NEA PANACEA

North East Atlantic project on biodiversity and eutrophication assessment integration and creation of effective measures

Final report

MARINE STRATEGY FRAMEWORK DIRECTIVE:
SUPPORT TO THE PREPARATION OF THE NEXT 6-YEAR CYCLE OF IMPLEMENTATION

"DG ENV/MSFD 2020"

OSPAR QSR2023

Co-funded by the European Union

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Name of beneficiary of grant agreement - Ministry of Infrastructure and Water Management – Rijkswaterstaat (NL)
Address - Zuiderwagenplein 2, 8224 AD Lelystad, The Netherlands
Project Coordinator - Dr. J. Schilder
Partners
University of Plymouth (UK)
Centre National de la Recherche Scientifique (affiliation: Université du Littoral Côte d'Opale) (FR)
AquaEcology GmbH & Co. KG (DE)
Office Français de la Biodiversité (FR)
BioConsult Schuchardt & Scholle GbR (DE)
JNCC Support Co (UK)
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PREFACE

In 2020, the European Commission's Directorate-General for the environment (DG ENV) issued a call for proposals with action towards support of the preparation of the next 6-year cycle of implementation of the Marine Strategy Framework Directive (MSFD). The focus of proposals was to be on supporting the (sub)regional assessment of the extent to which Good Environmental Status (GES) has been achieved, on supporting the quantification (notably ex-post) of the effect of the Progammes of Measures (PoMs), and on supporting the establishment of new (sub)regionally-coordinated measures. For the North-East Atlantic specific topics of interest were identified: Assessment of GES of highly mobile species, identification of ecologically relevant assessment scales and broad habitat types for pelagic and benthic habitats, delivery of thematic biodiversity assessments, supporting the Quality Status Report (QSR) delivery process when it comes to assessing the effectiveness of measures, and informing measures to reduce pressures on seafloor habitats.

In response to the call, 8[1] partners from 5 countries that are Contracting Party (CP) to the OSPAR Regional Sea Convention for the protection of the marine environment of the North-East Atlantic proposed the Action NEA PANACEA (North-East Atlantic project on biodiversity and eutrophication assessment integration and creation of effective measures). The work in NEA PANACEA is highly focused on indicator development (including monitoring, data processing and assessment methodology), coherence between assessments (including assessment scales, threshold values and pressure versus state assessments), integration of indicator assessments (to the ecosystem component level) and evaluating and informing measures.

This is the technical report presenting the scientific output of the NEA PANACEA. This collaboration was executed in the context of the work of the OSPAR convention for the protection of the marine environment in the North-East Atlantic and its periodic Quality Status Report (QSR), with specific aim to inform the reporting for the Marine Strategy Framework Directive (MSFD) of EU Member States that border the North-East Atlantic.

The main body of text of this report summarizes the initial aims of the project, the process towards delivery of the deliverables, the outcomes and potential next steps. Full technical and scientific details are found in the 44 Annexes to this report. Every "work package", called Activity in this project, has produced its own chapter with these elements, following the structure of the proposal and grant agreement. Because the nature of the work (e.g. more or less technical), the group composition (size, geographical dispersion, number of partners and subcontractors involved) and the resulting work arrangements varied between the Activities, the level of detail in the main body of text varies between chapters, at the discretion of the Activity leads.

We, the project members, have worked together with great intensity and pleasure, driven by a passion for the marine environment and for marine science at the science-policy interface. We are grateful for the funding and support we received: The European Union for providing the majority of the funding and the partner institutes for providing the co-funding, the OSPAR secretariat for technical and organizational support, the wider OSPAR expert and policy maker communities for the interaction and feedback, and Rijkswaterstaat for providing substantial support of the various workshops and meetings.

1 Rijkswaterstaat (NL), University of Plymouth (UK), Centre National de la Recherche Scientifique (affiliation: Université du Littoral Côte d'Opale) (FR), AquaEcology GmbH & Co. KG (DE), Office Français de la Biodiversité (FR), BioConsult Schuchardt & Scholle GbR (DE) JNCC Support Co (UK), Consejo Superior de Investigaciones Científicas (Instituto Español de Oceanografía at the time of signing of grant agreement) (ES)

Notes to the reader

- Figure numbering is organized per chapter, so a reference to Figure 3 refers to Figure 3 in the chapter that contains that reference.
- For deliverables that are indicator or thematic assessments:
  - Data processing protocols and assessment methodologies are detailed in an OSPAR CEMP document (Coordinated Environmental Monitoring Programme), which is provided as an Annex.
  - Assessment results and outcomes are provided in an Annex that links to the OSPAR Assessment Portal (OAP).
  - For indicator and integrated ecosystem component assessments, the results are also available as an MSFD-table that facilitates EU Member State reporting for article 8. These tables can be found in the "Assessment metadata" section under "Summary results" in OAP.
  - Underlying data can be accessed through the assessment page on OAP.
  - Computer scripts are published on the OSPAR GitHub repository after publication on OAP.
- For deliverables that are not indicator or thematic assessments, a detailed report with all the technical and scientific information is provided in an Annex.

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SUMMARY

NEA PANACEA delivered 11 indicator and pilot indicator assessments, and 3 biodiversity thematic assessments supporting the reporting of EU MS for article 8 of the MSFD through the OSPAR QSR 2023 process. In addition, a number of products on topics of a cross-cutting nature (for example integration between MSFD Descriptors, the types of Threshold Values used in biodiversity indicators and their narratives, and a study on the evaluation of the effectiveness of MPA's using benthic pressure indicators). Figure 1 shows how the Action proposed work in 5 Activities: Pelagic Habitats, Eutrophication and Physical Conditions, Benthic Habitats, Marine Birds and a Coordination Activity. Each of these Activities consisted of 3-7 Tasks, each of which delivered on one or more of the working themes that form the backbone of the proposal, and the original call for funding. In addition to the large amount of technical work and research that underpins the products delivered in the Annexes to this report, an important aspect of NEA PANACEA was involving and activating the wider (biodiversity) expert community in OSPAR. This was not only done through the three large workshops organized by Activity 4 and 5, but also by invigorating OSPAR's pelagic and benthic habitats expert groups, providing experts from CPs (and EU Member States) not directly involved in NEA PANACEA an opportunity to contribute to the work.

The total budget for the Action NEA PANACEA was € 1.211.352,35, of which € 1.134.235,27 has been used (94%). Especially the costs for the two major events in NEA PANACEA (SuperCOBAM and UltraCOBAM) proved less costly than planned, because Rijkswaterstaat was able to benefit from in-house services (not charged to the project). For subcontracting costs no other costs than foreseen in the application annex III were claimed.

This summary continues below with a brief description of the outcomes of the work that was performed in the Tasks under each Activity. For every Activity, a table is provided that lists the deliverables from the proposal and the grant agreement with a direct reference to the Annex where the associated products may be found.

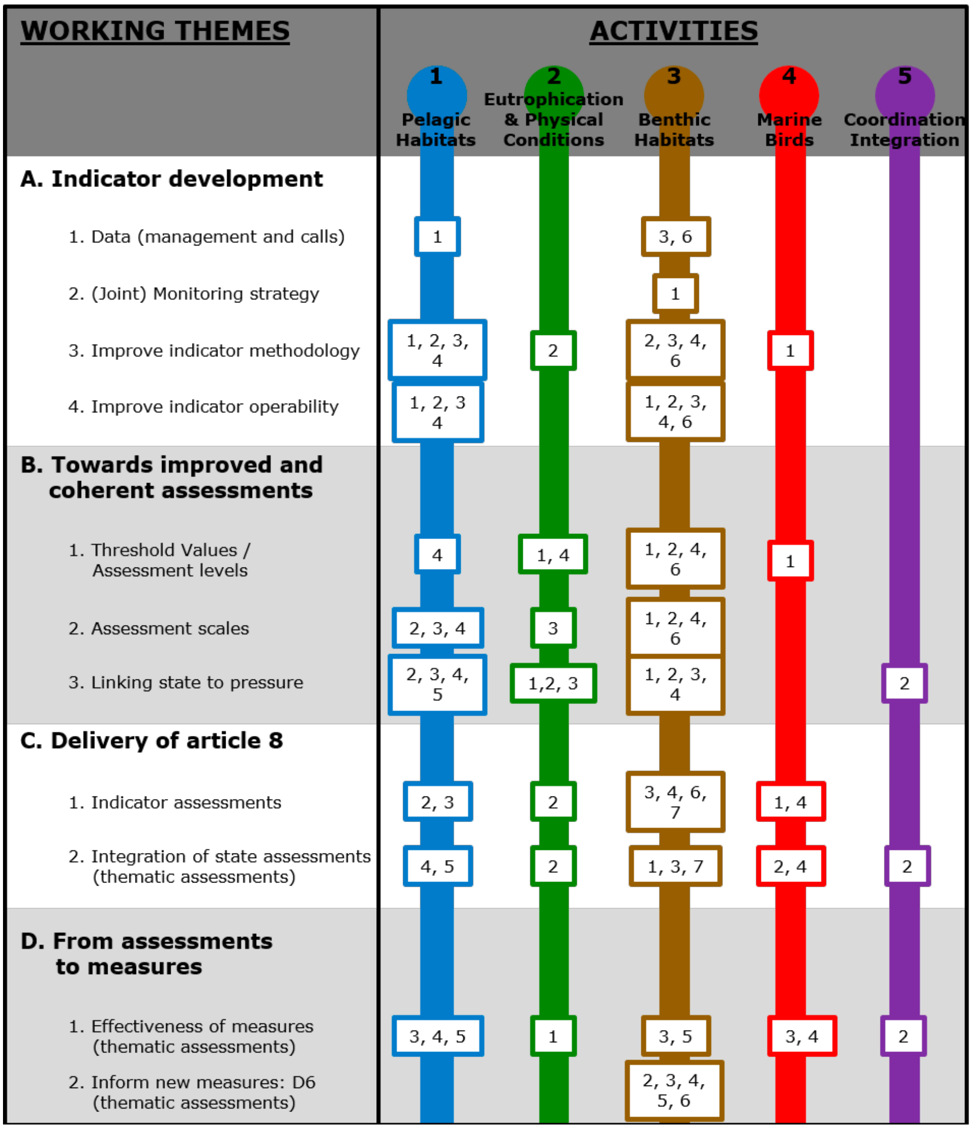

Figure 1. Overview of which of the Tasks (numbers in boxes) of the 5 Activities adress the 4 main Working Themes (left column) of NEA PANACEA.

Activity 1: Pelagic habitats

Activity 1 was centered around further development of the pelagic habitats (and some food webs) indicators compared to the previous assessment cycle, delivery of these assessments and integrating them at the ecosystem component level, and integrating these indicators with other (biodiversity and eutrophication) indicators. The basis of any assessment is formed by the data, and in Task 1 the team worked to update the data that were used in the previous assessment cycle, to issue a data call to receive data from the CPs for the current assessment, and to include data types that were not used in previous assessments (such as satellite observations). As a result, the current assessments that can feed into EU MS MSFD reporting for D1C6 (3 assessments) and D4 (1 assessment; primary productivity) are based on more data and with a better geographical coverage than the previous assessments. Annex A is a resulting data ingestion protocol to facilitate the current and future data submissions by CPs.

Table 1. The 9 deliverables agreed in the Grant Agreement for Activity 1 and the 14 delivered products associated with these deliverables.

Activity	Task	Deliverable (as appearing in Grant Agreement)	Associated product
1	1	D1.1 Protocol for data ingestion	Annex A
1	2	D1.2a PH1/FW5 indicator extraction and assessment guidance (CEMP)	Annex B
1	2	D1.2b Assessment for PH1/FW5	Annex C
1	3	D1.3a PH2 and PH3 indicator assessments	Annex D (PH2) Annex E (PH2 CEMP) Annex F (PH3) Annex G (PH3 CEMP)
1	4	D1.4a Options for integration with and between pelagic indicators, and for setting pelagic baselines, targets, and threshold values	Annex H
1	4	D1.4b Pelagic thematic assessment	Annex I Annex J (CEMP)
1	5	D1.5a First proposition of FW2/FW6 indicator assessment	Annex K (FW2) Annex L (FW6)
1	5	D1.5b Options for integrating pelagic indicators with eutrophication indicators	Annex M
1	5	D1.5c Options for integrating pelagic indicators with other ecosystem components	Annex N

The methods underpinning the indicator assessments of PH1/FW5 (Changes in Phytoplankton and Zooplankton Communities), PH2 (Changes in Phytoplankton Biomass and Zooplankton Abundance), and PH3 (Changes in Plankton Diversity) were improved and the improvements were recorded in OSPAR CEMP (Coordinated Environmental Monitoring Programme) guidelines (Annexes B, E and G, respectively). Improvements include the focus on a core group of 8 important plankton lifeforms (PH1), development of a set of procedures to determine the environmental status of the pelagic habitat at the level of the MSFD Pelagic Habitat types and OSPAR/MSFD regions (PH1, 2 and 3), assessment of all pelagic habitats indicators at the same assessment scale (which is coherent with those used in eutrophication assessments), and incorporation of remote sensing data (PH2). Moreover, an algorithm was developed for linking detected changes in the indicators with changes in environmental variables. Using a novel method, this linkage allowed provisional assessment of Good / Not Good Environmental Status for MSFD reporting purposes (in absence of a Threshold Value). The resulting assessments are presented in Annexes C, D and F. In a next step, options on integrating the three pelagic habitats indicator assessments into a single ecosystem component (MSFD criterion D1C6) assessment at the scale of the MSFD region, per MSFD Pelagic Habitat Type were explored (Annex H) and the outcomes of this study were used to produce an integrated assessment of pelagic habitats to support EU MS MSFD reporting (D1C6) in the pelagic habitats thematic assessment (Annexes I and J).

The work of the OSPAR pelagic habitats experts is not only relevant for D1C6 (pelagic habitats) assessments, but also contributes to OSPAR's D4 (food webs) assessments. PH1 also serves as a food web indicator (FW5), for example, and FW2 (Pilot assessment primary productivity) is produced by this expert group that also has FW6 (Biomass, species composition and spatial distribution of zooplankton) under development. Under NEA PANACEA, FW2 was delivered (Annex K), using the same assessment scales and algorithms to link changes in the outcomes to environmental change (and consecutively assess GES) as used for the PH indicators (thus extending the coherence between pelagic habitats and eutrophication to the food web assessments). Unfortunately, the CPs did not deliver enough data to assess FW6, but under Task 1.5 the experts did work with older data (2008-2011) to produce a case study in order to keep the development of this food web indicator ongoing (Annex L).

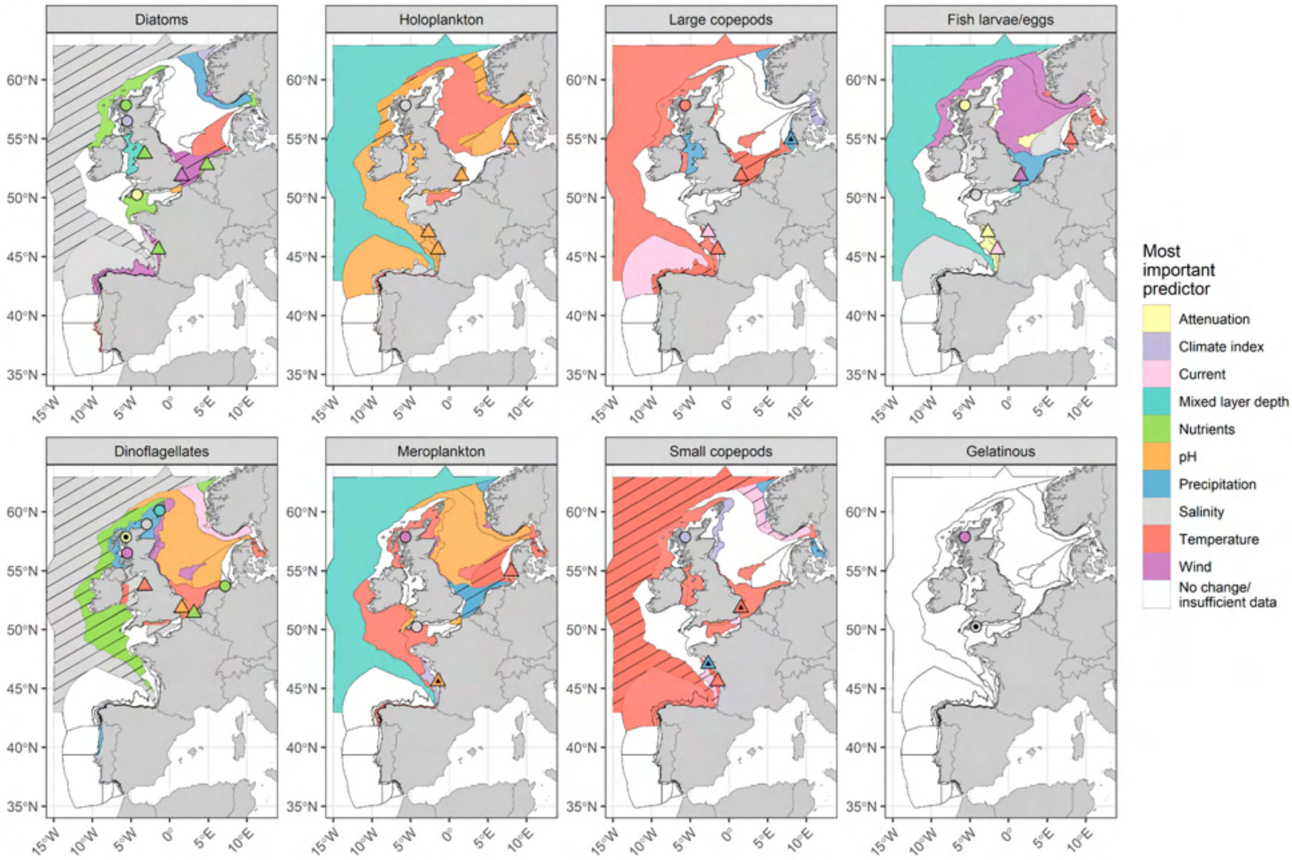

Figure 2. One of the many outputs of the PH1/FW5 indicator assessment. The figure showcases 3 important achievements of Activity 1: Further development of the indicator methodology, usage of the assessment scales developed for eutrophication assessments in OSPAR throughout the pelagic habitats assessments, and linking trends identified in plankton to (anthropogenic and natural) pressure.

The experts in this Activity also explored ways in which the pelagic indicators dealing with algae biomass or primary productivity may, in the future, be integrated with D5 (eutrophication) indicators that deal with nutrient concentrations or chlorophyll-*a* concentrations (Annex M). Finally, a small case study was produced to see how the pelagic habitats indicators may be linked to other D1 (Biodiversity) components through Ecological Network Analysis (which has been developed as indicator FW9 in OSPAR) (Annex N). These preliminary studies are an example of the way experts working on the MSFD will have to frame and conceptualize their work, if we want to take the next step in making the MSFD as holistic in its assessment of the state of the marine environment as it was meant to be.

Activity 2: Eutrophication and physical conditions

Activity 2 focused on pressures, notably eutrophication, climate change and physical conditions, with special attention for how tools developed in the framework of the OSPAR eutrophication assessments may be used in biodiversity assessments supporting EU MS MSFD reporting. A second main aspect of this activity was the use of models (literature and data based) to gain insight in the way natural and anthropogenic pressures affect (benthic) fauna and in the structure of the food web in terms of trophic interactions and energy or biomass flows between trophic levels.

Table 2. The 5 deliverables agreed in the Grant Agreement for Activity 1 and the 6 delivered products associated with these deliverables.

Activity	Task	Deliverable (as appearing in Grant Agreement)	Associated product
2	1	D2.1a LiACAT ready for eutrophication analysis and D2.1b LiACAT analysis ready for target values under eutrophication *(D2.1b is an iterative step following D2.1a)*	Annex O (LiACAT) Annex P (Climate)
2	2	D2.2a ENA ready for eutrophication analysis and D2.2b ENA analysis ready for target values under eutrophication *(D2.2b is an iterative step following D2.2a)*	Annex Q
2	3	D2.3 Evaluation of assessment scales for pelagic and benthic indicators	Annex R
2	4	D2.4a Joint list of feasible options to improve coherence of baseline and threshold value setting methods for (future) D1/D6 (pelagic and benthic habitats, birds), D4 and D5 assessments	Annex S
2	4	D2.4b. Final Activity 2 synthesis report	Chapter 3

Task 2.1 set out to adapt the mathematical network model ACIM (Automated Cumulative Impact Model) to investigate the impact of environmental change related to climate change and nutrient inputs on case study areas in the Eastern North Sea and in the so-called Elbe-plume of the German coast. The model was informed by an exisiting model for the marine physico-chemical environment developed by Deltares and by information extracted from the literature using the LiACAT tool (Literature-based Cumulative Assessment Tool). Biological data (zoobenthos) was provided by Activity 3. Supporting information from the Deltares model, a climate scenario desk study (Annex P) and information from the literature was obtained. However, the biological data was less comprehensive than anticipated. Due to staffing problems and issues of a personal nature (see the chapter on Activity 2 below for details), the final operational model and associated deliverable (planned Annex O) could unfortunately not be delivered. There were, however, no consequences for other Tasks and deliverables in the project, nor on the MSFD reporting in 2024 by EU MS as this was a pilot study to explore potential for support of future holistic MSFD biodiversity (D1, D4, D6) assessments.

A model approach called ENA (Ecological Network Analysis) was used in Task 2.2 to investigate changes in the structure of the food web over time, for example in terms of biomass of the different trophic guilds or trophic levels (Annex Q). Due to limited data availability (it requires relatively comprehensive monitoring data throughout the trophic levels) the study was limited to 4 case study areas and delivered as OSPAR candidate indicator pilot assessment (FW9). The case studies demonstrate the potential of ENA to model the relative importance of different trophic levels at the regional scale, showing great potential to fulfil the requirements of MSFD Descriptor 4 (food webs), which requires analyses over 3 or more trophic levels.

