JERICO-S3 DELIVERABLE

Joint European Research Infrastructure for Coastal Observatories

Science, Services, Sustainability

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1. EXECUTIVE SUMMARY

This Deliverable D2.5 aims at helping the future JERICO-RI liaise with potential users within the policy realm of their (innovative) data sets.

Regular monitoring activities are to a large extent carried out by, or on behalf of, governance bodies, often national governments. Many of these monitoring activities are carried out to fulfil the requirements of EU legislation (*e.g.* Marine Strategy Framework Directive (MSFD) and Habitat and Birds Directives) and other legal requirements. Creating substantiated links with these establishments and bodies and exploring how these policy-driven needs can be supported by the JERICO-RI is of high importance for creating a sustainable network.

This subtask investigated the policy data needs from the Regional Sea Conventions (RSCs) as identified in their recent holistic assessments of the state of the marine environment that are an essential part of MSFD implementation. It also investigated the products and services developed in WPs 3, 4 (Pilot Supersites) & 6 (JERICO-S3 map-catalogue). The map-catalogue was searched for data sets that are delivered by more than one JERICO-S3 partner institute and in all three sea regions: North-East Atlantic, Baltic Sea and Mediterranean Sea (JERICO-S3 data supply). Potential matches between demand and supply have been identified and recommendations to strengthen the connection between JERICO-RI and its potential clients are given.

2. INTRODUCTION

National governments, working together in Regional Sea Conventions (RSCs) and other EU/international cooperation, are responsible for monitoring and assessing the coastal and marine environment. For the purpose of assessing the environmental status of Europe's marine waters in a coherent way, EU member states also follow the reporting obligations under the European Marine Strategy Framework Directive (MSFD).

The objective of the JERICO-RI project has been to improve and further develop the existing coastal and marine monitoring structure in the EU, by a number of actions. Among these are the development of (pilot-)Super Sites, Integrated Monitoring Sites, enabling Trans National Access to monitoring equipment, promoting Virtual Access to data, and the creation of a JERICO-RI catalogue. These activities of the integrated RI cover a wide range of themes, like impact of human activities, *e.g.* chemical pollution, noise and litter effects, fisheries, and eutrophication effects.

The existing European marine data Infrastructures that have been developed and enhanced in the past decades are the European Global Ocean Observing System (EuroGOOS), the Copernicus Marine Environmental Monitoring Service (CMEMS), the European Marine Observation and Data network (EMODnet) and the Pan-European Infrastructure for Ocean & Marine Data Management (SeaDataNet). Since their establishment, the EuroGOOS and the SeaDataNet network of National Oceanographic Data Centers have widely contributed to International Oceanographic Data Exchange and more in general to the Global Ocean Observing System (GOOS) policies in sharing ocean data and co-production of oceanographic services. Moreover, they have widely contributed to design and set up the operational data infrastructures of the CMEMS and EMODnet data systems, which, mimicking the international organisation and management of the observations network, are often organised by observing platform (*i.e.* Argo floats, gliders, research vessels, ferry boxes on ships of opportunity, fixed point observatories etc.).

Capitalising on national and European projects and programmes, in situ data FAIRness (Findable, Accessible, Interoperable and RE-Usable) has significantly improved in some domains. This includes better harmonisation, interoperability, and integration of data and metadata services at regional or observing networks level. However, many gaps and barriers still exist and must be addressed.

In this subtask an analysis has been made of needs and expectations from the policy realm, versus the JERICO-RI products and services. The policy realm is represented by the European Regional Sea Conventions OSPAR, HELCOM and BARCOM-UNEP/MAP (addressed as UNEP/MAP in this deliverable), since these deliver assessments of environmental status and overlap with the sea areas considered in JERICO-S3. Annex 1 presents the Regional Sea Convention's areas and relevant subdivisions. The results of this analysis can serve to inform government bodies, and existing international groups (e.g. the RSCs, but also the groups collaborating under the EU MSFD Common Implementation Strategy) that are responsible for monitoring and data gathering, on how the integrated RI provided by the JERICO project brings added value. Moreover, data providers, *i.e.* the JERICO community, can build on these results to approach potential new users and inform them on datasets that help solving data needs.

In addition, aligning efforts (operational observing & monitoring), will maximise the use of the limited available resources, which in a challenging environment such as the marine, makes absolutely sense. It will also favour joint actions on the design and implementation of operations minimising gaps, harmonisation activities on data gathering, processing and distribution, the establishment and adoption of best practices, the training of the new generation etc.

The analyses in this Deliverable were based on the most recent holistic assessments of the status of the marine environment, delivered by the Regional Sea Conventions (RSCs):

- OSPAR (North-East Atlantic): Quality Status Report 2023;

- HELCOM (Baltic Sea): third HELCOM holistic assessment of the Baltic Sea 2016-2021 (HOLAS 3);
- UNEP/MAP (Mediterranean Sea): 2023 Mediterranean Quality Status Report.

The OSPAR, HELCOM and UNEP/MAP assessments are completed in 2023. The OSPAR QSR 2023 and HELCOM HOLAS3 cover all MSFD descriptors, presented in indicator assessments and thematic reports. In addition, they include assessments of ocean acidification.

On the MED QSR 2023 web page the key messages resulting from three thematic reports are presented.

These three thematic reports are:

- Pollution and marine litter, including the Quality status assessment of the Mediterranean regarding Common Indicators of Ecological Objective (EO) 5 eutrophication;
- Biodiversity and Fisheries, including EO 1 – biodiversity assessment regarding CI1 (Habitat distributional range) CI2 (Condition of the habitat's typical species and communities), CIs 3, 4, 5 (Bird species, Monk Seal, Marine Turtles, Cetaceans), but no assessment of pelagic habitats;
- Coast and hydrography, focusing on EO 7 - alteration of hydrographic conditions, CI15: Location and extent of the habitats impacted directly by hydrographic alterations, and EO8 - (terrestrial) coastal ecosystems and landscapes, CI16: Length of coastline subject to physical disturbance due to the influence of human-made structures; and Candidate common indicator 25 (CCI 25): Land cover change.

The MED QSR 2023 does not include an assessment of ocean acidification, since this is not part of the MSFD descriptors, as well as the 11 EOs defined in the Ecosystem Approach (EcAp) Roadmap 2008-2021 do not address climate change impacts/vulnerability. However, UNEP/MAP considers developing an Ecological Objective on climate change and ocean acidification vulnerability and resilience. This work would be part of the update of the EcAp Roadmap.

The RSC's assessments are intended to serve as a basis for regional coordination by EU member states for mandatory reporting under the Marine Strategy Framework Directive (MSFD) Article 8 (The European Parliament and the Council of the European Union, 2008), following a six-year cycle. The assessments delivered in 2023 will be used for the MSFD 2024 reporting. The next MSFD Article 8 reporting is scheduled for 2030.

In order to improve the assessments in the future reporting cycles, the assessments generally contain so-called knowledge gaps sections, where various types of knowledge gaps are highlighted, including lack of data coverage. It is in the interest of the expert groups working under the RSCs to actively search for ways to close these knowledge gaps. OSPAR and HELCOM have listed the knowledge gaps in the previous assessments (2018 MSFD reporting cycle) in their Science Agendas. Unfortunately, the HELCOM 2021 science agenda does not contain data coverage related knowledge gaps, while the OSPAR 2018 science agenda does. HELCOM and OSPAR are currently updating their science agendas using the knowledge gaps identified in the 2023 assessments. The science agenda for the Mediterranean Sea will likely be developed under the Renewed Ecosystem Approach Policy that will also include IMAP upgrade and enhancement. At the EU level initial steps are taken to develop a MSFD research agenda, which will build on the RSC science agendas. Since we prefer to base the identification of RSC data needs on the most recent information, only the assessments under the HOLAS3 report and the OSPAR and MED QSRs 2023 have been used.

On the basis of the information described above and the relevant JERICO-S3 deliverables an initial selection of potential matches has been made. A potential match indicates JERICO-S3 datasets that can help to solve data coverage needs identified by the Regional Sea Conventions.

3. MAIN REPORT

3.1. Aim and rationale

The aim of this exercise is to help the future JERICO-RI liaise with potential users within the policy realm of their (innovative) data sets.

The rationale is that:

1. **Data providers** need reliable users that are willing to use and potentially pay for the cost of data gathering;
2. **Data users** are only interested in the uptake of new data sets if the parameters measured:
   a. Fit with the data requirements of (mandatory) assessments of the state of the marine environment under EU law or Agreements in Regional Sea Conventions;
   b. Are identified as poorly monitored, *i.e*. data coverage knowledge gaps, and that closing these data gaps is considered important (*need to know*).

Furthermore, it is acknowledged that user friendliness and actual use of data repositories for the policy realm benefit from interaction with users, as has been shown by e.g. the ICES data centre, that holds monitoring data for OSPAR and HELCOM contracting parties and delivers tailor-made assessments and full transparency regarding the methods and data used. UNEP/MAP uses the IMAP Info System, operated by the Information and Communication Regional Activity Centre (INFO/RAC). The IMAP Info System will be improved to better ensure validation of data reported by contracting parties and boost its efficiency and accessibility. The present deliverable aims at facilitating interaction between providers and users of data.

The importance of coherence and comparability of data sets across European sea regions, being one of the drivers for MSFD implementation, is illustrated by the development and potential future deployment of JERICO's coastal Generic Instrument Module (cEGIM). This is further described in section 3.6.

3.2. Scope

Finding concrete potential matches between user's data needs and providers' data supply is a large and complex task, given the wide range of topics addressed in marine policies and the number of data infrastructures. Within the available capacity for Task 2.5.1 a pragmatic solution is to limit the search to parameters currently included in the map-catalogue as delivered under WP6.2 and stations/line data positioned in the OSPAR, HELCOM and UNEP/MAP sea regions (taken as the policy realm). Sources for data user needs are described in chapter 2: published (and in prep) assessments of the status of the marine environment. This enables identification of **potential matches.** Deliverable 2.5 should be regarded as a starting point and guidance for data providers to identify potential users. Further investigation of actual matches needs direct communication between data providers and data users (expert level), which is beyond the scope of this deliverable.

3.3. Method

Within the scope and available capacity of Task 2.5.1 a pragmatic stepwise process has been followed to identify potential matches:

1. Step 1: Data supply:
   a. Identification of all parameters (except tidal and non-EU data) in the JERICO-RI map-catalogue database, provided by Ifremer. This step also includes:
   b. identification of sea region (OSPAR, HELCOM or UNEP/MAP) for each entry in the database;

   c. Identification of map-catalogue parameters provided by multiple countries and in more than one sea region;
2. Step 2: Data demand:
   a. Listing of RSC indicator assessments for which the respective map-catalogue parameters might be of use, and successively:
   b. for these parameters identification of 'need to know' data gaps, identified in the RSC's indicator assessments. These data gaps are specified to the extent possible, on the basis of available information, including monitoring guidances.
   c. further investigate, using the information in the map-catalogue and provided in the JERICO PSS, whether the required metadata match the specification of the data gaps.
3. Step 3: Identify potential matches between data supply (step 1) and data demand (step 2): what (parameter) and where (Regional Sea area).

3.4. Step 1: Data supply

In this task, the following products have been addressed:

- Pilot Supersites (WP4)
- JERICO-RI inventory of platform, dataset and data products (called the map-catalogue) (WP6.2)

Pilot Supersites (WP4)

A JERICO S3 PSS is described as follows:

The JERICO Supersite is a regional (or sub-regional) coastal marine observatory. As marine observatories are considered infrastructures dedicated to multiple *in situ* observations (from air–sea interface to seafloor interface) at appropriate spatiotemporal resolution, in a restricted geographical region, maintained over long timescales, and designed to address interdisciplinary objectives, driven by science and society needs.

JERICO Supersites have the following key features:

- High spatial density of multiple observing platforms offering the required spatiotemporal resolution to study phenomena at nested spatiotemporal scales up to mesoscale;
- Multi-interface coverage (land-sea, air-sea, offshore-coastal, pelagic-seafloor) via well-established links to other RIs and addressing, in collaboration with other RIs, themes (common being defined by the RI) at global and regional levels as well as to specific local requirements;
- Multidisciplinary and interdisciplinary activities with scientific excellence;
- Multivariable and adequate spatiotemporal coverage (i.e. required resolution) of Essential Ocean Variables (EOV). Multivariable coverage of essential biodiversity variables (EBVs);
- Transnational and trans-institutional character, if necessary, to obtain full spatial and variable coverage;
- Generic platforms with capacity to adopt new technology (plug and play instrumentation & sensor web enablement), and acting as contact point to marine industries;
- Capacity to adopt new technologies and approaches;
- Centralised steering of observations;
- Part of an established (or under a roadmap) National RI.

In addition, JERICO Supersites have the following characteristics supported by the JERICO-RI:

- Well-established research themes based upon local, national, regional and global requirements driven by science and society (following the Framework for Ocean Observing);
- Shared, synoptic, interoperable, and openly available biological, biogeochemical, and physical data;

- Operational delivery of data to International (EU) portals;
- Coordinated and interoperable data management streams to international portals;
- Well established dissemination strategy, including joint dissemination products with other Supersites;
- Interoperability (including sharing) of platforms, equipment, knowledge, products, tools and services;
- Common design and implementation of missions with other Supersites and other JERICO observation systems and sites;
- Fully documented harmonized procedures and best practices;
- Well established links to users, especially in science, society, industry and policy;
- Products provision jointly with:
  - related Services (e.g. CMEMS) and Regional initiatives;
  - National and EU RIs related to interfaces of land-sea, air-sea, offshore-coastal, pelagic-seafloor;
  - Remote sensing and operational modelling communities;
  - other Supersites and other JERICO observation systems and sites.

Inventory of platform, dataset and data products (map-catalogue)

JERICO-S3 brings together institutions involved in coastal observation from all over Europe, preparing for a later JERICO-RI. The partners span a large geographical area and manage a number of coastal platforms related to coastal observation and have dedicated some of these to the JERICO-S3 project. To improve the overview of involved platforms a catalogue was required to describe each platform with their associated metadata (who monitors, what, how, why, where).

To enable partners to describe their country's coastal monitoring potential, in the JERICO S3-project a second, simpler catalogue with a map interface has been set up to visualise the monitoring potential. The information to create this catalogue and map to create a platform overview was collected in WP6. The catalogue has been created in Sextant (Ifremer) and is available at the Ifremer site.

The map-catalogue has also been published on the JERICO website, and can be used in JERICO-S3 as well as in JERICO-DS work, which will support publicity for it. No other specific dissemination and communication efforts were planned. As the availability of two separate catalogues was considered confusing, there have been plans to merge the two, but that could not be done in the current WP6. To further develop this map, JERICO partners would need to agree on contents of the catalogue. At this moment partners approach this differently, some partners have included (almost) their complete monitoring network, others have only included test/innovation platforms developed in the JERICO-projects. The analysis presented in this deliverable is based on the current (limited) map-catalogue and may help to develop an improved catalogue, based on a better insight of required metadata.

When opening the map interface, the user will see all stations available in the European regions:

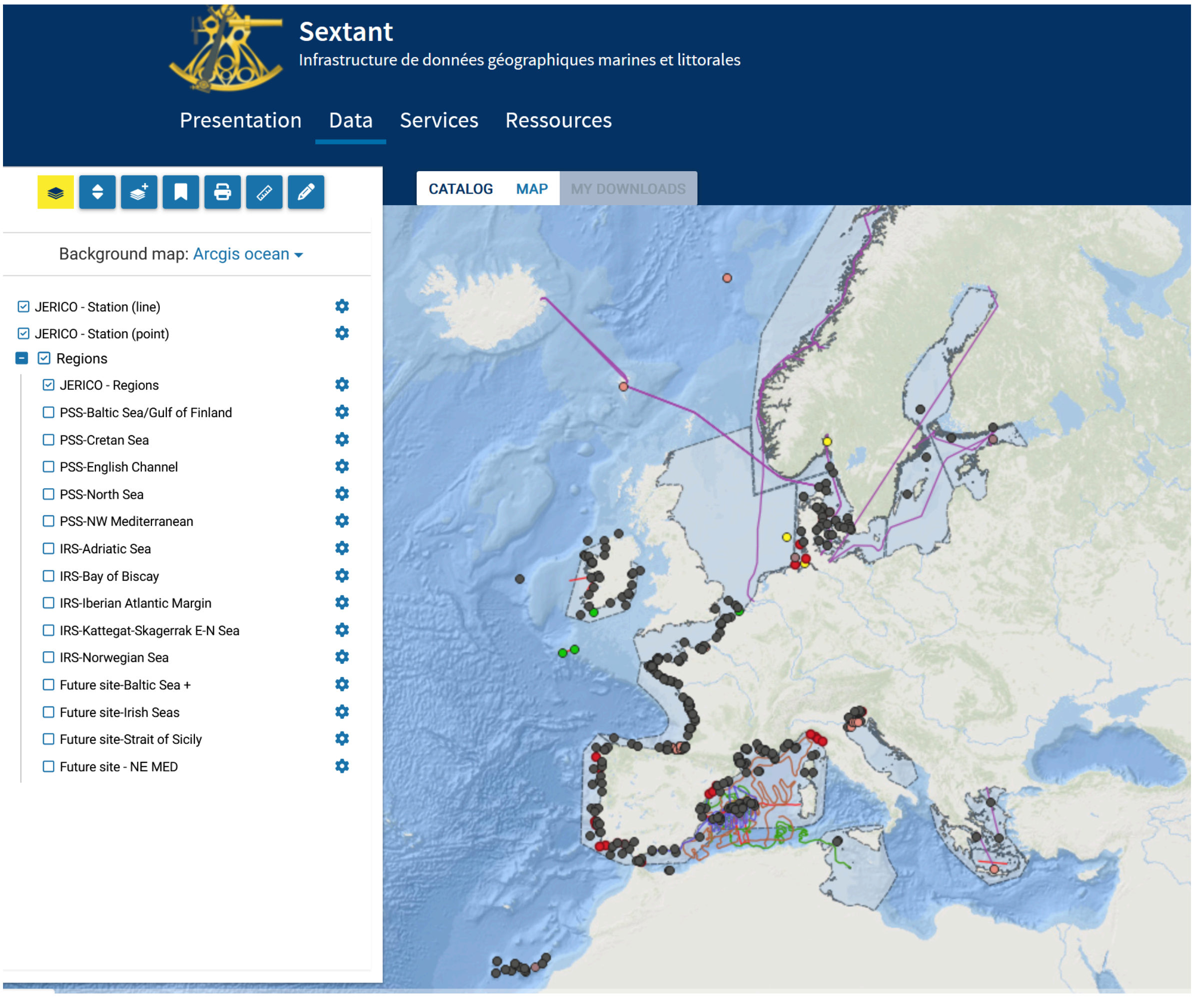


Figure 1. Screenshot of JERICO map-catalogue station overview.

After zooming in, a specific station can be selected and additional data about the station are shown:

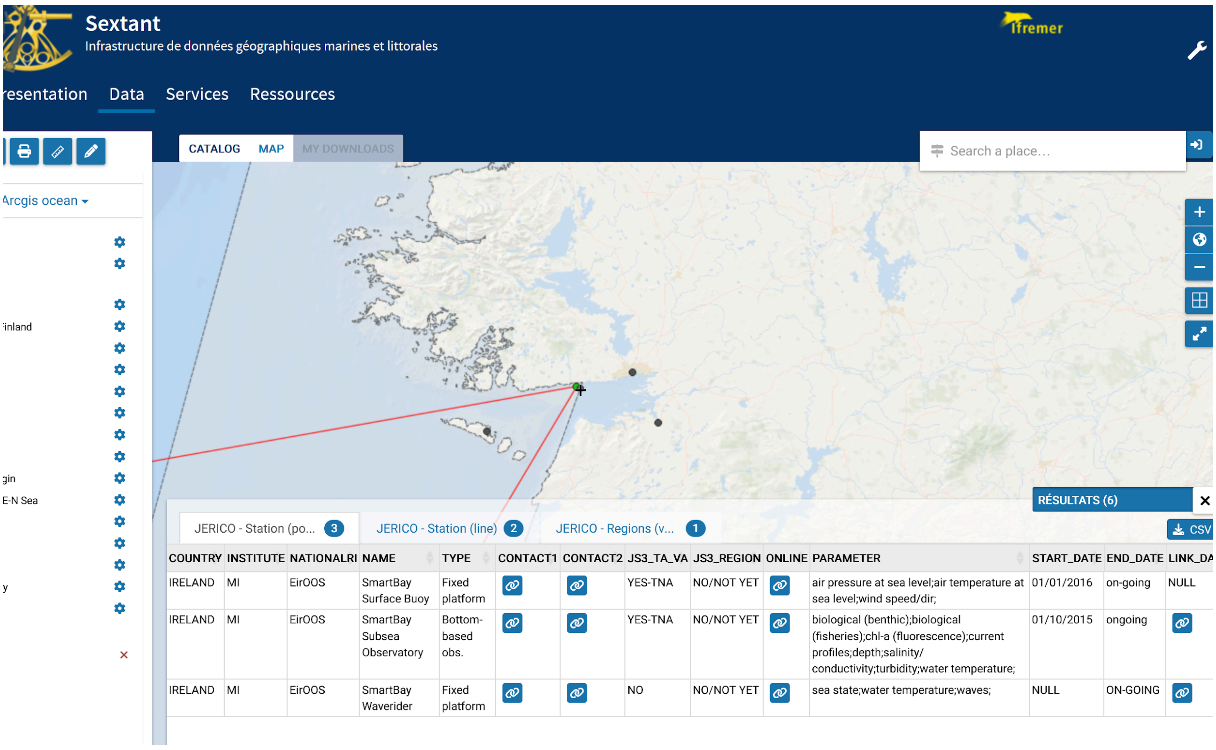


Figure 2. Screenshot of JERICO map-catalogue station information.

