OSPAR CEMP Guideline

Common indicator PH2 “Changes in Phytoplankton Biomass and Zooplankton Abundance”

Adopted by BDC(2) 2022

OSPAR Agreement 2019-06[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

Plankton biomass and/or abundance in the ocean are hydro-climatic variables and as such have been demonstrated to reflect environmental changes, as illustrated by already numerous phytoplankton and zooplankton published studies. Being at the base of the food-web and representing a food of importance for numerous species of higher trophic levels, such as fish of commercial interest, the fluctuation of plankton biomass and/or abundance can have significant impacts on the whole trophic food web but also on carbon cycles and nutrient recycling. The intrinsic characteristics of these organisms at the base of the food web, such as small size, short life cycles and distribution over the whole globe, render them particularly interesting in the frame of monitoring programmes and they have a high potential to reflect environmental changes at short and long-term scales in the marine systems.

In practice, the use of total biomass and/or abundance is often favoured over indicators using species, since indices of species-specific abundance are frequently subject to large inter-annual variation, often due to natural physical dynamics rather than anthropogenic stressors (de Jonge, 2007). Combining both phytoplankton biomass and zooplankton abundance can provide an indication of changes in the energy transfer from primary to secondary producers.

The indicator is still under development. Further investigations are needed to precise the assessment method, and to make the indicator flexible enough to include data from innovative approaches and techniques (see further).

Since different indices provide complementary information on the community structure, we propose a combination of diversity indices to assess GES for plankton communities. Moreover, each PH indicator considers the 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.

2 Monitoring

2.1 Purpose

PH2 is a state indicator which does not provide yet a direct link to pressures. It belongs to the category of “surveillance” indicators, such as defined by Bedford et al. (2018). They are early-warning indicators of physical hydro-climatic changes and can result in triggering management action when pre-defined bounds are passed. However, PH2 could be used in conjunction with pressure descriptors such as Eutrophication (MSFD D5), if links to human pressures can be found in further assessments of the ongoing development of the indicator.

2.2 Quantitative Objectives

Plankton sampling collects data, which can be used for pelagic diversity indicators and for food web indicators. One plankton sample can be used to inform PH1/FW5, PH2 and PH3. Data collected can also be used to inform MSFD D2, D3, D4 and D5. Therefore, one set of monitoring data can be used in multiple ways.

- Which parameter needs to be measured?
    - Phytoplankton biomass. It can be measured as biovolume, carbon content or assessed through chlorophyll-*a*, which is present in all phytoplankton organisms, as a proxy from fixed

monitoring stations and from non-station monitoring on scientific cruise Estimates of chlorophyll-*a* from satellite ocean colour algorithms provide a wide spatial cover and a synoptic view, at higher frequency than classical monitoring. A semi-quantitative measurement of phytoplankton biomass is also possible by using the so-called Phytoplankton Colour Index (PCI), a method applied on the Continuous Plankton Recorder (CPR) data. This assessment uses both chlorophyll-*a* data as they represent long-term time-series from discrete monitoring stations and satellite data as they provide regular and synoptic spatio-temporal coverage

- Zooplankton abundance. To date, only copepods (total copepod abundance) are considered in the calculation as a proxy for main zooplankton abundance. Abundance is monitored at discrete monitoring station and from non-station on 'ships-of-opportunity' (i.e. CPR data).

- For which criteria is PH2 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)
    - Also used to inform MSFD D2, D3, D4, D5.

2.3 Monitoring Strategy: design of specific monitoring strategy

Plankton abundance or biomass must be monitored. PH2 has been developed using existing datasets which are required for informing the indicator. Several protocols can be used. It's most cost effective to go with what we already have than to get all CPs to use the same methodology; this also enables establishment of baselines through use of historical data. Integration of existing time-series is key – the pelagic team has considered this practical approach throughout.