One of the major initial aims of NEA PANACEA was to achieve coherence in the way eutrophication as a pressure is assessed and how pelagic habitats are assessed. At the basis of this, lies the spatial scale or assessment areas that are being used. In Task 2.3 the experts collaborated closely with Activity 1 experts to investigate the suitability for plankton abundance and diversity assessments of the so-called COMP4 assessment areas which have been developed for OSPAR eutrophication assessments (Annex R). This has led to a successful application of these assessment areas in indicators PH1, PH2, PH3 and FW2, which can be seen as a major advance towards the future integration of these pressure and state assessments.

The final Task in this Activity involved threshold values for biodiversity and eutrophication, with special attention to the degree in which they are coherent with each other. This was based on the outcomes of the EU MSFD workshop Horizontal Issues – Threshold values (September 2020) and the present Task can be considered as a next step in comparing threshold value narratives. Many indicators (and MSFD criteria) are related to each other. For example, nutrient concentrations can be an important driver of phytoplankton productivity. A threshold value for nutrient concentrations should therefore be compatible with those for plankton assessments, to avoid situations where one indicator reports good status (no management action needed) and the other indicates non-satisfactory status (implying management action may be in order). Annex S provides an analysis of the threshold values in use in OSPAR for biodiversity and eutrophication, including the narrative that is being used and the method that is being used to set the threshold value. Threshold value setting is a complex and sensitive matter: the basis should be in the science, which is sometimes hampered by data and/or knowledge gaps, but a threshold value also needs to be supported by the policy makers, which requires thorough discussions between experts and policy makers as well as insight in any consequences in terms of management action to facilitate that discussion. Figure 3 shows a decision tree from Annex S that can help guide such discussions when it comes to coherence between threshold values.

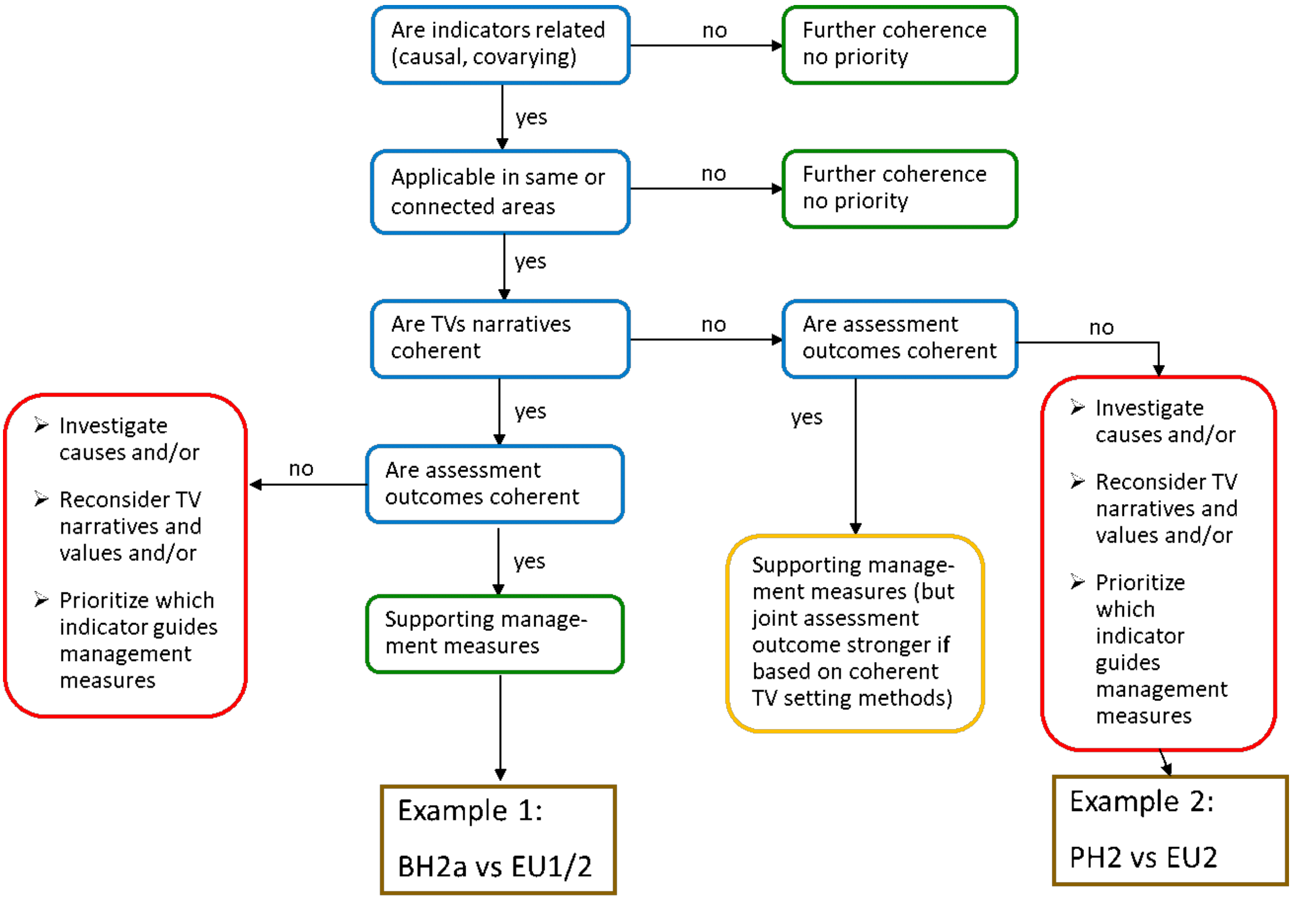

Figure 3. (In)coherence between threshold value setting narratives or assessment outcomes - problem or not? Successive questions (blue boxes) lead to either acceptable situations (green boxes) or need for further work to improve the coherence (red and orange boxes). The examples are described in Annex S, section 3.2.3.

Activity 3: Benthic habitats

The work in Activity 3 involved a range of deliverables, including 3 common indicator assessments, 2 candidate indicator assessments and the benthic habitats thematic assessment, all of which were tailored to support EU MS MSFD reporting for Descriptor 6. In addition, this largest of the 5 Activities included work on the implementation of Descriptor 6 (Seafloor Integrity) by EU Member States and the use of regional products, on Threshold Values, on using OSPAR indicators to evaluate measures to protect benthic communities and on the functional integration of benthic indicators that are pressure-data driven (risk indicator) and those that are based on monitoring of biota (quality status indicator).

Table 3. The 8 deliverables agreed in the Grant Agreement for Activity 3 and the 14 delivered products associated with these deliverables.

Activity	Task	Deliverable (as appearing in Grant Agreement)	Associated product
3	1	D3.1 Review D6, in link with D4 and D5	Annex T
3	2	D3.2 BH1 2022 indicator assessment plus CEMP (Coordinated Environmental Monitoring Programme) update	Annex U (CEMP) Annex V (BH1)
3	3	D3.3 BH2a 2022 indicator assessment	Annex W Annex X (CEMP)
3	4	D3.4 BH3 2022 Indicator assessment	Annex Y (CEMP) Annex Z (BH3a) Annex AA (BH3b) Annex AB (TVs)
3	5	D3.5a Reports and maps on scenarios according to various options of thresholds and disturbance categories for BH3 indicator *(also a deliverable under Task 3.4)*	Annex AC (Management)
3	5	D3.5b Contributions to D3.7b Benthic habitat 2022 advanced draft thematic assessment	Annex AF
3	6	D3.6 BH4 pilot assessment and CEMP update	Annex AD (CEMP) Annex AE (BH4)
3	7	D3.7 Benthic habitat thematic assessment	Annex AF

In an extensive report (Annex T) a synthesis and analysis of the elements reported under MSFD Descriptor 6 (article 9, the previous reporting cycle) by 23 EU Member States is provided, also taking into account recent activities in the MSFD Common Implementation Strategy (CIS) such as by TG Seabed and advice by the International Council for the Exploration of the Sea (ICES). The relationships with the Desciptors Food Webs and Eutrophication (D4 and D5) were explored, focusing on the OSPAR context, and recommendations for future technical work and harmonisation of GES elements are offered. The experts working on this publication further prepared the Water Framework Directive (WFD) assessment of coastal habitats exposed to nutrient and organic enrichment (OSPAR indicator BH2a) for use in reporting for the MSFD. It was assessed for two time periods available of WFD assessment cycles. This enabled a first-time comparison at this scale of the results and notably the effect of the gaps in waterbodies assessed or not assessed. The data flow, compared to the assessment from the previous cycle, was much more robust and improved as most of data were provided through the European WISE reference database. The updated assessment and CEMP guidelines are provided as Annexes W and X.

The indicator BH1 (Sentinel of the Seabed) assesses the degree of disturbance of the sea floor by bottom trawling based on the occurrence of benthic species that are sensitive to this type of disturbance. Under NEA PANACEA, the indicator methodology was improved to better fit the 2017 Commission Decision on Good Environmental Status (Annex U). Following these technical developments, an assessment of BH1 was delivered for the Bay of Biscay and the Iberian Coast (Annex V). Under Task 2 the experts also performed a pilot study to explore the degree to which seafloor disturbance assessed with a quality status indicator agrees with disturbance assessed through a risk-based approach (using extent of pressure as information source, see BH3 below) (Figure 4). A resulting proposal to use information from BH1 to inform pressure categories underpinning conclusions in the BH3 assessment can be found in Annex U, which may underpin future integration of indicator assessments for MSFD Descriptor 6.

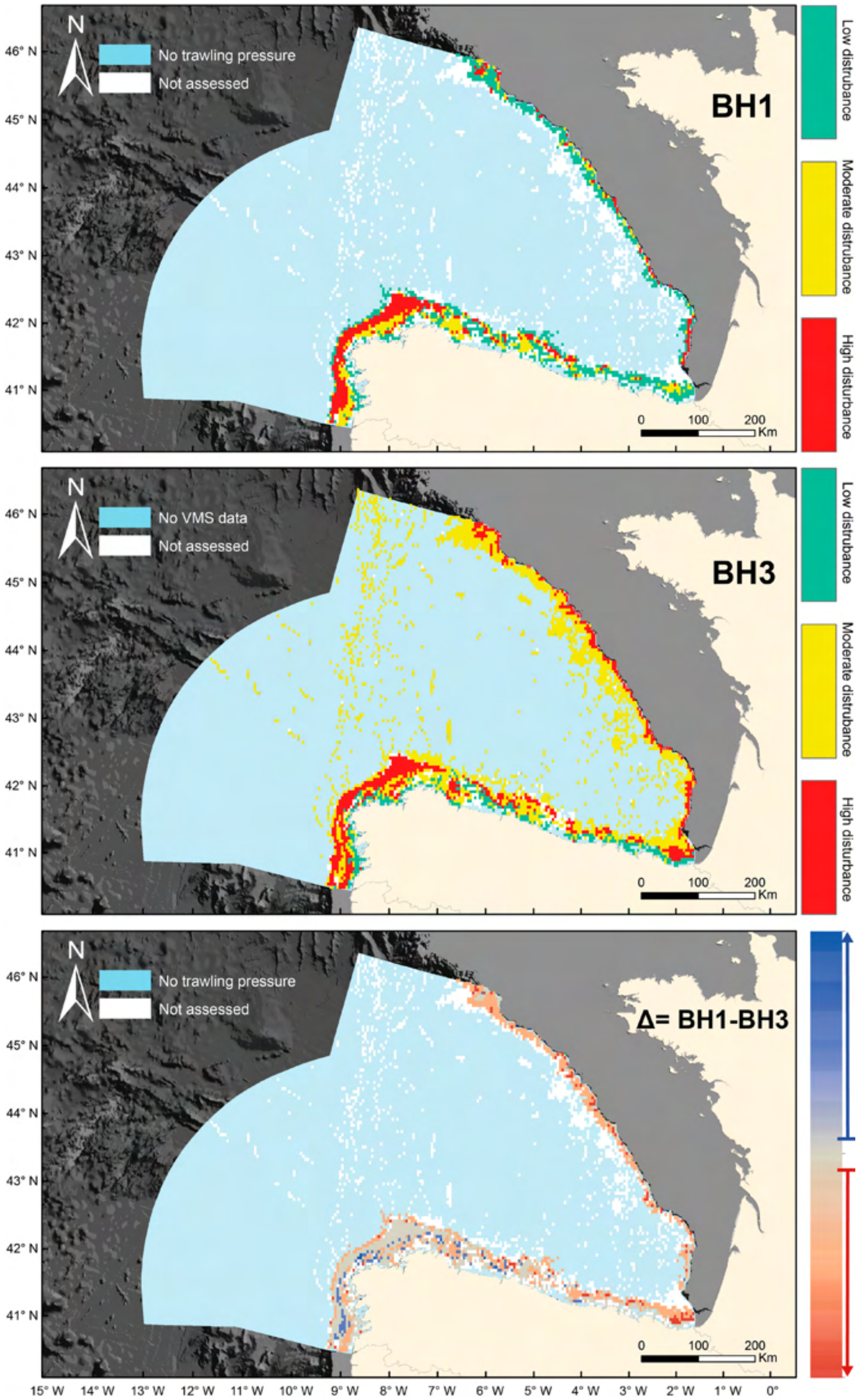

Figure 4. Risk-based benthic level of disturbance estimations determined by BH1 (a status indicator) and BH3 (a risk-based indicator) and the differences for the North Iberian Atlantic assessment unit. This showcases the progress that has been made to integrate indicators that assess the same pressure using different types of information, where ideally BH1 (information on in-situ habitat conditions) informs BH3 (information on the extent of the human activity leading to pressure).

The BH3 indicator (Extent of physical disturbance to benthic habitats) was further developed by NEA PANACEA in several ways. In addition to the abovementioned pilot on relationships with BH1, the spatial coverage of the assessment was expanded through pilots in the Arctic region and the Wider Atlantic (OSPAR region I and V), the operability of the indicator was improved by developing semi-automated elements (allowing for more cost-efficient assessment), and the assessment of physical disturbance was expanded by including an assessment of the pressure of aggregate extraction next to the one on the pressure of bottom-trawling, thus expanding the breadth of the products available to EU MS for MSFD-reporting on seabed disturbance. The updated procedures can be found in Annex Y and the assessments in Annexes Z and AA. The experts worked on a proposal (Annex AB) for the setting of Threshold Values for the extent of physical disturbance involving workshops with both benthic experts and policy makers, and prepared documents informing policy makers on the practical implementation of various Threshold Value options. This process occurred in parallel with similar work in TG Seabed, where NEA PANACEA experts contributed to the process. Given the complex nature and the need for further discussion on the policy side, NEA PANACEA experts were asked to await further discussion in TG Seabed, which continued beyond the timeframe of the NEA PANACEA project. The OSPAR benthic expert group will continue to feed into that discussion. Finally, the experts working on BH3 explored the degree in which the indicator information can be used to evaluate the effect of fisheries measures in MPAs (Annex AC), allowing for evaluation of MSFD Programmes of Measures. While the study shows potential, it also identified critical knowledge gaps, not in the least place on management measures and practice in place.

Indicator BH4 (Area of habitat loss) is a candidate indicator that assesses the extent of substrate that is permanently altered (changed or lost) by human activities, complementing the outcomes of the BH3 assessments and increasing the evidence base EU MS can use to report on MSFD criterion D6C4. NEA PANACEA delivered indicator methodologies (Annex AD) and a pilot assessment (Annex AE) for the Greater North Sea. Although there was not data available for all types of structures and activities, limiting the scope of the assessment, the work delivered provides a solid foundation to further develop the indicator and expand its geographical scope.

The final deliverable (Annex AF) for Activity 3 is the thematic assessment of benthic habitats. This assessment offers an integrated view on the state of the benthic habitats in the North-East Atlantic based on the various OSPAR indicator and status assessments, including “Broad Habitat Types” as well as habitats considered under threat and/or declining. As such, it provides EU MS with a narrative and context to report on the status of the seabed integrity for the MSFD.

Activity 4: Marine birds

The central focus of Activity 4 was the delivery of the marine birds thematic assessment in the OSPAR QSR. This not only provides EU Member States with an integrated assessment of the state of marine birds at the "feature" level for MSFD reporting, but also embeds that assessment in the context of human activities that exert pressure on marine birds, the ecosystem services they deliver and (the impact of) policy response.

Table 4. The 4 deliverables agreed in the Grant Agreement for Activity 4 and the 8 delivered products associated with these deliverables.

Activity	Task	Deliverable (as appearing in Grant Agreement)	Associated product
4	1	D4.1 Indicator assessment of bird breeding productivity indicator (B3)	Annex AG (B3) Annex AH (CEMP)
4	2	D4.2 OSPAR Thematic Assessment of marine birds	Annex AI Annex AJ (CEMP)
4	3	Supplementary information for D4.2 OSPAR thematic assessment of marine birds	Annex AK Annex AL Annex AM
4	4	D4.4 Action plan for marine bird assessments in OSPAR Region	Annex AN

One of the indicator assessments underpinning the marine birds thematic assessment is B3 (marine bird breeding productivity), informing MSFD criterion D1C3. This indicator was improved under NEA PANACEA, and an assessment was delivered for the QSR (Annexes AG and AH). The indicator was improved from a breeding success/failure indicator that was used in the previous assessment cycle, that focused on the extreme events of colony breeding failure (i.e. incidents). The new methodology permits also to detect less extreme years in which breeding productivity is poor and takes the long-term perspective of the assessed marine bird species into consideration by projecting the impact of current breeding productivity on population growth-rates. As such, the indicator now also provides information on potential future problems rather than merely observing events that have already occurred, providing for more opportunities to intervene with a measures response. In line with the new method, a revised Threshold Value was developed and applied.

The thematic assessment for marine birds (Annexes AI and AJ) was produced by integrating the OSPAR common indicator assessments following the methodology developed by the Joint Research Centre and outlined in the article 8 guidance for MSFD reporting. In addition to the integrated assessment of the state of marine birds at the "feature" level (Figure 5), the experts conducted desk studies to inform the wider narrative involving an inventory of the pressures on marine birds (Annex AK), measures that have been taken in the context of the MSFD (Annex AL) and responses in the framework of the Birds Directive (Annex AM). The compiled information was used to rank the pressures on marine birds according to relative importance. The information on measures in place to improve the state of marine birds was relatively scarce, and it was concluded that it was not enough information to properly evaluate the success of existing measures. The results from the desk studies were used to inform the marine birds thematic assessment, which was reviewed by the OSPAR-HELCOM-ICES Joint Working Group on Marine Birds and then agreed by all OSPAR CPs (including those that are EU MS).

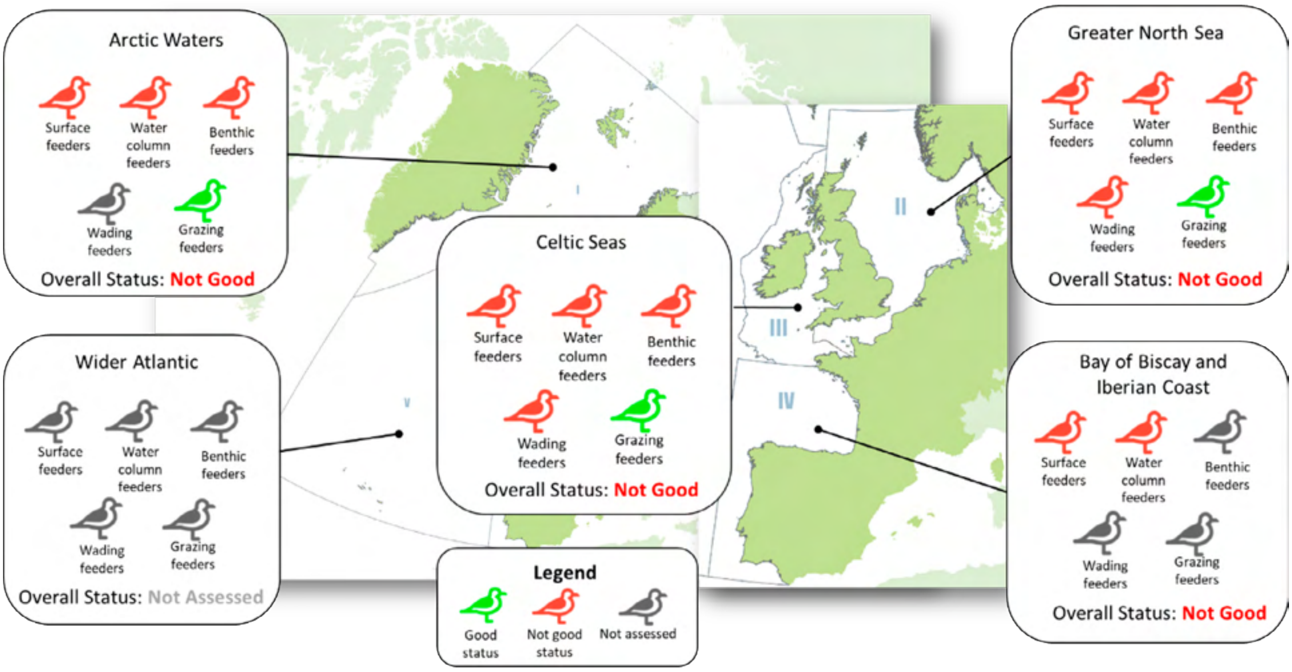

Figure 5. Graphical summary of the results of the integrated assessment of state of marine birds. The integration was performed at the MSFD "feature" level, using the integration rules agreed at Union level. It showcases the advances that have been made for this ecosystem component, but also relays the concerning message that marine birds in the North-East Atlantic are in trouble.

The final task in Activity 4 involved the organization of a workshop with experts from the North-East Atlantic, the Baltic, the Mediterranean, the Black Sea and Macaronesia. In the workshop, the experts from all European Sea Regions exchanged approaches to assess Good Environmental Status for marine birds for the MSFD (and other relevant EU directives, such as the Birds Directive). Efforts to restore or maintain marine bird species were also discussed, as well as potential synergies and important differences between the regions. The workshop report (Annex AN) contains an action plan for future collaboration that identifies priorities for collaboration, ways and options to maintain the engagement between the Sea Regions and avenues to secure funding in the future.