The parameters observed are roughly described, but specific metadata that further specify the monitoring are not available in the map-catalogue (e.g. depth of measurement, frequency of observations). The data stored in the map-catalogue are available for download, in WP 2.5.1 these were organised in an excel-sheet for further analysis. In the larger aggregated database, much more information can be found, but not sorted in one database in one specified format.

In WP6 no specific use was planned for the map-catalogue, but in WP 2.5.1 an analysis was made of how such a map could be used by the policy domain.

Results

The results of the inventory of potentially useful parameters for further investigation against data needs is a restricted list of parameters that are measured in more than one sea region and by more than one country. This enhances the chances of being of interest for RSC assessments, which are typically performed in cross-border subregions or assessment areas. The selected parameters are listed in Table 1.

Table 1. JERICO-RI map-catalogue parameters measured by more than one country in the three sea regions.

	Theme eutrophication and pelagic habitats						Theme ocean acidification			
Sea region	**Chloro-phyll a**[1]		**Phyto-plankton**[2]		**Dissolved O2**[3]		**pH**		**pCO_2**[4]	
	stations in (country)		**stations in (country)**		**stations in (country)**		**stations in (country)**		**stations in (country)**	
	point	**line**	**point**	**line**	**point**	**line**	**point**	**line**	**point**	**line**
OSPAR	ES, UK, Faroe Islands (DK), DE, IE, NO, Canary Islands (ES), FR, PT	NO, IE, NL, SE	ES, Faroe Islands (DK), DE, FR, UK	-	ES, UK, DE, NO, BE, FR, PT	NO, IE, NL, SE	ES, DE, NO, Canary Islands (ES), BE, FR	NO	-	NO
UNEP/MAP	IT, GR, ES, FR, HR	GR, ES	IT, GR, FR, HR	-	IT, FR, HR, GR, ES	GR, ES	IT, GR, ES	-	IT, GR	GR
HELCOM	FI, SE, EE	FI, EE	FI	-	SE, FI, EE	FI, EE	FI	-	FI	-

The master spreadsheet that contains all information is embedded here:
DL2.5.1_Catalogue_List of available parameters vs needs_v20240306_LE.xlsx .

3.5. Step 2 and 3: Data demand and potential matches

For the parameters identified in Step 1 (Table 1: chlorophyll *a*, phytoplankton, dissolved oxygen, pH and pCO_2) a literature study was performed using the latest indicator assessments in the Quality Status Reports (QSR) 2023 of OSPAR and UNEP/MAP and the HELCOM HOLAS3 (*cf.* chapter 2).

The RSCs are supportive of technological innovations in ocean observation. As an example, UNEP-MAP states that in order to close the knowledge gaps identified in the 2023 MED QSR the Contracting Parties (CPs) should focus on *inter alia* application of observing and remote techniques to strengthen the IMAP-based monitoring practices and improve forecasts of the state of the marine environment (MED-QSR 2023).

HELCOM states that monitoring and assessment of eutrophication is still largely dependent on *in-situ* observations from research vessels, although satellite data and ferry box data are increasingly used. *In-situ* sampling is expensive, which results in assessments often having a poor temporal and spatial confidence. New technologies, such as gliders instrumented with oxygen, light, sulphide and chlorophyll/turbidity/phycocyanin sensors, together with miniature autoanalyzers (so-called "lab-on-a-chip" systems) would permit a massive improvement in data availability with a corresponding decrease in cost-per-sample. This would improve both spatial and temporal assessment confidence in the physical chemical data. These systems could permit the proper resolution of coastal – offshore gradients, which could explain the –seemingly illogical – result that offshore waters in some basins are more eutrophic than their coastal water bodies. In addition, eutrophication assessments need to become increasingly supplemented by modelling efforts, for instance to determine the area and spatial extent of oxygen deficiency (HELCOM, 2023f).

[1] Listed as 'chl-a' or 'chl-a (fluorescence)'
[2] Listed as 'phytoplankton' or 'phytoplankton diversity (microscopy)'
[3] Listed as 'dissolved O_2' or 'oxygen'
[4] Listed as 'partial pressure of CO_2' or 'water pCO_2'

RSCs apply monitoring manuals, including metadata associated with indicators/parameters and QA/QC procedures:

- OSPAR: OSPAR Coordinated Environmental Monitoring Programme (CEMP)
- UNEP/MAP: Integrated Monitoring and Assessment Programme of the Mediterranean Sea and coast and related Assessment Criteria (IMAP)
- HELCOM: Manual for marine monitoring in the COMBINE programme

Under these general manuals, more specific guidelines are available that can inform data providers on the precise data needs and QA/QC systems for a (set of) monitored parameters. Relevant manuals (including links/references) are identified in the description of data needs below.

3.5.1 Theme eutrophication and biodiversity - pelagic habitats

Overview of indicators, assessment areas, monitoring guidelines and databases

MSFD descriptor D5 - Eutrophication is assessed by the three Regional Sea Conventions. Several indicators are used, of which chlorophyll *a* concentration, oxygen concentration and phytoplankton composition are addressed in this deliverable. Phytoplankton composition is also included in the MSFD descriptors D1 - Biodiversity and D4 - Food webs. Each Regional Sea Convention composes its own combination of indicators for these assessments.

A note on confidence: where possible, OSPAR and HELCOM provide confidence scores for the indicator assessments. The methods used are fairly similar, and described in the assessment manuals (see below). A general description is given in HELCOM 2023e:
Confidence is assessed based on expert evaluation of the information that underlies the confidence scoring. Specifically, this requires a categorical scoring of four different criteria: accuracy of estimate (where, if present, standard error or statistical outputs are used), temporal coverage, spatial representability of data, and methodological confidence. Confidence can be scored as high, intermediate or low for these criteria. Temporal coverage is scored based on monitoring data cover during the assessment period (year range for assessment and variation such as temporal frequency). For spatial representability, spatial cover (e.g. patchiness) is evaluated. For methodological confidence, scoring of conducted monitoring and data quality are scored. The result for confidence in this [phytoplankton pre-core] indicator evaluation reflects all of these criteria.

In the present analysis we focus on low temporal and spatial confidence.

OSPAR

For the most recent Eutrophication assessment OSPAR developed a new approach, ensuring coherence in assessment outcomes between countries as a joint basis for measures to combat eutrophication (The Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area, OSPAR, 2022). The following common indicators, for which chlorophyll *a* and oxygen concentration data are used, have been applied to the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast:

- Concentrations of Chlorophyll *a* (MSFD criterion D5C2)
- Concentrations of Dissolved Oxygen Near the Seafloor (MSFD criterion D5C5).

Some countries also apply the additional parameters total N, total P and Secchi depth.

These indicators, together with winter concentrations of dissolved nitrogen and phosphorus (DIN and DIP), are assessed for each assessment area within these Regions. In the Common Procedure ecologically relevant assessment areas and harmonised assessment thresholds were developed, enabling a regionally coherent assessment outcome. The assessment areas, called COMP4 areas, have been defined by oceanographic criteria rather than international boundaries (*cf.* Annex 1, Figure A2). The same assessment areas have also been applied in the Biodiversity pelagic habitats assessments:

- Changes in Phytoplankton Biomass and Zooplankton Abundance (MSFD criterion D1C6)
- Changes in Plankton Diversity (MSFD criterion D1C6)
- Changes in Phytoplankton and Zooplankton Communities (MSFD criterion D1C6).

The first of these assessments uses chlorophyll *a* as a proxy for phytoplankton biomass. The remaining two assessments use *inter alia* data on phytoplankton abundance and species composition.

Monitoring guidelines are available for these indicators (Table 2).

Table 2. OSPAR monitoring guidelines for the eutrophication indicators chlorophyll a and dissolved oxygen and pelagic habitats indicators using phytoplankton data.

OSPAR indicator	**Guideline**
Concentrations of Chlorophyll-a	JAMP Eutrophication Monitoring Guidelines: Chlorophyll a in Water (Agreement 2012-11) (Replaces Agreement 1997-04)
Concentrations of Dissolved Oxygen Near the Seafloor	Revised JAMP Eutrophication Monitoring Guideline: Oxygen (Agreement 2013-05) (Replaces Agreement 1997-03)
Changes in Phytoplankton Biomass and Zooplankton Abundance	OSPAR CEMP Guideline Common indicator PH2 "Changes in Phytoplankton Biomass and Zooplankton Abundance"
Changes in Plankton Diversity	OSPAR CEMP Guideline Common indicator PH3 "Changes in Plankton Diversity"
Changes in Phytoplankton and Zooplankton Communities	OSPAR CEMP Guideline Common indicator: PH1/FW5 Change in plankton communities

OSPAR contracting parties submit their data for the eutrophication assessments to the ICES data centre using a data reporting format. These data are then quality controlled and added to the COMPEAT tool, that shows the outcome of the indicator assessments, and informs about the underlying data and monitoring stations. This tool was inspired by HELCOM's HEAT and developed by the ICES data centre together with OSPAR's eutrophication group (ICG-Eut), based on collaborative expert knowledge.

HELCOM

For HOLAS3 the eutrophication assessment procedure has been further improved compared to the previous assessment (HOLAS II). These include refining assessment areas by subdividing regions with considerable spatial gradients (for example the Gulf of Finland), adjusting and agreeing previously missing threshold values, developing indicators, and including additional data types. A new generation of the HEAT tool (HEAT HOLAS 3) has been developed to address many of the needs identified after the HOLAS II assessment. Also, the confidence rating has been improved (HELCOM, 2023f).

For the indicator-based assessment of eutrophication regularly monitored data are provided by the contracting parties. These are responsible for producing the assessment, with ICES acting in the role of data host. All parties follow the instructions in the Eutrophication Assessment Manual (HELCOM, 2015).

HELCOM uses chlorophyll *a*, oxygen concentration and phytoplankton data for the following indicators under the Baltic Sea Action Plan (BSAP) segment Eutrophication:

- Chlorophyll (MSFD criterion D5C2)
- Cyanobacterial bloom (MSFD criterion D5C3)
- Oxygen debt (MSFD criterion D5C5)
- Shallow-water oxygen (MSFD criterion D5C5).

HELCOM uses phytoplankton data for one pre-core indicator assessment under the BSAP segment Biodiversity:

- Phytoplankton (MSFD criterion D4C1).

The Baltic Sea is divided in 17 open sea sub basins and 40 coastal areas (*cf.* Annex 1, Figure A3 and Table A2). This division is used in both eutrophication (D5) and food web (D4) indicator assessments.

Monitoring guidelines are available for these indicators (Table 3).

Table 3. HELCOM COMBINE monitoring guidelines for the eutrophication indicators chlorophyll a, cyanobacterial blooms and dissolved oxygen and the food webs indicator phytoplankton.

HELCOM indicator	**Guideline**
Concentrations of Chlorophyll-a	Guidelines for monitoring of chlorophyll a
Cyanobacterial bloom	Annex C-12 Guidelines concerning bacterioplankton abundance determination
Oxygen debt and Shallow-water oxygen	Guidelines for sampling and determination of dissolved oxygen in seawater Appendix 2 Technical note on the determination of dissolved oxygen in seawater
Phytoplankton	Guidelines for monitoring of phytoplankton species composition, abundance and biomass (2021)

HELCOM contracting parties submit their data for the eutrophication assessments to the ICES data centre using a data reporting format. These data are then quality controlled and added to the HEAT tool, that shows the outcome of the indicator assessments, and informs about the underlying data and monitoring stations.

UNEP-MAP

IMAP Ecological Objective 5 on Eutrophication is defined as "Human-induced eutrophication is prevented, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters", in line with MSFD Descriptor 5. Key elements for IMAP are the Common Indicators (CI) to assess the degree of threat or change in the marine ecosystem and to deliver valuable information to decision makers. The CI that uses chlorophyll a data is:

- Common Indicator 14: Chlorophyll-a concentration in water column (MSFD criterion D5C2).

The monitoring of eutrophication under IMAP builds on the existing monitoring system of UNEP/MAP MED POL Monitoring programme, and most of the Contracting Parties already have monitoring programmes in place for eutrophication all over the Mediterranean basin. Temporal scales are not harmonised among countries ranging from weekly to monthly/bimonthly for parameters such as chlorophyll a.

EU Member States in the Mediterranean are obliged to monitor eutrophication for WFD and MSFD. Therefore these states are also including in their monitoring programs concentrations of Dissolved Oxygen Near the Seafloor (MSFD criterion D5C5), Harmful Algal Blooms (MSFD criterion D5C3), Secchi depth (MSFD criterion D5C4), as well 3 secondary criteria (D5C6, D5C7, D5C8) related to the benthic ecosystem. However, no assessment of these parameters is available in the MED QSR 2023 and hence no evaluation of data coverage is available.

Table 4. UNEP/MAP monitoring guideline for the eutrophication indicator chlorophyll a.

UNEP-MAP indicator	**Guideline**
Concentrations of Chlorophyll-a (CI 14)	Monitoring Guideline for Reporting Monitoring Data for IMAP Common Indicators 13, 14, 17, 18 and 20

UNEP/MAP supports the NEAT (Nested Environmental status Assessment Tool) approach as an assessment tool. NEAT is a structured, hierarchical tool for making marine status assessments (Berg *et al*., 2017; Borja et al., 2016). Though NEAT was developed to assess biodiversity status of marine waters under the MSFD its use is not limited to the assessment of biodiversity but can be used for assessment of pollution impact (UNEP/MAP – MED POL). The analysis provides an overall assessment for each case study area and a separate assessment for each of the ecosystem components included in the assessment.

Parameter Chlorophyll-a

Chlorophyll *a* is a central parameter in the assessment of eutrophication, indicating phytoplankton biomass. It is a primary criterion under MSFD Descriptor 5 - Eutrophication and monitored in all European Sea Regions. It is also used for descriptor D1 -Biodiversity (pelagic habitats).

Indicator assessments and data needs - OSPAR

OSPAR published the common indicator assessment 'Concentrations of Chlorophyll *a* in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast' (Prins and Enserink, 2022) and the Eutrophication thematic assessment (OSPAR, 2023a), as well as 'Changes in Phytoplankton Biomass and Zooplankton Abundance' (Louchart et al, 2023) as part of the QSR 2023. These indicators use data on chlorophyll *a* concentrations.

While previous assessments were based on *in situ* sampling, the current assessments incorporates EO data. This implies that for the OSPAR Regions included in the eutrophication 'Chlorophyll *a*' assessment the total confidence in the assessment (*in situ* plus EO) is high or moderate in the areas assessed (Figure 3). However, since OSPAR still uses *in situ* data, additional *in situ* sampling in areas with low *in situ* sampling confidence is considered useful, especially to validate EO observations (so-called match up sampling, within a specific time window before and after the satellite scans the area), but strictly not needed for a reliable assessment.

In the biodiversity indicator assessment 'Changes in Phytoplankton Biomass and Zooplankton Abundance' the spatial representativeness was high in the Greater North Sea and the Celtic Seas, but low in the Bay of Biscay an Iberian coast (coastal, shelf and oceanic assessment areas). OSPAR will address this issue by further improving the use of *in situ* and EO chlorophyll *a* data sets in the ICES database for this assessment. A need for more chlorophyll *a* data has therefore not been identified.

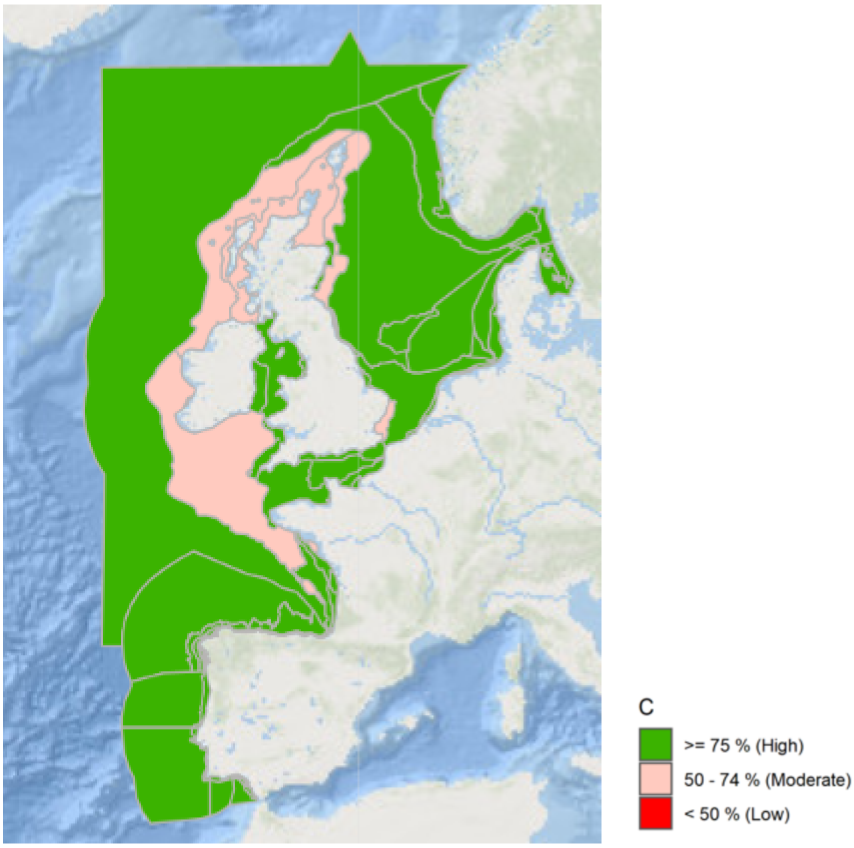


Figure 3. OSPAR Eutrophication Confidence 2015 - 2020. Chlorophyll-a (in-situ and satellite). Months 3 - 9. Depths 0 - 10. Metric: Mean. Available via: https://odims.ospar.org/en/submissions/ospar_chl_confidence_2020_01/

A knowledge gap related to data coverage has been identified in the chlorophyll *a* assessment: The combination of in situ and satellite data needs to be worked out further, given the differences in sampling strategies between Contracting Parties. The JERICO community may contribute to harmonisation of sampling strategies in the OSPAR area.

Indicator assessments and data needs - HELCOM

HELCOM published the core indicator assessment Chlorophyll (HELCOM, 2023a). It evaluates the average summer (June – September) chlorophyll *a* concentration in surface water (0 – 10 m) during the assessment period 2016–2021 in almost all subdivisions, open sea as well as coastal assessment units. The latter are assessed under the EU Water Framework Directive.

The average chlorophyll-a concentration in open sea assessment units is a combined estimate of three types of data (depending on availability, applicability, and regional agreement): 1) *in situ* measurements 2) Earth Observation (EO) remote sensing satellite data, and 3) FerryBox data. These data are combined as annual averages, applying weighting based on data availability and confidence. The combined confidence is depicted in Figure 4 for the open sea subdivisions, see also Table 5. Low indicator confidence calls for an increase in monitoring effort. The use of Ferrybox data in all assessment units should be investigated (HELCOM, 2023a).