- The following data sources were used for the QSR2023 (**Table 1**):
    - o Data from the Continuous Plankton Recorder (CPR) survey (Marine Biological Association; MBA), a regional monitoring programme at European scale, including offshore areas. The CPR is funded by UK with limited funding from other contracting parties. For the PH2, only (total copepod abundance for the Greater North Sea (OSPAR region II) and the Celtic Seas (OSPAR Region III) for the period 1960–2019 were used.
    - o Remote sensing data of chlorophyll-*a* provided by the Royal Belgian Institute for the Natural Sciences for the Greater North Sea (OSPAR region II) and the Celtic Seas (OSPAR Region III) for the period 2009-2020 and by Plymouth Marine Laboratory for OSPAR the Greater North Sea (OSPAR Region II) and the Celtic Seas (OSPAR region III) for the period 1997-2016.
    - o Discrete station data for coastal areas with long-term datasets where provided by Denmark (Aarhus University), Germany (Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (LLUR) and Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten und Naturschutz (NLWKN)), Spain (Instituto Espanol de Oceanografia (IEO)), Sweden (Swedish Meteorological and Hydrological Institute (SMHI)) and UK (Centre for Environment, Fisheries and Aquaculture Science (Cefas), Environment Agency (EA), Marine Scotland Science (MSS) and Plymouth Marine Laboratory (PML)).

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

Contracting Party	Institute	Dataset name	Date range
Belgium	Royal Belgium Institute of Natural Sciences (RBINS)	CHL_RBINS	2009-2020
Denmark	Aarhus University	NOVANA chlorophyl data	2009-2020
Germany	Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (LLUR)	OSPAR_LLUR-SH Phytoplankton Biomass_2010-2020	2010-2020
	Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten und Naturschutz (NLWKN)	OSPAR_NLWKN_1999-	1999-2019
Spain	Instituto Espanol de Oceanografia (IEO)	IEO_RADIALES_Cla	1989-2020
		IEO_RADIALES_Zoo	1991-2018
Sweden	Swedish Meteorological and Hydrological Institute (SMHI)	National data_SMHI phytoplankton biomass	1986-2020
		National data_SMHI_ zoo	1996-2020
United Kingdom	Centre for Environment, Fisheries and Aquaculture Science (Cefas)	Cefas SmartBuoy Marine Observational Network - UK Waters Phytoplankton Data 2001-2019	2001-2019
	Environment Agency (EA)	EA CHL 2000-2020	2000-2020
	Marine Biological Association (MBA)	CPR dataset 1960-2019	1960-2019
		CPR PCI chlorophyll index	1960-2019
	Marine Scotland Science (MSS)	MSS Loch Ewe biomass	2002-2020
		MSS Loch Ewe zooplankton	2002-2017
		MSS Stonehaven biomass	1997-2020
		MSS Stonehaven zooplankton	1999-2020
	Plymouth Marine Laboratory (PML)	PML_L4 chl a	1992-2020
		PML_L4 zooplankton	1988-2020
		PML ICES satellite	1997-2016

2.4 Sampling Strategy - ensure adequate sampling or observation methodologies

- PH2 is assessed at a spatial assessment unit scale (the 'COMP4 eutrophication areas' from the EU Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data; JMP-EUNOSAT; Enserink et al., 2019) where possible (**Table 2**). Considering the natural temporal variability of phytoplankton biomass and zooplankton abundance and the relative short response time of the indicator, the frequency of samplings should be at least monthly or fortnightly[2]. Changes

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

in PH2 trends could be detected at least within 2 or 3 years, which should reasonably be set as the frequency of indicator updates.

Table 2: Minimum sampling strategy:

	Coastal	**Shelf**	**Open Sea**
[3]Frequency of data collection*	Monthly	Monthly	Monthly
Monitoring method	*In situ/Remote sensing*	*In situ/Remote sensing*	*In situ/Remote sensing*
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 spatial assessment units (Comp4 assessment units).	Monitoring must cover all spatial assessment units (Comp4 assessment units).	Monitoring must cover all spatial assessment units (Comp4 assessment units).
Current data availability	Single point stations exist mainly in coastal waters but there are gaps in some regions. Station data accessibility is not always guaranteed. Remote sensing data can be used if possible and if the data are suitable for coastal correction.	Remote sensing data should be used as it provides synoptic and regular sampling at regional scale. The CPR is a European scale plankton monitoring programme, focusing on the shelf and offshore regions. Regular fisheries and/or research cruises should also be used for plankton collection.	Remote sensing data should be used as it provides synoptic and regular sampling at regional scale. The CPR is a European scale plankton monitoring programme, focusing on the shelf and offshore regions. Regular fisheries and/or research cruises should also be used for plankton collection.

