OSPAR CEMP Guideline

Common indicator PH3 “Changes in Plankton Diversity”

Adopted by BDC(2) 2022

OSPAR Agreement 2019-07[1]

This OSPAR biodiversity indicator has been further developed from its initial use in the Intermediate Assessment 2017. As a result of iteration and learning, it is anticipated that there will continue to be evolution of the methods and approaches documented in the CEMP guidelines. Version updates will be clearly indicated and will be managed in a phased approach via ICG-COBAM through its expert groups and with the oversight and steer of BDC.

Contents

[1] This Guideline exists in English only. Update 2023

1 Introduction

1.1 General introduction to the indicator

Species composition and abundance of plankton assemblages are influenced by environmental conditions and their variability, such as available light, nutrients, prey, currents and climate. As a result, plankton communities fluctuate in space and time. Environmental perturbations such as pollution and/or eutrophication (i.e. excessive nutrients) can create unusual marked changes in community composition because only a small number of species can cope with/benefit rapidly from the new situation. In the Baltic Sea, for example, phytoplankton species composition has been observed to change with different nutrient levels and ratios (HELCOM, 2017 and references therein).

Monitoring plankton diversity is important since long-term and drastic changes in biodiversity can alter marine ecosystems in terms of their functioning, such as food webs and the uptake and transfer of carbon in the oceans, and the services they provide. In order to quantify changes in biodiversity**,** indices based on the number of species and/or their relative abundances in the community can be calculated for water quality assessment. A plethora of indices exist in the scientific literature but their use depends on (1) the objective of the study, (2) their ecological relevance and (3) mathematical properties. Currently, taxonomic diversity indicators for plankton are being revised within the Marine Strategy Framework Directive for French waters (Duflos et al., 2018). In a wider management context (MSFD), only a few community composition indicators are currently applied and this probably reflects the difficulty in setting reference conditions and environmental objectives for these indicators (Garmendia et al., 2013). On the other hand, diversity indices are relatively easy to calculate and their interpretations are intuitive.

The aim was to develop a multimetric indicator to describe the structure, composition and change in the plankton community (Budria et al., 2017). The Changes in Plankton Diversity Pelagic Habitat Indicator (PH3) describes the alpha diversity, i.e. the diversity within a site or sample, and the beta diversity that focuses on the rate of change, or turnover, in species composition (Rombouts et al., 2019). New insight since IA 2017, implement now the Ecological Quality Ratio which aims to simplify multimetric indices to one simple and normalized metric to better compare in space and time plankton communities. For QSR2023, the concept of proof described in IA 2017 is applicable to data of the Celtic Seas (OSPAR Region III) to produce a common assessment in this region. The concept is also applicable to the data of the Greater North Sea (OSPAR Region II) and the Bay of Biscay and Iberian Coasts (OSPAR Region IV) to produce a pilot assessment of the PH3 as the indicator remained candidate in these regions.

To date PH3 focuses on phytoplankton and zooplankton organisms separately. The final aim of PH3, however, will be to integrate both phytoplankton and zooplankton assessments into one metric. Until then, considerable work is still required to understand potential plankton community responses to human pressures.

Finally, for a more robust assessment of pelagic habitats, other measurements, such as total biomass/abundance of the community and information on functional groups should be included in addition to the information on the community composition. A combination of each common pelagic habitat indicator (PH) will then consider the plankton community at different resolutions, PH1 at the life-form level of the community, PH2 the total biomass/abundance of the community and PH3 at the species level. Hence, by combining the information from these three indicators, a more holistic assessment of plankton dynamics can be obtained than from each indicator individually. Such work on the integration across indicators has been started to be conducted, especially between the PH1 and the PH3 (Bedford et al., 2020).

2 Monitoring

2.1 Purpose

- What is the objective of assessing the indicator; only status of the environment, or also to support identification of pressures and programmes of measures?

PH3 is a state indicator which does not provide yet a direct link to pressures. PH3 belongs to the category of 'surveillance' indicators, such as defined by Bedford et al. (2018). These surveillance indicators are early-warning indicators of physical hydro-climatic changes and can result in triggering management action when pre-defined bounds are passed. With continued development PH3 can be used for the identification of “events”, i.e. unusual temporal changes in community structure, and will provide information supporting evidence for D2, D3, D4 and D5.