Activity 5: Coordination

Activity 5 was responsible for the coordination and organization of the larger workshops. Its members communicated on behalf of the NEA PANACEA experts with the European Commission, offered assistance to the partners on administrative issues where needed, provided timely instructions for the delivery of the financial statements and collated them for reporting to the European Commission. On a technical level, Activity 5 oversaw the delivery of the interim (Annex AP) and final technical report (this report), discussing the structure and content with the Activity leads, and coordinated the request for a 3-month no-cost extension of the Action (which was granted).

Table 5: The 6 deliverables agreed in the Grant Agreement for Activity 5 and the 6 delivered products associated with these deliverables.

Activity	Task	Deliverable (as appearing in Grant Agreement)	Associated product
5	1	D5.1 periodic financial, administrative and scientific reporting (when required)	This report Annex AP
5	2	D5.2a SuperCOBAM workshop	Annex AQ
5	2	D5.2b UltraCOBAM workshop programme	Annex AR
5	2	D5.2c UltraCOBAM workshop	Annex AR
5	2	D5.2d UltraCOBAM workshop report	Annex AR
5	3	D5.3 Written and/or oral presentations to relevant groups and committees (when required and/or appropriate)	Chapter 6
-	-	Final project meeting notes *(Not in Grant Agreement, as the meeting was initially not planned)*	Annex AO

One of the main challenges the coordinating team was faced with was dealing with the restrictions related to the COVID-pandemic. Not being able to travel and meet face-to-face was a new circumstance, and the changes in ways of working in an online environment required the necessary adaptations, not seldom “on the fly”. The task at hand, delivering and improving assessments of the marine environment for the OSPAR QSR and the MSFD, remained the same, however. We were forced to design our interactions in new and innovative ways. Combined with the continuous uncertainty about the pending installment or lifting of restrictions, this put extra strain on the work of Activity 5. Still, we have been succesful in building a team, having fruitful workshops and meetings, and keeping communication lines open, and learned many a lesson that will allow us to collaborate in more environmental-friendly ways than before.

The coordinating team met (online) on a weekly basis to discuss progress and steps needed to deliver on the workshops and reporting. In addition, Activity 5 met on a 4-6 weekly basis with the leads of the other 4 Activities to monitor the progress and discuss the needs and wishes of the wider NEA PANACEA team with regards to the reporting and the contents and structure of the workshops.

Activity 5 organized an online kick-off meeting as well as a final meeting (Annex AO). The final meeting was originally planned to be 1 day online, but in the end there was travel budget to have a fruitful in-person session as well, so the final meeting was 1 day hybrid and 2 days in-person. In addition to these smaller meetings, two large workshops were organized: SuperCOBAM and UltraCOBAM. SuperCOBAM (Annex AQ) was aimed at early alignment of indicator and thematic assessments within and between biodiversity (D1), food webs (D4), eutrophication (D5) and seafloor integrity (D6), and preventing expert groups working in isolation (including ecosystem component expert groups not directly involved in the project). It was a hybrid meeting, where NEA PANACEA members (25) participated in-person in Utrecht and experts not involved in the project joined virtually (40). UltraCOBAM (Annex AR) was aimed at the delivery of the seven biodiversity thematic assessments for QSR2023. Thematic assessments not only contain an integrated assessment of the state of each ecosystem component, but they also tie biodiversity (State) in with societal Drivers, associated Activities, resulting Pressures, Impacts on ecosystem services and policy Response (the DAPSIR framework) and with climate change. It was attended by 56 (50 in-person, 6 online for selected elements) experts, covering all ecosystem components and many types of pressure (see also Figure 6). Through the meetings and workshops, NEA PANACEA has been very instrumental in supporting the QSR process (beyond the 3 ecosystem component groups active in the Action), especially considering the challenges the pandemic posed, and thus informing EU Member State MSFD reporting.

Figure 6. Participants to the UltraCOBAM workshop in June 2022. By bringing 50 experts (covering all ecosystem components and many pressure-types) from the OSPAR network together for 3 days of working, discussing and learning from each other, NEA PANACEA contributed significantly to the delivery of all 7 biodiversity thematic assessments in the QSR.

Meetings in the context of OSPAR and the EU CIS-process were reduced in frequency during a large part of the Action's running time, and the meetings that were held often had reduced agendas and slightly less efficient procedures because of the online and later hybrid nature of the meetings. As a result, there has been no opportunity to present the proposal, the progress or the results of NEA PANACEA in any of the CIS working groups. However, we did interact with other projects under the same call (QUIETSEAS, ABIOMMED, HELCOM BLUES, HARMONIZE and CetAMBicion) by presenting at their meetings and/or having them present at our meetings. NEA PANACEA's work was strongly tied in to the wider OSPAR effort to deliver the QSR2023 and Activity 5 did have frequent interactions and presentations at meetings of OSPAR committees and intersessional correspondence groups dealing with biodiversity and eutrophication, the editorial board of the QSR and the policy makers in the Coordination Group.

ACTIVITY 1 – PELAGIC HABITATS

Activity 1 summary

Institutions involved:

France: Centre national de la recherche scientifique
Germany: AquaEcology GmbH & Co. KG
The Netherlands: Deltares
United Kingdom: The University of Plymouth, Plymouth Marine Laboratory, The Marine Biological Association

The purpose of Activity 1 was to deliver an integrated thematic assessment of the North-East Atlantic pelagic habitat quality status (MSFD D1C6), based on the latest indicator developments and assessments. This activity addressed the four working themes of the NEA PANACEA project (Figure 1) and involved the development and implementation of new assessment methods and connected Pelagic Habitats indicators with Food Webs (MSFD D4) indicators through pressures outlined under Activity 2, such as eutrophication (MSFD D5) and climate change.

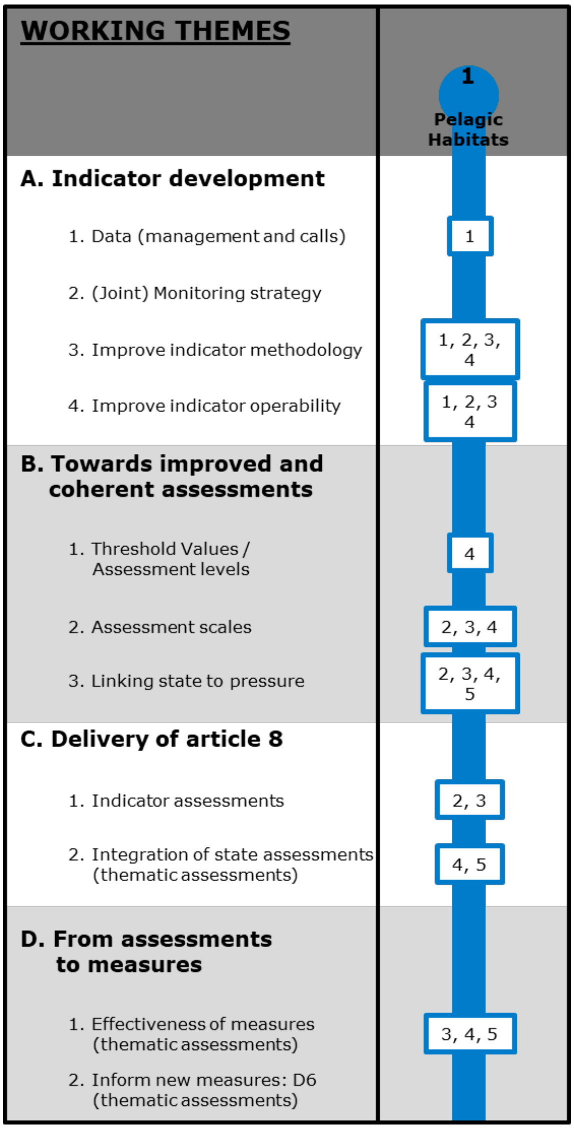

Figure 1. Structure of working themes (left column) and how they relate to each task (Tasks 1.1, 1.2, 1.3, 1.4, and 1.5, blue boxes) under Activity 1 of the NEA PANACEA project.

All Activity 1 Task teams reported to the wider Activity 1 team at three-monthly online meetings to ensure task deliverables remained on track and to address any challenges that arose (Figure 2). At each meeting a detailed list of actions was produced, with clear allocation of all actions to individuals within each Task team. The Activity 1 deliverables were greatly improved through non-NEA PANACEA expert involvement, including those from other EU Member States, drawing on the professional networks of both the French and UK Activity 1 Task teams. The Activity 1 team drew on the advice of both the OSPAR and UK Pelagic Habitats Expert Groups in cases where deliverables could benefit from expert guidance, or when this was mandated by the OSPAR process.

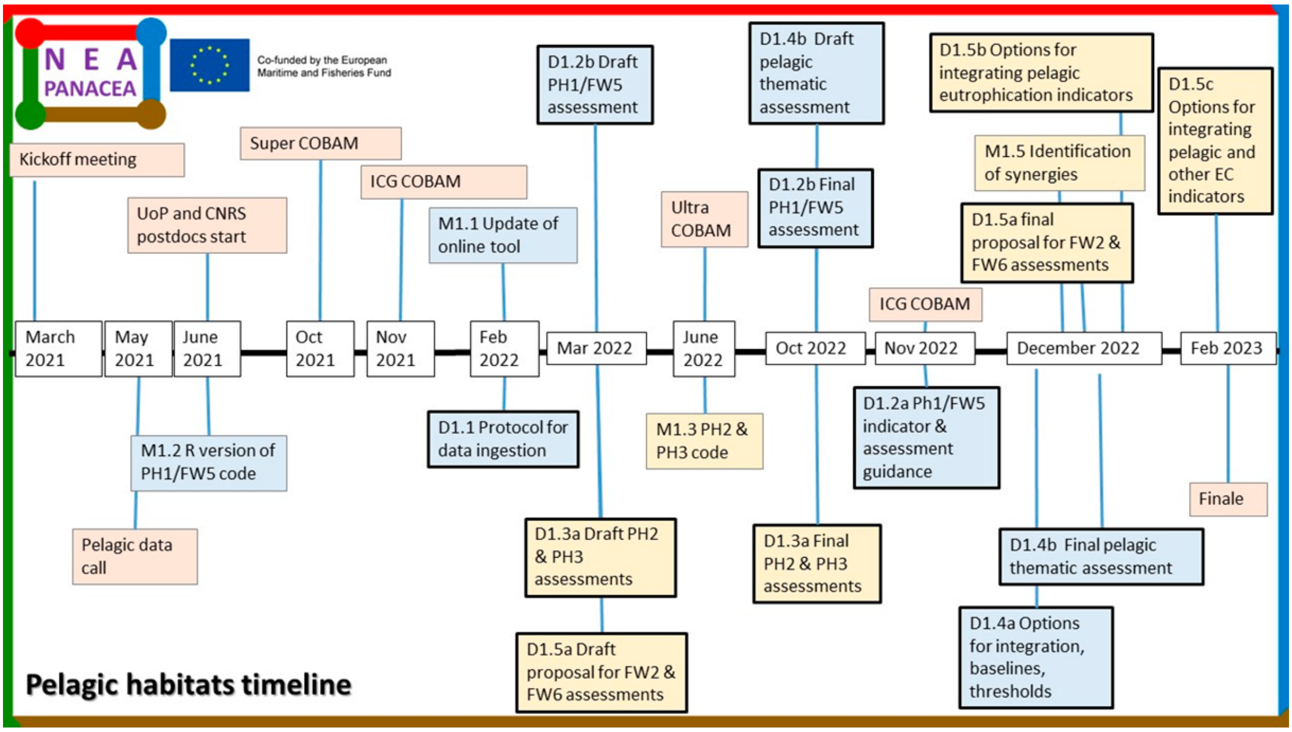

Figure 2. Delivery timeline for each milestone and deliverable under Activity 1 of the NEA PANACEA project.

The NEA PANACEA project team held an in-person MiniPANACEA workshop in Madrid, Spain (25 to 27 May 2022), which partially focused on addressing and agreeing outcomes for Tasks 1.2 and 1.3, which support pelagic indicator assessments for EU MS reporting for the MSFD (D1C6, D4C1, D4C2) through the OSPAR QSR. This workshop included representatives from Task teams 1.2 and 1.3, as well as external pelagic habitats experts from different institutions and CPs. Experts from Task 1.5 and external Food Webs experts were also involved in this workshop in relation to pelagic-related food webs indicators which also support food web assessments for EU MS reporting for the MSFD (D1C6, D4C1, D4C2) through the OSPAR QSR. Additionally, the Task 1.4 and 1.5 teams participated in the Super- and UltraCOBAM meetings (20 to 22 October 2021 and 14 to 16 June 2022, respectively, in Utrecht, the Netherlands; see Activity 5), which were essential for developing the necessary integration and cross-cutting methodologies to support delivery of the Pelagic Habitats Thematic Assessment. Finally, participation of Activity 1 team members in some meetings of Activity 2 was complemented by a combined meeting between partners of both activities, held in Uppsala, Sweden (30 January to 1 February 2023) and attended virtually by Activity 1 team members. Progress by all Activity 1 tasks occurred in collaboration with and was reviewed by the OSPAR COBAM Pelagic Habitats Expert Group, to ensure scientific consensus and robustness.

In February 2023 the Activity teams took stake of progress on the overall NEA PANACEA project. While most Pelagic Habitats deliverables had been completed by this stage, a few deliverables (namely for Tasks 1.4 and 1.5) were in a state where they could be significantly improved through further experimentation and consultation with experts. The project was granted a three-month no-cost extension, which greatly improved our ability to deliver our promised integration work.

The NEA PANACEA project team held the end of project meeting in Den Haag, the Netherlands (3 to 5 May 2023), to share experiences among the five project activities, discuss the delivery of the project report, and finally to discuss knowledge gaps and next steps for developments coming out of the NEA PANACEA project, in the context of delivering MSFD products through OSPAR.

Task 1.1: Expanding data coverage and developing data tools to support robust assessment (Annex A)

Task Lead: Abigail McQuatters-Gollop (UoP, UK) (Partner)

Others involved: Felipe Artigas (CNRS, FR) (Partner), Matthew Holland (UoP, UK) (Partner), Arnaud Louchart (CNRS, FR) (Partner), Kevin Paxman (Marine Biological Association, UK) (Sub-contractor)

Other Activities involved: Activity 2 (Tasks 2.1, 2.3)

Milestones: M1.1 Update of online tool

Deliverables: D1.1 Protocol for data ingestion

Task 1.1 summary

To support MSFD assessments through the OSPAR QSR 2023, we required expanded data coverage and updated procedures for acquiring suitable data from contracting parties. As discussed in the project proposal, we initially issued a data call through OSPAR to 1) update datasets that were already used to support the previous assessment cycle and 2) capture additional datasets that were not yet used in IA2017, including those using non-microscopy data and especially JMP-EUNOSAT satellite data on chlorophyll-*a* (provided by Activity 2), as well as zooplankton biomass and primary production data (in situ, in situ simulated and also modelling and satellite data (provided by Activity 2)). These datasets supported the OSPAR Pelagic Habitats indicators "Change in plankton biomass and abundance" (PH2) and "Change in plankton diversity" (PH3), as well as the food web indicators "Production of phytoplankton" (FW2), "Biomass, species composition and spatial distribution of zooplankton" (FW6) and "Change in plankton communities" (PH1/FW5), which are linked to the food webs FW9 (Ecological Network Analysis) indicator work in Activity 2 (Task 2.2). As an indicator suite, these indicators inform three MSFD Descriptor-Criterion sets: D1C6, D4C1, and D4C2. In response to the data call, we received a total of 34 plankton abundance datasets from 9 contracting parties and 15 plankton biomass datasets from 7 contracting parties (Figure 3). Data were not provided by Norway nor by Ireland. Data were finally provided by France, but only after the data call deadline had passed (1 December 2021), and therefore these data could not be used for this assessment cycle. All other contracting parties with marine territories in the Greater North Sea, the Celtic Seas and the Bay of Biscay and Iberian Coast submitted plankton data which were used to support the assessments.

For the OSPAR indicator PH1/FW5, we required the microscopy data to be taxonomically consistent and 'clean' (e.g. no double counting of individual plankters); a procedure to do this was developed by the UK as part of the EMFF/MMO funded ICEGRAPH Project (Improving Confidence Evaluating GES for Regional Assessments of Pelagic Habitats). UoP supported data holders throughout this process to ensure consistency in the cleaning of their data. For PH1/FW5, data were ingested into the online Plankton Lifeform Extraction Tool (PLET; https://www.dassh.ac.uk/lifeforms/) which converts plankton datasets into the lifeforms required for assessment of the PH1/FW5 indicator, a normally resource-intensive process. To ensure this process was robust, two steps were required: 1) New species from additional datasets were ingested into our Master Taxa List which assigns biological traits to taxa, allowing them to be sorted into lifeforms for PH1/FW5 (UoP led this aspect) and 2) The tool was further developed to support current and future MSFD and OSPAR biodiversity assessments (Milestone M1.1). The MBA (subcontracted by UoP) led the process of updating the PLET. Finally, we worked with data holders to develop a protocol for submitting data (Deliverable D1.1) and to test and check all our work and ensure a robust process when extracting indicator PH1/FW5. This was done for all datasets, for all lifeforms, and at various spatio-temporal scales. The processes implemented for PH1/FW5 also ensured that the taxonomic data used to calculate PH2 and PH3 indicators were consistent.

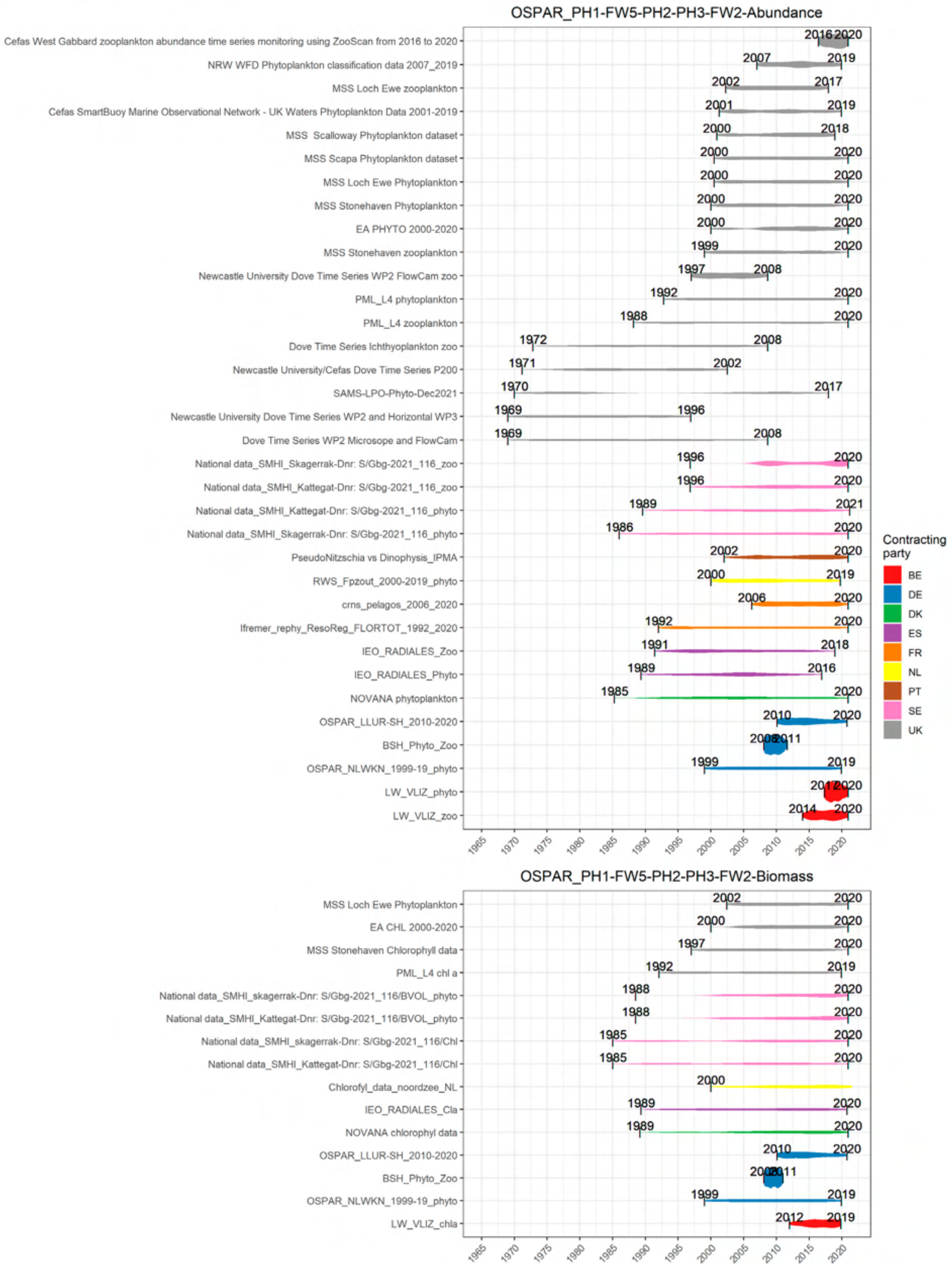

Figure 3. Violin plots outlining the start and end dates and distribution of samples across each plankton abundance (upper panel) and plankton biomass (lower panel) dataset received through the OSPAR data call. The thickness of each coloured bar indicates the distribution of sample effort through time for each dataset. Datasets are coloured according to the contracting party that provided them.