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

2.5 Quality assurance/ Quality Control

For zooplankton, the CPR has a QA/QC method which has remained virtually unchanged since 1948. MBA procedures are documented, plankton analysts have BEQUALM qualifications and MBA chairs the UK's National Marine Biological Analytical Quality Control Scheme which is working to develop first a standard and then a quality control scheme. The analysts of the Swedish samples do yearly inter-calibrations using either the service of IPI or HELCOM. Quality assurance (QA) for chlorophyll *a* is described extensively in the JAMP guidelines on Quality Assurance for biological monitoring in the OSPAR area[4] and CEMP appendices 6 and 7[5].

[3] Monthly frequencies would be optimal and may not be achievable for all Contracting Parties
[4] OSPAR Agreement 2002-15
[5] OSPAR Agreement 2016-01

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*
    - See "Quality assurance/ Quality Control"
- *Data flows described (Additional to information in CEMP Appendix)*
    - *Each dataset will eventually perform its own analysis once the methodology is finalised. The indicator lead will then aggregate this information.*
- *Data Storage*
    - *A vulnerability of the process is that there is no central storage area for data or documents.*
    - *A central temporary storage area, such as a server at OSPAR is required and could support the process for the following assessments.*

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)*
    - Each different dataset is used alone, no normalisation is done. Different depths in different datasets will have to be normalised if used together.
    - The indicator relies on existing monitoring programmes but further development will depend on funding and the accessibility of additional datasets. Also, the possibility for integration of plankton data from different sources and sampling strategies (fixed point data, scientific and fisheries cruises and platforms of opportunity) will need further investigation. Moreover, as for the WFD, the discussion will be established on the relevance of including data from innovative/automated approaches and techniques, as continuous recording (of total chlorophyll *in vivo* fluorescence and zooplankton).

- *Aggregation and integration of data acquired*
    - Phytoplankton biomass and zooplankton abundance are aggregated into means for each calendar month (e.g. January 1960, February 1960, etc). All years are used, regardless of how many monthly data are present.
    - Across the Greater North Sea (OSPAR Region II), the Celtic Seas (OSPAR Region III) and the Bay of Biscay and Iberian Coast (OSPAR Region IV), data were analysed at the scale of 'COMP4 assessment units' (Enserink et al., 2019).

3.3 Assessment criteria

- *Defining assessment unit/scale (Temporal and spatial)*
    - For the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian coasts, we report state according to COMP4 assessment units (Enserink et al., 2019).
- *Baseline/ reference condition/ assessment value*
    - The present time-series analysis treats the totality of the time series, and reports the direction of change by comparing the trends of 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 change for an indicator and/or the lack of a significant correlation between the indicator 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 Environmental target*
    - Plankton biomass/abundance is not subjected to changes. If changes are observed, they are not significantly influenced by anthropogenic pressures.

3.4 Spatial Analysis and / or trend analysis

This indicator is based on identification of phytoplankton biomass and zooplankton abundance anomalies within plankton time-series. Anomalies represent deviations from the assumed natural variability of a time-series. Thus, the greater the magnitude of the anomaly (in terms of absolute value, since anomalies can be positive or negative), the greater the change. An anomaly value of zero indicates no difference from the time-series mean (which must be de-seasonalised). Anomalies were calculated for both phytoplankton and zooplankton datasets. To understand the changes presented (i.e. annual anomalies) and to be most useful for decision makers, the annual anomalies must be considered using details given by the monthly anomalies (since an early warning indicator should be assessed at the best temporal resolution possible). An R script for the plankton time series was first developed by Ibanez (reported in Berline et al., 2009), and then adapted for this assessment.