2.2 Quantitative Objectives

- Phytoplankton monitoring guidelines are relevant for several other indicators in development such as for food webs and eutrophication.
- Information from monitoring phytoplankton can be used to (see CEMP Eutrophication Monitoring Guidelines: Phytoplankton Species Composition):
    - establish the composition, spatial distribution and frequency of phytoplankton blooms;
    - establish long term temporal and spatial trends in phytoplankton species composition and their relative abundance in order to detect:
        - changes that may be caused by eutrophication, warming, ocean acidification, etc.,
        - changes in frequency and magnitude of harmful algal blooms,
        - occurrence of non-indigenous/cryptogenic species,
        - changes in the foodweb,
        - changes in diversity indices.
        - changes in length of growing season, timing of blooming, etc.,
- Information from monitoring zooplankton can be used to:
    - establish long term temporal and spatial trends in zooplankton species composition and their relative abundance in order to detect:
        - changes that may be caused by eutrophication, warming, ocean acidification, etc.,
        - occurrence of non-indigenous/cryptogenic species,
        - changes in the foodweb,
        - changes in diversity indices.
- Also, one plankton sample can be used to inform the two Pelagic Habitat indicators PH1/FW5, and PH3. Therefore, one set of monitoring data can be used in multiple ways.

- Which parameters need to be measured?
    - Phytoplankton abundance and composition (per species/genera/taxa)

- Zooplankton abundance and composition (per species/genera/taxa)

- For which criteria is PH3 relevant?
  - The condition of the habitat type, including its biotic and abiotic structure and its functions [...] is not adversely affected due to anthropogenic pressures (D1C6). It is also relevant for criteria D4C1: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.
  - Also used to inform MSFD D2, D3, D5

2.3 Monitoring Strategy: design of specific monitoring strategy

- Monitoring methods have to be consistent over a long time period to facilitate the detection of changes and trends and to allow comparison within the monitoring program (HELCOM 2017).
- Currently, data for computing the indicator (**Table 1**) comes from fixed point stations in coastal areas (e.g. Germany, Sweden, UK) and from the Continuous Plankton recorder (CPR) survey for shelves and offshore areas covered by this survey. In addition, several other CP's have monitoring programmes in place for calculating PH3 (e.g. UK, Germany, Netherlands, Spain).
- In further testing, regular annual or seasonal fisheries and/or research cruises will be integrated but the indicator should be adapted before use as they are unlikely to meet the measurement frequency requirement.

Table 1: Contracting parties and institutes that provided the datasets for the pelagic assessment.

Contracting Party	Institute	Dataset name	Date range
Germany	Bundesamt für Seeschifffahrt und Hydrographie (BSH)	BSH_Phyto_Zoo	2008-2011
	Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (LLUR)	OSPAR_LLUR-SH_2010-2020	2010-2020
	Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten und Naturschutz (NLWKN)	OSPAR_NLWKN_1999-19_phyto	1999-2019
Spain	Instituto Espanol de Oceanografia (IEO)	IEO_RADIALES_Phyto	1989-2016
		IEO_RADIALES_Zoo	1991-2018
Sweden	Swedish Meteorological and Hydrological Institute (SMHI)	National data_SMHI_Kattegat-Dnr: S/Gbg-2021_116_phyto	1989-2021
		National data_SMHI_Kattegat-Dnr: S/Gbg-2021_116_zoo	1996-2020
		National data_SMHI_Skagerrak-Dnr: S/Gbg-2021_116_phyto	1986-2020
		National data_SMHI_Skagerrak-Dnr: S/Gbg-2021_116_zoo	1996-2020
United Kingdom	Centre for Environment, Fisheries and Aquaculture Science (Cefas)	Cefas SmartBuoy Marine Observational Network - UK Waters	2001-2019

		Phytoplankton Data 2001-2019	
	Environment Agency (EA)	EA PHYTO 2000-2020	2000-2020
	Marine Biological Association (MBA)	CPR dataset 1960-2019	1960-2019
	Marine Scotland Science (MSS)	MSS Scalloway Phytoplankton dataset	2000-2018
		MSS Loch Ewe Phytoplankton	2000-2020
		MSS Loch Ewe zooplankton	2002-2017
		MSS Scapa Phytoplankton dataset	2000-2020
		MSS Stonehaven Phytoplankton	2000-2020
		MSS Stonehaven zooplankton	1999-2020
	Plymouth Marine Laboratory (PML)	PML_L4 phytoplankton	1992-2020
		PML_L4 zooplankton	1988-2020
	Scottish Association for Marine Science (SAMS)	SAMS-LPO-Phyto-Dec2021	1970-2017