M1.1 Update of online tool

The online Plankton Lifeform Extraction Tool (PLET) was updated to expand its functionality and improve user-experience. The updates to the previous version of the tool were as follows:

- Datasets in the drop-down selection box now have their provider listed alongside.
- All datasets are now listed in a table at the bottom of the page, along with their data access permission, and DOI (if one was provided by the data holder).
- The datasets are all now shown on the map, either as makers for static sites, or coloured dots for moving samplers (e.g. the Continuous Plankton Recorder).
- Constructing further options for lifeform extraction. A new lifeform has been added for "total copepods", to support the PH2 indicator.
- "PlanktonType" trait is now included as a column in the raw extract, to make it possible for users to compare raw data to aggregated lifeform counts.
- The lifeform(s) are now included as a column in the raw extract.
- Datasets listed as "Restricted" by the data holder are now protected. Users can download an aggregated lifeform product (for abundance datasets only) but the tool will issue an error message if a user requests the raw extract.
- Issuing Digital Object Identifiers (DOIs)
- Updating and checking metadata
- Assigning confidence flags to data samples and datasets and enabling extraction of lifeforms at different spatial scales so assessment areas can match up with those from Activity 2 (Task 2.3).

D1.1 Protocol for data ingestion (Annex A)

The OSPAR pelagic habitat monitoring programme is made up of multiple independent plankton monitoring programmes, including both continuous and station-based sampling designs (Figure 4). Each separate institution contributing data to pelagic habitats indicator assessment is responsible for managing their own dataset.

To contribute to a better understanding of the state of pelagic habitats throughout the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast, Contracting Parties are required to report data that will enable an assessment of biodiversity Indicators. To facilitate the collection of plankton datasets to support MSFD assessments for Pelagic Habitats we produced a protocol document describing how to format and ingest new complex, biological pelagic datasets into our assessment process to ensure data were accessible and fit-for-purpose. We outlined detailed procedures for pre-processing three different data types (plankton abundance data, plankton biomass data, primary productivity data) and outlined the role of data providers and their responsibility to participate in the biodiversity assessment process through responding to routine OSPAR data calls. We also developed a set of Excel file templates for data reporting in both matrix and list format, with detailed instructions in the protocol document describing the variables to include and how the templates are to be populated. This protocol document and templates will now be used by OSPAR whenever a new data call is issued.

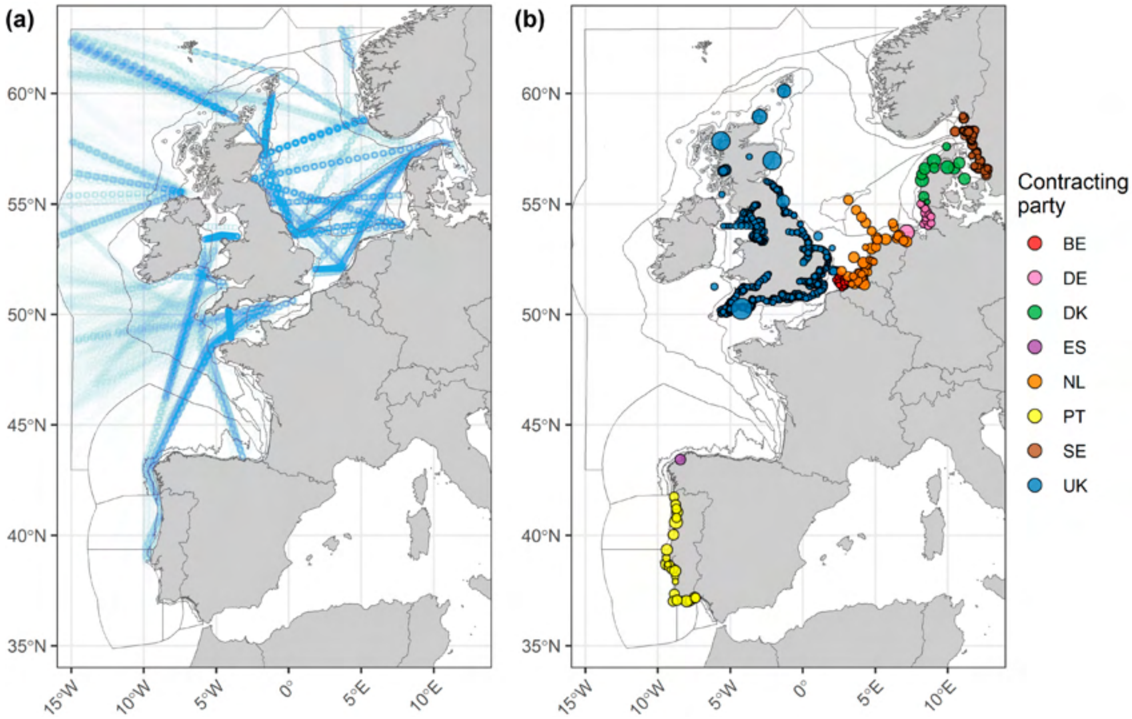

Figure 4. Locations of the Continuous Plankton Recorder (CPR) samples (a) and locations of the national plankton timeseries datasets (b) currently integrated in data flows for the Plankton Community Indicator. Datasets are grouped by contracting party.

Task 1.1 knowledge gaps and next steps

- Mobilise additional datasets and ingest into the PLET.
- Improve the ability to deal with non-microscopy data and indicators (e.g. satellite products, flow cytometry, functional and size-based plankton groups, plankton imaging data from Cefas Plankton Imager).
- Develop protocols for ingestion of the above 'new' types of data, define new lifeforms according to these new types of data, and define new lifeforms from the already included taxonomical data on the PLET.
- While the PH1/FW5 indicator tool is currently only accessible from a personal GitHub repository, it should be migrated over to a dedicated GitHub repository which can be accessed from the PLET via hyperlink.
- Link up data call with ICES – ICES database would store pelagic data. We can help ICES define how the data should be stored. We can then extract the data directly from ICES to the PLET.

Task 1.2: Refinement, operationalisation, and assessment of OSPAR´s pelagic habitats (and food web) indicator PH1/FW5: Change in plankton communities (Annexes B and C)

Task Lead: Abigail McQuatters-Gollop (UoP, UK) (Partner)

Other involved: Felipe Artigas (CNRS, FR) (Partner), Matthew Holland (UoP, UK) (Partner), Arnaud Louchart (CNRS, FR) (Partner)

Other Activities involved: Activity 2 (Task 2.1, 2.3)

Milestones: D5.2a SuperCOBAM workshop; M1.2 R version of PH1/FW5 code

Deliverables: D1.2a PH1/FW5 indicator extraction and assessment guidance; D1.2b Assessment for PH1/FW5

Task 1.2 summary

The Plankton Community Change indicator (PH1/FW5), describes changes in plankton functional types, or lifeforms (D1C6, D4C1, D4C2) (Figure 5). Once lifeforms are extracted from the PLET, the online tool described in Task 1.1, the PH1/FW5 indicator uses a Kendall trend test to determine the direction of change in plankton abundance time-series (i.e. increasing, decreasing, or stable) and a Plankton Index (PI) to quantify the relative change among ecologically-meaningful lifeform pairs. This tool was rewritten using open-source software (R; R Core Team, 2020) to make it more accessible to a broader user base (Milestone M1.2).

In addition to this updated tool, we made improvements to the PH1/FW5 indicator, including limiting the scope of the assessment to focus on a core group of eight important plankton lifeforms representing changes in phytoplankton and zooplankton communities. We also incorporated an algorithm for linking change in the indicator with changes in environmental variables, some of which are strongly influenced by anthropogenic pressures (e.g. sea temperature and nutrients), and developed a new set of procedures for integrating results across these eight lifeforms to determine GES at the level of MSFD Pelagic Habitat types and at the level of OSPAR regions. We developed a fully documented updated procedure for evaluating the indicator in a detailed Coordinated Environmental Monitoring Programme (CEMP) document to ease reproducibility in future assessments (Deliverable D1.2a, Annex B). Finally, an assessment for PH1/FW5 was produced (Deliverable D1.2b, Annex C), using the updated assessment protocol described above (led by UoP).

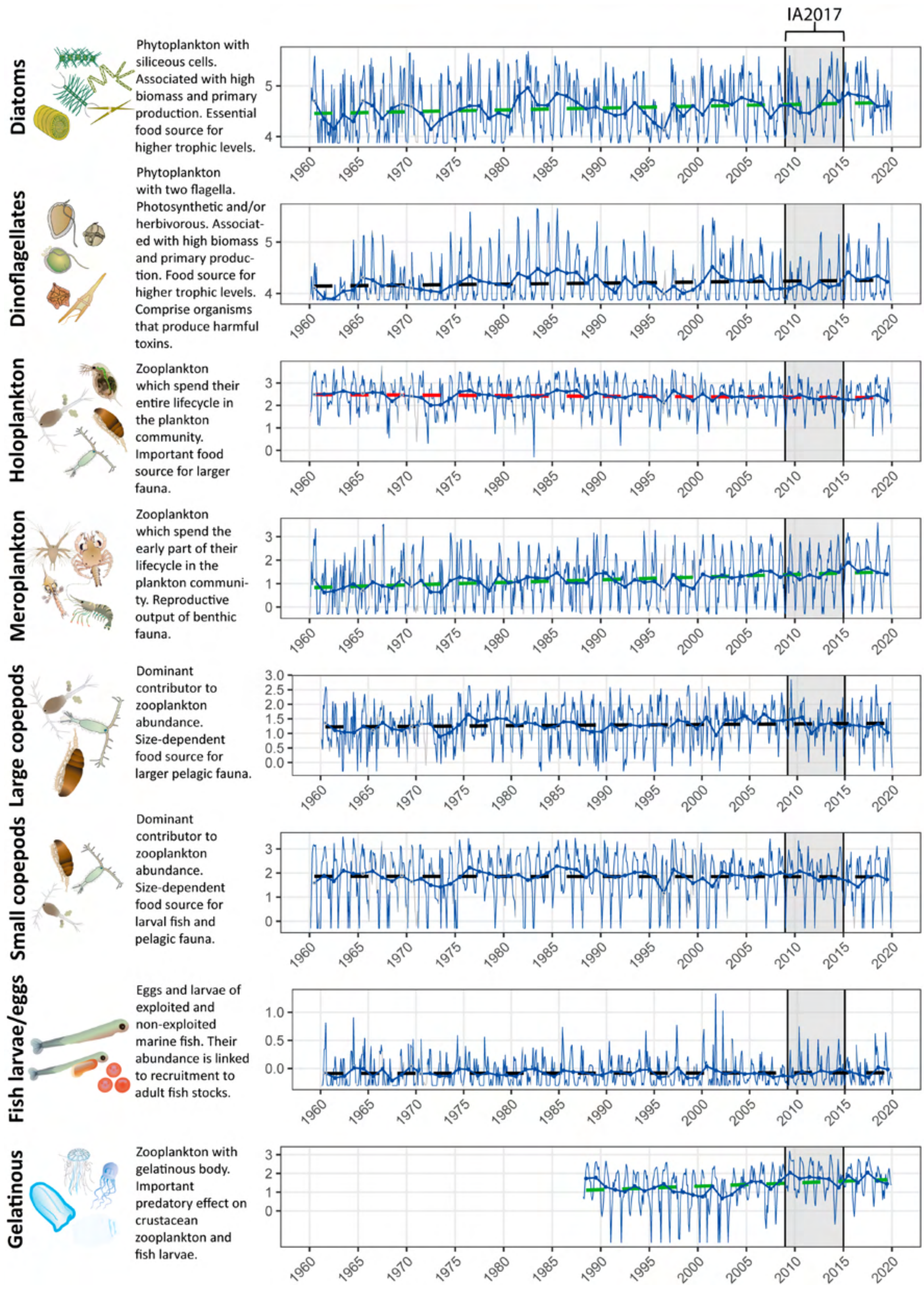

Figure 5. Long-term monthly and annual log10 transformed abundance time-series for eight plankton lifeforms in the Western Channel. Blue lines display monthly variability (thinner line), and annual mean abundance (thicker line) values. Dashed lines indicate linear trend lines in annual abundance without any inference on statistical significance. The Kendall trend test is used to infer significance of trends, with red: decreasing trend, green: increasing trend, and black: no trend. Data obtained from the Continuous Plankton Recorder (CPR) survey and Plymouth Marine Laboratory (for gelatinous zooplankton only due to non-quantitative capture of gelatinous taxa by CPR). The shaded region represents the time-period of IA2017. Plankton images courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

M1.2 R version of PH1/FW5 code

Prior to the NEA PANACEA project, the code that generated the PH1/FW5 indicator only existed in Matlab, the language it was originally written in, which is proprietary and therefore not free to use. We translated the core functions of the script into R, an open-source language which is free to use and understood more widely across the scientific community. UoP further developed this script to calculate the PH1/FW5 indicator by interfacing directly with outputs from the PLET. This new tool has been greatly improved from the original Matlab version and now generates graphical outputs (Figure 6), including maps representing the location of the assessment unit used to extract the data from the online tool, as well as Excel results tables. The tool now provides functionality for calculating the PH1/FW5 indicator, allowing users to compare user-specified comparison and assessment periods, as well as the ability to compare an assessment period with every year in a time-series. These improvements will increase accessibility of the indicator, thereby improving and streamlining regional coherence in indicator methods, data use, and assessment for MSFD D1C6, D4C1, and D4C2 through the OSPAR QSR. The tool is currently available from https://github.com/hollam2/PH1_PLET_tool, but there are plans to host this tool on a dedicated platform going forward. The tool is already being used by Sweden and other contracting parties to support their MSFD assessments for 2024.

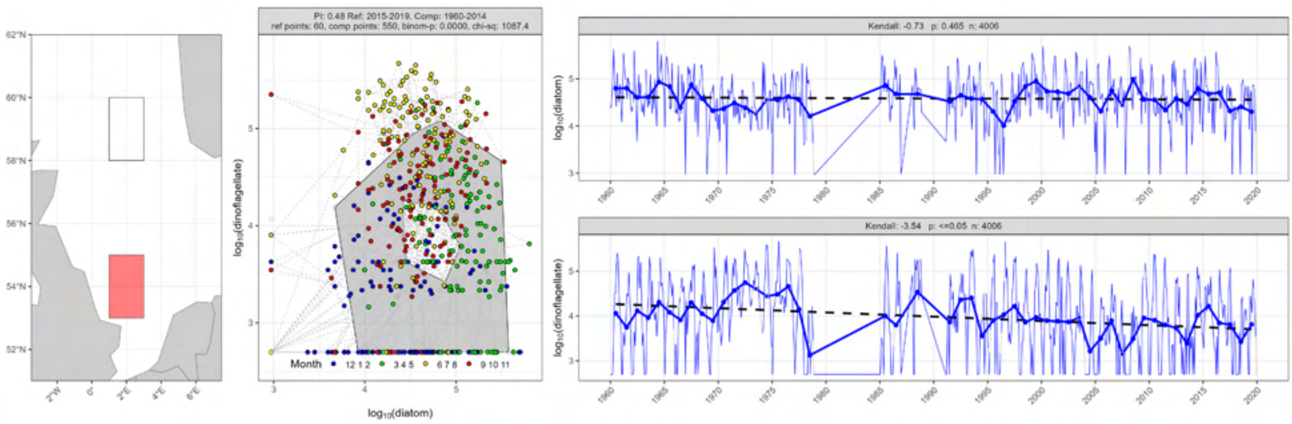

Figure 6. PH1/FW5 graphical output from updated R code, indicating the geographic location of the relevant assessment unit in red and the outline of other assessment units used in the extraction from the online tool (leftmost panel), the PI representing the relative change in an ecologically-meaningful lifeform pair (middle panel) and the monthly and annual time-series for the two lifeforms (rightmost two panels). Gaps in the time-series indicate periods when samples were not available within the relevant assessment unit.

D1.2a PH1/FW5 indicator extraction and assessment guidance (Annex B)

The updated procedure for conducting the PH1/FW5 indicator assessment was written up as a dedicated Coordinated Environmental Monitoring Programme (CEMP) guideline document to improve the reproducibility of the indicator for future assessments. These new CEMP guidelines describe detailed procedures for plankton monitoring and sampling strategy, quality assurance / quality control procedures from 14 institutes that submitted data, and a thorough description of the current assessment methodology, including links to the updated R code for evaluating PH1/FW5 (Milestone M1.2).

D1.2b Assessment for PH1/FW5 (Holland et al., 2023) (Annex C)

The PH1/FW5 indicator was further tested with the COMP4 assessment units, a new set of spatial areas aligned with Contracting Parties national reporting regions and with those developed by OSPAR´s Intersessional Correspondence Group on Eutrophication (ICG-Eut). We first extracted the lifeforms based on these updated areas (Task 1.1, collaboration with Task 2.3), generated a Kendall trend test and a PI for each lifeform, and then examined the results for consistency and robustness. Spatial modelling (Geographic Information System tools and statistical approaches) was employed to determine the most ecologically relevant scale in the relationships between activities, pressures and impacts on pelagic habitat and state. The distribution of trends across a uniform square grid was closely aligned with the distribution of trends across the COMP4 assessment units (Figure 7), providing suitable justification for their use in MSFD assessments of the three Pelagic Habitats indicators. The spatial alignment of patterns in the PH1/FW5 indicator with the delineation of the COMP4 assessment units was further explored under Task 2.3. The use of the COMP4 assessment units for Pelagic Habitats indicator assessments has now greatly improved the spatial comparability between PH1/FW5 and Food web and Eutrophication assessments (Tasks 1.5 in this Activity and Task 2.3 in Activity 2), as well as supporting the Pelagic Habitats Thematic Assessment.

PH1/FW5 currently uses monthly time-series of plankton data collected via light microscopy, which must be at least 8 years in length (sampling must cover 4 years of the assessment period and at least 4 years of the comparison period). To further increase indicator robustness by including as much data as possible, the indicator was tested on different types of data, lengths of datasets, and frequencies of sampling. These data were gathered via the data call in Task 1.1. In addition, to improve the interpretability of the assessment, the list of lifeforms considered in the assessment was reduced to focus on a core group with easy identification to represent changes in phytoplankton (diatoms and dinoflagellates) and zooplankton (meroplankton, holoplankton, large copepods, small copepods, fish larvae, and gelatinous zooplankton).

In the previous assessment cycle we identified changes in pelagic indicators but did not link these with drivers of change. For the current indicator assessment, we built on work of the EMFF-Funded ICEGRAPH project (Increasing Confidence in Evaluating GES for Regional Assessments of Pelagic Habitats) to identify the causes of change PH1/FW5 (Bedford et al., 2020a). Indicator responses to key anthropogenic pressures and climate drivers were quantified using tree-based models (random forest) to determine magnitude and direction of indicator change relative to these drivers. We developed procedures for integrating results from these tree-based models to distinguish responses from anthropogenic pressures from those due to prevailing conditions (including climate change) (in collaboration with Activity 2). This analysis was required to assess indicator progress in light of the lack of suitable assessment thresholds and across sub-regions. We examined these state-pressure links at multiple spatial scales, including the assessment scales used by ICG-Eut (i.e. COMP4 assessment units; in collaboration with Activity 2), as well as MSFD pelagic habitat types (i.e. variable salinity, coastal, shelf, and oceanic / beyond shelf habitats), and OSPAR regions.

The PH1/FW5 indicator assessment produced for this assessment cycle concluded that long-term trends (1960-2019; Figure 8) indicate that most plankton lifeforms, including diatoms, dinoflagellates, holoplankton, fish larvae/eggs, and large (adult ≥2 mm) and small (adult <2 mm) copepods are declining in abundance throughout the North-East Atlantic. Spatial patterns in the direction of change for both small and large copepods closely match those of the diatoms. Conversely, meroplankton demonstrate a pattern of increasing abundance or no change throughout all assessment units and all but one fixed-point station. Patterns apparent from the widely distributed CPR data are reflected by the fixed-point stations from adjacent transitional waters, except in the case of dinoflagellates, which demonstrate an increasing trend in transitional waters of Scotland (MSS, United Kingdom) and Germany (NLWKN, Germany).