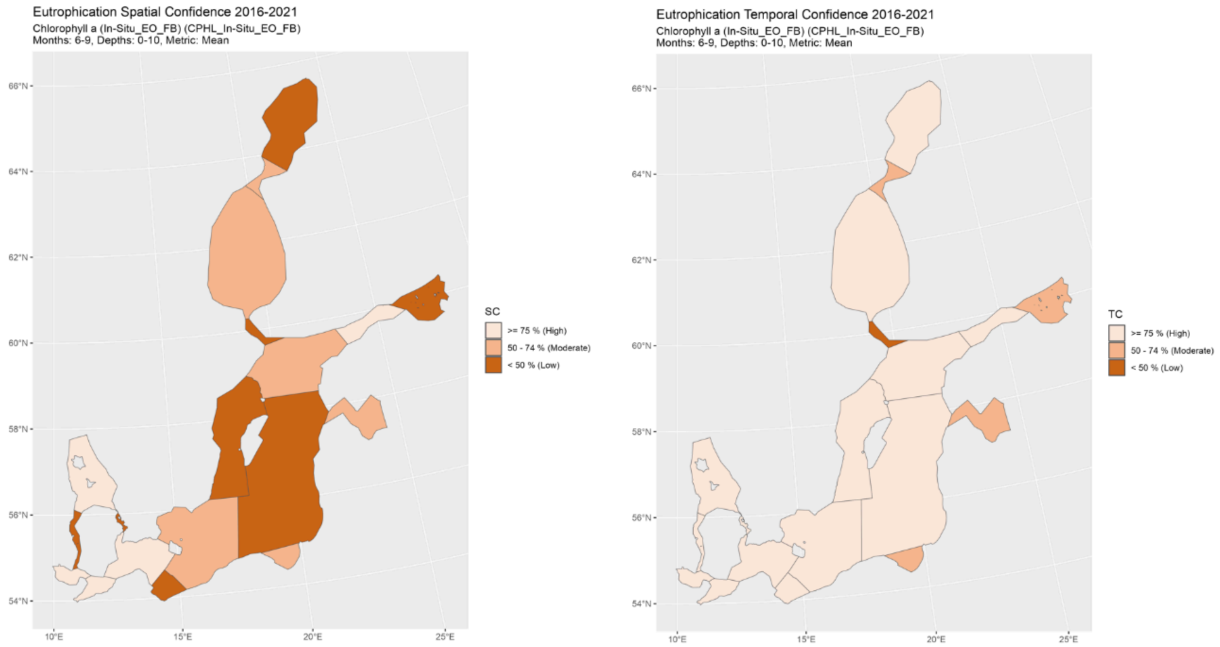
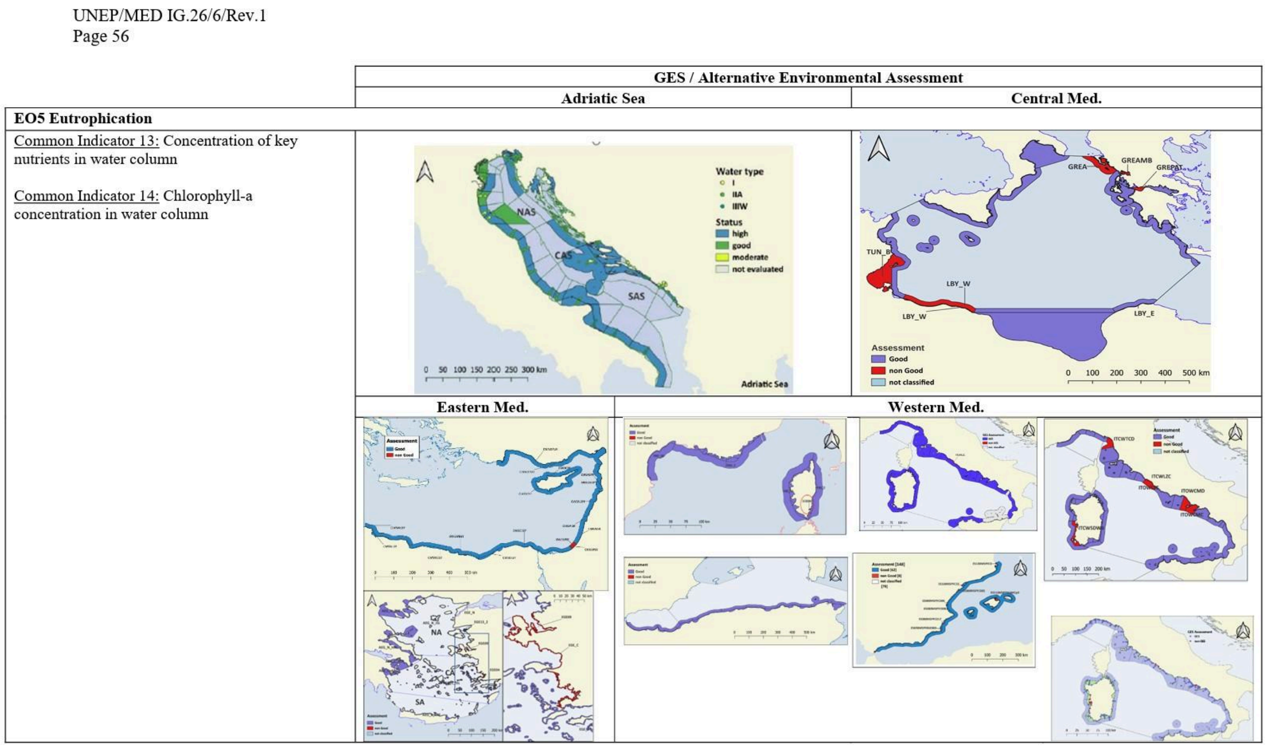


Figure 4. Chlorophyll a indicator confidence determined by combining information from In Situ, Earth observations (EO) and Ferrybox (FB) data. Spatial confidence (SC, left panel) and temporal confidence (TC, right panel) of the GES evaluation. In: HELCOM, 2023a.

Indicator assessments and data needs - UNEP-MAP

In most of the Mediterranean Sea, for the QSR use was made of data for chlorophyll *a* available from remote sensing sources (*i.e.* Copernicus). As large areas of the Mediterranean Sea are oligotrophic, assessment of eutrophication focuses on the coastal (up to 1 nautical mile) and offshore waters (up to 20 km), see Figure 5.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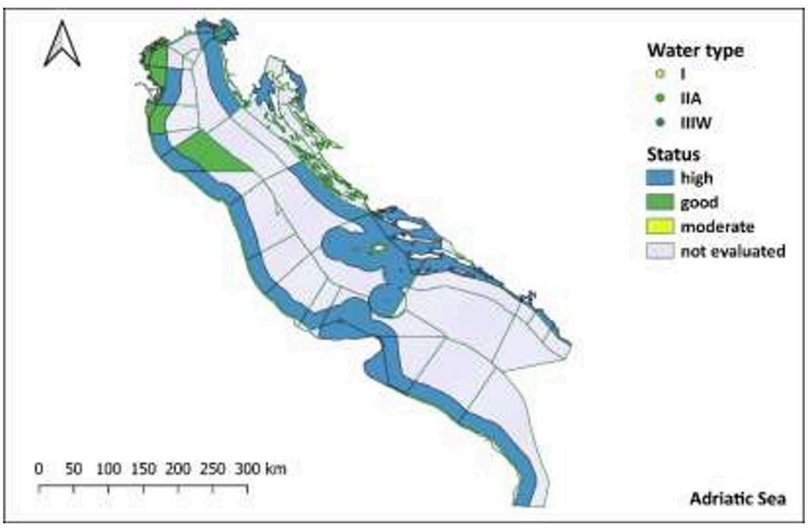
	GES / Alternative Environmental Assessment	
	Adriatic Sea	Central Med.
EO5 Eutrophication		
Common Indicator 13: Concentration of key nutrients in water column Common Indicator 14: Chlorophyll-a concentration in water column		
	Eastern Med.	Western Med.

Figure 5. The assessment of chlorophyll a in the Mediterranean focuses on the coastal subdivisions and offshore waters up to 20 km (upper panel). In: [UNEP/MED IG.26/6/Rev.1, page 56](#).

In the Aegean and Levantine Seas Sub-region (AEL), Copernicus data for chlorophyll *a* was used.

For the Adriatic Sea (ADR) sub-region, *in situ* data were used, and assessed using the NEAT tool, where available, but not for the entire sub-region an assessment was made (Figure 6). In the Northern part of the Adriatic Sea Sub-region (ADR), data reported by the Contracting Parties (Croatia, Italy, Montenegro, and Slovenia) for the period 2015-2020, were used for the sub-regional assessment for chl-a, for the southern part of the ADR data were considered insufficient or not reported in line with mandatory data standards.



Chl *a*

Figure 6. Assessment areas and results of chlorophyll a assessments in the Adriatic Sea (ADR) sub region. In: [2023 Med QSR: The IMAP Pollution Cluster Chapters](#), page 67.

For the ADR sub-division a confidence estimate is provided for the areas where the HEAT tool was used. For most (43) sub-areas a high confidence is given (> 90% or 100%), for 8 sub-areas confidences ranging from 56-82% are mentioned.

In the Central Mediterranean Sea (CEN) Sub-region, because of the lack of quality-assured, homogenous *in situ* data, the assessment of eutrophication was undertaken by evaluating data available from Copernicus data for Chl a obtained by remote sensing.

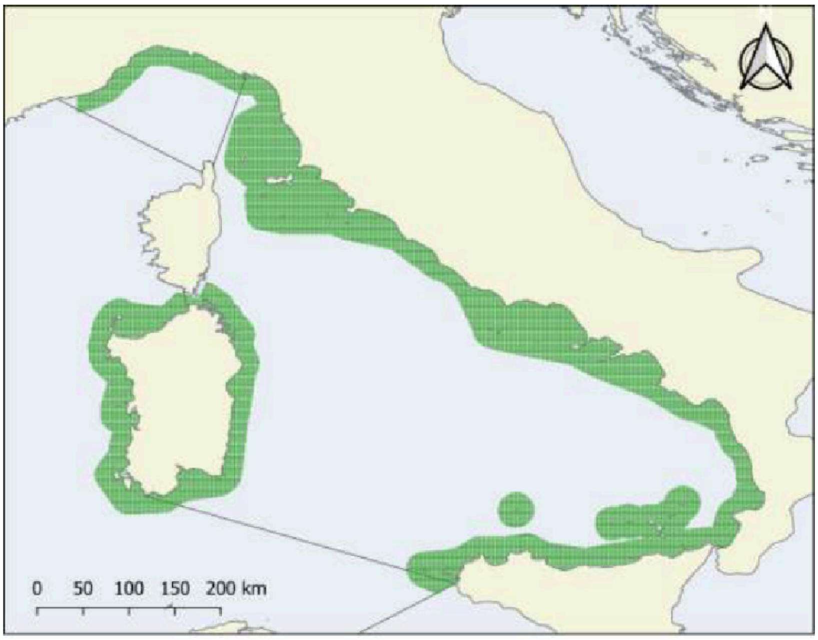


Figure 7. Use of remote sensing chlorophyll a data delivers a high spatial 1x1 km resolution (green dots in the assessment zone), illustrated in the Tyrrhenian Sea Sub-division and Italian part of the Central Western Mediterranean Sea Sub-division (lower panel). In: [2023 Med QSR: The IMAP Pollution Cluster Chapters](), page 87.

In most of the Western Mediterranean Sea (WMS) Sub-region, because of the lack of quality-assured *in situ* data, the assessment of Chl a was done using satellite-derived Chl a (the French waters of the Central Sub-division of the Western Mediterranean Sea Sub-region (CWMS), the Alboran (ALB) and the Levantine-Balearic (LEV-BAL) Sub-division). Only in the Tyrrhenian Sea Sub-division and the Italian part of CWMS Sub-division, next to satellite-derived chlorophyll *a* data (*cf.* Figure 7), *in situ* data were used.

Although remote sensing chlorophyll *a* products have been widely used in the MED QSR assessments, partly because of limited availability of *in situ* data that fulfil mandatory data standards, limitations concerning this data source apply to the Mediterranean Sea. These limitations concern coastal waters, where the detection of ocean colour is complicated by the presence of suspended particulate and dissolved matter (e.g., non-algal particles (NAP), coloured dissolved organic matter (CDOM)), making the retrieval of Chl-a concentration more complex in these systems (Pahlevan et al., 2020). In oligotrophic waters (Eastern Mediterranean) the signal is very weak.

For all areas where satellite data were used, no explicit confidence assessment was included in the QSR; but for the Tyrrhenian Sea, a statement was found that results obtained from an application of assessment methodology based on the use of satellite-derived chlorophyll *a* data were confirmed by an application of the methodology based on the *in situ* chlorophyll *a* data, both at the level of sub spatial assessment units (subSAUs) and monitoring stations. It was concluded that this confirms the accuracy of data obtained from remote sensing.

Chlorophyll *a* data are needed for the Central Mediterranean Sea Sub-region (CEN), the southern part of the Levantine Sea, the subdivision of the Aegean-Levantine Sea Sub-region, and the southern part of the Central part of the Western Mediterranean Sea Sub-region (WMS) which are underrepresented.

Overview of data needs in Regional Sea Conventions - Chlorophyll a

As can be concluded from above descriptions, assessment of eutrophication, and in particular monitoring the indicator chlorophyll-a, is subject to change as new technologies become available. Where the first RSC and MSFD assessments typically relied on *in-situ* measurements (mostly using point stations), satellite data and systems able to make continuous measurements in gliders and ferryboxes have become available. In regional cooperation 'joint monitoring programmes' are becoming operational where EU member states can use the same sensor (*e.g*. Copernicus Sentinel 2 and 3 satellites) to monitor.

All RSC assessments describe methodology, results and uncertainties, but no complete and uniform (between RSCs) data needs were described. In this WP the following analysis of user-data needs was made, and this can help the JERICO community to better align with the needs of its clients.

Table 5. Chlorophyll a Regional Sea data needs. Coloured cells: green – no data needs; red - data needs identified.

parameter chlorophyll a	**User – data needs**	**User – data needs**	**User – data needs**
metadata	**OSPAR**	**HELCOM**	**UNEP-MAP**
indicator	Mean concentration chlorophyll a in growing season	Concentration chlorophyll a	Common indicator 14 - Chlorophyll a
unit	µg/l	mg/m^3	µg/l
[1] months	Eutrophication: 3-9; Biodiversity – phytoplankton biomass_ 1-12		Seasonal or 1-12, depending on contracting party
Sampling resolution	Frequency: Eutrophication: not specified. Biodiversity: at least monthly or fortnightly; Spatial resolution: eutrophication and biodiversity: all COMP4 assessment areas in Regions II, II and IV	Cruise: >12 times per year* SoO**: every 200 m and every 1-3 days	Seasonal or 1-12, depending on contracting party
Sampling depth	Open sea: 1 m, 5 m, 10 m, 15 m, 20 m, and around thermocline, plus chlorophyll maxima at other depths; coastal waters, without stratification, 1 m or vertically integrated samples (1 – 10 m); helicopter: single sample from the mixed surface layer; for biodiversity also data from the Continuous Plankton Recorder: mean towing depth 6-7 m (Hays and Warner, 1993)Not specified in OSA	Open sea, upper water column: 1 m, 5 m, 10 m, 15 m and 20 m; plus chl a maxima at other depths; Coastal: 1 m or an integrated sample (1-10 m) SoO: single sample from the mixed surface layer	Euphotic zone.
Parameter applied in:	Eutrophication: Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast (all COMP4 assessment areas_	Entire area, except for (part of) coastal assessment units 2,6,13,14,15, 18,19, 21,23	AEG: coastal waters (CW; internal waters and < 1 nm coastline) LEV, CEN, WMS: CW+offshore waters (OW; < 20 km coastline)

parameter chlorophyll a	User – data needs	User – data needs	User – data needs
metadata	**OSPAR**	**HELCOM**	**UNEP-MAP**
			ADR: mostly CW (sea fig. xx)
Subregion – low temporal confidence	none	Åland Sea Swedish Coastal waters	not specified
Subregion – low spatial confidence	none	Bothnian Bay, Eastern part of Gulf of Finland, Åland Sea Swedish Coastal waters, Western Gotland Basin, Eastern Gotland Basin, South-Western part of Bornholm Basin, Sound, Great Belt	Central Mediterranean Sea Sub-region (CEN); the southern part of the Levantine Sea, the sub-division of the Aegean-Levantine Sea Sub-region; and the southern part of the Central part of the Western Mediterranean Sea Sub-region (WMS)

** basically monthly sampling but weekly in the vegetative period*
*** SoO: Ships of Opportunity*

How can current and future JERICO projects contribute to chlorophyll a data needs?

The objective of the JERICO projects is to improve the European observational infrastructure, bringing expertise and high- quality data on European coastal and shelf seas, to better answer societal and policy needs. Obviously, most of the efforts in the JERICO-S3 project are focused on improving technical expertise. But to better address societal and policy needs, the needs and expectations from the policy realm need to become visible. For chlorophyll *a* we have made an overarching description of needs.

Table 5 (above) provides the overview of results of QSRs and of data needs, including areas where coverage is insufficient. We have made an inventorisation of stations in the map-catalogue. This could bring us new information, as the map interface of the catalogue is a practical way of obtaining an overview whether suitable platforms may be available that can cover the needs of above identified users of data; and it can highlight both areas that are underrepresented in the data collection and where there is a data need, or the opposite, areas where data collection may exceed what is needed to ensure assessment confidence. We provide some examples.

Potential contribution to HELCOM areas of low confidence

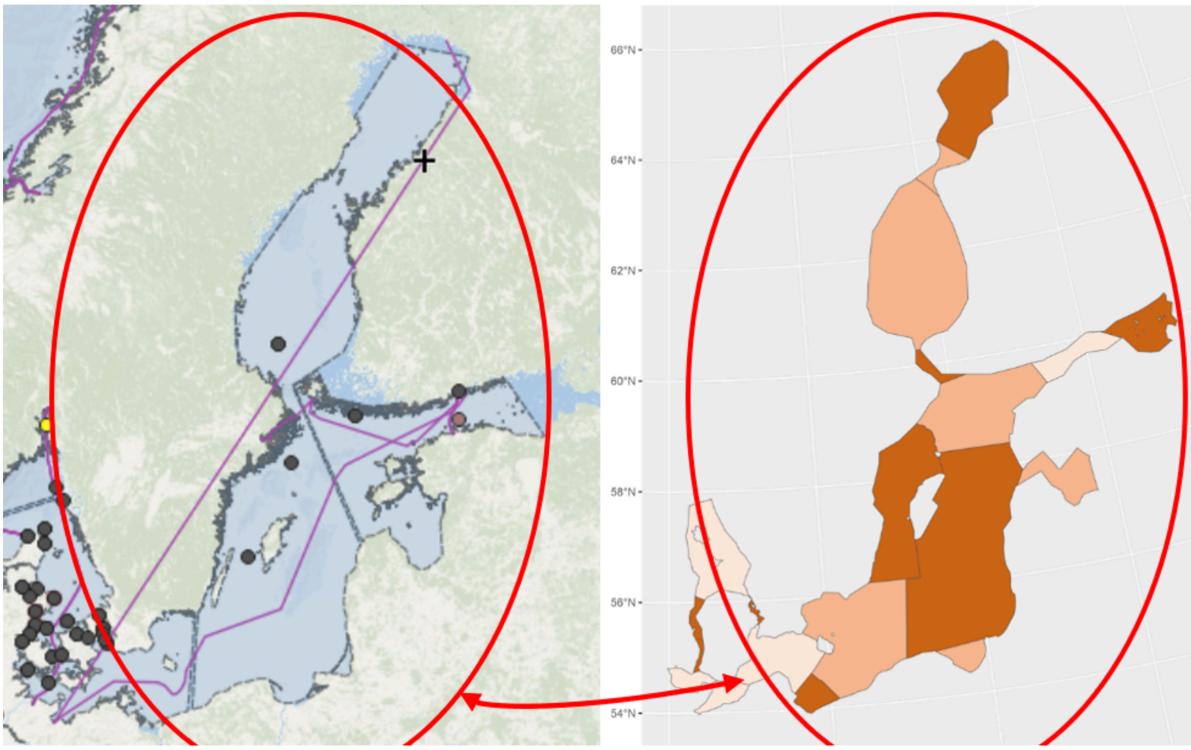


Figure 8. HELCOM eastern and northern areas: low coverage (left), low confidence (right)

Where the OSPAR QSR did not mention areas with low confidence in assessment results, HELCOM includes a number of larger areas where we note a low spatial confidence, and the map-catalogue contains only a few dedicated JERICO stations in this region (Figure 8). The stations in this area include a few (4) ferrybox-equipped ships, but most of this region is not addressed in the JERICO. This does not mean that there is no data collection- we noticed that some Member States only contributed data to the JERICO map-catalogue about monitoring platforms that are part of the JERICO project. As eutrophication is a main problem in HELCOM, this suggests that this could be a focus topic in a follow-on project.

