer boundary are the intermittently stratified waters | 3519 | 73 | 34.8 | II | UK |
| Coastal | ECPM2 | East Coast (permanently mixed) 2 | Permanently mixed coastal waters. The outer boundary are the intermittently stratified waters | 1444 | 43 | 34.5 | II | UK |
| Coastal | ELPM | Elbe plume | 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 | 18 | 30.8 | II | DE, DK |
| Coastal | EMPM | Ems plume | 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 | 19 | 31.4 | II | DE |
| Coastal | GBSW | Gulf of Biscay shelf waters | 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 | 106 | 34.9 | IV | FR |
| Coastal | LBPM | Liverpool Bay plume | Plume of Liverpool Bay. The outer boundary follows the 10 mg/l contour, based on a 10-year average (Greenwood et al., 2019). | 1361 | 15 | 30.6 | III | UK |
| Coastal | LPM | Loire plume | Plume of the Loire river. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019) | 1495 | 38 | 33.8 | IV | FR |
| Coastal | MPM | Meuse plume | 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 | 16 | 29.3 | II | NL |
| Coastal | NAAP2 | Noratlantic Area NOR-NorP2 | Assessment area based on phytoplankton productivity: Transition area between the coast and open ocean, internal. | 8327 | tbd | - | IV | ES |
| Coastal | NAAPF | Noratlantic Area NOR-Plataforma | Assessment area based on phytoplankton productivity: Transition area between the coast and open ocean, external. | 37101 | tbd | - | IV | ES |
| Coastal | RHPM | Rhine plume | 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 | 17 | 31 | II | NL |
| Coastal | SCHPM1 | Scheldt plume 1 | 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 | 13 | 31.4 | II | BE, NL |
| Coastal | SCHPM2 | Scheldt plume 2 | 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 | 15 | 30.9 | II | NL |
| Coastal | SS | Scottish Sea | Waters surrounding Scotland. Landward boundary defined by the 3nm WFD boundaries. Outer boundaries defined by stratification and old OSPAR boundary | 53273 | 89 | 35.1 | II, III | UK |
| Coastal | SPM | Seine plume | Plume of the Seine river. The area boundaries were based on combined modelling and data analysis work by SHOM (Cachera et al., 2019) | 1115 | 25 | 31.8 | II | FR |
| Coastal | SHPM | Shannon plume | Plume of the Shannon river. | 380 | 61 | 34.1 | III | IE |
| Coastal | SAAC1 | Sudatlantic Area SUD-C1 | Assessment area based on phytoplankton productivity: Coastal area influenced by river discharges, internal. | 405 | tbd | - | IV | ES |
| Coastal | SAAP1 | Sudatlantic Area SUD-P1 | Assessment area based on phytoplankton productivity: Transition area between coast and open sea, river influenced. | 2467 | tbd | - | IV | ES |
| Shelf | ASS | Atlantic Seasonally Stratified | Area between 100-250 m dept line, seasonally stratified. NW part of Region IV, SW part of region III. | 217301 | 134 | 35.2 | III, IV | FR, IE, UK |
| Shelf | CCTI | Channel coastal shelf tidal influenced | 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 | 40 | 34.8 | II | FR, UK |
| Shelf | CWM | Channel well mixed | 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 | 77 | 35.1 | II, III | FR, UK |
| Shelf | CWMTI | Channel well mixed tidal influenced | 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 | 59 | 35 | II | FR, UK |
| Shelf | CWAC | Coastal Waters AC | Coastal waters up to 100m contour for the area from the northern border with Spain to Cape Carvoeiro (A area) | 7395 | tbd | - | IV | PT |
| Shelf | ENS | Eastern North Sea | Seasonally stratified, east of the Dogger Bank, West of the 35m depth contour and the 34 psu contour | 60634 | 43 | 34.8 | II | NL, DE, DK |
| Shelf | GBC | German Bight central | Seasonally stratified | 4554 | 39 | 33.4 | II | DE |
| Shelf | IS1 | Intermittently Stratified 1 |  | 73501 | 138 | 35.3 | II, III | UK |
| Shelf | IS2 | Intermittently Stratified 2 |  | 26517 | 102 | 35.1 | II | IE, UK |
| Shelf | KC | Kattegat Coastal | Kattegat shallower than 35m | 9632 | 21 | 25.7 | II | DK, SE |
| Shelf | KD | Kattegat Deep | Kattegat deeper than 35m | 4958 | 50 | 27.6 | II | DK, SE |
| Shelf | NAAC1D | Noratlantic Area NOR-NorC1D | Assessment area based on phytoplankton productivity: Inner Galician Estuaries (Rías Gallegas), water body D. | 12 | tbd | - | IV | ES |
| Shelf | NAAO1 | Noratlantic Area NOR-NorO1 | Assessment area based on phytoplankton productivity: Oceanic area | 261727 | tbd | - | IV | ES |
| Shelf | OWAO | Ocean Waters AO | 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 | - | IV | PT |
| Shelf | SNS | Southern North Sea | Mostly less than 35 m deep, permanently mixed | 61758 | 32 | 34.3 | II | FR, BE, NL, UK, DE |
| Shelf | SAAOC | Sudatlantic Area SUD-OCEAN | Assessment area based on phytoplankton productivity: Oceanic area | 10076 | tbd | - | IV | ES |
| Shelf | THPM | Thames plume | 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 | 22 | 34.4 | II | UK |
| Oceanic | ATL | Atlantic | All areas west of 250 m depth line, separating deeper Atlantic Ocean from shallower areas in Bay of Biscay, Celtic Seas, Greater North Sea. | 934260 | 2291 | 35.3 | II, IV, V | ES, FR, IE, UK, NO |
| Oceanic | CWBC | Coastal Waters BC | Coastal waters up to 100m contour for the area from Cape Carvoeiro to Ponta da Piedade (B area) | 4230 | tbd | - | IV | PT |
| Oceanic | OWBO | Ocean Waters BO | Oceanic waters form 100m contour out to 200 nautical miles for the area from Cape Carvoeiro to Ponta da Piedade (B area) | 184458 | tbd | - | IV | PT |
| Oceanic | OWCO | Ocean Waters CO | 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 | - | IV | PT |
| Oceanic | SK | Skagerrak | Salinity and geography | 5759 | 134 | 31.8 | II | DK, SE |
| Oceanic | SAAC2 | Sudatlantic Area SUD-C2 | Assessment area based on phytoplankton productivity: Coastal area influenced by river discharges, external. | 267 | tbd | - | IV | ES |