2.4 Sampling Strategy - ensure adequate sampling or observation methodologies

- Phytoplankton communities are highly dynamic with a strong temporal (inter-annual and seasonal) and spatial variability. Therefore, the monitoring should be organised accordingly to capture rapid variations and/or patchiness in plankton communities[2]. Zooplankton follows phytoplankton dynamic. Thus, zooplankton and phytoplankton should have the same monitoring strategy.
- A detailed account of sampling and monitoring equipment for phytoplankton community composition is outlined in the CEMP guidelines for eutrophication (OSPAR 2016).
- PH3 will be assessed at the scale of COMP4 assessment units (Enserink et al., 2019) where possible (**Table 2**). The identification of the COMP4 assessment units has been established by modelling techniques by Deltares institute.
- In order to capture the temporal trends, sampling needs to cover the entire growth season, which can extend over the entire year (HELCOM 2017). To calculate PH3, at least monthly samples of plankton for community composition and abundance analyses across all seasons are required.

[2] Monthly frequencies would be optimal and may not be achievable for all Contracting Parties

Table 2: Minimum sampling strategy

	Coastal	Shelf	Open ocean
[3]Frequency of data collection*	Monthly	Monthly	Monthly
Monitoring method	*In situ*	*In situ*	*In situ*
Who is responsible for monitoring?	Member state	Member state	Member state
Frequency of indicator update and assessment	2 or 3 years	2 or 3 years	2 or 3 years
Minimal amount of monitoring locations	Monitoring must cover all water masses or COMP4 assessment units.	Monitoring must cover all water masses or COMP4 assessment units.	Monitoring must cover all water masses or COMP4 assessment units.
Current data availability	Regular (monthly). Single point stations exist mainly in coastal waters but there are gaps in some regions.	Regular (yearly or seasonal) fisheries and research cruises could be used for sample collection but relevance for the current indicator needs to be tested especially in terms of temporal frequency).	Regular (yearly or seasonal) fisheries and research cruises could be used for sample collection but relevance for the current indicator needs to be tested especially in terms of temporal frequency).

*A complementary need exists for both long-term time-series as well as high frequency monitoring, particularly in habitats considerably potentially influenced by anthropogenic pressures.

2.5 Quality assurance/ Quality Control

Extensive knowledge of the taxonomy, identification and counting procedures of phytoplankton is essential in order to produce high-quality data (HELCOM 2017).

2.6 Data reporting, handling and management

- *Reporting format (Available via a link in the CEMP Appendices)*
- *Data metadata schema (Link to ODIMS, INSPIRE compliant)*
    - Each dataset is responsible for its own metadata
- *Confidence levels in data*
    - CPR data: The CPR has a QA/QC method which has remained virtually unchanged since 1948. MBA procedures are documented, plankton analysts have International Phytoplankton Intercomparison (IPI; formerly known as BEQUALM) qualifications and MBA chairs the NE Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme which is working to develop first a standard and then quality control scheme for zooplankton analysis.
    - PML data: The main PML analyst for L4 was trained by a skilled MBA CPR analyst and holds NMBAQC qualifications.

[3] Monthly frequencies would be optimal and may not be achievable for all Contracting Parties

- SMHI data: The analysts of the Swedish samples do yearly intercalibrations using either the service of IPI or HELCOM. The analysts are taxonomically trained continuously and updated with taxonomic changes.
- The quality of the data depends largely on the sample collection and taxonomic expertise of the analysts and of the quality control for each of the monitoring networks. Hence, caution is required when compiling data from different sources, at least at the first stage.

- *Data flows described (Additional to information in CEMP Appendix)*
  - Data flows will be established according to the policy on data sharing of each network and institution.
- *Data storage*
  - Raw data is currently stored in national databases.

3 Assessment

3.1 Data acquisition

- *How you extract the data specifically for your assessment question*

Data were extracted by their respective institute (**Table 1**) after getting contacted by the coordinator of each member state. Additional data have been provided via the pelagic data call which came out in 2021. Those data have not been used into the assessment due to insufficient temporal extent.

3.2 Preparation of data

- *Normalisation of data (If it has come from different monitoring methods)*

The indicator relies on existing monitoring programmes but further development will depend on funding and the accessibility of additional datasets. Also, the integration of plankton data from different sources and sampling strategies (fixed point data, scientific and fisheries cruises and platforms of opportunity) still need further investigation. Moreover, as for WFD, the discussion will be established on the relevance of including data from innovative approaches and techniques, as continuous recording data, allowing to consider the whole size range of plankton species, on a regular and high frequency monitoring basis.