Potential contribution to UNEP/MAP areas of low confidence

The situation in the Mediterranean area is a bit different. If we look at the map-catalogue (Figure 9) one could conclude that there is little data collection in most of this region (notably the Ionian and Central Mediterranean, and the Aegean-Levantine).

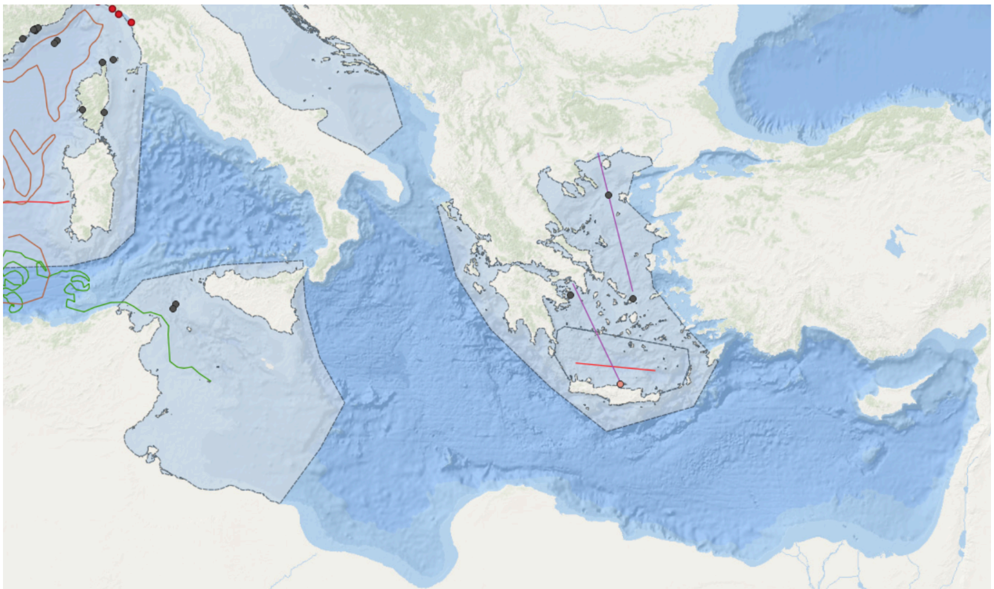


Figure 9. Low number of JERICO stations in the eastern half of the Mediterranean.

The eutrophication assessment of the Mediterranean tells us something different: there is actually a lot of data collection in these regions (see *e.g.* MED QSR, table 3.1.3.1.1.), there are thousands of measurements, including by non-EU Member States. But the QSR concludes that despite these numbers, there is a lack of homogenous and quality assured data reported in line with IMAP requirements; it was deemed necessary to explore the use of alternative data sources, and for the QSR only existing satellite remote sensing data (Copernicus) was used for assessing eutrophication in these areas. Eutrophication is (compared to the HELCOM region) less of a problem in most of the Mediterranean and restricted to the coastal areas. A large increase of the number measurements may therefore not be the first priority. However, improving quality of data collection could be a focus topic for JERICO, as much of the (probably expensive) monitoring effort of countries is not used to the extent needed, *e.g.* in the Southern part of the Adriatic.

Parameter Phytoplankton

This parameter informs about phytoplankton composition. It is used for MSFD descriptors D1 - Biodiversity (pelagic habitats), D4 - Food webs and D5 - eutrophication. This parameter is not addressed in the MED QSR.

Indicator assessments and data needs - OSPAR

OSPAR published the indicator assessments 'Changes in Plankton Diversity' (Louchart et al., 2023b) and 'Changes in Phytoplankton and Zooplankton Communities' (Holland et al., 2023) and the 'Pelagic Habitats Thematic Assessment' (OSPAR, 2023b) as part of the QSR 2023. One (phyto)plankton sample can be used to inform both assessments. In these assessments, bimonthly plankton data from diverse sources were used (e.g., Continuous Plankton Recorder (CPR), microscopy counts, FlowCAM), following several sampling and analytical protocols. This pragmatic approach was considered more cost effective than to get all contracting parties to use the same methodology. The computation of diversity indices was conducted separately for each dataset and separately for phytoplankton. The spatial distribution of the data sets used in the assessment is illustrated in Figure 10.

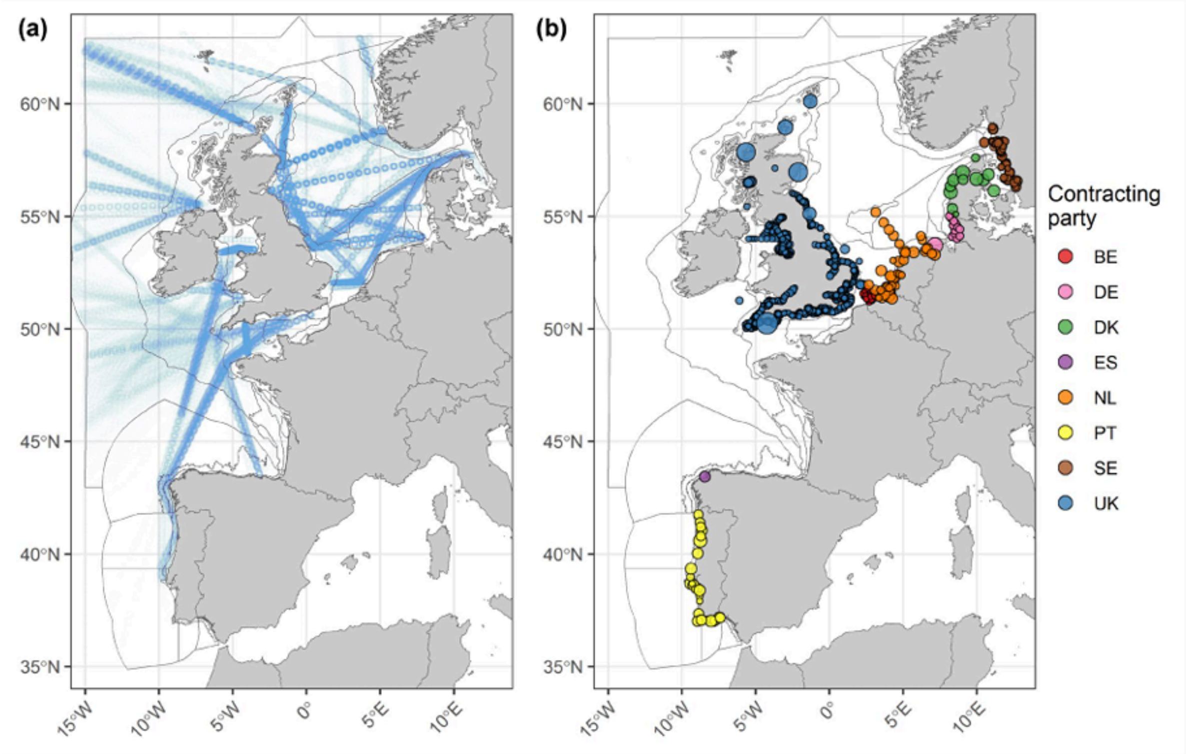


Figure 10: CPR tracks (a) and the locations of samples from all other datasets (b) used in the assessment. For (b), point size is proportional to the number of samples taken at each location. Points are coloured according to contracting party. In: [OSPAR CEMP Guideline Common indicator: PH1/FW5 Change in plankton communities]()

For the assessment Change in plankton communities, species were grouped into so-called life forms, *ie.* for phytoplankton:

- Diatoms: phytoplankton with silicate cell walls. Essential for marine photosynthetic and oxygen production;
- Dinoflagellates: Phytoplankton with flagella. Thrive in nutrient rich environments. Important for marine photosynthetic production.

Cryptic speciation (species with near-identical appearance) within the plankton community, alongside the limitations of identifying plankton using routine light microscopy techniques, make it difficult to generate accurate counts at a species or genus level. Functional group abundance is more reliable as many plankton lifeforms are easily identified, making comparisons between different laboratories and institutes feasible (OSPAR CEMP guideline change in plankton communities).

No assessment of the spatial and temporal confidence, addressing the sampling effort in the pelagic habitats within OSPAR Regions, was performed. Spatial and temporal confidence indices will be implemented in future assessments. However, the indicator assessments contain a spatial representativeness score, which should be 50% or higher for a reliable assessment. On the basis of this information, low spatial confidence is inserted in Table 6.

The following gaps in knowledge related to data coverage were identified:

- Pelagic Habitats Thematic Assessment:

  - Improve the frequency and spatial coverage of plankton observations by integrating both remote sensing products, but also automated in vivo/in situ approaches at high spatial and temporal resolution
- Changes in Plankton Diversity:
  - For a regional and habitat assessment, better acquisition of region-wide plankton data sets is required.
  - Winter sampling: There needs to be more consistent winter monitoring to reliably assess plankton diversity since winter is a period of high richness. Focusing only on the productive period (March to November) is a possible way to overcome this issue in data analysis.
  - Include additional data sets: characterising marine plankton by manual counting and identifying plankton in a small sample of seawater through a microscope has its limitations. Additional methods could include state-of-the-art (semi-)automated methods and molecular methods. Combining multiple methods may help fill the gaps in microscopic examinations and applying complementary methods will facilitate monitoring the full-size range of the phytoplankton community.
- Changes in Phytoplankton and Zooplankton Communities:
  - It will be important to obtain plankton datasets within pelagic habitats lacking sufficient coverage in the current assessment.
  - Establishment of monthly monitoring programmes for pico and nanoplankton to provide data on them.
  - For a more robust assessment, spatial and temporal confidence of the results should be developed and implemented. This will lead to targeting the location which requires a better sampling effort. Spatial and temporal confidence indices (which will be implemented in future assessments) will address the sampling effort in the pelagic habitats within OSPAR Regions. These spatial and temporal confidence indices will be implemented in future assessments.

Indicator assessments and data needs - HELCOM

The pre-core indicator 'Cyanobacterial blooms' consists of two parameters: 1) cyanobacterial surface accumulations (CSA), combining information of volume, length of bloom period and severity of surface accumulations estimated from remote sensing observations and 2) the cyanobacterial biomass in the water column analysed from in-situ observations. Cyanobacterial surface accumulations are measured using earth observation (satellites) and cyanobacterial biomass is measured by *in situ* techniques. The latter metric is included in the present analysis (*cf*. Figure 11). See for the indicator assessment 'Cyanobacteria bloom index' HELCOM, 2023b.

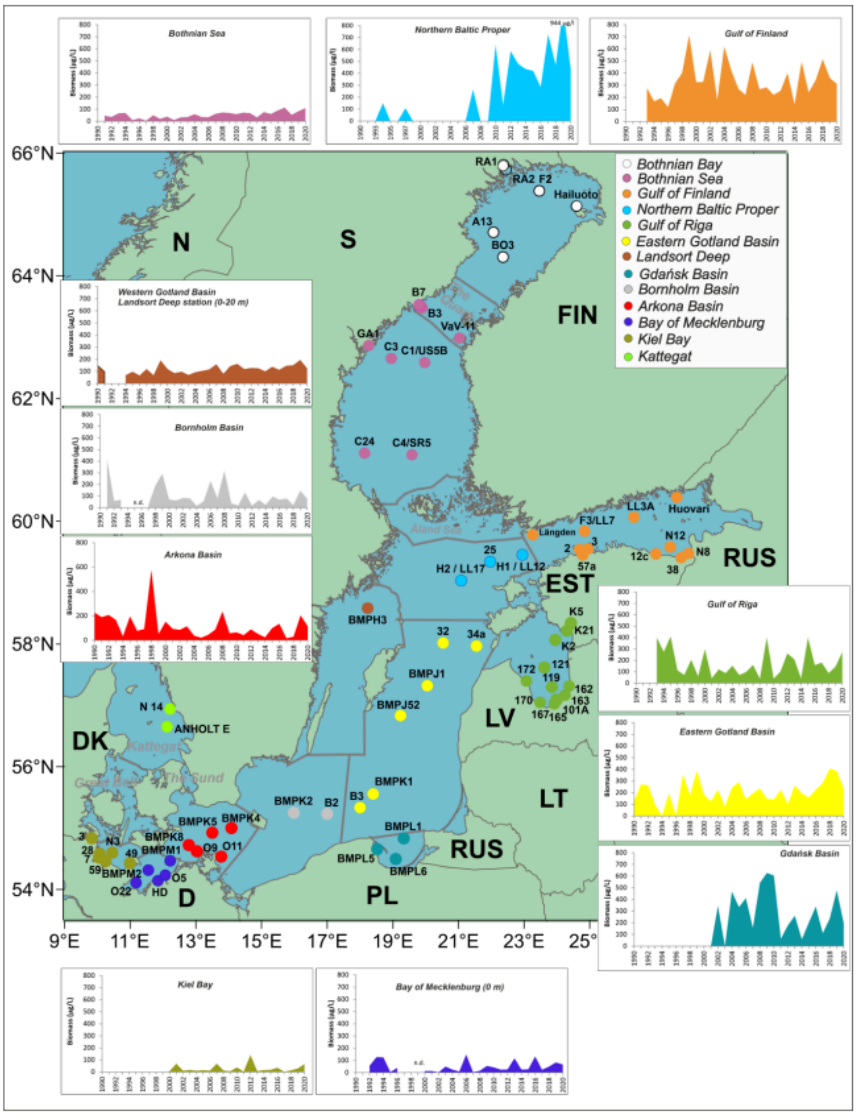


Figure 11. Map of the regularly sampled stations, containing assessment unit specific graphs on diazotrophic cyanobacteria biomass (seasonal mean biomass µg/L). Names of some Finnish coastal stations are abbreviated. Stations in Bothnian Bay and Kattegat have been tested but the results are not presented. Figure from: Kownacka et al. 2022. In: HELCOM, 2023b.

The pre-core indicator assessment 'Seasonal succession of functional phytoplankton groups' (HELCOM, 2023e) addresses seasonal succession of dominating phytoplankton groups. The selection of groups may differ between sub-basins or assessment units of the Baltic Sea, and expert judgement based on long-term monitoring data is required to identify the correct and most suitable candidate groups. In all test areas cyanobacteria, auto- and mixo-trophic dinoflagellates, diatoms and the autotrophic ciliate *Mesodinium rubrum* were selected. In the Eastern Gotland Basin Lithuanian Coastal waters and in the Quark Swedish Coastal waters, green algae were included in the analysis as an extra component.

Current monitoring is not formalised for this indicator. Sufficiently frequent sampling is seldom available through monitoring programs. Moreover, the open sea monitoring activities of many countries have been reduced during the last years. This is in some areas (Gulf of Finland, Northern Baltic Proper) compensated by increasing activities of sampling by FerryBox systems.

The spatial and temporal confidences were assessed for cyanobacterial biomass. Temporal confidence was high or moderate in the subdivisions assessed, but spatial confidence was low in all of these subdivisions.

The assessment 'Seasonal succession of functional phytoplankton groups' also includes an evaluation of confidence. For most of the assessed areas, the confidence of indicator status is intermediate to high according to temporal and intermediate according to spatial resolution. Confidence level depends on the length of the time-series and regularity of phytoplankton sampling during the growth period.

Overview of data needs in Regional Sea Conventions - Phytoplankton

Monitoring of phytoplankton composition is not (yet) strictly formalised in OSPAR and HELCOM, although monitoring and reporting guidances exist, see Table 6 for metadata. In OSPAR available datasets are used to the extent possible for the relevant indicators, due to a lack of long term data sets in many assessment areas. In HELCOM, data needs in the entire Region have been identified for cyanobacterial biomass (Table 6).

Table 6. Phytoplankton Regional Sea data needs. Coloured cells: green – no data needs; red - data needs identified. As there are two indicators with different metadata in the HELCOM region two columns are used.

parameter phytoplankton	**User – data needs**		
metadata	**OSPAR**	**HELCOM**	**HELCOM**
indicator(s)	Changes in Plankton Diversity; Changes in Phytoplankton and Zooplankton Communities	Cyanobacterial bloom – biomass parameter	Seasonal succession of dominating phytoplankton groups
metric	Plankton abundance or biomass (per species/genera/taxa)	Phytoplankton species composition, abundance, biomass	Phytoplankton species composition, abundance, biomass
species	Species grouped into life forms: diatoms and dinoflagellates	genera Nodularia, Aphanizomenon and Dolichospermum (previously Anabaena)	Area specific. In all areas: cyanobacteria, auto- and mixo-trophic dinoflagellates, diatoms and *Mesodinium rubrum*
unit	units/L?	Counting units/dm3 and µg/L (wet weight)	µg/L (wet weight)
months	1-12	June-August, in the Bothnian Sea June-October	1-12
Sampling resolution	Minimum: monthly; spatial coverage: all COMP4 assessment areas, spatial representativeness ≥0.5	Cruise: >12 times per year* SoO: every 10 km and every 1 - 3 weeks.	Cruise: >12 times per year* SoO: every 10 km and every 1 - 3 weeks.
Sampling depth	CPR: mean 6-7 m; other stations not specified	integrated samples from 0 to up to 20 m (generally 0-10 m)	integrated samples from 0 to up to 20 m (generally 0-10 m)

parameter phytoplankton	**User – data needs**		
metadata	**OSPAR**	**HELCOM**	**HELCOM**
Parameter applied in:	COMP4 assessment units in Regions II, III and IV	open sea assessment units: Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Pomeranian Bay, Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland Western, Gulf of Finland Eastern, Åland Sea and Bothnian Sea	Open sea: Kattegat, Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland, Åland Sea, Bothnian Sea, Bothnian Bay, Coastal: 1,3,4,8,11,12,14, 15,16,19,24,26,31,32 (cf. Annex 1)
Subregion – low temporal confidence	-	none	none
Subregion – low spatial confidence	Indicator Changes in Plankton Diversity: Greater North Sea - variable salinity and coastal assessment areas. Indicator Changes in Phytoplankton and Zooplankton Communities: Greater North Sea – variable salinity; Bay of Biscay and Iberian Coast: variable salinity, coastal and oceanic assessment areas.	all assessment units	none

* basically monthly sampling but weekly in the vegetative period

In this Deliverable the following analysis of user-data needs was made, and this can help the JERICO community to better align with the needs of its clients.

How can current and future JERICO projects contribute to phytoplankton data needs?

Table 6 (above) provides the overview of methods used and phytoplankton data needs in the OSPAR QSR 2023 and HELCOM HOLAS3, identifying areas where coverage is insufficient. We have made an inventorisation of stations measuring phytoplankton in the map-catalogue. Comparison with the data needs generates an overview whether suitable platforms may be available that can contribute to enhancing the confidence of indicator assessments.

Potential contribution to OSPAR areas of low confidence

For the indicators 'Changes in Plankton Diversity' and 'Changes in Phytoplankton and Zooplankton Communities' low confidence assessment areas have been included in Table 6.