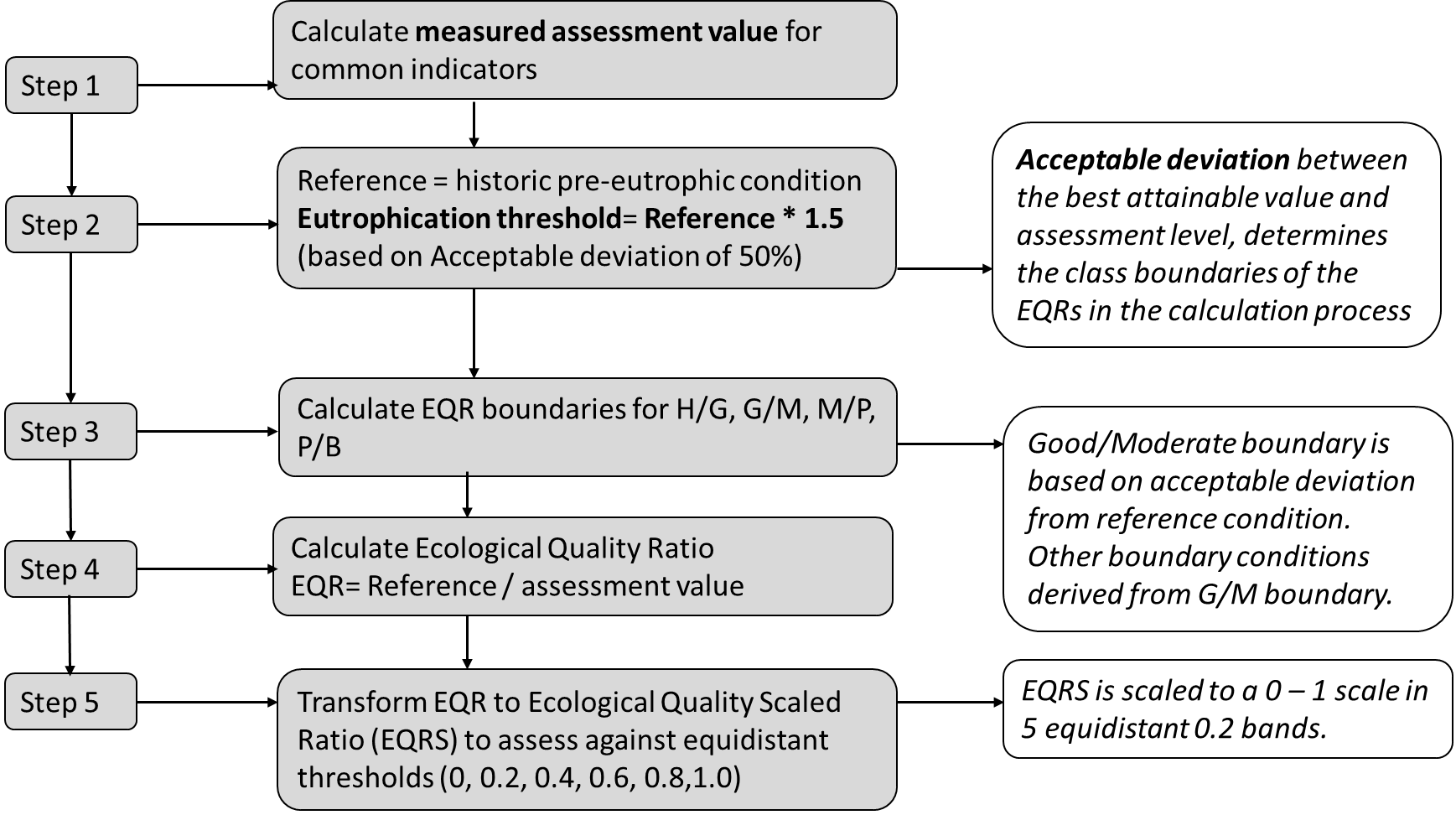
Supplementary Table S : Development of harmonised assessment levels agreed for application in COMP4 for all assessment areas.