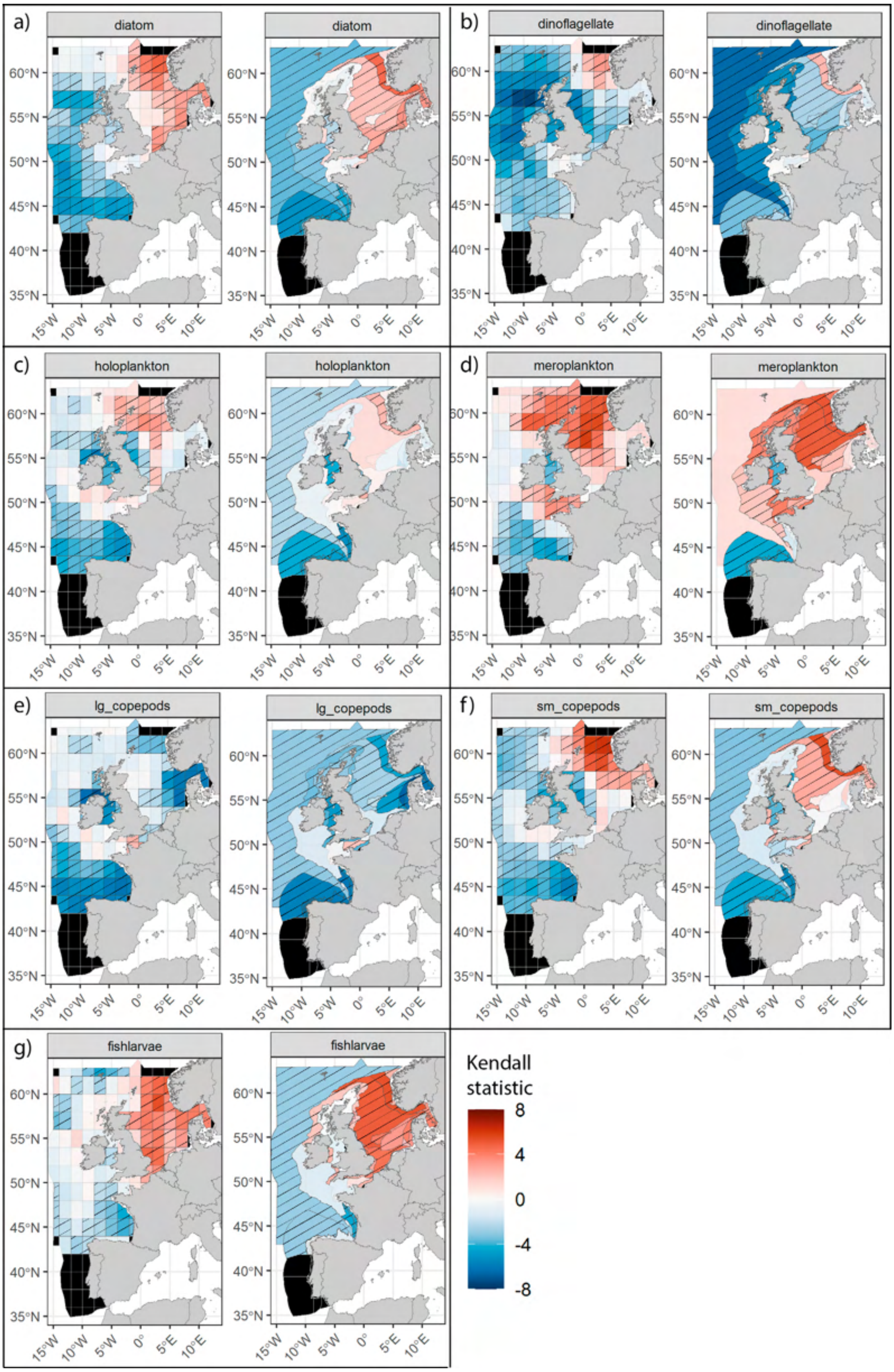

Figure 7. The distribution of Kendall trend test results (1960-2018) derived from CPR data and distributed across a 2° square grid (left panel for each lifeform) and across the COMP4 assessment units (right plot for each lifeform) for seven plankton lifeforms which were analysed for the PH1/FW5 indicator assessment, including: a) diatoms, b) dinoflagellates, c) holoplankton, d) meroplankton, e) large copepods, f) small copepods, and g) fish larvae/eggs. Assessment units are coloured according to the results of the Kendall trend test, which indicate the magnitude of long-term increase (> 0) and decrease (< 0) in lifeform abundance from 1960-2018. Patterned assessment units indicate statistically significant change (p ≤ 0,05). Assessment units filled in black indicate insufficient data to evaluate a trend.

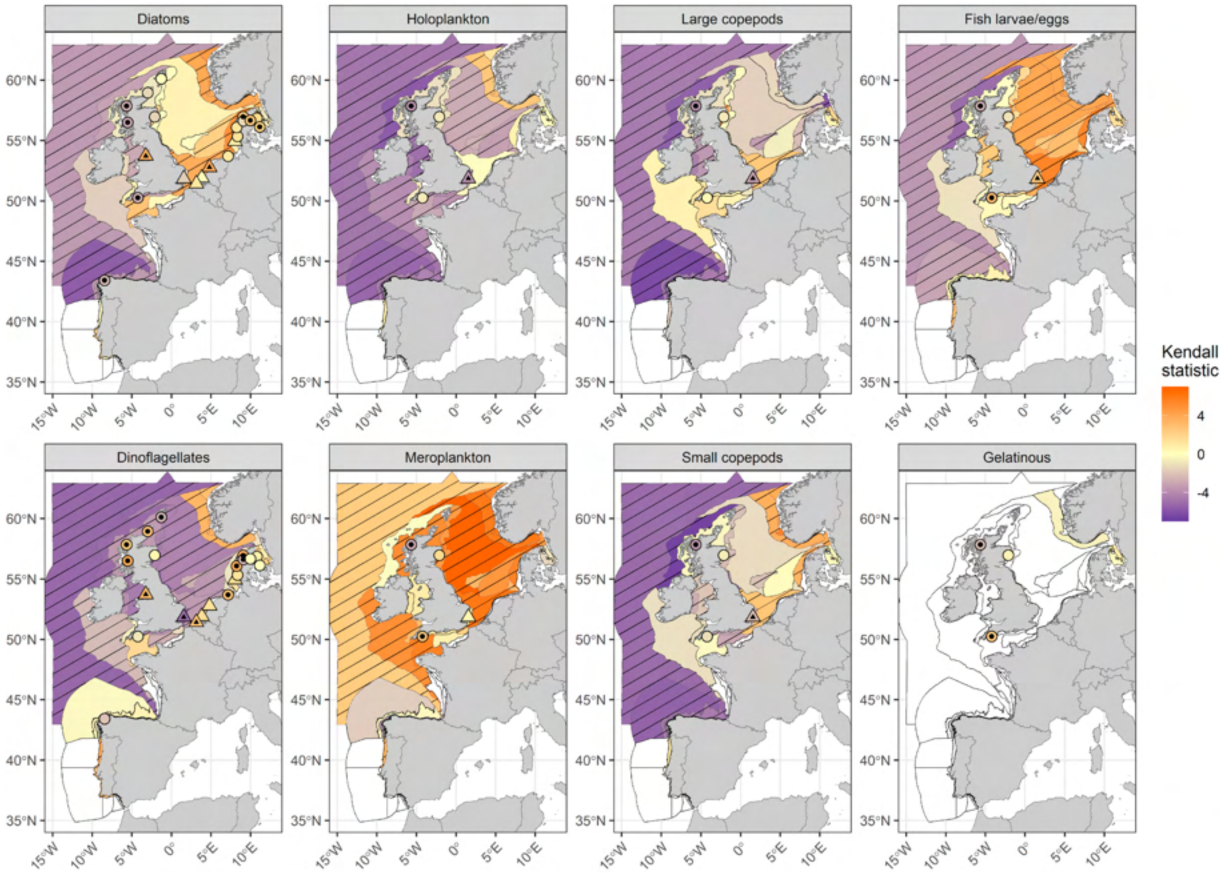

Figure 8. Kendall statistics for eight plankton lifeforms displayed over COMP4 assessment units and fixed-point stations in the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast. River plumes are represented as triangles. Assessment units are coloured according to the results of the Kendall trend test, which indicate the magnitude of long-term increase (> 0) and decrease (< 0) in lifeform abundance from 1960-2019 (or a shorter period for fixed-point stations). Patterned assessment units, fixed-point stations and river plumes with an internal black symbol indicate statistically significant change (p ≤ 0,05). Assessment units filled in white indicate insufficient data to evaluate a trend.

Changes in lifeform abundance were linked to variation in environmental pressures, acting both externally (e.g., precipitation, wind speed) and internally (e.g., pH, water temperature) on the marine environment. Many of these pressures are influenced indirectly by climate change (Figure 9). Modelling results have shown that increased sea surface temperatures were linked to declining abundances of plankton lifeforms, particularly small and large copepods in the Atlantic. Change in water temperature was also strongly linked to increasing meroplankton abundance within the Eastern North Sea. Impacts of increasing temperature were most frequently detected in shelf and oceanic pelagic habitats. While increasing temperatures can have direct impacts, they can also be linked to greater stratification and resulting nutrient limitation. Links to nutrient concentration were less clear since it is difficult to assess the impact of nutrient concentrations on lifeforms due to the lag period between occurrence and phytoplankton uptake and assimilation. However, model results suggest that they were more apparent in coastal regions. Changes in diatom and dinoflagellate abundance in these assessment units were mainly linked to increases in the N:P ratio, driven by reductions in phosphorus concentrations.

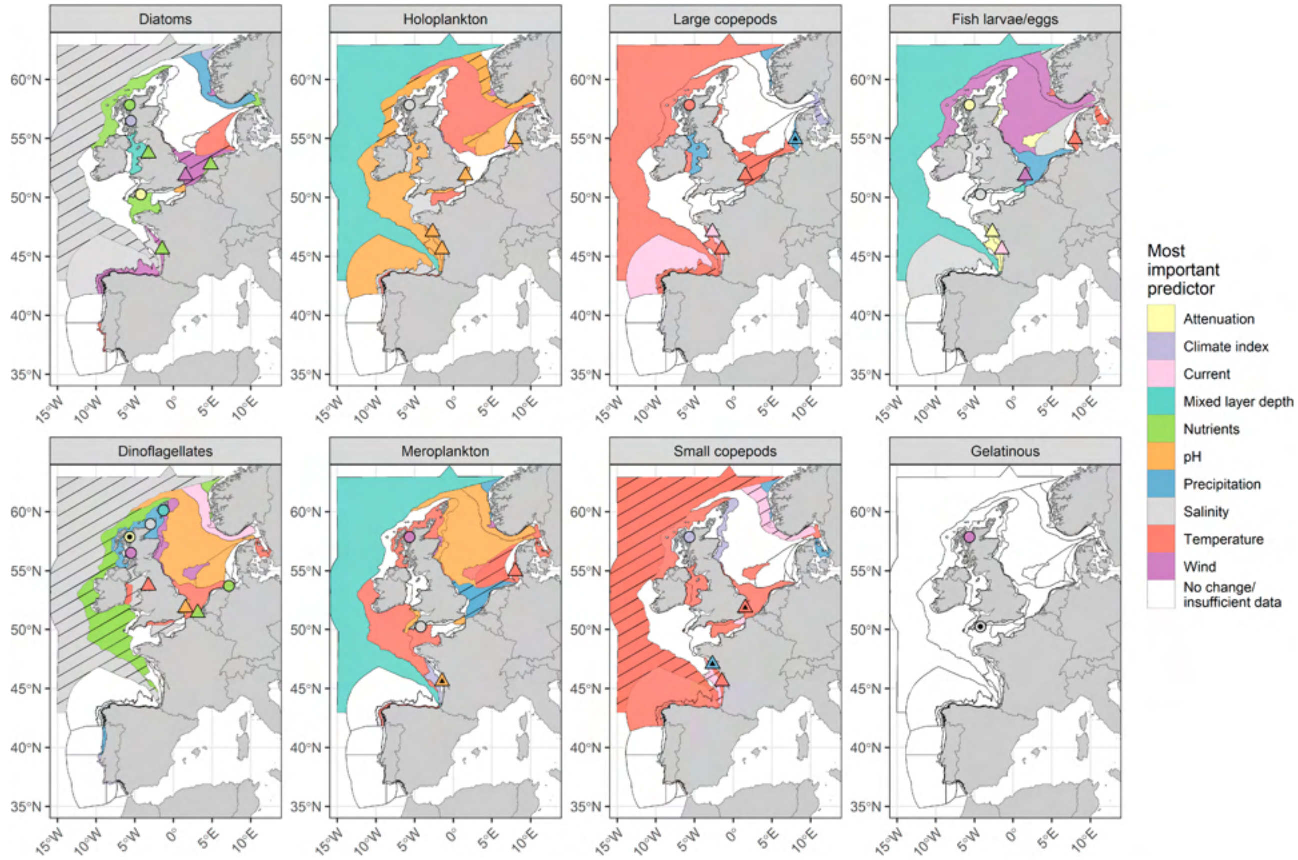

Figure 9. COMP4 assessment units for eight plankton lifeforms, coloured by a categorisation of the most important environmental variable to predict lifeform abundance. Patterned assessment units, fixed-point stations and river plumes with an internal black symbol indicate statistically significant correlation between predicted and observed testing data, indicating greater reliability of reported results. Assessment units filled in white indicate no change in lifeform abundances or insufficient data to evaluate a trend. Fixed-point stations and river plumes are only displayed where a trend in lifeform abundance is present.

Based on the current criteria used to determine GES (McQuatters-Gollop et al., 2022) and outlined in greater detail under Task 1.4, the relationships between PH1/FW5 indicator results and environmental pressures, the quality status of shelf habitats within the Greater North Sea (Region II; Table 1), Celtic Seas (Region III; Table 2), and Bay of Biscay and Iberian Coast (Region IV; Table 3) was "Not good". Coastal habitats in the Celtic Seas and oceanic / beyond shelf habitats in the Bay of Biscay and Iberian Coast were also "Not good". All remaining assessed pelagic habitats had an "Unknown" quality status.

Table 1. Integration of the indicator results for the Greater North Sea. Column names are described as follows: ↓: the number of COMP4 assessment units and fixed-point stations where decreasing trends have been detected, -: the number of COMP4 assessment units and fixed-point stations where no trends have been detected, ↑: the number of COMP4 assessment units and fixed-point stations where increasing trends have been detected, Dir: the net direction of change in the lifeform (↓: decreasing, ↑: increasing, -: stable), Trend: the percentage of assessment units exhibiting the respective trend, Conf: the mean confidence of datasets considered in the assessment, Change: a logical variable (TRUE/FALSE) to report whether a net trend is likely given the proportion of locations expressing the trend and the confidence and spatial representativeness scores, Press1: the environmental pressure with the greatest mean rank for the respective trend, Rank1: the mean rank of the environmental pressure indicated under Pres1, nStn: the total number of fixed-point stations considered, totAssess: The total number of COMP4 assessment units and fixed-point stations considered, totCOMP4: The total number of potential COMP4 assessment units for the habitat category, spatialRep: the spatial representativeness score of the analysis. The status of the individual lifeforms are indicated by the colours in the Lifeform column, with orange: unknown status, red: not good status, and grey: not assessed. The overall status of the habitat category is indicated by the colour of the first column, which also identifies pelagic habitat types and follows the same colour key.

Habitat	Lifeform	↓	-	↑	Dir	Trend	Conf	Change	Press1	Rank1	nStn	totAssess	totCOMP4	SpatialRep
Variable salinity	Diatom	0	4	1	-	80%	51%	FALSE	np	3.5	1	5	9	44%
	Dinoflagellate	1	2	2	↑	40%	51%	FALSE	np	2.5	1	5	9	44%
	Holoplankton	1	0	0	↓	100%	30%	FALSE	ph	1.0	0	1	9	11%
	Meroplankton	0	1	0	-	100%	30%	FALSE	psal	1.0	0	1	9	11%
	Large copepods	1	0	0	↓	100%	30%	FALSE	sst	1.0	0	1	9	11%
	Small copepods	1	0	0	↓	100%	30%	FALSE	sst	1.0	0	1	9	11%
	Fish larvae	0	0	1	↑	100%	30%	FALSE	wspd	1.0	0	1	9	11%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	9	0%
Coastal	Diatom	2	9	8	-	47%	71%	FALSE	psal	3.2	9	19	12	83%
	Dinoflagellate	5	8	6	-	42%	71%	FALSE	ntot	2.3	9	19	12	83%
	Holoplankton	3	8	1	-	67%	59%	FALSE	psal	2.8	2	12	12	83%
	Meroplankton	0	4	8	↑	67%	59%	TRUE	sst	3.1	2	12	12	83%
	Large copepods	3	7	2	-	58%	59%	FALSE	precip	2.1	2	12	12	83%
	Small copepods	2	6	4	-	50%	59%	FALSE	sst	2.2	2	12	12	83%
	Fish larvae	0	6	6	↑	50%	59%	TRUE	psal	3.2	2	12	12	83%
	Gelatinous	0	3	1	-	75%	64%	FALSE	psal	1.0	2	4	12	17%
Shelf	Diatom	1	5	5	↑	45%	74%	FALSE	phos	3.2	0	11	11	100%
	Dinoflagellate	7	3	1	↓	64%	74%	TRUE	wspd	3.9	0	11	11	100%
	Holoplankton	6	4	1	↓	55%	74%	TRUE	sst	2.0	0	11	11	100%
	Meroplankton	0	2	9	↑	82%	74%	TRUE	sst	2.2	0	11	11	100%
	Large copepods	3	8	0	-	73%	74%	FALSE	sst	2.3	0	11	11	100%
	Small copepods	4	4	3	↓	36%	74%	FALSE	sst	1.3	0	11	11	100%
	Fish larvae	1	4	6	↑	55%	74%	TRUE	attn	2.7	0	11	11	100%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	11	0%

Table 2. Integration of the indicator results for the Celtic Seas. An explanation of column names can be found in the caption for Table 1.

Habitat	Lifeform	↓	-	↑	Dir	Trend	Conf	Change	Press1	Rank1	nStn	totAssess	totCOMP4	SpatialRep
Variable salinity	Diatom	2	0	1	↓	67%	70%	TRUE	np	1.0	2	3	2	50%
	Dinoflagellate	0	0	3	↑	100%	70%	TRUE	attn	2.5	2	3	2	50%
	Holoplankton	1	0	0	↓	100%	99%	TRUE	psal	1.0	1	1	2	0%
	Meroplankton	1	0	0	↓	100%	99%	TRUE	wspd	1.0	1	1	2	0%
	Large copepods	1	0	0	↓	100%	99%	TRUE	sst	1.0	1	1	2	0%
	Small copepods	1	0	0	↓	100%	99%	TRUE	amo	1.0	1	1	2	0%
	Fish larvae	1	0	0	↓	100%	99%	TRUE	attn	1.0	1	1	2	0%
	Gelatinous	1	0	0	↓	100%	99%	TRUE	wspd	1.0	1	1	2	0%
Coastal	Diatom	1	2	0	-	67%	63%	FALSE	precip	2.0	0	3	3	100%
	Dinoflagellate	2	1	0	↓	67%	63%	TRUE	sst	2.0	0	3	3	100%
	Holoplankton	2	1	0	↓	67%	63%	TRUE	ph	1.5	0	3	3	100%
	Meroplankton	0	2	1	-	67%	63%	FALSE	mld	2.5	0	3	3	100%
	Large copepods	2	1	0	↓	67%	63%	TRUE	sst	1.5	0	3	3	100%
	Small copepods	2	1	0	↓	67%	63%	TRUE	sst	1.0	0	3	3	100%
	Fish larvae	0	2	1	-	67%	63%	FALSE	mld	2.5	0	3	3	100%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
Shelf	Diatom	1	2	1	-	50%	87%	FALSE	precip	2.5	0	4	4	100%
	Dinoflagellate	3	1	0	↓	75%	87%	TRUE	np	3.0	0	4	4	100%
	Holoplankton	3	1	0	↓	75%	87%	TRUE	ph	2.7	0	4	4	100%
	Meroplankton	0	1	3	↑	75%	87%	TRUE	sst	1.0	0	4	4	100%
	Large copepods	1	3	0	-	75%	87%	FALSE	sst	1.7	0	4	4	100%
	Small copepods	1	3	0	-	75%	87%	FALSE	precip	1.3	0	4	4	100%
	Fish larvae	1	3	0	-	75%	87%	FALSE	psal	2.7	0	4	4	100%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	4	0%

Table 3. Integration of the indicator results for the Bay of Biscay & Iberian Coast. An explanation of column names can be found in the caption for Table 1.

Habitat	Lifeform	↓	-	↑	Dir	Trend	Conf	Change	Press1	Rank1	nStn	totAssess	totCOMP4	SpatialRep
Variable salinity	Diatom	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Dinoflagellate	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Holoplankton	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Meroplankton	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Large copepods	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Small copepods	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Fish larvae	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	3	0%
Coastal	Diatom	0	2	1	-	67%	52%	FALSE	mld	1.0	0	3	12	25%
	Dinoflagellate	0	0	3	↑	100%	52%	TRUE	amo	2.3	0	3	12	25%
	Holoplankton	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
	Meroplankton	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
	Large copepods	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
	Small copepods	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
	Fish larvae	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	12	0%
Shelf	Diatom	2	1	0	↓	67%	63%	TRUE	wspd	1.0	0	3	6	50%
	Dinoflagellate	1	2	0	-	67%	63%	FALSE	np	2.0	0	3	6	50%
	Holoplankton	3	0	0	↓	100%	63%	TRUE	sst	2.3	0	3	6	50%
	Meroplankton	1	1	1	↓	33%	63%	FALSE	sst	1.0	0	3	6	50%
	Large copepods	2	1	0	↓	67%	63%	TRUE	sst	1.0	0	3	6	50%
	Small copepods	2	1	0	↓	67%	63%	TRUE	sst	1.0	0	3	6	50%
	Fish larvae	0	3	0	-	100%	63%	FALSE	wspd	2.0	0	3	6	50%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	6	0%
Oceanic / beyond shelf	Diatom	2	0	0	↓	100%	84%	TRUE	psal	1.0	0	2	6	33%
	Dinoflagellate	1	1	0	↓	50%	84%	TRUE	psal	1.0	0	2	6	33%
	Holoplankton	2	0	0	↓	100%	84%	TRUE	mld	1.5	0	2	6	33%
	Meroplankton	0	1	1	↑	50%	84%	TRUE	mld	1.0	0	2	6	33%
	Large copepods	2	0	0	↓	100%	84%	TRUE	sst	1.5	0	2	6	33%
	Small copepods	2	0	0	↓	100%	84%	TRUE	sst	1.0	0	2	6	33%
	Fish larvae	2	0	0	↓	100%	84%	TRUE	mld	1.5	0	2	6	33%
	Gelatinous	0	0	0	NA	NA	0%	FALSE	NA	NA	0	0	6	0%

Task 1.2 knowledge gaps and next steps

- Test state-pressure relationships at multiple spatial and temporal scales.
  - Consider blocks of time for indicator assessment.
  - Examining national datasets at a finer spatiotemporal scale, which will help establish clearer links between climatic and anthropogenic pressures with changes in pelagic habitats and plankton diversity.
- Identify ecological mechanistic links between environmental variables and indicators using current and relevant scientific literature.
- Identify consequences of change in pelagic indicators on other trophic levels (linking with Food Webs assessments).
- Examine the rate and direction of change in the Plankton Index with respect to each lifeform pair.
- Examine the ecological consequences of changing lifeform abundance on higher trophic levels, not considered in the pelagic habitats assessment.
  - This could help link both the Pelagic Habitats and Food Webs assessments in terms of identified changes and impacts.
- Test introduction of lag into the variable selection process to test for delayed effects of environmental pressures on lifeform abundance (e.g., the effects of winter nutrient concentrations on lifeform abundance during the growing season).
- Investigate the impacts of long-term changes in lifeform abundance on pelagic food webs.
- Obtain pressure datasets that would present an indicator of predation on plankton from higher trophic levels (e.g., forage fish density).
- Obtain high quality plankton monitoring data for several pelagic habitat types which were underrepresented in this assessment. In particular there is a need for: zooplankton data for variable salinity habitats in the Greater North Sea and Celtic Seas (OSPAR Regions II and III), zooplankton data for coastal habitats, both phytoplankton and zooplankton data for variable salinity habitats in the Bay of Biscay and Iberian Coast (OSPAR Region IV), and gelatinous zooplankton data for all pelagic habitats within the three OSPAR Regions.
- Determination of the traits for many plankton species – for some species even information about basic biological characteristics, such as diet, is not yet known.
- Understanding the role of pico- and nano-plankton (small plankton composed by cells with sizes between 0.2 µm and 2 µm, and 2 µm and 20 µm, respectively) in the ecosystem. These small size categories are difficult to measure routinely and are thus mainly ignored, even though some sustained observations are being carried out at a national or institutional level in some OSPAR Contracting Parties. However, they make up a significant proportion of the plankton biomass, diversity and trophic roles (De Vargas et al., 2015) relevant to marine food webs and carbon export (Leblanc et al., 2018). Their ecosystem role needs further investigation so that they can be included in an appropriate new or existing lifeform.
- Developing a better understanding for the extent of pico- and nano-plankton biological interactions in the context of their environments.
- Proposition of adding new lifeforms and lifeform pairs formed from these new data types, as well as exploring other lifeforms not currently considered due to regional specificity or low confidence in their category assignment (McQuatters-Gollop et al., 2019), as stated in the EcApRHA project.
- Assess PH1/FW5 as biomass, in addition to abundance once we have developed trait information to describe average volume or carbon content per taxa.
- Consideration of the Nitrogen to Phosphorus ratio (N:P) in linking to relevant drivers of change.