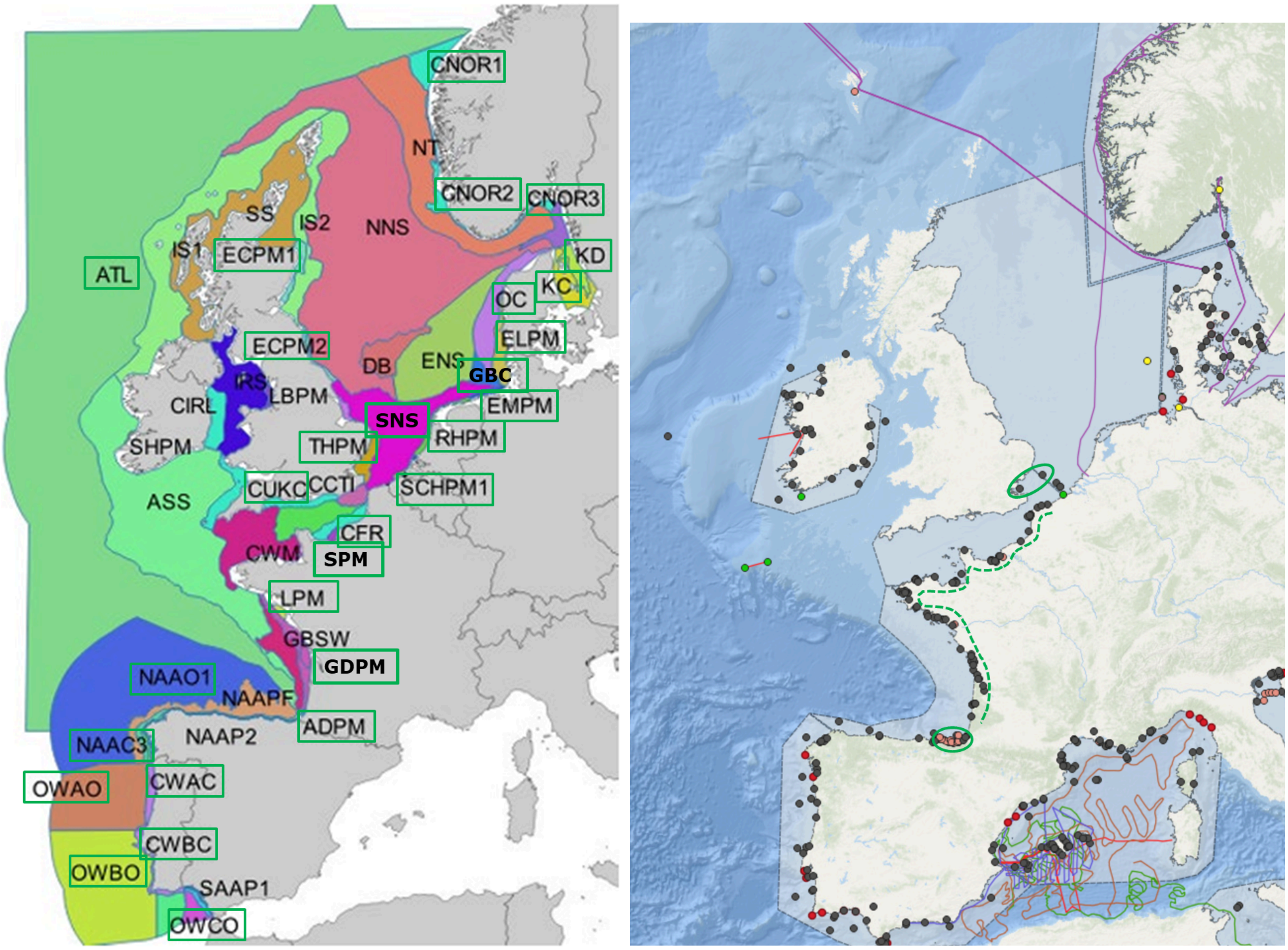


Figure 12. Phytoplankton low confidence areas (left panel, area codes with green borders) versus phytoplankton data sets submitted to the JERICO-RI map-catalogue (right panel, green dotted line and ovals).

In the Greater North Sea these concern variable salinity (river plumes) and coastal assessment areas and in the Bay of Biscay and Iberian Coast: variable salinity, coastal and oceanic assessment areas. When shown in a map these low confidence assessment areas can be compared with the stations including phytoplankton data in the map-catalogue (Figure 12). Although it is not obvious from the map which point or line stations measure phytoplankton, the underlying database reveals that:

- In the Spanish part of the Bay of Biscay AZTI operates 19 point stations (orange points along the Basque coast), where manual samples are collected with ongoing time series started between 1986 and 2006. The stations in the variable salinity and coastal assessment areas may contribute to the phytoplankton assessments;
- Along the French coast of the Bay of Biscay and the Greater North Sea Ifremer operates 18 point stations where phytoplankton is sampled in ongoing time series that started between 1987 and 2012. These datasets could contribute to enhancing the low confidence phytoplankton assessments in the variable salinity and coastal assessment areas. The map-catalogue shows many point stations in this area, some collecting phytoplankton samples, but it is not clear from the map which ones.
- In UK waters Cefas operates two smart buoys. One is located in the low confidence assessment area Thames Plume and the other in the Southern North Sea. Phytoplankton samples are analysed using microscopy and (ongoing) time series started in 2000 and

2002. Both datasets could contribute to enhancing the confidence of the relevant indicator assessments.

Figure 10 shows that the phytoplankton data sets along the French coast and along the Basque coast most probably were not included in the OSPAR assessments. Since these data sets overlap with the low confidence areas this can be an opportunity for JERICO to contact the relevant expert group in OSPAR (see chapter 4) and offer support. The UK smart buoy data sets probably were already included in the OSPAR assessments.

From the user perspective there is an interest in (semi-)automated observations of phytoplankton and molecular methods, which can complement microscopy and improve spatial and temporal resolution. In addition, long time series are very important for these indicator assessments. There is also a wish to extend the assessments to pico- and nanoplankton.

We suggest interested partners in the JERICO network to collaborate with the Pelagic habitats expert groups in OSPAR (see Table 12) and discuss how existing datasets can contribute to improving the indicator assessments, but also to explore how innovative sampling techniques can help to improve spatial and temporal resolution.

Potential contribution to HELCOM areas of low confidence

Low confidence has been identified in the entire HELCOM area for the parameter cyanobacterial biomass under the indicator 'Cyanobacterial blooms'. No low confidence was found for the indicator 'Seasonal succession of functional phytoplankton groups'. Figure XX compares the point stations included in the assessment of cyanobacterial biomass with the map-catalogue stations measuring phytoplankton. Only two stations were found in the map-catalogue (indicated with a green circle and a green arrow in Figure 13):

- A Syke (Finland) point station measuring phytoplankton from a fixed platform. The start date of the time series is unknown, but the monitoring is ongoing.
- Taltech (Estonia) manages the ferrybox on the ferry line Talinn-Helsinki. This ferrybox measures phycocyanin, a pigment found in cyanobacteria. The time series started in 1997 and is ongoing.

The Syke station does not show in Figure 13, left panel, so this may not have been included in the indicator assessment and therefore could enhance the confidence in the Åland Sea. The ferrybox data set may have been included, this is not completely clear from the indicator assessment.

Therefore, it is worthwhile for the JERICO-RI to liaise with the relevant HELCOM expert groups, see Table 12. However, the number of stations in the map-catalogue is very limited and does not reflect current ongoing monitoring efforts for phytoplankton. Since there is a need for more data on cyanobacterial biomass in the entire HELCOM area, this is an opportunity for JERICO to contribute.

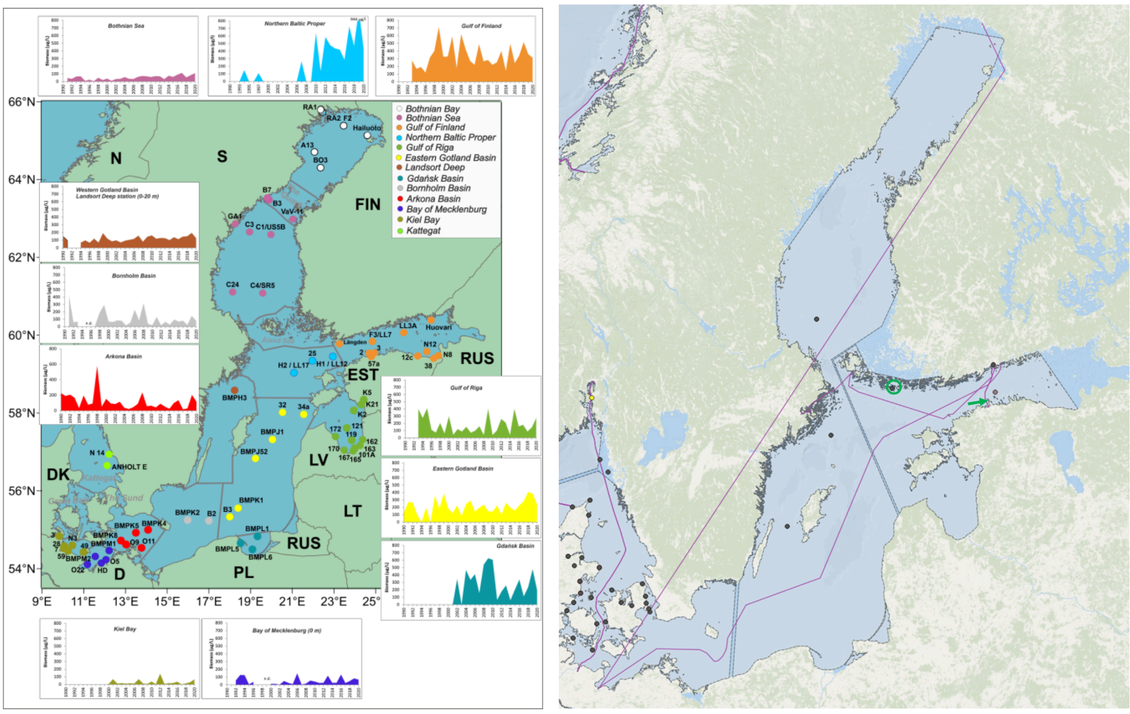


Figure 13. Phytoplankton point stations included in the parameter cyanobacterial biomass under the Cyanobacterial blooms indicator assessment (left panel, same as Figure 6) versus phytoplankton data sets submitted to the JERICO-RI map-catalogue (right panel, green arrow pointing at Tallinn-Helsinki ferrybox and green circle indicating point station).

Parameter Dissolved O_2

Dissolved oxygen (DO) is a central parameter in the assessment of eutrophication. It is a primary criterion under MSFD Descriptor 5 - Eutrophication and monitored in all European Sea Regions. Reduced oxygen concentrations close to the seafloor can affect benthic organisms. The significance of dissolved oxygen, next to anthropogenic nutrient inputs, depends on hydrological conditions such as temperature, water depth and stratification. The MED QSR does not contain an assessment of oxygen concentration.

Indicator assessments and data needs - OSPAR

OSPAR delivered the common indicator assessment ‘Concentrations of Dissolved Oxygen Near the Seafloor in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast’ (Devlin *et al*, 2023) as part of the QSR 2023. Dissolved oxygen data is filtered first to include only oxygen concentrations close to the seabed, in waters shallower than 500 m as oxygen depletion in deeper waters is unlikely to be due to eutrophication. The assessment process selects the deepest sample at each station and only used data within 10 m of the seabed. The spatial distribution of the data sets used in the assessment is illustrated in Figure 14.

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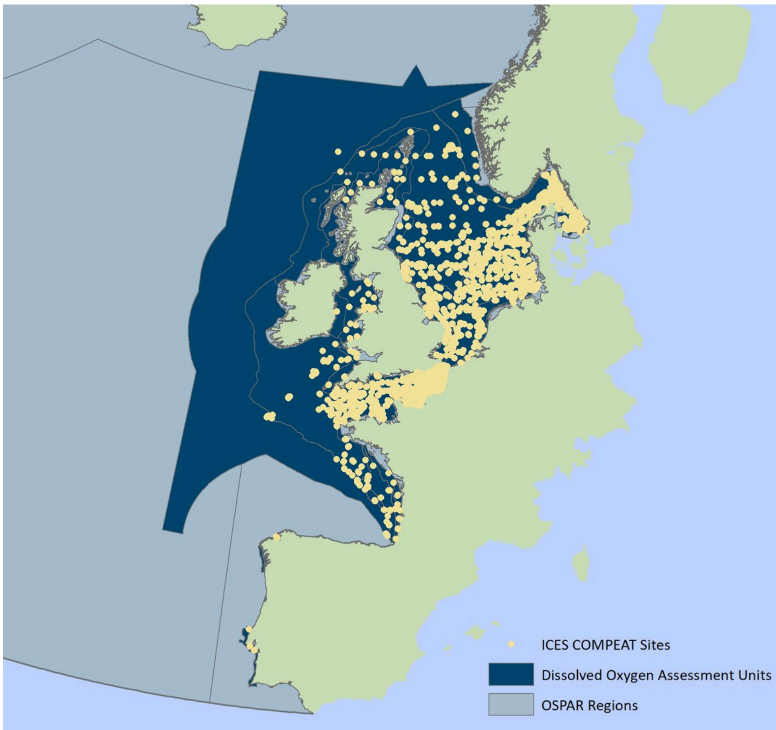

Figure 14. Assessed area showing sites where ICES oxygen concentration data were available for the period 2015–2020 Filtered by season (stratification season 1 July–31 October), depth (within 10 m of the seafloor) to obtain the specific data required for the assessments.

The temporal confidence (year-to-year variation and the continuity of observations during the parameter-specific assessment seasons) and spatial confidence (spatial representability) of the parameter is depicted in Figure 15, using the eutrophication assessment areas. If smaller subdivisions of the assessment areas (grid cells) are used, the confidence is even lower.

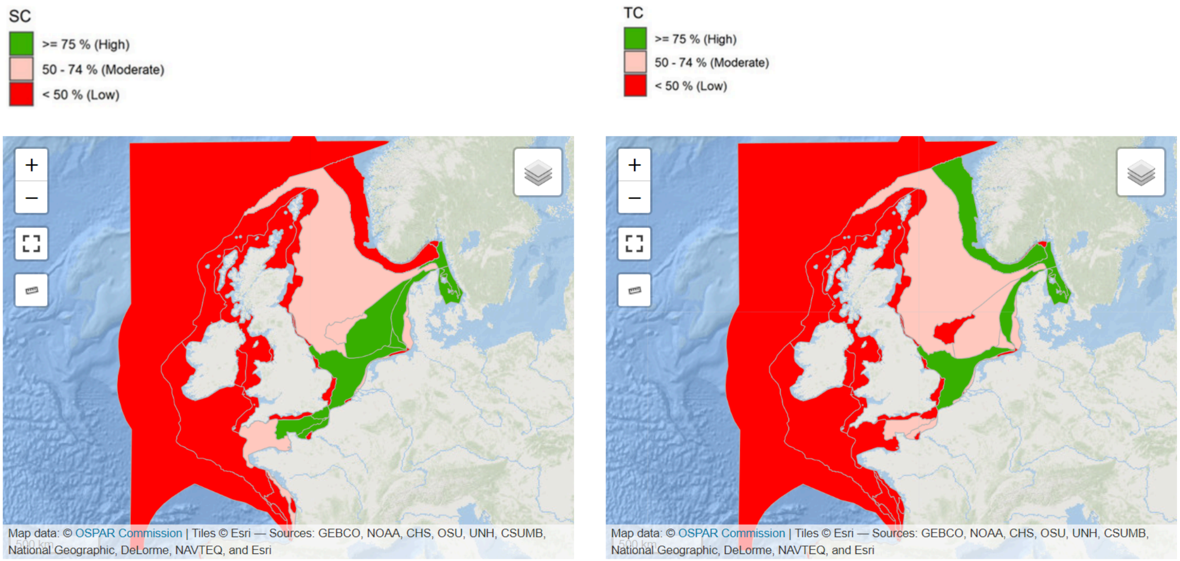

Figure 15. OSPAR Eutrophication Confidence 2015 - 2020. Months 3 - 9. Depths 0 - 10. Metric: dissolved oxygen close to the seafloor. Left panel: spatial confidence. Right panel: temporal confidence. Available at: https://odims.ospar.org/en/submissions/ospar_dissolved_oxygen_sc_2020_06/ and https://odims.ospar.org/en/submissions/ospar_dissolved_oxygen_tc_2020_06/

A knowledge gap related to data coverage has been identified in the dissolved oxygen assessment: Improve future assessments by strengthening the ICES database by uploading existing monitoring and/or research data, which are held in local or regional databases (Devlin et al, 2023).

Indicator assessments and data needs - HELCOM

HOLAS3 contains two indicator assessments that use dissolved oxygen concentration data: 'Oxygen debt' (HELCOM, 2023g) and 'Shallow water oxygen'(HELCOM, 2023c).

In stratified Baltic waters, dissolved oxygen depletion occurs regularly below the halocline. The core indicator 'Oxygen debt' is defined as the "missing" oxygen relative to a fully saturated water column, another term often used is the apparent oxygen utilization (AOU). By using the oxygen debt instead of the actual oxygen concentration, the variations due to temperature-controlled solubility are excluded. Data were provided by contracting parties and reported to the ICES Data centre. The confidence of the indicator status evaluation is based only on the accuracy of the threshold-setting protocol. In the areas assessed this confidence is high. No evaluation of the spatial and temporal confidence is given.

In shallow Baltic waters the pre-core indicator 'Shallow water oxygen' uses area-specific approaches to evaluate near bottom oxygen conditions. Assessment methods for this pre-core indicator are yet to be commonly agreed in HELCOM. Data reported to ICES were combined with national databases, see HELCOM 2023c for details. Most of the subdivisions where this indicator was applied the confidence was considered high or moderate. However in the Pomerian Bay the spatial confidence was low, because less than 60% of the area was sampled per year, leaving a large part of Pomeranian Bay without monitoring and without substantial information on oxygen concentrations.

Overview of data needs in Regional Sea Conventions - dissolved oxygen

Monitoring and reporting of dissolved oxygen follows well-developed guidelines in OSPAR and HELCOM, see Table 7 for metadata. The OSPAR indicator 'Concentrations of dissolved oxygen near the seafloor' and the HELCOM indicator 'Shallow water oxygen near the bottom' both use data close to the seafloor. The other HELCOM indicator 'Oxygen debt below the halocline' uses vertical profiles. For the latter parameter no low confidence assessments were found, hence there is no imminent need for more vertical profiles. However, data needs concerning oxygen concentrations close to the seafloor have been identified for a number of OSPAR assessment areas and for one HELCOM subdivision (Table 7).

Table 7. Dissolved O_2 Regional Sea data needs. Coloured cells: green – no data needs; red - data needs identified.

Dissolved O2 (DO)	**User – data needs**		
metadata	**OSPAR**	**HELCOM**	**HELCOM**
indicator	Concentrations of Dissolved Oxygen Near the Seafloor in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast	Oxygen debt below the halocline (taken from DO depth profiles)	Shallow-water oxygen near bottom
Metric	dissolved oxygen concentration	Dissolved oxygen (DO); oxygen saturation	Dissolved oxygen (DO); oxygen saturation
unit	mg/l O_2	ml/l O2 at STP** and/or in % of saturation	ml/l O2 at STP** and/or in % of saturation
months	7-10	Mapping stations: late Summer/Autumn (july-October) in critical areas	Mapping stations: late Summer/Autumn (july-October) in critical areas
Sampling resolution	not specified. Dependent on spatial and temporal variability in an assessment area and acceptable statistical power to detect a change in O_2 concentration in a 6-year assessment period.	mapping stations/cruises: few times per year cruise: >12 times per year*	mapping stations/cruises: few times per year cruise: >12 times per year*
Sampling depth	within 10 m from the seafloor	Oxygen debt: preferably whole water column; CTD cast: Water samples at depths of 1, 2.5 (Polish marine areas), 5, 10, 15, 20, 25 (Kattegat and the Belt Sea only), 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 300 and 400 meters; and as close to the bottom as possible Mapping stations: preferably less than 1 m from the sediment surface	Oxygen debt: preferably whole water column; CTD cast: Water samples at depths of 1, 2.5 (Polish marine areas), 5, 10, 15, 20, 25 (Kattegat and the Belt Sea only), 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 300 and 400 meters; and as close to the bottom as possible Mapping stations: preferably less than 1 m from the sediment surface
Parameter applied in:	all assessment areas in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast (see Annex 1, Fig. A2)	Bornholm Basin and Baltic Proper (containing Gdansk Basin, Western Gotland Basin, Eastern Gotland Basin, Northern Baltic Proper and Gulf of Finland Western assessment units)	Bothnian Sea, the Quark, Bothnian Bay, Gulf of Riga, Pomeranian Bay, Kattegat, Danish Straits and Arkona Basin
Subregion – low temporal confidence	ADPM, ASS, ATL, CCTI, CIRL, CNOR3, CUK1, CUKC, CWBC, CWM, DB, ECPM2, EMPM, GBCW, GBSW, GDPM, HPM, IRS, IS1, IS2, LBPM, NAAC2, NAAC3, SCHPM2, SPM, SS, THPM (see Annex 1, Table A1)	none	none
Subregion – low spatial confidence	ADPM, ASS, ATL, CIRL, CNOR3, CUK1, CUKC, CWBC, ECPM2, EMPM, GBSW, GDPM, HPM, IRS, IS1, IS2, LBPM, NAAC3, NT, SCHPM1, SPM, SS, THPM (see Annex 1, Table A1)	none	Pomeranian Bay (part of Bornholm Basin German Coastal Waters)

* basically monthly sampling but weekly in the vegetative period
** STP = standard temperature and pressure

In this Deliverable the following analysis of user-data needs was made, and this can help the JERICO community to better align with the needs of its clients.