- *Aggregation and integration of data acquired*

For the calculation of the indicator, data were integrated per sampling station where abundance data was pooled monthly. All years are used. The minimum of eight months of observations per year is required to consider the year as complete. .

Spatial aggregation was done at this time with non-station datasets per spatial assessment unit (the COMP4 assessment units).

3.3 Assessment criteria

- *Defining assessment unit/scale (Temporal and spatial)*

  Assessment will be done at the level of COMP4 assessment units. However, additional data is still needed to perform a robust regional scale analysis. A minimum of monthly data of plankton community composition should be used in order to best capture the possible variation in community composition on a seasonal and yearly basis. For detecting long-term trends, a minimum of 10 years of data should be used.

- *Baseline/reference condition/assessment value*
    - The present analysis treats the totality of the time series, and reports the evolution of the different alpha and beta diversity indices. The **Ecological Quality Ratio** (EQR) is used to simplify the results of three or four indices to one metric. Thus, the results are normalised and comparable in time and across the COMP4 assessment units. The direction of changes was done by comparing the trends of the EQR for a reference and an assessment period. The reference period is set to be the whole period before the assessment. The assessment period corresponds of the five or six last years of observations. The assessment value is evaluated as "absence of significant increasing or decreasing trend".
    - In accordance with our target, the absence of significant changes for the EQR and/or the lack of a significant correlation between the EQR and the human pressure can be used as evidence that the target for GES (for that criterion and the plankton community as a whole) has been met. However, this presupposes that the reference point of the time-series represented baseline (or reference) conditions and hence GES. This may not be the case. Where data exist, it will be necessary to use this to determine the current status of the plankton at those locations but at least 5 years of data (which set the length of the reference and the assessment periods identical) will have to be collected to characterise the status of the plankton. If, however, existing types of data sets can be used to characterise GES for plankton communities (using ecological theory, remote sensing, modelling, the absence of obvious human pressure and expert opinion), it may be possible to use such data as baseline conditions for new monitoring sites and existing sites at which the status of the plankton does not meet GES.

- *Proposed assessment value*
    - Plankton community at species/genus/taxa level.

3.4 Spatial Analysis and / or trend analysis

- *Statistical analysis (e.g. method for trend analysis, establishment of confidence limits)*

For fixed station data, seasonal and annual trends in community composition (diversity indices) were calculated. In terms of longer trend analysis, community variance across years was investigated for each dataset (Legendre and Gauthier, 2014). More specifically, the Local Contributions to Beta Diversity (LCBD) indices were calculated following the method described in detail by Legendre and De Cáceres (2013). This index could indicate an important change/shift or uniqueness in species composition of the local community. We report an integrated measure of alpha and beta diversity indices. An Ecological Quality Ratio (EQR) has been proposed in the French MSFD to simplify and harmonize the multimetric results to one metric. The Trends in this integrated metric reports the direction and the amplitude of changes in plankton diversity. More details on this method are available in the assessment "changes in plankton diversity" drafted for the QSR2023 and published on the OSPAR website.

- **Previous assessment**

During the previous assessment, PH3 indicator was at the stage of candidate indicator. It is now a common indicator. The previous assessment (OSPAR Intermediate Assessment; IA 2017) was based on the examination of the seasonal and annual variability of phytoplankton community composition only, at five sites. The different indices were compared in space and time and their amplitude of variation was used to identify years with significant changes. However, during the previous assessment a gap remained in statistical testing of both temporal and spatial variation of the indices, except for the LCBD within each site. To synthetise the information provided by the different indices, a single and averaged EQR is proposed. The present assessment keeps the methodology from the previous assessment with some improvements, as expressed above. Most of the improvements have already been used in the MSFD assessment for France (Duflos et al., 2018).