Task 1.3: Refinement, operationalisation, and assessment of OSPAR´s pelagic habitats indicators PH2: Change in plankton biomass and abundance and PH3: Change in plankton diversity (Annexes D, E, F and G)

Task Lead: Felipe Artigas (CNRS, FR) (Partner)

Other involved: Abigail McQuatters-Gollop (UoP, UK) (Partner), Matthew Holland (UoP, UK) (Partner), Arnaud Louchart (CNRS, FR) (Partner), Anouk Blauw (Deltares, NL) (Sub-contractor)

Other Activities involved: Activity 2 (Tasks 2.1 and 2.3)

Milestones: D5.2a SuperCOBAM workshop; M1.3 PH2 and PH3 code

Deliverables: D1.3a PH2/PH3 indicator assessments

Task 1.3 summary

The Pelagic Habitat indicators addressed for Task 1.3 concerned changes in phytoplankton biomass and zooplankton abundance in the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast (PH2 indicator; D1C6, D4C2) and changes in plankton diversity (PH3 indicator; D1C6, D4C1) in the Celtic Seas (as a common indicator), the Greater North Sea and the Bay of Biscay and Iberian Coast (as a pilot assessment of a candidate indicator).

Improvements to each indicator's assessment methodology were developed based on content from the recommendations and knowledge gaps sections of Intermediate Assessment 2017 reports. We are now able to compute Pelagic Habitats indicators for the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast through mobilisation of numerous datasets of different formats (e.g. non-station distributed data from mobile sampling platforms and long-term fixed-point monitoring stations). We carried out the assessment of Pelagic Habitats using a consistent spatial scale across the three Pelagic Habitats indicators. For this, we use the current COMP4 assessment procedure and classifications of assessment units into the four MSFD Pelagic Habitat types (i.e. variable salinity, coastal, shelf and oceanic/beyond shelf habitats), in an identical format to that used by Activity 2. Finally, we made improvement towards the determination of GES by linking environmental pressures with indicator results.

Datasets used for NEA PANACEA Task 1.3 were mobilised and gathered from the OSPAR data call described under Task 1.1. Datasets were formatted separately for each indicator and each monitoring type (e.g. fixed-point monitoring stations versus non-station distributed data) prior to ingestion into their respective indicator's R code. The refinement of R code for each indicator was carried out to compute results for each assessment unit and for each fixed-point monitoring station through an automated procedure.

The PH2 indicator results revealed large decreases in phytoplankton biomass and zooplankton abundance had likely occurred throughout the three regions assessed. The PH3 indicator results revealed that plankton diversity had undergone several changes, but only at a few specific locations in certain years, suggesting that some short-term changes in plankton diversity occurred in the assessed region (Region III).

D5.2a SuperCOBAM workshop

To support the progress of the NEA PANACEA project and the delivery of MSFD assessment products through the QSR 2023, the SuperCOBAM workshop was held from 20 to 22 October 2021 at the LEF Future Centre in Utrecht, the Netherlands. The aims of this workshop were to facilitate the delivery of biodiversity assessments and to discuss cross-cutting actions between eutrophication and biodiversity experts to support the production of NEA PANACEA deliverables. Additionally, SuperCOBAM represented an opportunity for the OSPAR Secretariat to provide instructions and requirements to the biodiversity experts on the Drivers, Activities, Pressures, and Response section of the DAPSIR framework, following the QSR 2023 guidance.

The SuperCOBAM workshop focused closely on the following topics for each biodiversity group in attendance (i.e. Pelagic Habitats, Benthic Habitats, Birds, Marine Mammals, Fish, Food Webs, Non-Indigenous Species):

- Integration of indicator assessments
- Assessment scales and spatial integration
- Threshold values
- Cross-cutting actions

The conclusions of the OSPAR Pelagic Habitats expert group (PHEG) from the SuperCOBAM workshop were as follows:

Pelagic Habitats data call:

- At the time of this meeting, the data call had already been extended twice, since several OSPAR contracting parties had not yet provided any data to support the Pelagic Habitats indicator assessments. We asked OSPAR Pelagic Habitats Expert Group (PHEG) members from these specific contracting parties to pursue the issue of missing data through their national reporting hierarchies to determine whether any data would be provided before the submission deadline. A final extension of the data call was made for 1 December 2021. Any data submitted after this date could not be used for the QSR 2023.

Integration of indicator assessments:

- At the time of this meeting, initial results had been produced for the PH1/FW5 and PH2 indicators. Formatting data for ingestion into the PH3 R code (see next sub-section) was still underway. Discussions at the meeting focused on how we should report the results per indicator, targeting the integration of results from the three indicators to support the thematic assessment. Since our objective was to achieve a spatial integration of Pelagic Habitats indicators and deliver simple and easily interpreted message to policy audiences, it was decided that indicator results would be best represented as graphical maps of the OSPAR maritime area.

Assessment scales and spatial integration:

- The COBAM Pelagic Habitats Expert Group (PHEG) discussed the utility of the COMP4 assessment units (based on sub-divisions proposed by the JMP-EUNOSAT project) to support the assessment of Pelagic Habitats for the upcoming MSFD assessment cycle. The outcome of the discussion was to use these assessment units for Pelagic Habitats assessment to create better alignment with results from the eutrophication expert groups through direct spatial comparability of indicator results.

Threshold values:

- Thresholds were not applied to the Pelagic Habitats indicators during the previous assessment cycle. For this assessment cycle, the updated methodology focused on detecting statistically significant changes (trends) and linking these change to environmental pressures to help interpret the direct and indirect drivers of change. The PHEG decided in the end to not use threshold values, and to instead focus the assessment on the direction and magnitude of change. A narrative description illustrated with primary references was the format chosen by the PHEG to help interpret the nature of changes.

Cross-cutting actions:

- Integrated actions between MSFD descriptors were planned between the PHEG, Eutrophication, and Food Webs expert groups to support writing of NEA PANACEA project deliverables. Discussions focussed on selecting appropriate temporal and spatial resolution for assessment, as well as deciding which hierarchical level of results to compare across assessments (e.g. at the level of indicator results or GES results). We decided an important action to support this cross-cutting would be to identify several spatial assessment units containing extensive biodiversity sampling, in connection with NEA PANACEA Activity 2. Case study areas were selected to support integration among biodiversity indicators and MSFD descriptors.

The outcomes of these actions were presented at the ICG-COBAM meeting, which was held 13 to 16 December, 2021 in Copenhagen, Denmark and attended virtually by the Activity 1 team due to COVID restrictions at the time.

M1.3 PH2 and PH3 code

For the previous assessment cycle, the code for PH2 and PH3 indicators was not available. The script for PH2 and PH3 was developed in R during the French MSFD assessment in 2018. Calculation of the indicators is done via a Graphical User Interface (GUI) to limit modifications on the code, allow reproducible use between users and allow use by people who are not skilled in computer code.

For PH2, the code requires a table containing three columns to compute the results: station, date, and value of interest (phytoplankton biomass or zooplankton abundance). Then, it is mandatory to select the start and end of each period (assessment period and comparison period).

For the PH3 indicator, the code is flexible. It requires taxon labels to be in a single column labelled "taxon" and associated with their abundance or the taxon can be displayed in a multiple set of columns, with one column per taxon. Nevertheless, the code requires information on:

- Station
- Day
- Month
- Year
- Longitude
- Latitude
- Taxon
- Abundance

For both PH indicators, tables containing all the intermediate information necessary to understand or produce the indicators are automatedly computed. Graphs allowing quick visualisation are also automatedly produced for PH2 (Figure 10) and for PH3 (Figure 11). During the NEA PANACEA project, it was necessary to adapt this code to English language format. The data import had to be modified including the date format, decimal format, and delimiter type for tables. The text of the graphical outputs as well as the column headers of the tables have now been translated into English. The codes are currently available in the NEA PANACEA SharePoint under Task 1.3 of Activity 1. A Readme document and datasets as reproductible examples are included along with the R package.

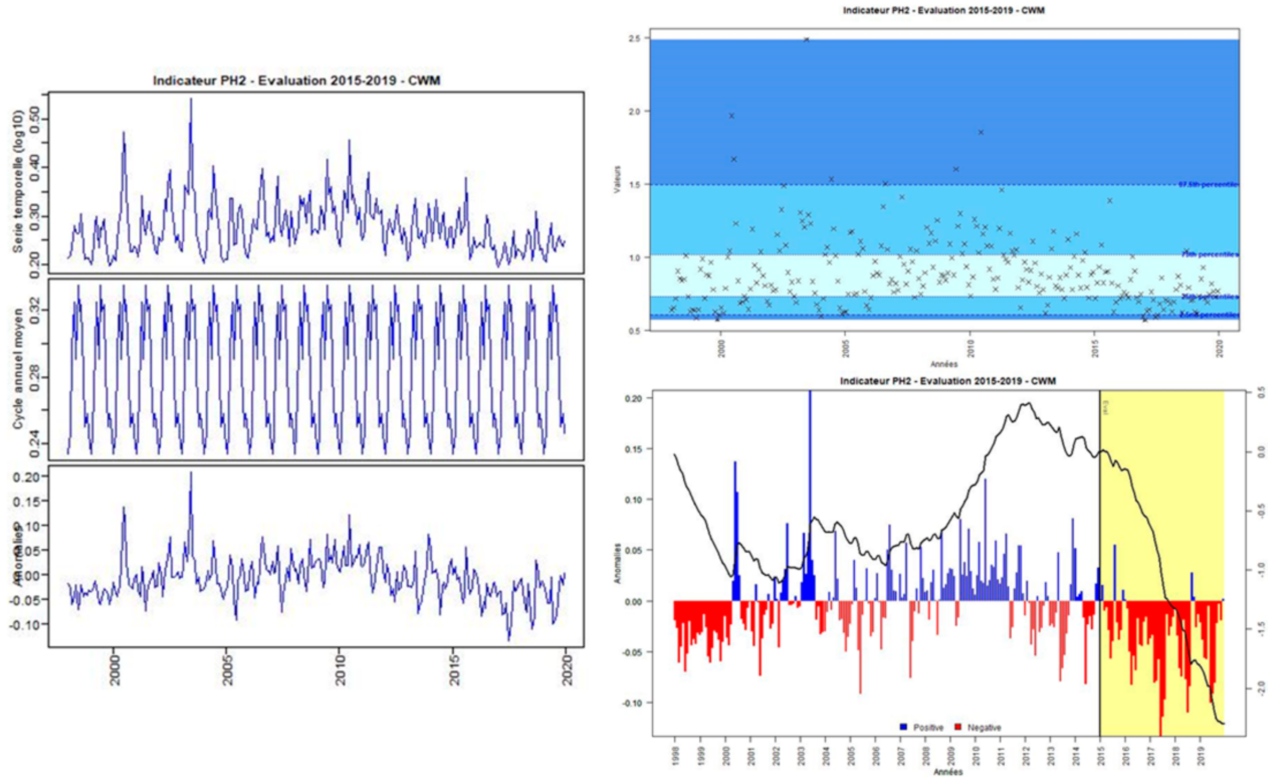

Figure 10. Example of PH2 graphical outputs from the R toolbox indicating the time series from original data, the average annual cycle and the anomalies (time series minus the average annual cycle) of the relevant assessment unit (left panel), the categorisation of the anomalies (top right panel) as important changes (below percentile 2.5 and above percentile 97.5), intermediate changes (in between percentile 2.5 and percentile 25 and in between percentile 75 and percentile 97.5) and small changes (in between percentile 25 and percentile 75) and the cumulative sum of the anomalies (bottom right panel) for trend analysis to analyse the trend between the comparison period (blank panel of the graph) and the assessment period (yellow panel of the graph).

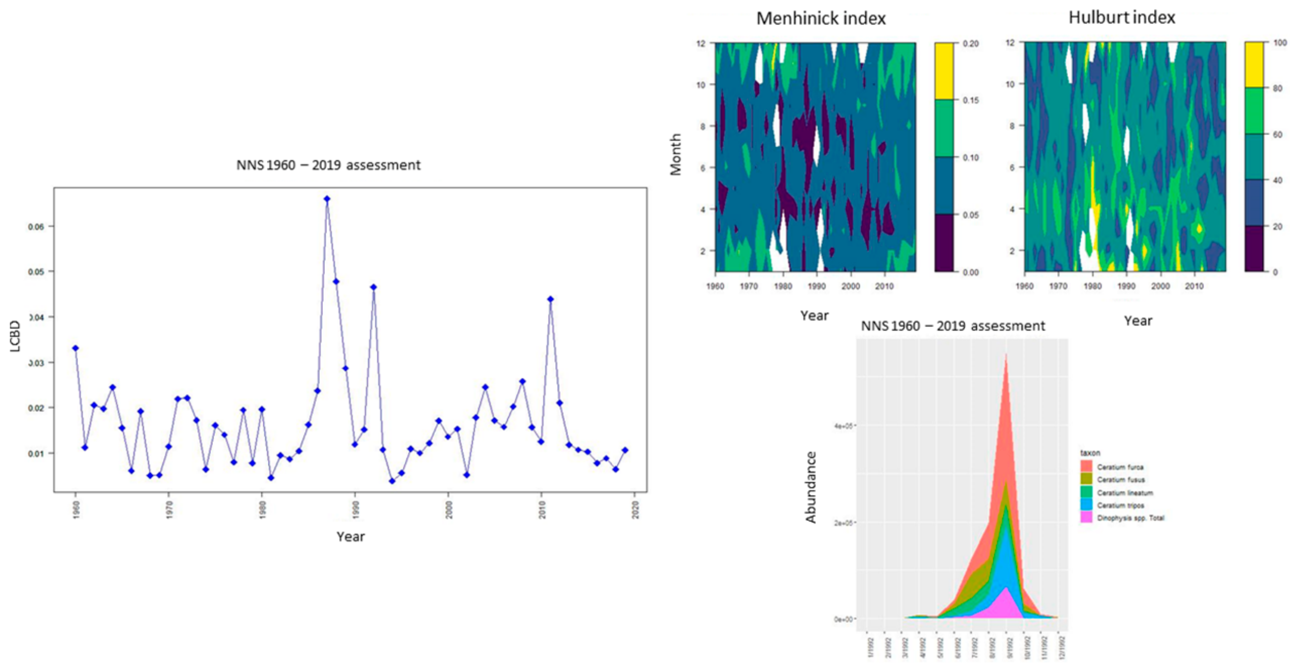

Figure 11. Example of PH3 graphical outputs from the R toolbox indicating the Local Contribution to Beta Diversity (left panel), the Menhinick and Hulburt indices (α-diversity indices; top right panel) and the Importance value Index (bottom right panel) of the relevant assessment unit.

D1.3a PH2/PH3 indicator assessments

The PH2 and PH3 indicators were further tested at different spatial scales. For better integration within the Pelagic Habitats and comparison across MSFD descriptors (D4 and D5), we used the COMP4 assessment units, the latest set of OSPAR spatial sub-divisions developed by OSPAR´s Intersessional Correspondence Group on Eutrophication (ICG-Eut). First, we formatted the data received through the OSPAR data call (Task 1.1) considering the sampling locations within the COMP4 assessment units. Then, data were ingested into the R toolbox. This procedure was done separately for each indicator. Once the results were obtained, we linked each component in the indicator with environmental pressures to determine GES, as described under Task 1.2. The set of environmental pressures were selected according to their relevance for each plankton component. The aim was to rank the relative importance of each environmental pressure within the COMP4 assessment units to obtain the most important pressure in each habitat within each region. For this we used multiple random forest regressions to evaluate the best combination of environmental variable for each plankton component.

PH2 indicator assessment (Louchart et al., 2023a) (Annexes D and E)

The PH2 indicator provides a means of identifying changes (anomalies) in the quantities of two fundamental groups within a plankton community, phytoplankton biomass and zooplankton abundance as represented by the abundance of copepods since they are the most numerous zooplankton group. Such changes represent deviations from the assumed natural variability in a plankton time-series. Changes in phytoplankton biomass and zooplankton abundance are measured between a historic comparison period (prior to 2015) and a contemporary assessment period (2015 – 2019). The direction of change is statistically identified as either increasing, stable, or decreasing. This indicator has been assessed at the subregional scale, using COMP4 assessment units (Enserink et al., 2019) to subdivide data for samples collected within the three regions.

Anomalies in phytoplankton biomass and zooplankton abundance exhibited decreasing trends across the majority of COMP4 units assessed (Figure 12). Change over the assessment period (2015-2019) was marked by strong and significant decreases in phytoplankton biomass in 82% of the assessment units studied. For zooplankton abundance, strong decreases occurred in 59% of the assessment united studied. In agreement with the results for this indicator presented in the previous assessment cycle, phytoplankton biomass has continued to increase in the North Sea. Although the previous assessment reported a negative trend in zooplankton abundance for the Southern North Sea, the current assessment period (2015–2019) detected no significant change in zooplankton abundance for this area.

Environmental pressures shape phytoplankton biomass/zooplankton abundance across temporal and spatial scale (Figure 13). Changes in phytoplankton biomass/zooplankton abundance and climate change over the assessment period were evident in the Celtic Seas and the Bay of Biscay and Iberian Coast. Several environmental variables are indirectly linked to climate change, including increasing sea surface temperature (SST), decreasing wind speed, decreasing light attenuation, and increasing mixed layer depth. These pressures were linked to decreases in phytoplankton biomass and zooplankton abundance. Similarly, nutrient imbalance (only directly affecting phytoplankton) and decreases in pH were observed to co-occur with decreases in phytoplankton biomass in the variable salinity and coastal habitats of the Celtic Seas and the Greater North Sea regions.

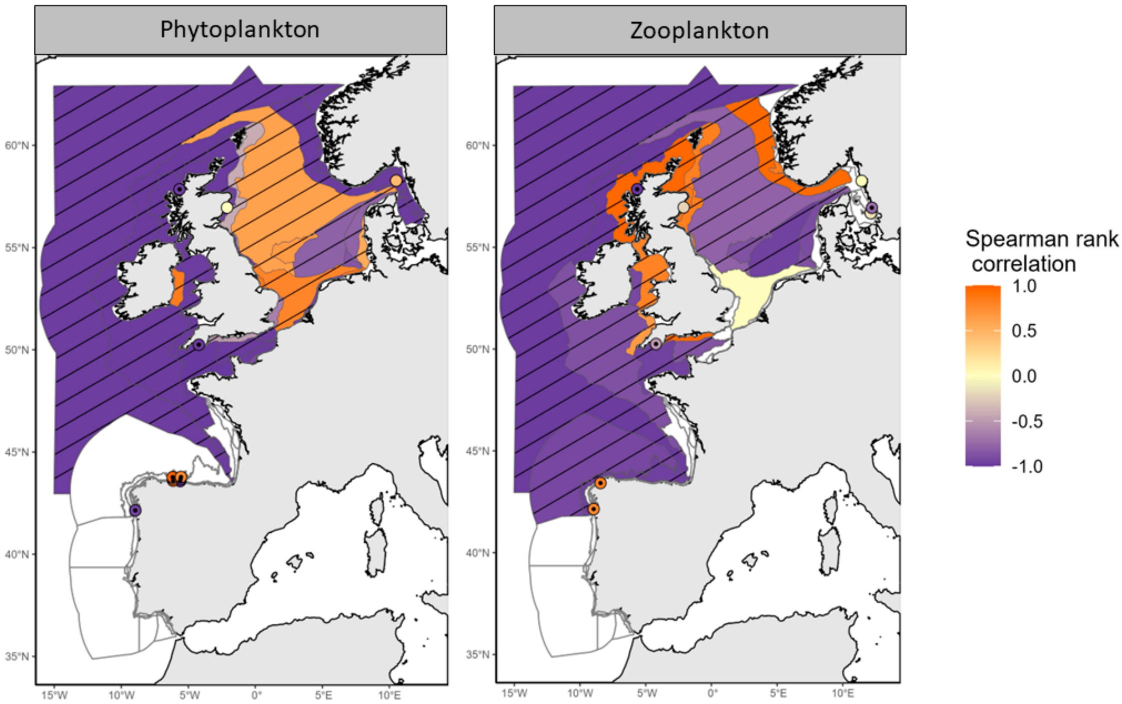

Figure 12. Trend in phytoplankton biomass and zooplankton abundance anomalies between the assessment period (2015–2019) and the comparison period (station data: 1992–2014; non-station data: 1997–2014 for phytoplankton and 1960–2014 for zooplankton). Hatched areas were characterised by significant changes (p≤0.05) in phytoplankton biomass or zooplankton abundance between the comparison and the assessment periods. White areas indicate no data or insufficient data to assess the area.