How can current and future JERICO projects contribute to dissolved oxygen data needs?

Table 7 (above) provides the overview of methods used and dissolved oxygen data needs in the OSPAR QSR 2023 and HELCOM HOLAS3, identifying areas where coverage is insufficient. We have made an inventorisation of stations measuring dissolved oxygen in the map-catalogue. Comparison with the data needs generates an overview whether suitable platforms may be available that can contribute to enhancing the confidence of the indicator assessments. However, the map-catalogue in many cases does not inform about the sampling depth, which is crucial for the indicators under consideration.

Potential contribution to OSPAR areas of low confidence

The JERICO map-catalogue contains 71 point stations in 8 countries (BE, DE, DK - Faroer, ES, FR, NO, UK) measuring dissolved oxygen. However, the OSPAR indicator requires dissolved oxygen samples within 10 m from the seafloor. For only two German stations (one located near Spitsbergen) and 9 stations along the French coast (Figure 16) we could find information indicating that samples were taken close to the seafloor, although numerical distance from the seabed was lacking. In order to find this information we used the web links included in the map-catalogue (heading ONLINE). The French website www.somlit.fr was sufficiently user friendly and enabled identification of stations in the OSPAR area, where dissolved oxygen close to the seafloor is measured. See Figure 16 for the outcome of this selection. However, many of the other web links do not directly connect to a database containing metadata and most of them are in national languages only. Hence, for the other 57 stations found in the map-catalogue we could not find sufficient sampling depth information for dissolved oxygen.

Figure 16. French stations measuring dissolved oxygen close to the seafloor in the OSPAR area. Locations: Roscoff (Astan), Wimereux (Point C, Point L), Gironde (pk 30, pk 52, pk 86). In: www.somlit.fr

Figure 17 shows the positions of the stations with identified bottom sampling, of which the Gironde stations fall outside of the OSPAR assessment areas, since these do not include WFD water bodies. The Roscoff and Wimereux stations can contribute to improving the low temporal confidence in the

OSPAR assessment areas named Channel well mixed and Channel coastal shelf tidal respectively (CWM and CCTI, see Figure A2 and Table A1). The Helgoland station is not located in a low confidence area, but may contribute to improving the confidence. However, most probably these stations are already included in the dataset underlying the oxygen indicator assessment (Figure 14).

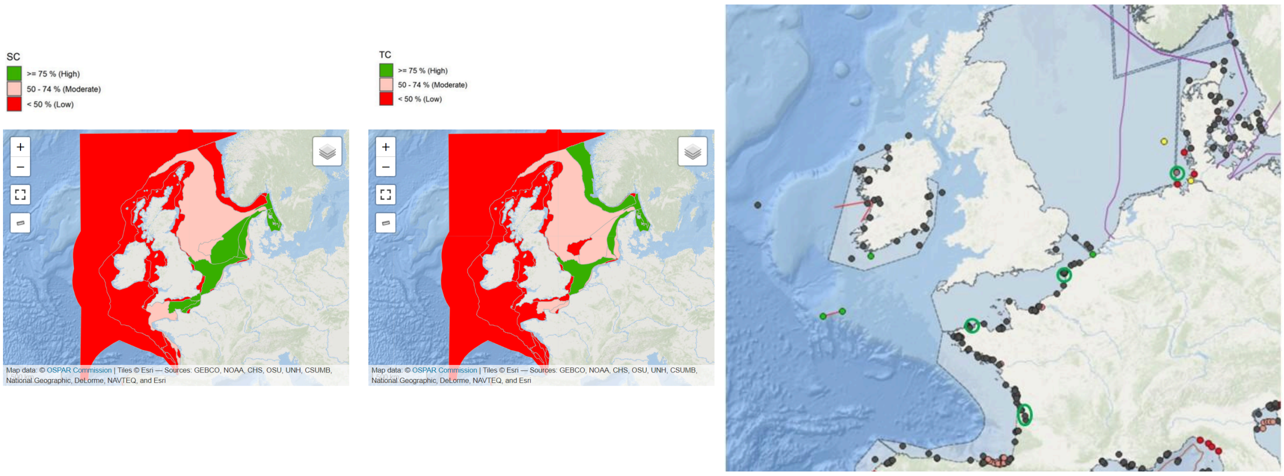

Figure 17. Low confidence assessment areas in the OSPAR indicator assessment Oxygen concentrations close to the seafloor (left panel, same as Figure 8) versus stations in the JERICO map-catalogue measuring dissolved oxygen close to the seafloor (right panel, green circles).

Data needs related to assessing eutrophication status, phytoplankton composition and the carbonate system have been addressed for instance in the Channel and North Sea PSSs. Deliverable D4.1 presents actions to improve the data coverage and coherence of observations between platforms and institutes. 3D hydrographical models can also help to complement and guide *in situ* sampling, especially through identification of areas sensitive to oxygen depletion.

Given the outcome of the present analysis it is of primary importance for the JERICO network to better communicate the metadata, in order to identify which stations measure bottom oxygen concentrations. Furthermore, due to the gaps in reporting to the map-catalogue, we cannot see whether it contains datasets that may complement the datasets already used in the indicator assessment. This should be clarified by contacting the relevant expert group mentioned in Table 12. The occurrence of oxygen depletion very much depends on oceanographic conditions, such as depth, stratification and temperature and on the weather. An exchange with the RSCs expert groups could clarify the oxygen depletion sensitive areas, where monitoring should be specifically enhanced.

Potential contribution to HELCOM areas of low confidence

The HELCOM assessment of the indicator 'Shallow water oxygen' highlights low spatial confidence in the Pomeranian Bay (Pommersche Bucht in German). For this indicator observations within 1 m (or as close as possible) from the seafloor are used, in addition to vertical profiles. In the map-catalogue no stations in the Pomeranian Bay are included (Figure 18). We found four point stations measuring dissolved oxygen, located in SE, FI and EE waters, but information on sampling depth was not easily accessible. We assume that the line stations (notably Ferryboxes mounted on ships) included in the map-catalogue will not deliver bottom oxygen concentrations.

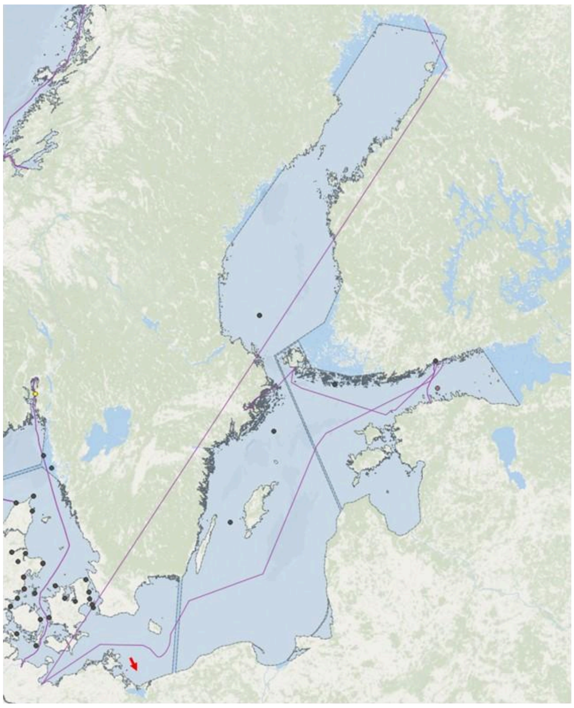

Figure 18. Low spatial confidence in the Pomerarian Bay (red arrow) in the HELCOM indicator assessment 'Shallow water oxygen'. In this area no stations appear in the JERICO map-catalogue.

3.5.2 Theme ocean acidification

Ocean acidification (OA) is currently not assessed under the MSFD. However, OSPAR and HELCOM have delivered assessments under this theme in their QSR 2023 and HOLAS3 respectively. The UNEP/MAP QSR does not yet include such an assessment, since it follows the MSFD requirements.

Overview of indicators, assessment areas, monitoring guidelines and databases

OSPAR

Ocean acidification has been observed in all OSPAR Regions during the past decades and is projected to keep occurring and even accelerate under the higher carbon dioxide emission scenarios. OSPAR's North East Atlantic Environment Strategy mentions the need for monitoring and assessing this theme. The first OSPAR assessment 'Ocean Acidification' (McGovern et al,, 2022) focuses on the parameters pH and aragonite saturation state (ΩArag). No (common) indicators for ocean acidification have yet been defined.

A monitoring guideline is available for all four measurable carbonate species: total dissolved inorganic carbon (DIC), total alkalinity (TA), partial pressure (of dissolved) carbon dioxide (pCO_2), and hydrogen ion concentration measured as pH_2 (JAMP Guidelines for Monitoring Chemical Aspects of Ocean Acidification (Agreement 2014-03)). In order to quantify trends in ocean acidification at least two out of these four parameters determining the carbonate system need to be monitored.

OSPAR contracting parties submit their data for the ocean acidification assessments to the ICES data centre using a data reporting format. These data are then quality controlled and available in the ICES DOME (Marine Environment) database.

In addition, OSPAR uses the Global Ocean Data Analysis Project (GLODAP) data product to illustrate variability in pH and ΩArag in the ocean interior of selected areas of the OSPAR Regions.

It is advised that all monitoring laboratories should be involved in the Global Ocean Acidification Observing Network (GOA-ON) to keep up-to-date with quality control efforts as well as feedback and develop these.

HELCOM

HELCOM has delivered the 'Baltic Sea acidification' element indicator assessment as part of its HOLAS3 (HELCOM, 2023d). The Baltic Sea carbonate system is undergoing large changes due to: 1) increasing CO_2 in the atmosphere, 2) increasing inputs of total alkalinity (A_T) from land, 3) changes in the balance between primary production and respiration due to eutrophication/ oligotrophication, and 4) warming, shifting the carbonate speciation towards higher CO_2 partial pressure (pCO_2) and lower pH levels. Central parameters in the assessment are pH and pCO2.

HELCOM has included total alkalinity (TA or A_T) and pH in its COMBINE General Guidelines for monitoring of the Baltic Sea (HELCOM, 2006). Updated Guidelines for sampling and determination of pH in seawater are also available (Guidelines for sampling and determination of pH in seawater). For measuring pH in brackish waters the potentiometric measurement is recommended. HELCOM intends to closely follow the progress in theory and technology of this method for brackish water applications, because of its high accuracy and superior long-term traceability. Long-term traceable measurement of pH at a resolution reflecting gradual nature in brackish water systems is considered important. HELCOM also has published Draft guidelines for sampling and determination of total alkalinity. However, no guideline for sampling and determination of pCO2 is available.

HELCOM contracting parties submit their data annually to the HELCOM COMBINE database, hosted by ICES.

Parameter pH

The parameter pH does not occur in the MSFD reporting. However, it is a central measure of ocean acidification and as such assessed by OSPAR and HELCOM.

Assessment and data needs - OSPAR

The parameter pH is used in the Ocean Acidification assessment, using the national data contributions for the calculation of de-seasonalised small scale trends in coastal and shelf waters. These have been calculated using the longer time series that were available from Contracting Parties' data submissions, for example from the 1970s or early 2000s to today. For time-series datasets where pH was not measured directly, pH was calculated from dissolved organic carbon (DIC) and total alkalinity (TA) or DIC and pCO2 when TA was not available. Information on reported OA measurements, *ie*. stations, responsible institutes, parameters, duration of time series, temporal resolution, sampling depth, analytical methods, database etc. is provided in McGovern et al., 2022 (see Tables S1 and S2 therein).

No evaluation of the confidence of the parameter is available, although it was stated that the continuous development and improvement of models used in the assessment (both in terms of spatial resolution and representation of the biological processes) requires an increasing amount of data to be collected in order to prove the validity of such improvements. Continuing and expanding current monitoring in *coastal regions* will be of great use to inform and support the modelling work. In addition, a bias towards measurements during Summer was found, indicating that *more Winter measurements* are needed to properly assess seasonal patterns and trends among years. The following knowledge gaps related to data coverage and data quality have also been identified in the ocean acidification assessment (McGovern et al, 2022):

- There are few long-term high-quality observational time series; there is a need for OSPAR Contracting Parties to provide continued support to sustain these long-term observations and to further expand the observing network.

- Short-term variability requires multidisciplinary and integrated higher sampling resolution than is presently available for most datasets in order to resolve physicochemical and biological processes and understand drivers and the implications for biological systems.
- Time-series stations need to be monitoring more than one variable of the carbonate system (*i.e.* not just pH) together with associated data, in order to fully elucidate the carbonate system, including aragonite saturation state, and investigate the drivers of change.
- Time-series stations need to continue with strong quality assurance (QUASIMEME, CRMs, and others) and follow standard operating procedures and guide for best practices.
- The data availability and transparency should be improved in order to increase data flow between data centres, so that data can be incorporated into synthesis products and reports, while still acknowledging and maintaining connection with the original data collectors.

Indicator assessment and data needs - HELCOM

The parameter pH is used in the Baltic Sea Acidification assessment, using the national data reported to the ICES data centre. In addition, historical data from various monitoring programs, generally with low precision but offering long trends with many observations, have been used.

The confidence of the assessment is overall moderate, and high in the central Baltic Sea. However, the following data needs were highlighted in the Acidification assessment. AT and pH are not consistently monitored across the Baltic Sea (Figure 19), and data have been measured and reported with varying precision and quality. Many areas only have a few spot samples, particularly in the coastal zone, whereas longer time series exist for the open Baltic Sea. The amount of pH observations increased from the 1970s and peaked in the early 2000s, reaching a contemporary level of ~1500 profiles per year. This is substantially lower than the similar data amount for nutrients, chlorophyll, and oxygen. A consequence is that acidification trends can be assessed only for the regular open water stations and a limited amount of coastal stations (HELCOM, 2023d). HELCOM advises contracting parties to include A_T and pH as standard hydrochemistry variables in their monitoring programs. A_T and pH are low-cost measurements that are fairly simple to analyse and therefore, adding these to existing monitoring programs will only marginally increase the cost of monitoring. The measurement procedures for pH should be further homogenized and mean quality of data should be improved (HELCOM, 2023d).

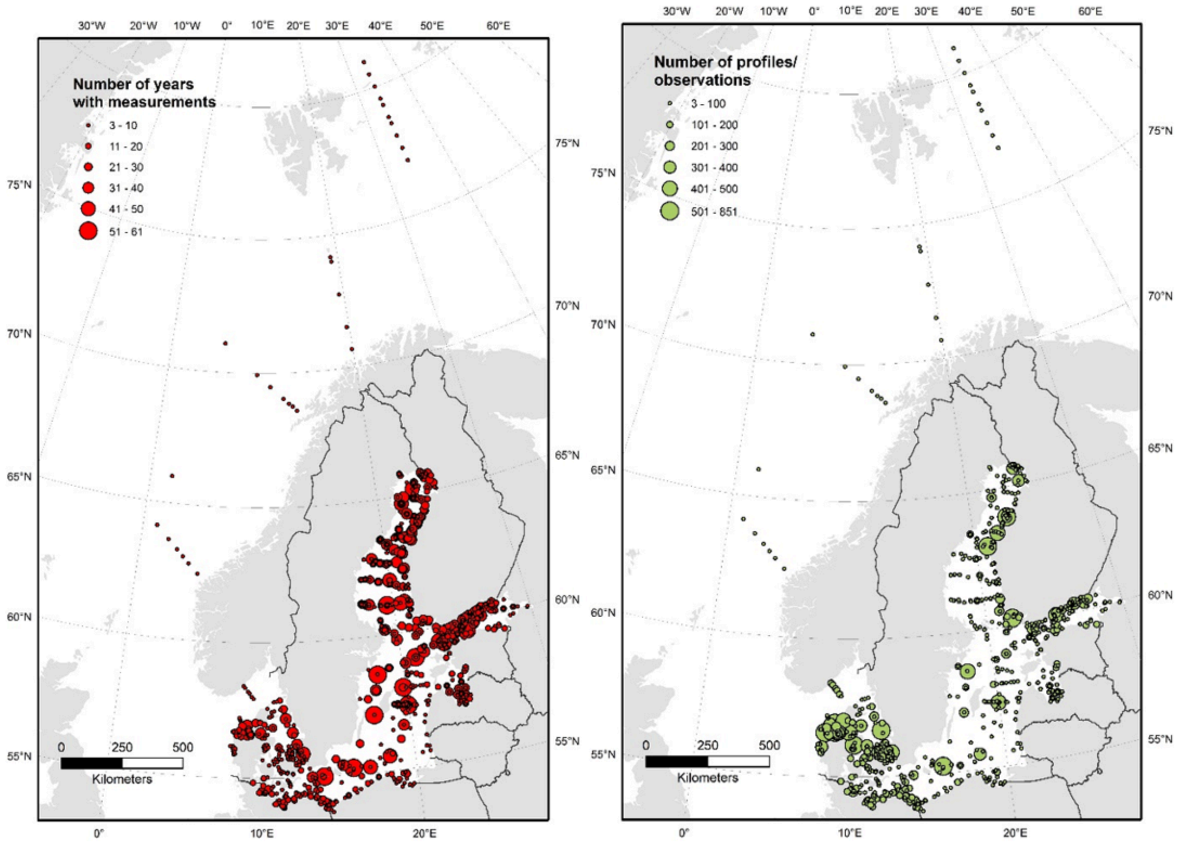

Figure 19: Length of time series and number of profiles/observations of pH across the Baltic Sea. Data from ICES and Danish monitoring program, compiled by the TRIACID project. In: HELCOM, 2023d.

Overview of data needs in Regional Sea Conventions - pH

There is no established EU-wide convention on how to apply pH-data for assessment of ocean acidification. There is no assessment of acidification in the Mediterranean, and as we can see in Table 8 (below) data needs are defined differently between OSPAR and HELCOM.

Table 8. pH Regional Sea data needs. Coloured cells: green – no data needs; red - data needs identified.

pH	**User – data needs**	
metadata	**OSPAR**	**HELCOM**
Metric	pH	pH
unit	total hydrogen ion scale	NBS scale
precision	desired analytical accuracy ± 0.002	pH values are reported with two decimal digits
months	1-12	1-12
Sampling resolution	spatial resolution: not specified. Use models to select representative monitoring stations. Coastal areas: along salinity gradients. Shelf: consideration of inflow of oceanic waters across the shelf break. Temporal resolution: not specified. Ranges from continuous to annual.	cruise: >12 times per year*

pH	User – data needs	
metadata	OSPAR	HELCOM
Metric	pH	pH
Sampling depth	not specified; surface, surface and bottom, or full water depth are monitored	Samples are collected at depths of 1, 5, 10, 15, 20, 25 (Kattegat and the Belt Sea only), 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 300 and 400 metres; and as close to the bottom as possible.
Subregion – low temporal confidence	Winter measurements are generally underrepresented; higher temporal resolution needed to capture short-term variability	need for long term time series with highest possible precision
Subregion – low spatial confidence	need to expand the monitoring in coastal areas to support models	open Baltic Sea

* basically monthly sampling but weekly in the vegetative period

How can current and future JERICO projects contribute to Regional Sea Convention's pH data needs?

The objective of the JERICO projects is to improve the European observational infrastructure, bringing expertise and high- quality data on European coastal and shelf seas, to better answer societal and policy needs. Obviously, most of the efforts in the JERICO-S3 project are focused on improving technical expertise. But to better address societal and policy needs, the needs and expectations from the policy realm need to become visible. For pH we have made an overarching description of needs.

Table 8 (above) provides the overview of metadata for the parameter pH used in the QSRs and of data needs, including areas where coverage is insufficient. We have made an inventarisation of stations measuring pH in the map-catalogue. We noticed the following:

- In the OSPAR region, 45 JERICO stations measure pH, mostly in Spanish (21) and French (18) waters;
- In the UNEP-MAP region, 12 JERICO stations measure pH, in French, Italian, Greek and Spanish waters;
- In the HELCOM region, there is 1 JERICO station measuring pH. This is a striking difference with the number of stations contributing to the ocean acidification assessment (Figure 19).