- **Spatial scales of the assessment**

Because plankton community composition, distribution, and dynamics are closely linked to their environment, the analysis was performed at the scale of the 'COMP4 assessment units' (COMP4 v8a; **Figure 1, Table b**). Assessment units within the Greater North Sea and Celtic Sea (OSPAR Regions II and III, respectively) were initially developed by Deltares and partner institutes as part of the EU Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data (JMP-EUNOSAT; Enserink et al., 2019) and further refined in the revision process of the eutrophication assessment by OSPAR expert groups ICG-EMO and TG-COMP. Assessment units with similar phytoplankton dynamics were derived from cluster analysis of satellite data for chlorophyll *a* and primary production. Boundaries between assessment units were derived by relating clustering results to the best-matching gradients in environmental variables obtained from the three-dimensional hydrodynamic Dutch Continental Shelf model version 6 (DCSMv6 FM). The variables which best matched the divisions highlighted by clustering were depth, salinity, and stratification regime. Additional geographic areas were added such as the Channel, Irish Sea and Kattegat. These assessment units are a geographical representation of the conditions which best suit plankton distribution, dynamics, and community composition.

Because the Bay of Biscay and Iberian Coast (OSPAR Region IV) extended beyond the boundaries of the DCSMv6 FM, assessment units within this region were developed using a different methodology, based on phytoplankton dynamics (Spain) and salinity dynamics (Portugal). To delineate assessment units for the Spanish coast, a polygon was created to extend from the coast to the exclusive economic zone (EEZ) boundary. Daily MODIS-Aqua Level-2 satellite images were used to calculate climatological mean values of chlorophyll *a* for each pixel. K-means clustering was then used to group pixels with similar dynamics, resulting in six distinct groupings within the main Spanish polygon. Portugal's three Water Framework Directive assessment units were extended to the boundaries of the Portuguese exclusive EEZ. These assessment units were further divided longitudinally to separate pelagic waters from coastal waters more subject to eutrophication from river influence by applying a salinity threshold, followed by a bathymetry threshold.

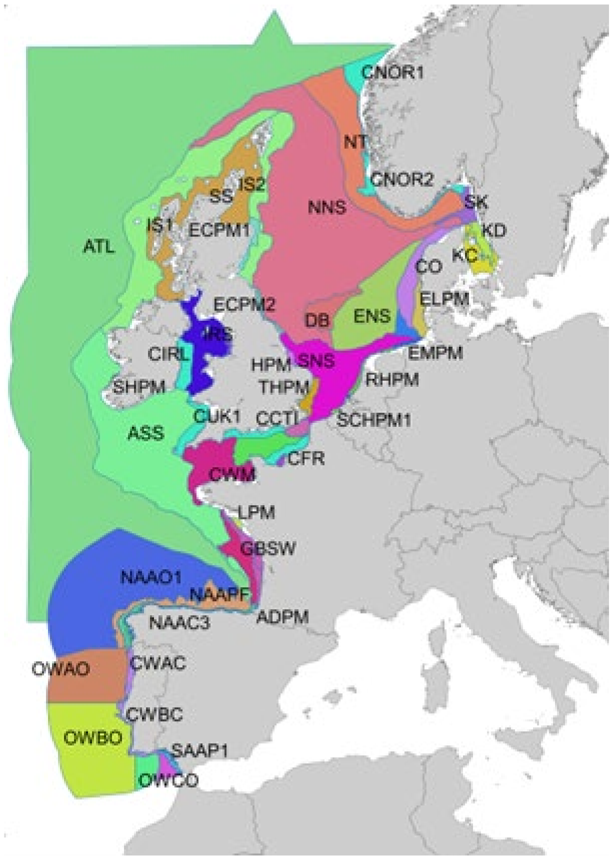

Figure 1: COMP4 assessment units developed by JMP-EUNOSAT and OSPAR.

- **Classification of the pelagic habitats**

Following the European Commission (2017) outlining criteria and methodological standards on good environmental status of marine waters, the COMP4 assessment units and the fixed-point stations are associated with a habitat type within their corresponding OSPAR region (**table b**). Habitat identifications were processed following strict criteria according to surface mean salinity and mean depth. Four habitats were identified: variable salinity (corresponding to river plumes and regions of freshwater influence (ROFI)), coastal habitat (nearshore areas adjacent to ROFIs with mean salinity < 34.5), shelf habitat (corresponding to offshore areas with mean depth less than 200 m and mean salinity > 34.5) and oceanic/beyond shelf habitats (corresponding to offshore areas with mean depth greater than 200 m).

Table b: classification of the COMP4 assessment units by habitat type within OSPAR regions.