**This table lists the area-specific assessment parameters agreed for the 4th application of the COMP for 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 Van Leeuwen et al., 2023. 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.**

| *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** | **Winter DIN (µM)** | | **Winter DIP (µM)** | **Total N (µM)** | **Total P (µM)** | **Mean growing season Chl-a (mg/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 | |
| 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 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 | |
| 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 | |
| 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. | |
| 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. | |
| 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 | |
| 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. | |
| 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 | |
| 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. | |
| 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. | |
| 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 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. | |
| 35 | LPM | Loire plume | FR | 19.3 | | 0.79 |  |  | 3.3 | | 6.0 | |  | ICG-EMO HS2 thresholds | |
| 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. | |
| 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 | |
| 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) | |
| 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 | |
| 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 | |
| 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. | |

Supplementary Figure S 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

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Supplementary Figure S :Assessment of temporal confidence

Confidence class boundaries for general temporal confidence for winter nutrients and chlorophyll in the growing season.

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

Confidence class boundaries for general temporal confidence for winter nutrients and chlorophyll in the growing season.

Temporal Confidence

|  |  |  |
| --- | --- | --- |
| **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 |



Spatial Confidence

Supplementary Figure S : Assessment of Spatial confidence

Confidence class boundaries for general temporal confidence for winter nutrients and chlorophyll in the growing season.

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 below are separated for winter nutrients and chlorophyll to account for different natural variabilities and associated different requirements.

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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 % |

Supplementary Figure S : Assessment of Accuracy confidence

*Confidence class boundaries for accuracy confidence aspect*.

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.14.4 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.

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.

|  |  |
| --- | --- |
| **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 |

Supplementary Figure S : Aggregation/Integration of parameter confidence

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

Averaging annual confidence results over the assessment period for temporal and spatial confidence aspects separately

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: particular when using different data types) to a parameter confidence result.

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.

Chlorophyll *a* and phytoplankton indicator species or results of pelagic indicators, where used, are aggregated by averaging or weighted averaging in category II

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