Table 9. pH monitoring stations as mentioned in JERICO map-catalogue

Region	Country	Number of stations
OSPAR	BE	1
OSPAR	FR	18
OSPAR	DE	4
OSPAR	NO	1
OSPAR	ES	21
UNEP-MAP	FR	4
UNEP-MAP	GR	2

UNEP-MAP	IT	4
UNEP-MAP	ES	2
HELCOM	FI	1
Canary Islands	ES	1

Again, the map-catalogue does not reflect the existing number of pH measurements, as many partner institutes only included dedicated JERICO stations in the map-catalogue. French and Spanish partners have been most active in submitting data. Furthermore, user data needs (sampling metadata, low confidence areas) are relatively unclear. A follow-on JERICO project could, as a priority, work on interregional harmonisation of pH measurement requirements, and the Spanish and French institutes most active in reporting these data to JERICO could take the initiative, as their measurements occur in two regional sea areas. The OSPAR knowledge gaps mentioned in section 'Assessment and data needs - OSPAR' may offer guidance.

Parameter pCO_2

The parameter pCO_2 (partial pressure of CO_2) does not occur in the MSFD reporting. However, it is a central measure of ocean acidification and as such assessed by HELCOM. OSPAR uses pCO_2 to indirectly estimate pH.

Assessment and data needs - OSPAR

The parameter pCO_2 is not used as such in OSPAR's Ocean Acidification assessment, which focuses on pH and aragonite saturation state. However it is one of the four measurable carbonate species and for time-series datasets where pH was not measured directly, pH was calculated from dissolved inorganic carbon (DIC) and total alkalinity (TA) or from DIC and pCO_2 when TA was not available. See Tables S1 and S2 in McGovern et al., 2022 for stations where pCO_2 is measured.

Data needs are not specifically targeted to pCO_2. Therefore, the information under Parameter pH applies (see section above) and has been copied in Table 9 (lines informing on sampling resolution and low temporal and spatial confidence).

Indicator assessment and data needs - HELCOM

The parameter pCO_2 has been used in the HELCOM acidification assessment. The carbonate system is described by four parameters, *i.e.* dissolved inorganic carbon (C_T), total alkalinity (A_T), pH, and pCO_2. Measurement of all four parameters is straightforward (Dickson et al., 2007). pCO_2 and C_T are not explicitly mentioned in the COMBINE General Guidelines for monitoring of the Baltic Sea (HELCOM, 2006), but straightforward SOPs exist (Dickson et al., 2007; Pfeil et al., 2013), and the methodological approach does not differ from that for open ocean waters. For the assessment of the carbonate system in surface waters, the measurement of pCO_2 through water-air equilibration coupled to infrared spectroscopy developed into an internationally used approach (Dickson et al., 2007), which led to the surface ocean CO_2 atlas (SOCAT). pCO_2 is monitored continuously on the commercial ship Finnmaid in a cooperation between IOW and SYKE. M/s Finnmaid travels approx. twice a week from Helsinki (Finland) to Travemünde (Germany) and back. Surface monitoring of pCO_2 is currently initiated on several other commercial vessels as an action of the BONUS Project BONUS INTEGRAL.

pCO_2 measurements are few and scattered, or non-existing, in the Kattegat, the Danish Straits, and the major gulfs (i.e., the Gulf of Bothnia, Finland, and Riga, respectively).

Overview of data needs in Regional Sea Conventions - pCO_2

Although pH is a central parameter in acidification assessment, both OSPAR and HELCOM have a requirement to understand the carbonate system, and have identified data needs: more regional coverage, and probably over more depths, is needed, but metadata for these data needs are not clearly specified (*cf.* Table 10).

Table 10. pCO_2 *Regional Sea data needs. Coloured cells: green – no data needs; red - data needs identified.*

PCO_2	**User – data needs**	
metadata	**OSPAR**	**HELCOM**
Metric	Partial pressure of (dissolved) CO_2 in water	Partial pressure of CO_2 in water
unit	microatmospheres (µatm)	*
precision	not specified	*
months	1-12	*
Sampling resolution	for assessment of air-sea fluxes monitoring with repeat-visit sites on at least a monthly basis in representative areas needs to be done. Coastal areas: along salinity gradients. Shelf: consideration of inflow of oceanic waters across the shelf break. Temporal resolution: not specified. Ranges from continuous to annual. Sufficient data should be collected to cover the maximum winter DIC concentrations.	*
Sampling depth	not specified; surface, surface and bottom, or full water depth are monitored	*
Subregion – low temporal confidence	Winter measurements are generally underrepresented; higher temporal resolution needed to capture short-term variability	Kattegat, the Danish Straits, and the major gulfs (i.e., the Gulf of Bothnia, Finland, and Riga, respectively)
Subregion – low spatial confidence	spatial resolution: not specified. Use models to select representative monitoring stations. Coastal areas: along salinity gradients. Shelf: consideration of inflow of oceanic waters across the shelf break. Temporal resolution: not specified. Ranges from continuous to annual.	Kattegat, the Danish Straits, and the major gulfs (i.e., the Gulf of Bothnia, Finland, and Riga, respectively)

* Not specified in Manual for marine monitoring in the COMBINE programme.

How can current and future JERICO projects contribute to Regional Sea Convention's pCO_2 data needs?

The JERICO map-catalogue only mentions 4 stations measuring pCO_2, and all of these stations are in the UNEP-MAP region (3 in Italian waters, 1 in Greek waters), suggesting that this is not well covered by JERICO stations.

Both OSPAR and HELCOM mention a requirement for a larger coverage, noting that pCO_2 is one of the four parameters in the carbonate system and should be measured together with at least one of the other parameters. For surface pCO_2 we noted that there are other initiatives to monitor this value, the above-mentioned Surface Ocean CO_2 Atlas (SOCAT) is a leading global initiative. We suggest the JERICO network to liaise with the relevant OSPAR, HELCOM and UNEP/MAP expert groups (Table 12) to further discuss user needs and potential added value of the JERICO observing network. It should be noted that ocean acidification is a relatively new topic under the Regional Sea Conventions and their focus ultimately is on ecosystem effects of acidification. Long term trends and high resolution in the more complex waters are particularly important to understand these effects.

3.6. Towards EU-wide data coherence and comparability - JERICO cEGIM

The GOOS (https://goosocean.org/what-we-do/framework/essential-ocean-variables/) has adopted EOVs, which are feasible to measure across platforms, and provide relevant information for conservation and management (Miloslavich et al., 2018). Europe's Marine Strategy Framework Directive sets out eleven descriptors (The European Parliament and the Council of the European Union, 2008) to assess marine environmental status and establishes a strategy to preserve the marine environment and to protect resources of socio-economic value.

Today, driven by the significant technological evolution, ocean observatories around the world differ in their equipment and methodologies. This variability often creates issues related to compatibility and interoperability of the acquired data. Such technical and organizational heterogeneity has driven the need to establish a permanent and sustainable framework to adopt and develop standards and common tools. Towards this, the European Multidisciplinary Seafloor and water column Observatory (EMSO) community designed and developed the Generic Instrument Module (EMSO-EGIM), a generic ocean sensor underwater system (Lanteri et al., 2022). The central feature of EGIM is a standardized approach to measure a set of significant oceanographic variables by using consistent sensor and hardware specifications and deployment concepts with the same setting for each sensor, the same qualification and calibration methods and the same data format.

Building on this concept, JERICO-S3 has developed a long-term observation module able to measure a set of common coastal EOVs on the one hand and to integrate different sensor packages adapted to particular fields of study (e.g. Plankton variability, BGC Eutrophication) on the other hand (Delory et al., 2021). In particular this module, named coastal EGIM or cEGIM, is adapted to the harsh coastal environment constraints. The module is based on the Communication and Storage Front-end (COSTOF2), a platform developed by Ifremer and able to accommodate twelve sensors by providing them controlled power, a common time base, large data storage capacity, communication channels with local or remote users as well as an active anti-biofouling protection. The platform is able to work in a very low power environment with an event triggering capability – increase frequency of measurements during phenomena.

Due to shortage of funds the prototype is fitted only with four sensors (NKE MP6, BBE Moldaenke Fluoroprobe, Hydroptic / LOV UVP6 and SATLANTIC ISUS) lent by JERICO-S3 partners. It is designed to sit on the seabed measuring Temperature, Conductivity, Pressure,

Dissolved Oxygen, Turbidity, Fluorescence, Chlorophyll, Pictures, and Nitrate concentration. Additional variables such as underwater sound and currents velocity and current direction have been also successfully tested during EMSO tests. During JERICO-S3 a pre-demonstration of the prototype implementation and its associated data access chain took place from 16 December 2022 to 9 February 2023. The module was installed at the shallow-water site of Sainte-Anne du Portzic, where it could export its measurement data to a dedicated web server conforming to the Sensor Web Enablement OGC framework. The cEGIM embeds a bloom detection algorithm. Although more test are required with the full capacity of sensors, first trials indicate the high potential of cEGIM not only for JERICO but also for the wider community (operational observing and monitoring). Embedded in an easy-to-deploy frame, the EGIM meets very diverse implementation scenarios and multidisciplinary scientific purposes whilst keeping a generic design. Although EGIM due to its generic nature has the capacity to host many different sensors, in its initial configuration as developed in the framework of EMSO, several MSFD descriptors can be addressed (Table 11).

Table 11: MSFD parameters and relevant measurements taken by the EGIM through its initial configuration (EMSO).

MSFD DESCRIPTOR	CRITERIA	EGIM contribution
D1: Species groups of birds, mammals, reptiles, fish and cephalopods	D1C1	Indirectly through Temperature, Salinity, Chlorophyll and Oxygen observations
D1: Pelagic habitats	D1C6	Directly through Salinity observations
D2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems	D2C1 D2C2	Indirectly through observations of Temperature, Salinity and Oxygen
D3: Populations of all commercially-exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock	D3C1 D3C2 D3C3	Indirectly through observations of Temperature, Salinity, Oxygen, Currents, Turbidity
D5: Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	D5C1 D5C2 D5C3 D5C4 D5C5 D5C6 D5C7 D5C8	Directly through Nutrient, Chlorophyll, Oxygen, Turbidity and Currents observations.
D6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected	D6C1 D6C2 D6C3	Directly through Turbidity and Current observations.
D7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems	D7C1 D7C2	Directly through Turbidity,Current, Temperature and Salinity observations.
D8: Concentrations of contaminants are at levels not giving rise to pollution effects	D8C1 D8C2 D8C3	Indirectly through Oxygen and Turbidity observations
D10: Properties and quantities of marine litter do not cause harm to the coastal and marine environment	D10C1 D10C2	Indirectly through Turbidity observations
D11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	D11C1 D11C2	Directly through hydrophone data

It can operate on any facility, mooring line, seabed station both cabled and non-cabled, surface buoy and can host a variety of sensors. The EGIM can also be deployed as a completely independent system. It must be noted that sensors are selected not only according to the variable measured but also in terms of their specifications (range, accuracy, sensitivity) in order to meet fit-for-purpose criteria (for example climate change).

cEGIM offers a collaboration platform with other infrastructures promoting the observation of key variables in a systematic way, facilitating the interoperability of data. Moreover, the interoperable cEGIM data can be easily shared across different initiatives.

4. CONCLUSIONS AND RECOMMENDATIONS

This deliverable intends to help data providers find potential data users within the policy realm. We focused on the European Regional Sea Conventions OSPAR, HELCOM and UNEP/MAP

(BARCOM) as representatives of the policy realm and on their most recent 2023 assessments (QSRs and HOLAS reports). These reports and related monitoring guidances are easily accessible on the RSC's websites. RSCs jointly assessed the status of the environment for the 2024 MSFD reporting.

The 2023 assessments explicitly identify data needs that emerge from in depth analyses of available data used for indicator assessments. Since gaps in data lead to low confidence in the assessment, which hampers policy decision making, there will be an interest in improving the data base for the next cycle of assessments (2028-2030). To the extent possible we reflect the data needs in terms of metadata: what, where and when?

We did this exercise for five parameters, which were chosen from the JERICO map-catalogue, being an accessible, yet incomplete, database of datasets provided by JERICO partner institutes. The five parameters were reported by more than one institute and in all of the three Regions: chlorophyll *a*, phytoplankton, dissolved oxygen, pH and pCO_2. These parameters (but not necessarily the data in the map-catalogue) have been used in the following assessments:

- chlorophyll a:
    - Concentrations of Chlorophyll *a* (OSPAR)
    - Chlorophyll (HELCOM)
    - Chlorophyll *a* concentration in water column (UNEP/MAP)
    - Changes in Phytoplankton Biomass and Zooplankton Abundance (OSPAR)
- phytoplankton:
    - Changes in Plankton Diversity (OSPAR)
    - Changes in Phytoplankton and Zooplankton Communities (OSPAR)
    - Cyanobacterial bloom (HELCOM)
    - Phytoplankton (HELCOM)
- dissolved oxygen:
    - Concentrations of Dissolved Oxygen Near the Seafloor (OSPAR)
    - Oxygen debt (HELCOM)
    - Shallow-water oxygen (HELCOM)
- pH and pCO_2:
    - Ocean Acidification (OSPAR)
    - Baltic Sea acidification (HELCOM)

In all of these assessments statements were found on the confidence of the assessment and the need for more data. The level of detail in these statements varied from general statements such as 'more observations of parameter X needed in Winter' to fairly concrete, *eg.* 'spatial confidence of parameter X in assessment area Y is low'. For the more concrete data needs we could investigate to which extent the data sets in the JERICO map-catalogue would match these data needs. Potential matches were:

- **chlorophyll *a***: remote sensing chlorophyll a products are used in all Regions, hence there is less emphasis on *in situ* measurements. However, these measurements are still used for various reasons. In the HELCOM area, where eutrophication is widespread, a limited number of ferry box-equipped ships may contribute to improving low spatial confidence in parts of the area. In the UNEP/MAP area eutrophication is restricted to the coastal zones and the main issue here is the need for improving the quality of the data collection. The catalogue-map contains only few chlorophyll *a* datasets.
- **phytoplankton**: several AZTI and Ifremer stations, located in low confidence OSPAR assessment areas, could improve the confidence in these areas, since they seem to complement the data used for the assessments. In the entire HELCOM area low spatial confidence in the cyanobacterial biomass indicator assessment was found. The number of Baltic stations measuring phytoplankton or phycocyanin (a pigment found in

cyanobacteria) in the map-catalogue is very small, but it could be a starting point for better collaboration, notably on the use of ferry box datasets, with the policy realm.

- **dissolved oxygen**: the assessments of dissolved oxygen focus on oxygen depletion close to the seafloor (OSPAR and HELCOM) and below the halocline (HELCOM). Therefore, we made an effort to find out at which depth the oxygen measurements in the map-catalogue were taken. This information was not readily available, but in one of the underlying databases (www.somlit.fr) we were able to find a few stations where oxygen was monitored close to the seafloor and which were located in OSPAR low confidence assessment areas. However, potential added value is not clear, as these datasets may already have been included in OSPAR's oxygen indicator assessment. In the HELCOM area, data needs were restricted to one subdivision only and no station in the map-catalogue appears in that area. Moreover, information on sampling depth was lacking.
- **pH and pCO_2:** the parameters pH and pCO_2 are part of the carbonate system that is used to assess the level of ocean acidification. This is a relatively new theme in the OSPAR and HELCOM assessments and not yet covered in UNEP/MAP, since it is not a descriptor under the MSFD. Data user needs are relatively unclear, although both HELCOM and OSPAR call for better data coverage, *i.e.* in Winter and in coastal areas to support models (OSPAR), more long and high precision time series, more data in the open Baltic (HELCOM). Again, the datasets included in the map-catalogue are relatively scarce. However, JERICO could contribute to improving the data coverage, in collaboration with user groups.

The potential matches summarised above need further specification, for instance on sampling and analytical techniques, precision, sampling depth, frequency, months sampled etc. Such detailed information generally is available in the Regional Sea Convention's monitoring guidances, although the level of detail varies among indicators. The JERICO map-catalogue contains relatively little of such information. Further investigation requires involvement of experts from user groups and data providers. The relevant user groups in OSPAR, HELCOM and UNEP/MAP are shown in Table 12. In order to contact a user group it is best to approach the contact person at the Regional Sea Convention's Secretariat, see Table 12.

JERICO, in the form of projects or as established long term joint infrastructure, can take the role to better connect data providers to relevant RSC groups and start collaboration, if this is not already established. In this way, more datasets can find their way in future updates of the QSRs/HOLAS assessments, the first of which are expected by 2028/2029 for the 2030 reporting under the MSFD. An interactive, well designed tool like a JERICO map-catalogue can be an extremely valuable tool to connect data users (*e.g.* policy realm, research institutes) to data providers (organisations responsible for monitoring). The information flow can go two ways: where can I find what I need, and where will my data have added value.

It is essential that there are clear expectations and defined requirements of what such a catalogue needs to do, as we found a number of issues that hampered use of the dataset.
Lessons learned on the map-catalogue from a user perspective:

- In some areas/countries we noticed the map-catalogue contained a very limited number of stations compared to stations included in RSCs assessments, indicating that the catalogue is far from complete- we assume that some countries added information on all existing monitoring capabilities, others only added information on stations that were explicit part of the current JERICO project.
- Information on overlap between catalogue stations and RSC stations can sometimes be concluded from maps (example: phytoplankton), but in many cases the overlap is unknown, meaning that we don't know whether the catalogue contains additional data sets;

- Lacking metadata in catalogue: sampling depth, eg. distance from seafloor for dissolved oxygen, temporal resolution/monitoring frequency, precise definition of parameters such as phytoplankton. This does not only hamper comparison with user data needs, but also an assessment of comparability between data sets from different providers;The analysis of dissolved oxygen datasets would have been much more effective if sufficient information was included on sampling depth.
- Websites under the heading LINK_DATA in the catalogue are difficult to understand (national languages) and in many cases we cannot find metadata.
- No option to select a specific parameter and show the stations collecting that parameter. Such an option would have made life so much easier.