Area code	Area name	Salinity (surface mean)	Depth (mean)	Habitat type	OSPAR region
ADPM	Adour plume	34.4	87	Variable salinity	IV
ELPM	Elbe plume	30.8	18		II
EMPM	Ems plume	31.4	19		II
GDPM	Gironde plume	33.5	34		IV
HPM	Humber plume	33.5	16		II
LBPM	Liverpool Bay plume	30.6	15		III
LPM	Loire plume	33.8	38		IV
MPM	Meuse plume	29.3	16		II
RHPM	Rhine plume	31.0	17		II
SCHPM1	Scheldt plume 1	31.4	13		II
SCHPM2	Scheldt plume 2	30.9	15		II
SHPM	Shannon plume	34.1	61		III
SPM	Seine plume	31.8	25		II
THPM	Thames plume	34.4	22		II
CFR	Coastal FR Channel	34.2	33	Coastal	II
CIRL	Coastal IRL 3	34.0	65		III
CNOR1	Coastal NOR 1	34.3	190		II
CNOR2	Coastal NOR 2	3.4.0	217		II
CNOR3	Coastal NOR 3	32.4	171		II
CUK1	Coastal UK 1	34.5	60		III
CUKC	Coastal UK Channel	34.8	37		II
CWAC	Coastal Waters AC	No information	No information		IV
CWBC	Coastal Waters BC	No information	No information		IV

CWCC	Coastal Waters CC	No information	No information	IV
ECPM1	East Coast (permanently mixed) 1	34.8	73	II
ECPM2	East Coast (permanently mixed) 2	34.5	43	II
GBC	German Bight Central	334	39	II
IRS	Irish Sea	33.7	65	III
KC	Kattegat Coastal	25.7	21	II
KD	Kattegat Deep	27.6	50	II
NAAC1A	NorAtlantic Area NOR-NorC1	No information	No information	IV
NAAC1B	NorAtlantic Area NOR-NorC1	No information	No information	IV
NAAC1C	NorAtlantic Area NOR-NorC1	No information	No information	IV
NAAC1D	NorAtlantic Area NOR-NorC1	No information	No information	IV
NAAC2	NorAtlantic Area NOR-NorC2	No information	No information	IV
NAAC3	NorAtlantic Area NOR-NorC3	No information	No information	IV
OC	Outer Coastal DEDK	33.4	27	II
SAAC1	SudAtlantic Area SUD-C1	No information	No information	IV
SAAC2	SudAtlantic Area SUD-C2	No information	No information	IV
SAAP2	SudAtlantic Area SUD-P2	No information	No information	IV

SNS	Southern North Sea	34.3	32		II
ASS	Atlantic Seasonally Stratified	35.2	134	Shelf	III, IV
CCTI	Channel Coastal shelf tidal influenced	34.8	40		II
CWM	Channel well mixed	35.1	77		II, III
CWMTI	Channel well mixed tidal influenced	35.0	59		II
DB	Dogger Bank	35.1	28		II
ENS	Eastern North Sea	34.8	43		II
GBCW	Gulf of Biscay coastal waters	34.6	53		IV
GBSW	Gulf of Biscay shelf waters	34.9	107		IV
IS1	Intermittently stratified 1	35.3	138		II, III
IS2	Intermittently stratified 2	35.1	102		II
NAAP2	NorAtlantic Area NOR-NorP2	No information	No information		IV
NAAPF	NorAtlantic Area NOR-Plataforma	No information	No information		IV
NNS	Northen North Sea	35.0	121		II
NT	Norwegian Trench	34.1	349		II
SAAP1	SudAtlantic Area SUD-P1	No information	No information		IV
SK	Skagerrak	31.8	134		II
SS	Scottish Sea	35.1	89		II, III
ATL	Atlantic	35.3	2291		II, IV, V

NAAO1	NorAtlantic Area NOR-NorO1	No information	No information	Oceanic / Beyond shelf	IV
OWAO	Ocean Waters AO	No information	No information		IV
OWBO	Ocean Waters BO	No information	No information		IV
OWCO	Ocean Waters CO	No information	No information		IV
SAAOC	Sudatlantic Area SUD-OCEAN	No information	No information		IV

3.5 Presentation of assessment results

- *Consideration of target audience and appropriate communication style*
- *Assessment metadata schema (link to ODIMS)*

The pilot assessment of the indicator is published on the OSPAR Assessment Portal

https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/habitats/pilot-assessment-changes-plankton/

4 Change Management

- *Responsibility for follow up of assessment (e.g. if the monitoring is not adequate)*
    - ICG-COBAM Pelagic expert group
    - BDC

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