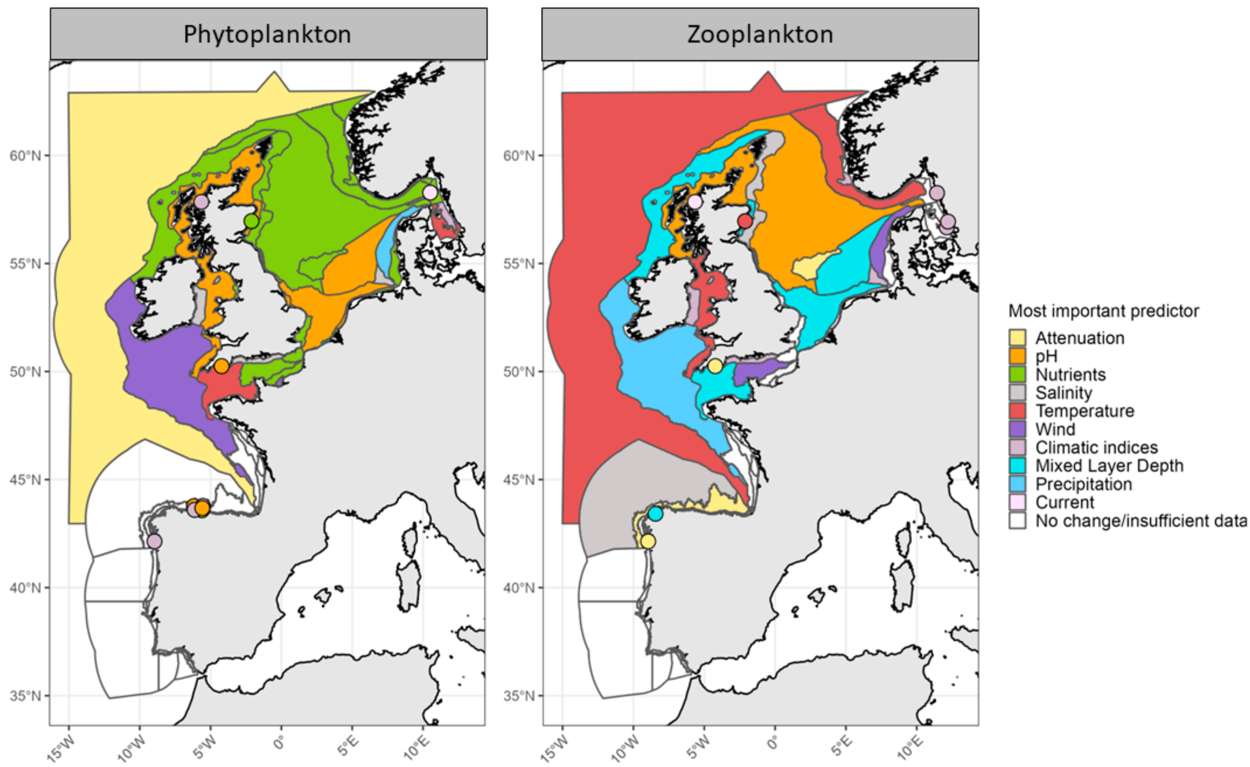

Figure 13. PH2 indicator results displaying the most important environmental variable linked to trends in phytoplankton biomass and zooplankton abundance. White areas indicate no data or insufficient data to assess the area.

Based on the criteria used to determine GES (McQuatters-Gollop et al., 2022) and described in detail under Task 1.4, the relationships between the indicators and environmental pressures, the quality status of most habitats within the regions was "Not good". Only variable salinity habitats in the Greater North Sea and the Celtic Seas had an "Unknown" quality status (Table 4).

Table 4. Integration of the indicator results for the Greater North Sea, the Celtic Seas and the Bay of Biscay and Iberian Coast. Column names are described as follows: Dir: the net direction of change in the plankton component (upward arrow: increasing trend, equality sign: no trend, downward arrow: decreasing trend), Trend: the percentage of assessment units exhibiting the respective trend (if no results were reported for assessment units, stations are used), Change: a logical variable (TRUE/FALSE) to report whether a net trend is likely given the significance of the results, Pressure: the environmental pressure with the greatest mean rank for the respective trend, Rank: the mean rank of the environmental pressure indicated under Pressure, nSt: the total number of monitoring fixed stations considered, nCOMP4: The total number of COMP4 assessment units considered, totCOMP4: The total number of potential COMP4 assessment units for the habitat category, spatialRep: the spatial representativeness score of the analysis.

OSPAR Region	Habitat	Plankton component	Dir	Trend	Change	Pressure	Rank	nSt	nCOMP4	totCOMP4	Spatial Rep
The Greater North Sea	Variable salinity	Phytoplankton	↓	60%	TRUE	phosp	2.8	1	9	9	100%
		Zooplankton	↓	100%	FALSE	sst	1.0	1	0	9	0%
	Coastal	Phytoplankton	↓	92%	TRUE	np	4.0	1	12	12	100%
		Zooplankton	↑	40%	TRUE	mld	2.8	4	6	12	50%
	Shelf	Phytoplankton	↓	75%	TRUE	np	2.3	1	11	11	100%
		Zooplankton	↓	67%	TRUE	mld	2.7	0	7	11	64%
	Oceanic	Phytoplankton	NA								
		Zooplankton	NA								
The Celtic Seas	Variable salinity	Phytoplankton	↓	100%	TRUE	ntra	2.0	1	2	2	100%
		Zooplankton	↓	100%	TRUE	cvel	1.0	1	0	2	0%
	Coastal	Phytoplankton	↓	67%	TRUE	pH	1.7	0	3	3	100%
		Zooplankton	↑	67%	TRUE	AMO	2.0	0	3	3	100%
	Shelf	Phytoplankton	↓	100%	TRUE	pH	3.5	0	4	4	100%
		Zooplankton	↓	75%	TRUE	pH	2.5	0	4	4	100%
	Oceanic	Phytoplankton	NA								
		Zooplankton	NA								
The Bay of Biscay and Iberian Coast	Variable salinity	Phytoplankton	NA								
		Zooplankton	NA								
	Coastal	Phytoplankton	↓	100%	TRUE	NAO	1.0	1	0	12	0%
		Zooplankton	↑	100%	TRUE	sst	2.5	2	0	12	0%
	Shelf	Phytoplankton	↑	43%	TRUE	wspd	1.0	6	1	6	17%
		Zooplankton	↓	100%	TRUE	mld	3.0	0	2	6	33%
	Oceanic	Phytoplankton	↓	100%	TRUE	attn	1.0	0	1	6	17%
		Zooplankton	↓	100%	TRUE	sst	1.5	0	2	6	33%

PH3 indicator assessment (Louchart et al., 2023b) (Annexes F and G)

The PH3 indicator quantifies changes in plankton diversity through the consecutive use of β- and α-diversity indices (through Local Contribution to Beta Diversity (LCBD) and Menhinick, Hulburt, Gini, and Patten indices respectively). In the PH3 assessment, the β-diversity focuses on the rate of change, or turnover, in species composition in a time-series (Rombouts et al., 2019). Statistical significance is calculated separately for each year. Years with significant β-diversity corresponded to a deviation from the usual community composition. For assessment units with significant years, α-diversity indices were calculated to highlight whether species richness or dominance was responsible for driving the detected changes. The biodiversity indices were computed separately for each dataset, and separately for zooplankton and phytoplankton. In addition, the computation of the indices was considered independently of the taxonomic level. The Menhinick, Hulburt, Gini, and Patten indices were calculated for every month. Only years with more than eight months of sample data were used. This procedure is spatially consistent with the PH1/FW5, PH2 and FW2 indicator assessments (Tasks 1.2, 1.3 and 1.5, respectively) since the same assessment units were used for all. Missing data were not interpolated in this assessment, as interpolation at the level of individual taxa can introduce large biases in species abundance. To examine spatial differences in diversity indices, we computed an ecological quality ratio (EQR). This EQR consisted of comparing the β-diversity of each year of the assessment period to the mean β-diversity of the comparison period. Finally, a Kendall trend test was run on the annual EQR of the β-diversity to account for inter-annual variation in diversity and to remove cyclical seasonal variation. While the annual β-diversity identified the short-term change of plankton diversity, the Kendal trend test allowed us to identify permanent or long-term change of plankton diversity during the assessment period.

Changes in diversity were addressed at the regional scale by assessing long-term changes in CPR data (1960-2019), and at local scale from fixed monitoring stations (1989-2019). To compare community composition across the assessment units, β-diversity was integrated through a yearly Ecological Quality Ratio. Whilst in assessment the PH3 has been adopted as a common indicator in the Celtic Seas, the PH3 indicator remained a pilot assessment in the Greater North Sea and the Bay of Biscay and Iberian Coast.

From 2015 to 2019 on an annual basis, 70% of the assessment units had an atypical phytoplankton community composition compared to the period prior to 2015, while only 7% of the assessment units displayed a phytoplankton community composition similar to that of the comparison period (prior to 2015). 23% of the assessment units fell somewhere in between. However, only one assessment unit had significant atypical composition (Channel Well Mixed Tidal Influenced in 2019; Western English Channel; β-diversity p-value < 0,05; Figure 14). Kendall trend test results were not statistically significant, revealing no long-term change in the phytoplankton community composition.

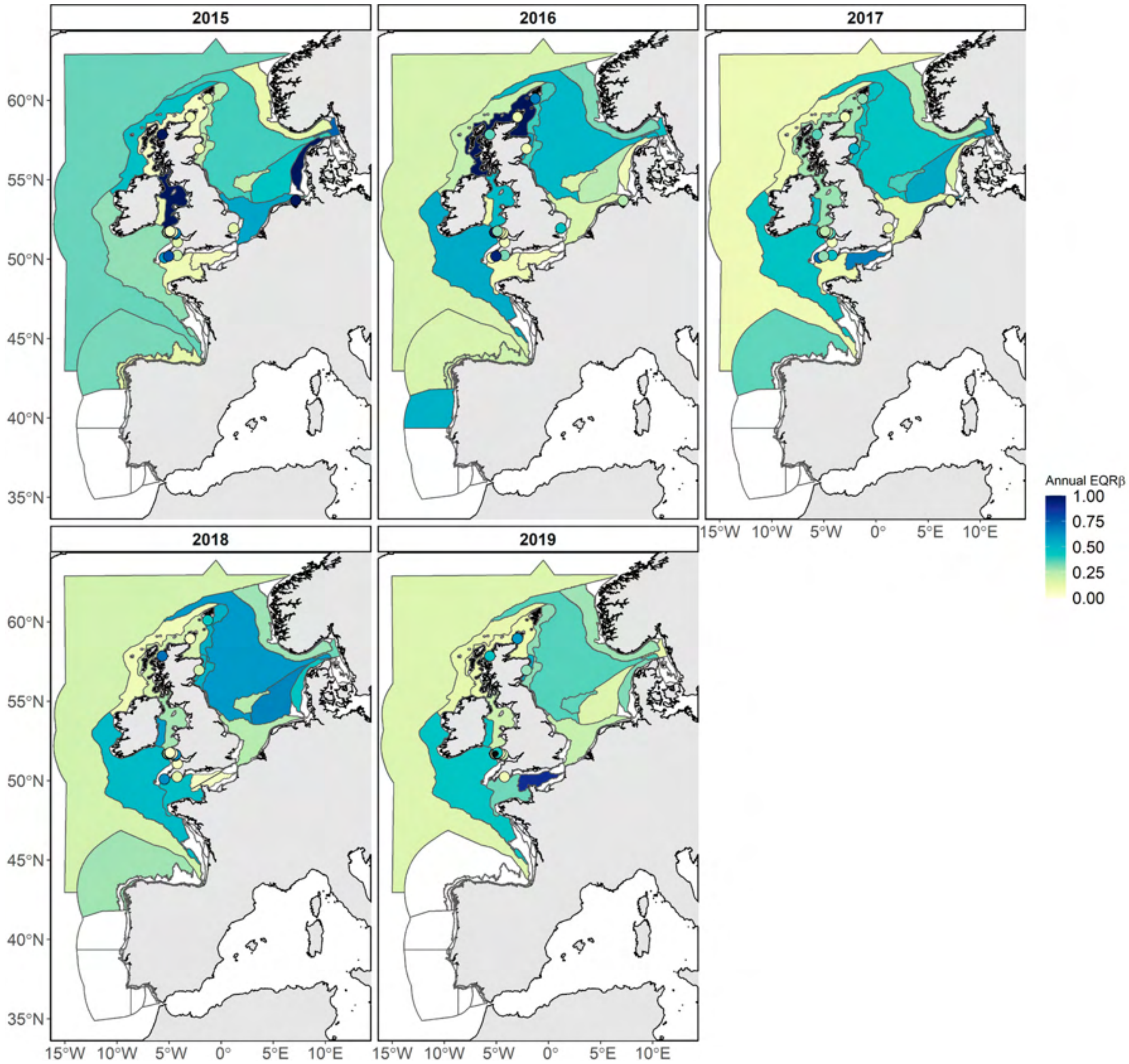

Figure 14. Evolution of the annual $EQR_β$ of phytoplankton diversity indices during the assessment period (2015–2019). Low $EQR_β$ indicating large difference between the comparison value of $EQR_β$ and the annual $EQR_β$ value are displayed in yellow; High $EQR_β$ indicating slightly difference between the comparison value of $EQR_β$ and the annual $EQR_β$ value are displayed in dark blue. White areas indicate no data or insufficient data to assess the area. COMP4 units with significant atypical composition (LCBD p-value < 0,05) are displayed as dashed areas. Monitoring fixed stations with significant atypical composition (LCBD p-value < 0,05) are displayed as dark dots. This is a hybrid figure showing results of the common indicator assessment for the Celtic Seas and for the pilot assessment for the Greater North Sea and the Bay of Biscay and Iberian Coast.

From 2015 to 2019 on an annual basis, 83% of the assessment units had an atypical zooplankton community composition compared to the period before 2015, while only 4% of the assessment units displayed a zooplankton community composition close to the period before 2015. 13% of the assessment units were in between. However, 8 sites (assessment units and monitoring stations) had significant atypical composition (Channel Well Mixed: 2015; Norwegian Trench: 2015; East Coast Permanently Mixed 1: 2016; Eastern North Sea: 2016; Nothern North Sea: 2016; Southern North Sea: 2016; Southern North Sea and Anholt station in 2019; β-diversity p-value < 0,05; Figure 15). Kendall trend test results were not statistically significant, revealing no long-term change in zooplankton community composition.

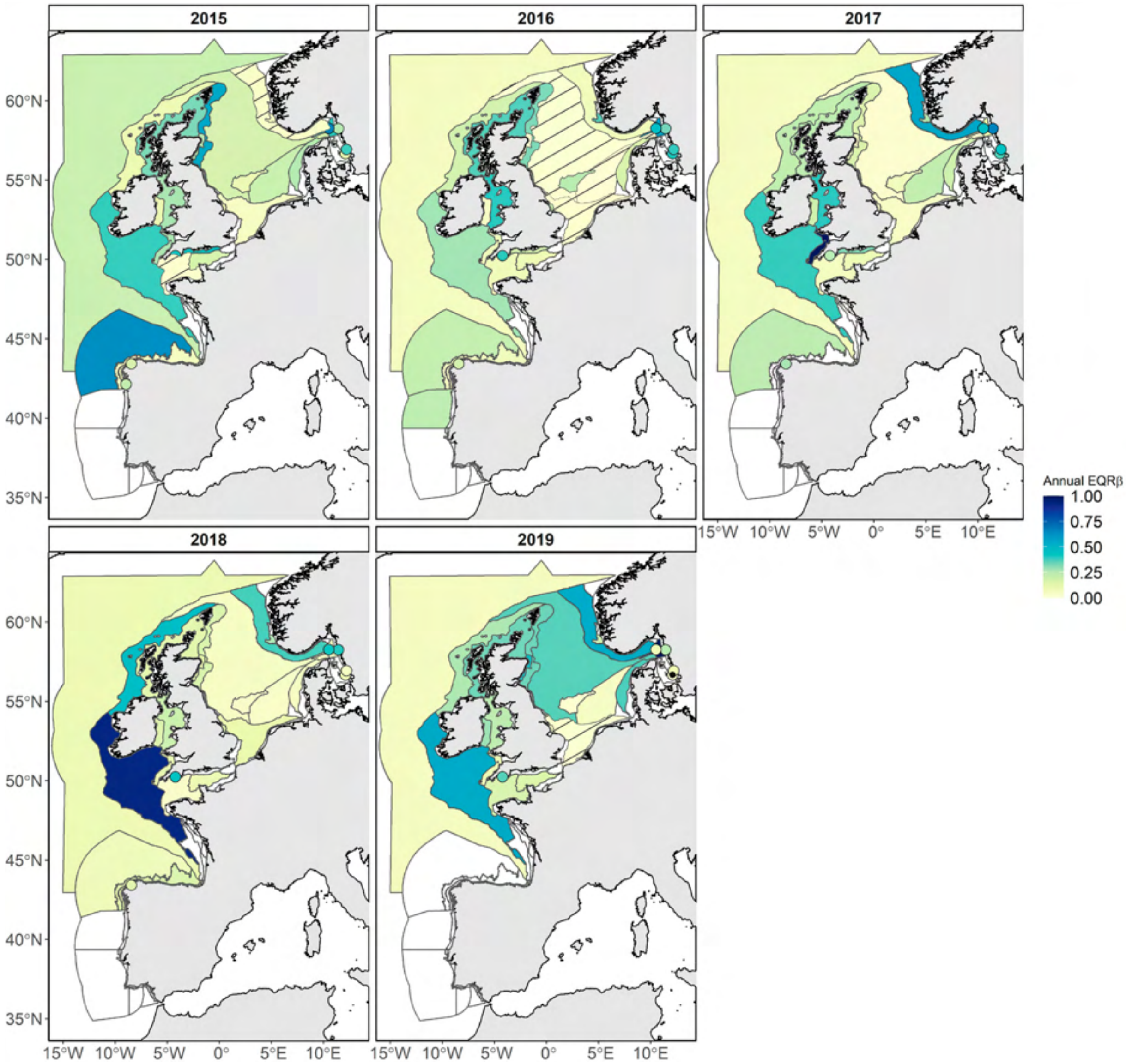

Figure 15. Evolution of the annual $EQR_β$ of zooplankton diversity during the assessment period (2015–2019). Low $EQR_β$ indicating large difference between the comparison value of $EQR_β$ and the annual $EQR_β$ value are displayed in yellow; High $EQR_β$ indicating slightly difference between the comparison value of $EQR_β$ and the annual $EQR_β$ value are displayed in dark blue. White areas indicate no data or insufficient data to assess the area. COMP4 units with significant atypical composition (LCBD p-value < 0,05) are displayed as dashed areas. Monitoring fixed stations with significant atypical composition (LCBD p-value < 0,05) are displayed as dark dots. This is a hybrid figure showing results of the common indicator assessment for the Celtic Seas and for the pilot assessment for the Greater North Sea and the Bay of Biscay and Iberian Coast.

Environmental variables were selected according to their relevance to determine the most important pressure in plankton diversity. The set of environmental variables used originated from different models targeting the North-East Atlantic area. The link between PH3 and pressures was conducted using the β-diversity results, as previous studies have demonstrated the ability to link environmental parameters to the LCBD (Vilmi et al., 2017). The EQR was used to maintain consistency and harmonisation among the COMP4 assessment units. Variations in plankton diversity were closely related to decreasing light attenuation and imbalance between nutrients for phytoplankton and primarily by natural climatic indices (e.g. NAO, AMO) for zooplankton (Figure 16).

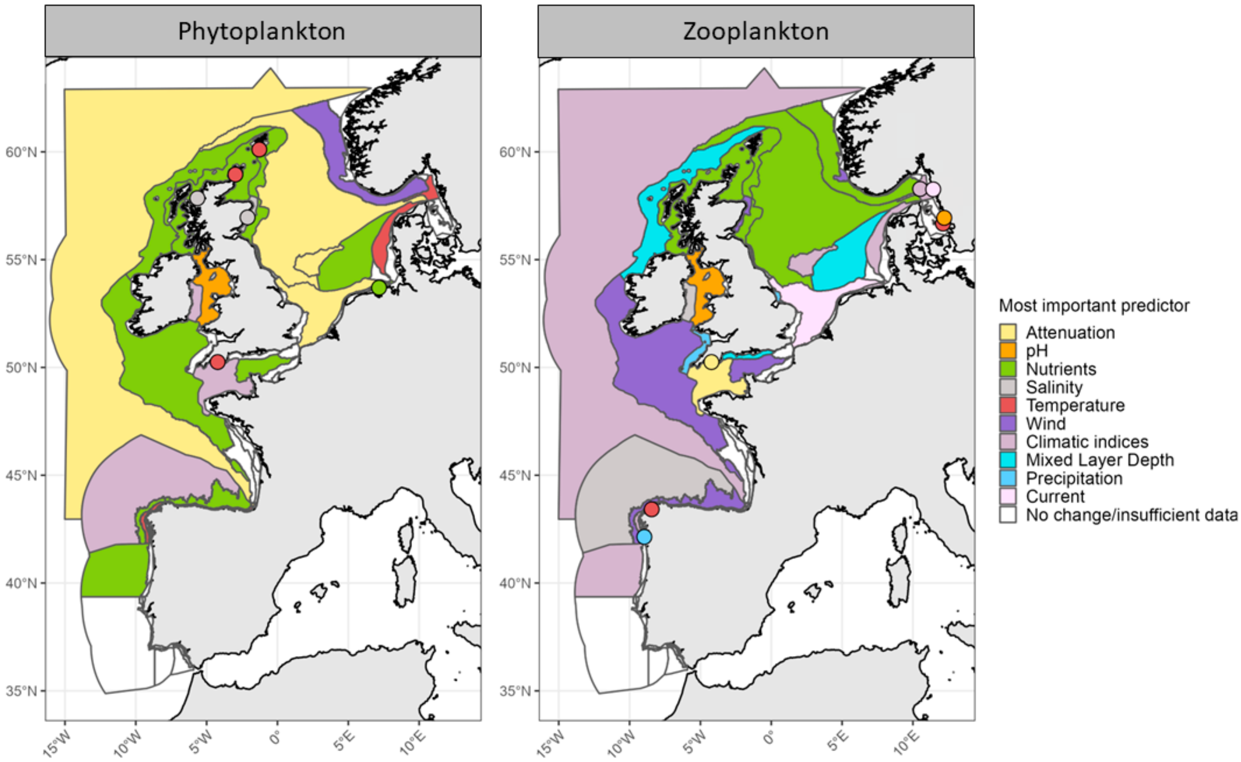

Figure 16. PH3 indicator results displaying the most important environmental variable linked to trends in phytoplankton and zooplankton diversity. This is a hybrid figure showing results of the common indicator assessment for the Celtic Seas and for the pilot assessment for the Greater North Sea and the Bay of Biscay and Iberian Coast.