Table 12. Expert groups in the three Regional Sea Conventions responsible for data gathering and assessment of indicators using the parameters mentioned

RSC	**expert group**	**RSC secretariat contact**	**parameter**				
			chl a	**phytoplankton**	**O_2**	**pH**	**pCO_2**
OSPAR	ICG-Eut	Barbara.Middleton@ospar.org	x		x		
	ICG-COBAM - Pelagic habitats expert group	Franziska.Bils@ospar.org	x	x			
	WG COCOA	Carole.Durussel@ospar.org				x	x
HELCOM	EG EUTRO	Joni.Kaitaranta@helcom.fi	x	x	x		
	EG Phyto	Laura.Kaikkonen@helcom.fi		x	x		
	Project based	n/a				x	x
UNEP/MAP	CorMons and online working Groups (OWG)	Jelena.Knezevic@un.org	x (eutrophication	x (biodiversity)			

Abbreviations:

ICG-COBAM - OSPAR Intersessional Correspondence Group on Coordination of Biodiversity Assessment and Monitoring
ICG-Eut - OSPAR Intersessional Correspondence Group on Eutrophication
WG COCOA - OSPAR Working Group on Changing Ocean Climate and Ocean Acidification
EG EUTRO - HELCOM Expert Group on Eutrophication
EG Phyto - HELCOM Expert Group on Phytoplankton
CORMONs - UNEP/MAP Integrated Meetings of the Ecosystem Approach Correspondence Groups on IMAP Implementation

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6. ANNEXES

Annex 1. Regional Sea Convention's subregions and assessment units

OSPAR

Regions

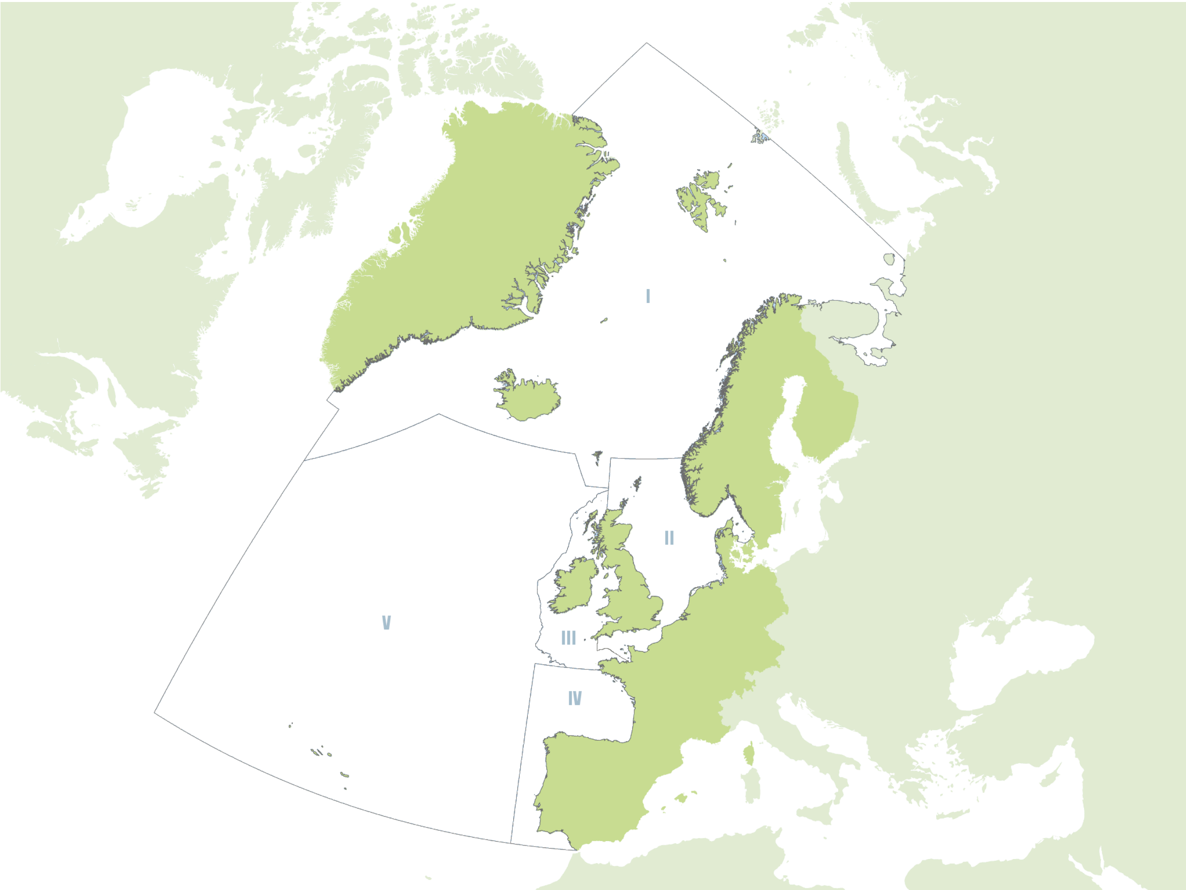


Figure A1. OSPAR has divided its Maritime Area into five regions: Region I – Arctic Waters; Region II – Greater North Sea; Region III – Celtic Seas; Region IV – Bay of Biscay and Iberian Coast; and Region V – Wider Atlantic

Eutrophication and pelagic habitats assessment areas

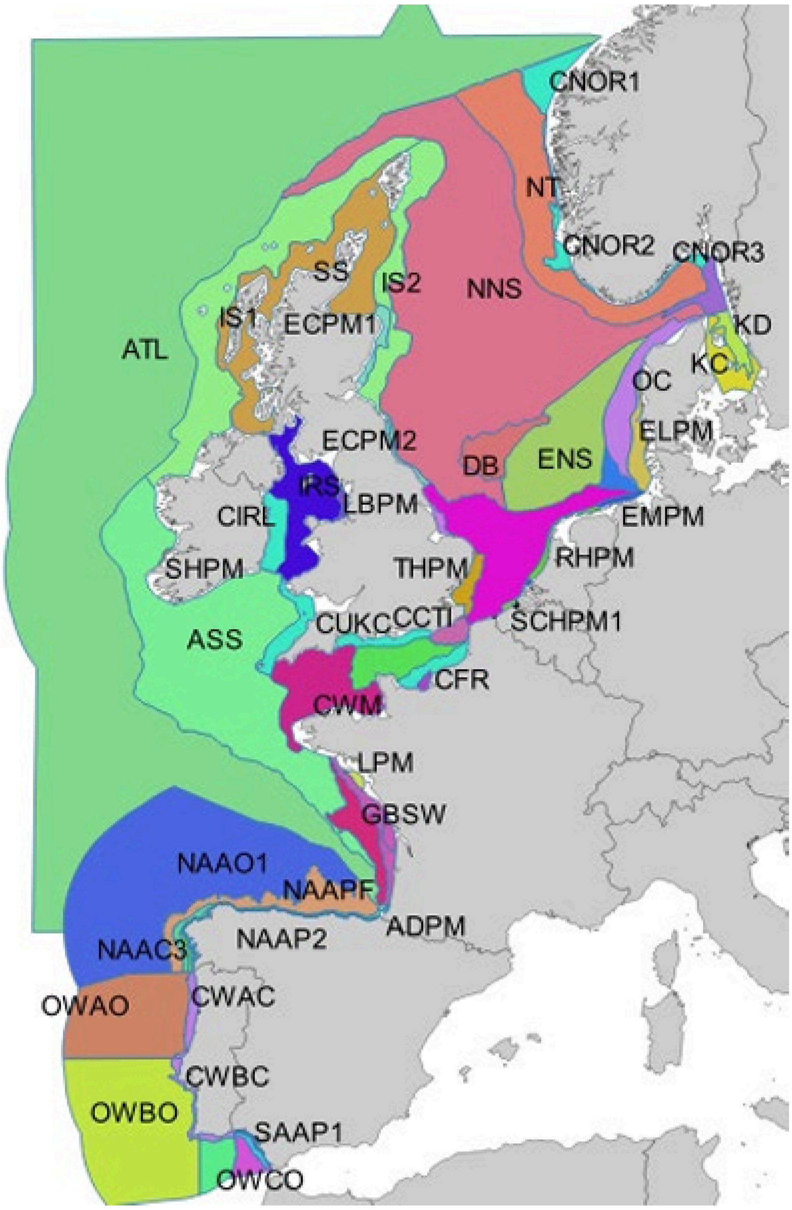


Figure A2: Overview of ecologically relevant assessment areas based on duration of stratification, mean surface salinity, depth, suspended particulate matter and primary production. In: OSPAR, 2022.

Table A1: COMP4 assessment areas of the North-East Atlantic grouped into categories of river plumes, coastal, shelf, and oceanic areas including allocation to OSPAR Regions (based on the largest share when region boundaries split assessment areas, indicated in bold).

Categories of COMP 4 assessment areas	Area code	Area name	OSPAR Region
River plumes	ADPM	Adour plume	IV
	ELPM	Elbe plume	II
	EMPM	Ems plume	II
	GDPM	Gironde plume	IV
	HPM	Humber plume	II
	LBPM	Liverpool Bay plume	III
	LPM	Loire plume	IV
	MPM	Meuse plume	II
	RHPM	Rhine plume	II
	SCHPM1	Scheldt plume 1	II
	SCHPM2	Scheldt plume 2	II
	SHPM	Shannon plume	III
	SPM	Seine plume	II
	THPM	Thames plume	II
Coastal areas	CFR	Coastal FR channel	II
	CIRL	Coastal IRL 3	III
	CNOR1	Coastal NOR 1	II
	CNOR2	Coastal NOR 2	II
	CNOR3	Coastal NOR 3	II
	CUK1	Coastal UK 1	III
	CUKC	Coastal UK channel	II
	CWAC	Coastal Waters AC (D5)	IV
	CWBC	Coastal Waters BC (D5)	IV
	CWCC	Coastal Waters CC (D5)	IV
	ECPM1	East Coast (permanently	II
	ECPM2	East Coast (permanently	II
	GBC	German Bight Central	II
	IRS	Irish Sea	III
	KC	Kattegat Coastal	II
	KD	Kattegat Deep	II
	NAAC1A	Noratlantic Area NOR-	IV
	NAAC1B	Noratlantic Area NOR-	IV
	NAAC1C	Noratlantic Area NOR-	IV
	NAAC1D	Noratlantic Area NOR-	IV
	NAAC2	Noratlantic Area NOR-	IV
	NAAC3	Noratlantic Area NOR-	IV
	OC	Outer Coastal DEDK	II
	SAAC1	Sudatlantic Area SUD-C1(D5)	IV
	SAAC2	Sudatlantic Area SUD-C2(D5)	IV
	SAAP2	Sudatlantic Area SUD-P2(D5)	IV
	SNS	Southern North Sea	II

Categories of COMP 4 assessment areas	Area code	Area name	OSPAR Region
Shelf areas	ASS	Atlantic Seasonally Stratified	**III**, IV
	CCTI	Channel coastal shelf tidal	II
	CWM	Channel well mixed	**II**, III
	CWMTI	Channel well mixed tidal	II
	DB	Dogger Bank	II
	ENS	Eastern North Sea	II
	GBCW	Gulf of Biscay coastal waters	IV
	GBSW	Gulf of Biscay shelf waters	IV
	IS1	Intermittently Stratified 1	II, **III**
	IS2	Intermittently Stratified 2	II
	NAAP2	Noratlantic Area NOR-	IV
	NAAPF	Noratlantic Area NOR-	IV
	NNS	Northern North Sea	II
	NT	Norwegian Trench	II
	SAAP1	Sudatlantic Area SUD-P1(D5)	IV
	SK	Skagerrak	II
	SS	Scottish Sea	**II**,III
Oceanic / beyond shelf	ATL	Atlantic	II, **IV**,V
	NAAO1	Noratlantic Area NOR-	IV
	OWAO	Ocean Waters AO (D5)	IV
	OWBO	Ocean Waters BO (D5)	IV
	OWCO	Ocean Waters CO (D5)	IV
	SAAOC	Sudatlantic Area SUD-	IV

HELCOM

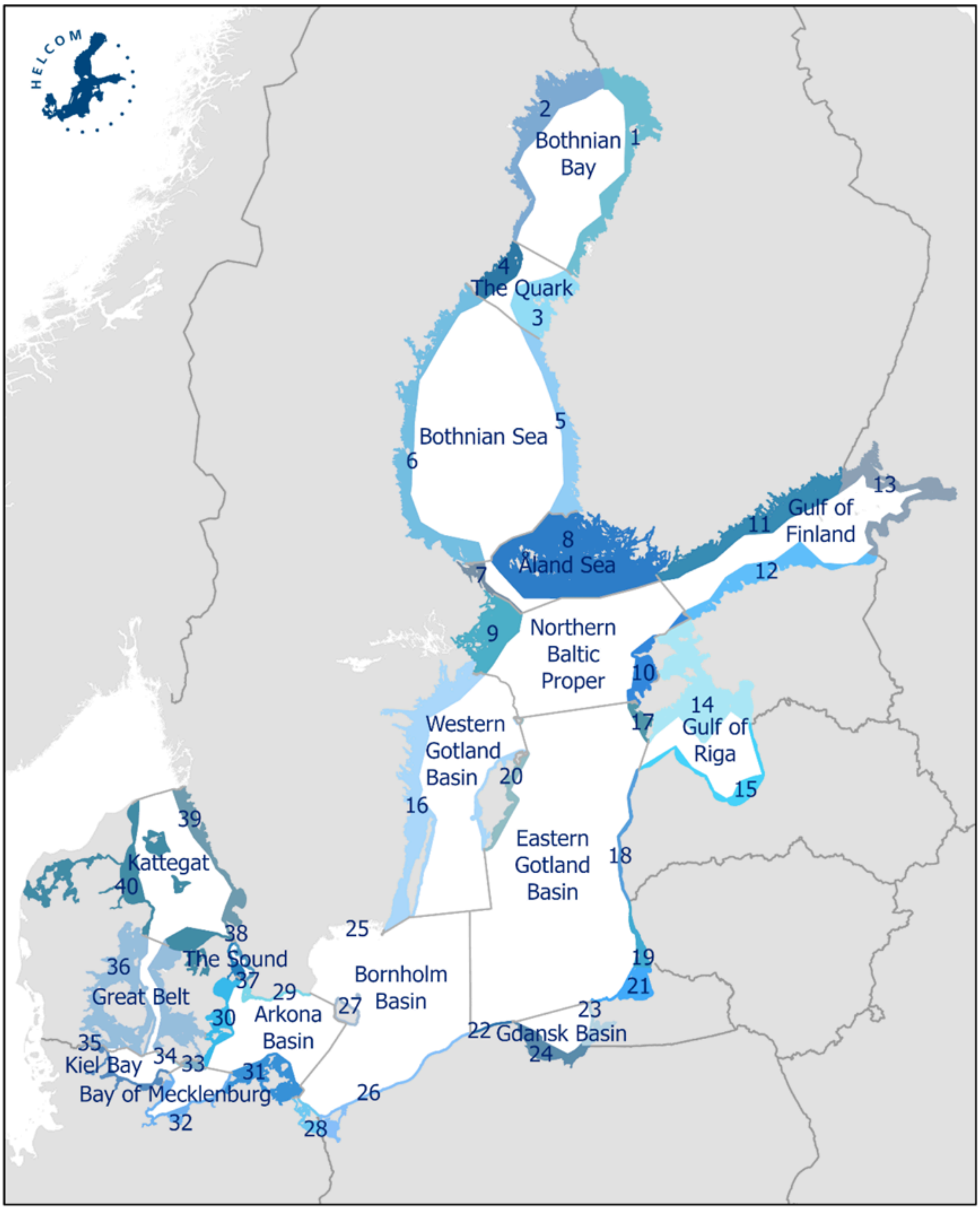


Figure A3. Map of the Baltic Sea presenting the HELCOM sub-division into 17 open sea sub basins and 40 coastal areas. The names of the open sea sub-basin and coastal areas are provided in Tables 1 and 2, respectively.

Table A2. Codes and names of open sea sub-basins of the Baltic Sea

HELCOM	ID Name
SEA-001	Kattegat
SEA-002	Great Belt
SEA-003	The Sound
SEA-004	Kiel Bay
SEA-005	Bay of Mecklenburg
SEA-006	Arkona Basin
SEA-007	Bornholm Basin
SEA-008	Gdansk Basin
SEA-009	Eastern Gotland Basin
SEA-010	Western Gotland Basin
SEA-011	Gulf of Riga
SEA-012	Northern Baltic Proper
SEA-013	Gulf of Finland
SEA-014	Åland Sea
SEA-015	Bothnian Sea
SEA-016	The Quark
SEA-017	Bothnian Bay

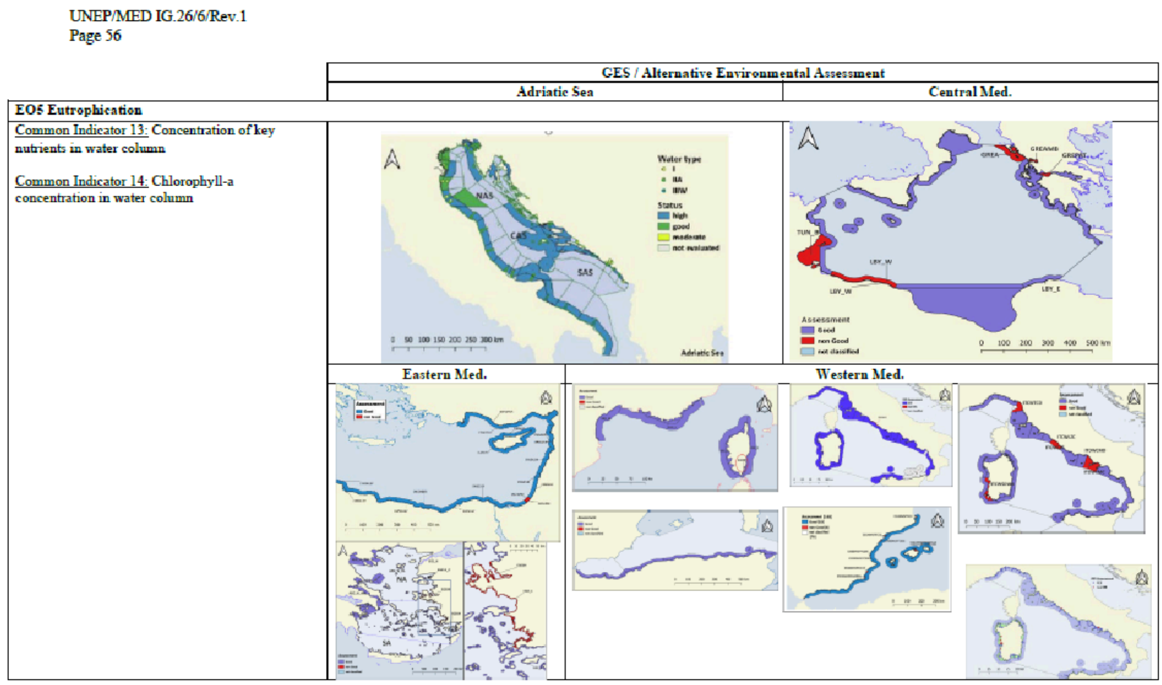
Table A3. Codes and names of the coastal water areas

HELCOM-ID	Name
1	Bothnian Bay Finnish Coastal waters
2	Bothnian Bay Swedish Coastal waters
3	The Quark Finnish Coastal waters
4	The Quark Swedish Coastal waters
5	Bothnian Sea Finnish Coastal waters
6	Bothnian Sea Swedish Coastal waters
7	Åland Sea Swedish Coastal waters
8	Åland Sea – Archipelago Sea Finnish Coastal waters
9	Northern Baltic Proper Swedish Coastal waters
10	Northern Baltic Proper Estonian Coastal waters
11	Gulf of Finland Finnish Coastal waters
12	Gulf of Finland Estonian Coastal waters
13	Gulf of Finland Russian Coastal waters
14	Gulf of Riga Estonian Coastal waters

HELCOM-ID	Name
15	Gulf of Riga Latvian Coastal waters
16	Western Gotland Basin Swedish Coastal waters
17	Eastern Gotland Basin Estonian Coastal waters
18	Eastern Gotland Basin Latvian Coastal waters
19	Eastern Gotland Basin Lithuanian Coastal waters
20	Eastern Gotland Basin Swedish Coastal waters
21	Eastern Gotland Basin Russian Coastal waters
22	Eastern Gotland Basin Polish Coastal waters
23	Gdansk Basin Russian Coastal waters
24	Gdansk Basin Polish Coastal waters
25	Bornholm Basin Swedish Coastal waters
26	Bornholm Basin Polish Coastal waters
27	Bornholm Basin Danish Coastal waters
28	Bornholm Basin German Coastal waters
29	Arkona Basin Swedish Coastal waters
30	Arkona Basin Danish Coastal waters
31	Arkona Basin German Coastal waters
32	Mecklenburg Bight German Coastal waters
33	Mecklenburg Bight Danish Coastal waters
34	Kiel Bight Danish Coastal waters
35	Kiel Bight German Coastal waters
36	Belts Danish Coastal waters
37	The Sound Swedish Coastal waters
38	The Sound Danish Coastal waters
39	Kattegat Swedish Coastal waters
40	Kattegat Danish Coastal waters, including Limfjorden

UNEP/MAP

Figure A4. Map of the Mediterranean Sea presenting the UNEP/MAP sub-division into 4 subregions. In: [02/21: Sub-regional workshops for the elaboration of the Post-2020 SAPBIO | Regional Activity Centre for Specially Protected Areas (rac-spa.org)]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	GES / Alternative Environmental Assessment	
	Adriatic Sea	Central Med.
EO5 Eutrophication		
Common Indicator 13: Concentration of key nutrients in water column Common Indicator 14: Chlorophyll-a concentration in water column		
	Eastern Med.	Western Med.

Figure A4. Map of the Mediterranean Sea presenting UNEP/MAP Common Indicator CI13 (nutrients) & CI14 (chlorophyll a) subregions and subdivisions as used in the MED QSR 2023. See also Table A3.

Table A3. UNEP/MAP Common Indicator CI13 (nutrients) & CI14 (chlorophyll a) subregions and subdivisions

CIs 13 & 14	
Subregion	Subdivision
Aegean and Levantine Seas (AEL)	Aegean Sea (AEGS)
	Levantine Sea (LEVS)
Adriatic Sea (ADR)	North Adriatic (NAS)
	Central Adriatic (CAS)
	South Adriatic (SAS)
Central Mediterranean Sea (CEN)	Central Mediterranean Sea (CENS)
	Ionian Sea (IONS)
Western Mediterranean Sea (WMS)	Alboran Sea (ALBS) and Levantine-Balearic Sea (LAVS-BAL) Sea Sub-division
	Central Western Mediterranean Sea (CWMS): Central and Southern parts
	Tyrrhenian Sea (TYRS)