- **Previous assessment:**

The previous assessment (OSPAR Intermediate Assessment; IA 2017) was based on the establishment and the categorisation of monthly anomalies of plankton biomass. Anomalies are categorised to improve the presentation of results from a graphical perspective and to simplify the results for use in management. The categorisation is based on percentiles; the 2.5, 25, 50, 75 and 97.5th percentiles have been used to categorise the anomalies within each time-series. Three categories are used: *small change* (anomalies within the 25–

75th percentile range), *important change* (anomalies within the 2.5–25th percentile range and 75–97.5th percentile range) and *extreme change* (anomalies within the 0–2.5th percentile range and 97.5–100th percentile range). Anomalies within the *small change* category represent the scenario least likely to represent significant shifts at the plankton community level, and thus least likely to impact the marine ecosystem. Anomalies within the *important change* and *extreme change* categories have increasing potential to represent significant modifications to the plankton community and the marine ecosystem. The present assessment is based on the previous assessment methodology with some improvements since IA2017. Most of these improvements have already been applied in the French MSFD assessment (Duflos et al., 2018).

- **Current analysis on biomass/abundance anomalies**

When the data are in the format of monthly mean values, they can be fitted to the COMP4 assessment units (see the subsection **Spatial scales of the assessment**). Following these steps, the time-series analysis can be run. Both phytoplankton and zooplankton time-series analyses are run using the same R script for both discrete-station data and non-station data, after the pre-analysis steps have been followed. The first step consists of removing seasonality from the time series by calculating the mean value within a 12-month moving window. This step produced monthly anomalies of the time-series. Improvements to the methodology since IA2017 now allow us to define distinct reference and assessment periods. A Spearman rank correlation test is now implemented to test the anomalies of the assessment period against in the anomalies of the reference period. For the QSR2023, the reference period included all data prior to 2015 and the assessment period was set from 2015 to 2019, due to post-2019 data not yet being available across all plankton datasets. The results provide an indication of change, moving toward a significant ($p \leq 0.05$) increase in phytoplankton biomass/copepods abundance (0 to 1), no change (=0) or decrease in phytoplankton biomass/copepods abundance (-1 to 0).

- **Spatial scales**

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.

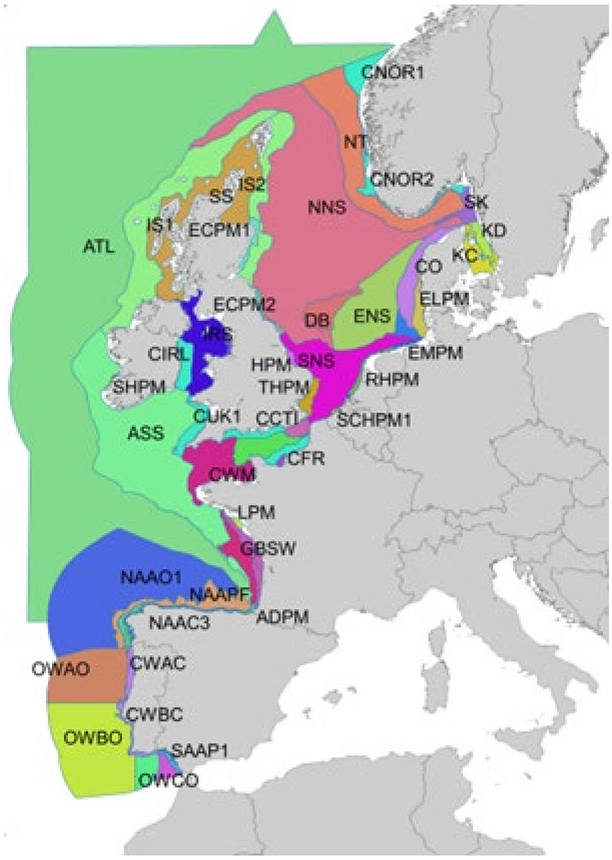

Figure 1: COMP4 assessment units developed by JMP-EUNOSAT and OSPAR.

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 3**). 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 3: 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	Oceanic / Beyond shelf	II, IV, V
NAAO1	NorAtlantic Area NOR-NorO1	No information	No information		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 common indicator assessment is published on the OSPAR Assessment Portal

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

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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