Based on the current criteria used to determine GES (McQuatters-Gollop et al., 2022) and described in detail under Task 1.4, the relationships between PH3 indicator results and environmental pressures, the quality status of coastal habitats within the regions was “Not good”. Variable salinity habitats in the Greater North Sea and shelf habitat in the Celtic Seas were also “Not good” (pilot assessment of the PH3 indicator for these two regions). Shelf habitats in the Greater North Sea and the Celtic Seas and Oceanic habitats of the Bay of Biscay and Iberian Coast had an “Unknown” quality status (Table 5)

Table 5. Integration of the indicator results for the Celtic Seas (common indicator), Greater North Sea (pilot assessment) and the Bay of Biscay and Iberian Coast (pilot assessment). Column names are described as follows: Dir: the net direction of change in the plankton component (upward arrow: increasing trend, equality sign: no trend, downward arrow: decreasing trend), Trend: the percentage of assessment units exhibiting the respective trend (if no results were reported for assessment units, stations are used), Change: a logical variable (TRUE/FALSE) to report whether a net trend is likely given the significance of the results, Pressure: the environmental pressure with the greatest mean rank for the respective trend, Rank: the mean rank of the environmental pressure indicated under Pressure, nSt: the total number of fixed-point stations considered, nCOMP4: The total number of COMP4 assessment units considered, totCOMP4: The total number of potential COMP4 assessment units for the habitat category, spatialRep: the spatial representativeness score of the analysis.

OSPAR /MSFD region	Habitat	Plankton component	Dir	Trend	Change	Pressure	Rank	nSt	nCOMP4	totCOMP4	Spatial Rep
The Greater North Sea (Pilot assessment)	Variable salinity	Phytoplankton	↑	60%	FALSE	np	1	4	1	9	11%
		Zooplankton	↓	50%	FALSE	mld	3	0	2	9	22%
	Coastal	Phytoplankton	↑	75%	FALSE	np	3,7	1	3	12	25%
		Zooplankton	↓	67%	FALSE	wdsp	4,2	4	5	12	42%
	Shelf	Phytoplankton	↑	40%	FALSE	attn	3,7	0	10	11	91%
		Zooplankton	↑	50%	FALSE	mld	3,9	1	10	11	91%
	Oceanic	Phytoplankton	NA								
		Zooplankton	NA								
The Celtic Seas	Variable salinity	Phytoplankton	NA								
		Zooplankton	NA								
	Coastal	Phytoplankton	↑	50%	FALSE	pH	1,5	0	2	3	67%
		Zooplankton	↓	67%	FALSE	sal	3,3	0	3	3	100%
	Shelf	Phytoplankton	↓	100%	FALSE	phosp	2,5	0	4	4	100%
		Zooplankton	↑	50%	FALSE	attn	3	0	4	4	100%
	Oceanic	Phytoplankton	NA								
		Zooplankton	NA								
The Bay of Biscay and Iberian Coast (pilot assessment)	Variable salinity	Phytoplankton	NA								
		Zooplankton	NA								
	Coastal	Phytoplankton	NA								
		Zooplankton	↓	100%	FALSE	sst	2,5	2	0	12	0%
	Shelf	Phytoplankton	↓	67%	FALSE	ntra	3,3	0	3	6	50%
		Zooplankton	↓	33%	FALSE	wspd	2	0	3	6	50%
	Oceanic	Phytoplankton	↓	67%	FALSE	AMO	2,7	0	3	6	50%
		Zooplankton	=	67%	FALSE	AMO	2,7	0	3	6	50%

Task 1.3 knowledge gaps and next steps

Knowledge gaps identified for the PH2 'Changes in phytoplankton biomass and zooplankton abundance' were as follow:

- Inclusion of additional datasets to improve the confidence of indicator's assessment results, especially for the Bay of Biscay and Iberian Coast. In addition, increased zooplankton monitoring is needed in variable salinity habitats. Finally, there is a need to include additional datasets to allow comparison between the different monitoring strategies.
- Comparison to relevant Pelagic Habitat and Food Webs indicators to understand how changes in pelagic habitats generate impacts through the food web.
- Improve coherence and integration between the PH2 indicator and relevant indicators within OSPAR's Hazardous Substances & Eutrophication Committee (HASEC) group.
- Integration of datasets originating from different chlorophyll-*a* methods: continual assessment of characterising the differences in chlorophyll-*a* methodologies is required.
- Improve the methodology for defining the natural cycle and subsequently for the trend characterisation and spatial and temporal confidence of the results.
- Refinement of the use of remote sensing data for improving coherence with the OSPAR eutrophication assessments at different spatial and temporal scales.
- Refinement of links between PH2 results and pressures to identify the origin of the pressures.

Knowledge gaps identified for the indicator PH3 'Changes in plankton diversity' were as follow:

- Consistency of spatial and/or temporal sampling:
  - Some datasets provided for Task 1.1 were not used because of limited temporal coverage, temporal inconsistency in sampling effort between years, or due to incomplete counting of plankton community (e.g. focusing on a limited number of genera or species). More datasets can be included in the future if Contracting Parties continue their monitoring to extend the temporal coverage. By doing this, several coastal and variable salinity habitats will be assessed in the future. In addition, the Hill concept will be explored in the future to incorporate the influence of sampling effort into indicator calculation.
- Inclusion of additional data sets to improve the confidence of indicator's assessment results:
  - The Bay of Biscay and Iberian Coast lacks available plankton datasets. Moreover, Celtic Seas has available phytoplankton (and some zooplankton) datasets that were not submitted before the data call closed (i.e. French data). It was also identified that more zooplankton monitoring is needed in variable salinity habitats in the North-East Atlantic. Finally, complementary approaches to microscopy can be included in the future to minimise sampling bias: inclusion of flow cytometry, DNA barcoding and metabarcoding and imaging sensors data.
- Define spatial and temporal confidence of the results:
  - The results depend strongly on the homogeneity of sampling in space and time. Spatial and temporal confidence indices need to be developed following the methodology implemented in the PH1/FW5 to address the sampling effort.
- Coherence of the methodology at a regional scale:
  - Common methodologies and taxonomic guides (Avancini et al., 2006) are available at the national level, but more effort is needed for the implementation of monitoring programmes at a regional scale (Caroppo et al., 2013).
- Comparison and integration to relevant Pelagic Habitat indicators:
  - Processing ecosystem scaling is important to fully understand ecosystem functioning and adequate determination of GES. Combining the information from the different level of organisation of the Pelagic Habitat indicators can provide a more holistic view of Pelagic Habitats. Therefore, it is mandatory to understand relationships among the three Pelagic Habitats indicators.

Task 1.4: Integration within and across pelagic indicators (Annexes H, I and J)

Task Lead: Abigail McQuatters-Gollop (UoP, UK) (Partner)

Other involved: Felipe Artigas (CNRS, FR) (Partner), Matthew Holland (UoP, UK) (Partner), Arnaud Louchart (CNRS, FR) (Partner)

Other Activities involved: Activity 2 (Task 2.4)

Milestones: D5.2c UltraCOBAM workshop

Deliverables: D1.4a Options for integration with and between pelagic indicators, and for setting pelagic baselines, targets, and threshold values; D1.4b Pelagic thematic assessment

Task 1.4 summary

Multiple levels of aggregation and integration are needed first within indicators, between indicators, and within the pelagic ecosystem component before integration of ecosystem components can occur, and thresholds to indicate the direction of GES can be explored. The pelagic indicators are complex and comprised of multiple metrics, with datasets from monitoring available at different spatial and temporal scales. This makes the integration of indicators representing different temporal and spatial scales very challenging. We applied statistical techniques to test options for integrating within individual pelagic indicators (e.g. across lifeforms within the Change in Plankton Communities indicator PH1/FW5 (D1C6, D4C1, D4C2) and between Pelagic Habitats indicators (e.g. PH1/FW5, PH2 Change in Plankton Biomass and Abundance indicator, and PH3 Changes in Plankton Diversity indicators (D1C6, D4C1, D4C2)). The challenging nature of indicator integration drove the need for a dedicated UltraCOBAM workshop where researchers from several OSPAR expert groups could share ideas, collaborate in person, and undertake cross-cutting activities to improve the biodiversity thematic assessments (Milestone D5.2c).

To further develop our work on indicator integration, two case study assessment units were used to construct scenarios to determine what additional information can be gained from directly comparing results from the PH1/FW5 and PH2 indicators (Deliverable D1.4a). Results from the PH1/FW5, PH2, and PH3 indicators were integrated at the scale of Pelagic Habitat types (i.e. variable salinity, coastal, shelf, and oceanic / beyond shelf habitats). With regards to assessing what reference conditions (e.g. Bedford et al., 2020b) and threshold values for GES could look like, we decided that the best approach was to compare results from the current assessment period (i.e. 2015 to 2019) to all previous years in each time-series, due to the variation in length of the time-series being assessed and the importance of evaluating all available data. Further, the assessment methodology we chose for all three Pelagic Habitats indicators overcame the need for threshold values, as we are now able to determine GES by assessing consistency in the direction of trends among indicator results, and the strength of links to specific pressures across assessment units within consistent MSFD pelagic habitat types. In the indicator assessments we provided an overview of existing pressures that will need to be addressed (linking with Tasks 1.2, 1.3, and 1.4 and Task 2.4), indicating what systems, data flows etc. could be used to support decision-making in future assessments and identify potential links with ecosystem services. To facilitate the decision-making process, it is also important to understand the type and quality of evidence underpinning the results, therefore an approach to undertake confidence assessment was also developed, based on methods already developed by ICG-Eut, and is further described below as part of the Thematic Assessment of Pelagic Habitats (Deliverable D1.4b, Annex I).

D5.2c UltraCOBAM workshop

From 14 to 16 June 2022 the UltraCOBAM workshop was held at the LEF Future Centre in Utrecht, the Netherlands, hosted by Rijkswaterstaat. UltraCOBAM was a workshop funded and organised by the NEA PANACEA project under the 2020 EU DG-ENV MSFD call. Its aims were to advance and accelerate the work on all biodiversity thematic assessments. To do so, a core component of each OSPAR ICG-COBAM expert group was invited. This workshop offered an opportunity to discuss, decide and deliver (draft) products, depending on the stage of development of each thematic assessment at the time. In addition, UltraCOBAM invited several OSPAR experts on a range of relevant themes for the biodiversity thematic assessments (such as the DAPSIR framework and elements, climate change and pressure Thematic Assessments) as well as representatives of OSPAR bodies to provide steer and support (such as BiTA, ICG-QSR and the secretariat) when needed.

Through participating in active cross-cutting sessions with Eutrophication, Food Webs, Climate Change and Pressures experts, the Pelagic Habitats experts attending the workshop developed a set of actions to implement into the Thematic Assessment of Pelagic Habitats, as described below:

- Take inspiration from the current confidence assessment methodology developed by ICG-Eut (as part of their COMPEAT tool) to develop a similar methodology to evaluate confidence as part of the assessments for Pelagic Habitats indicators.
- Check consistency of indicator assessment messaging with messages from the newly developed integration tables with colours which would be used in the state chapter of the Pelagic Habitats Thematic Assessment.
- Write a section about phytoplankton for the Climate Change Thematic Assessment to go along with the mostly zooplankton content in the existing document using resources such as UK MCCIP report on plankton, WGPME, WGHAB.
- Examine the Baltic assessment under HELCOM to see how they have assessed climate change for inspiration on messaging and themes.
- Compile a table of PH1/FW5 indicator results to provide to ICG-Eut to facilitate an assessment of spatial scales for OSPAR biodiversity assessments (supporting Task 2.3).
- Coordinate with ICG-Eut to conduct a case study comparing results for two specific assessment areas with different eutrophication status (i.e. case studies for Coastal Well Mixed and Northern North Sea COMP4 assessment units).
- Read and review the Impacts and Response sections of the Pelagic Habitats Thematic Assessment to make sure they are accurate and compatible with the results described in the State chapter.
- Ensure the activities described in the Activities section of the Pelagic Habitats Thematic Assessment are reflected accurately in the Response section once Drivers, Activities, and Pressures sections are sufficiently progressed.
- Consider what peer-reviewed scientific papers can be developed from the Pelagic Habitats Thematic Assessment in collaboration with the authors of the other chapters.

D1.4a Options for integration within and between pelagic indicators, and for setting pelagic baselines, targets, and threshold values (Annex H)

The overarching aim of this report was to demonstrate how the Changes in Phytoplankton and Zooplankton Communities, Changes in Phytoplankton Biomass and Zooplankton Abundance, and Changes in Plankton Diversity indicators (PH1/FW5, PH2 and PH3, respectively) from MSFD Descriptors 1 and 4 can be linked through a set of integration rules which evaluate the cumulative effects of multiple indicator results for particular habitat types and ultimately for entire MSFD regions. This report presented and critically evaluated options for a robust integration of multiple Pelagic Habitats indicator results.

We compared results from the PH1/FW5 and PH2 indicators directly for two assessment areas in the Greater North Sea. We also presented two options for integrating the results of the indicators which describe changes in phytoplankton and zooplankton communities (PH1/FW5) (Holland et al., 2023), phytoplankton biomass and zooplankton abundance (Louchart et al., 2023a), and in plankton diversity (Louchart et al., 2023b). Finally, we discussed the suitability of using threshold values for pelagic habitats assessment.

The direct comparison of PH1/FW5 and PH2 results for phytoplankton (diatoms and dinoflagellates compared with chlorophyll-*a* biomass) and zooplankton (large copepods and small copepods compared with total copepod abundance, data not shown) allowed us to observe relative differences in the annual cycle and how they vary at the subregional scale (Figure 17). This information is valuable for informing seasonal differences in the contributions of each lifeform to net plankton abundance/biomass.

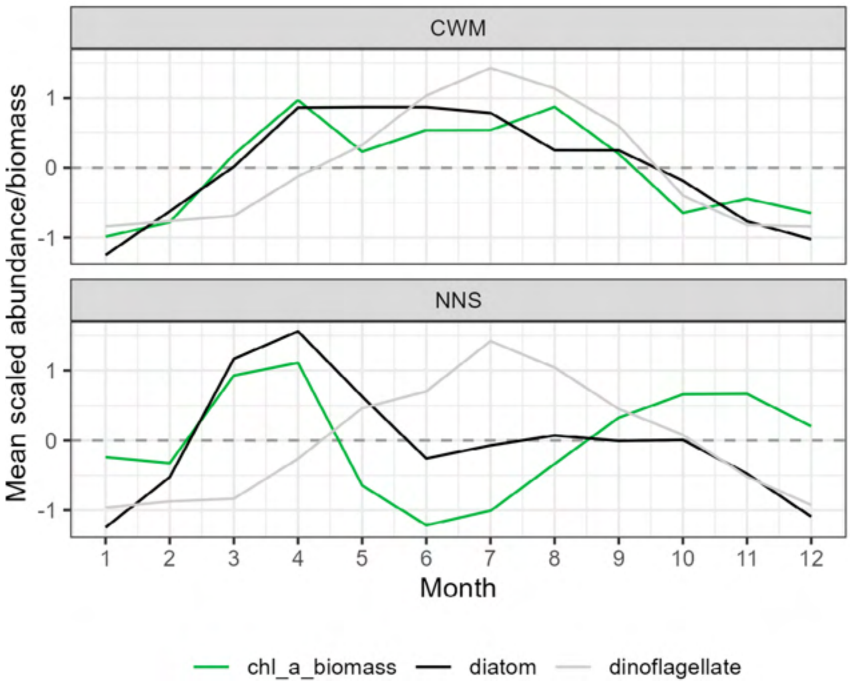

Figure 17. Mean scaled annual cycle for diatom and dinoflagellate abundance and chlorophyll-a biomass in the Channel Well Mixed (CWM) and Northern North Sea (NNS) COMP4 assessment units.

We directly compared PH1/FW5 and PH2 indicator results for phytoplankton to better understand how they covaried (Figure 18). It was decided to assess phytoplankton lifeforms using second order polynomial models, since maximum primary productivity is typically obtained at intermediate levels of phytoplankton abundance (Louchart et al., 2023c). We found that while zooplankton lifeform abundance (PH1/FW5) was highly correlated with total copepod abundance (PH2, data not shown), phytoplankton lifeform abundance (PH1/FW5) showed weak correlation with chlorophyll-*a* biomass (PH2).

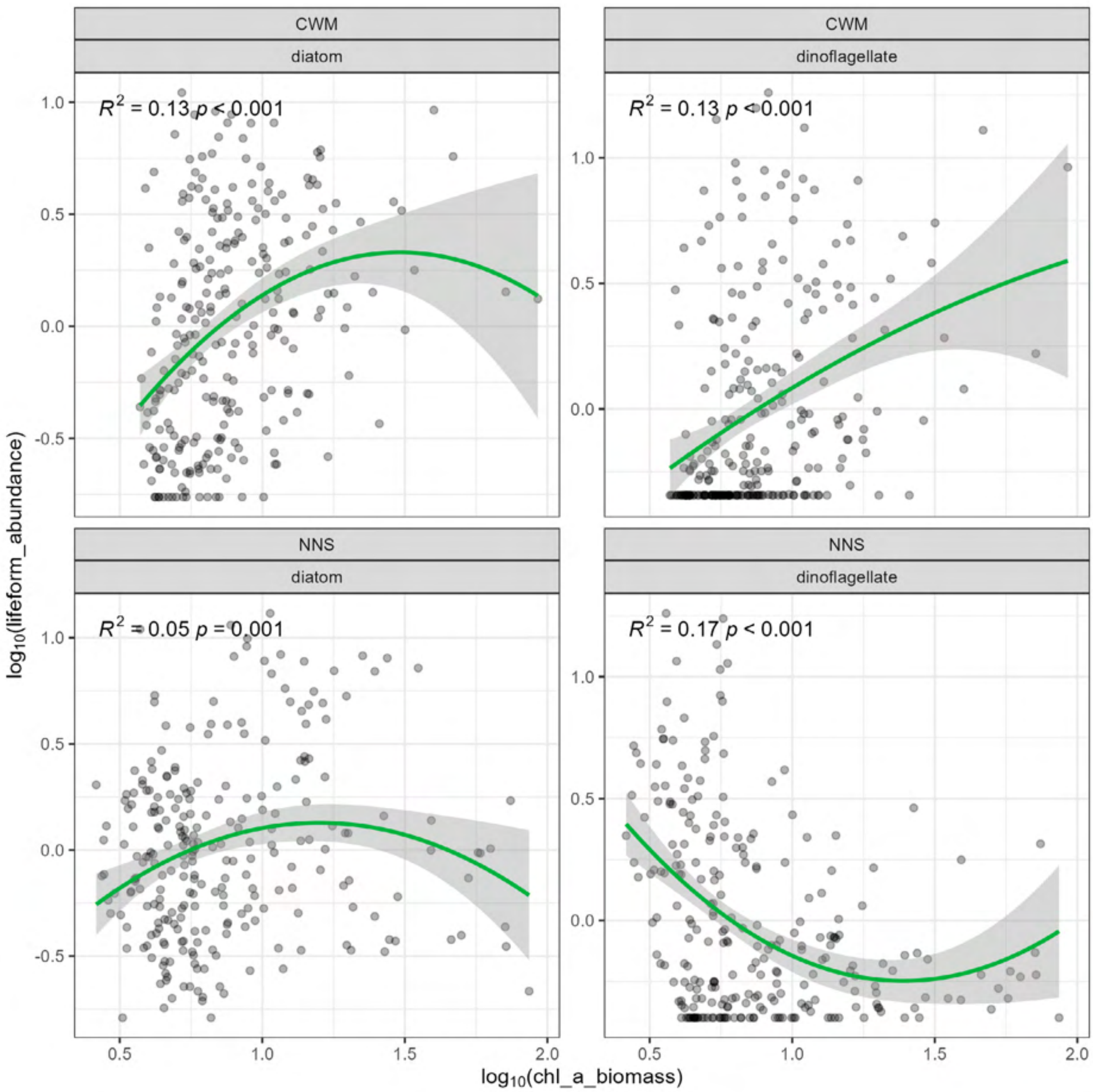

Figure 18. Second order polynomial correlations between the abundance of phytoplankton lifeforms and chlorophyll-a biomass. Trend lines indicate a linear model relationship between variables. R2 and p-values from Pearson correlation tests are indicated in each plot.

We calculated the lifeform pairs index (PH1/FW5) and overlaid PH2 results for chlorophyll-a biomass (Figure 19) and total copepod abundance (PH2, data not shown). This approach provided information on interannual seasonality of the PH2 indicator relative to variation in the PH1/FW5 indicator.

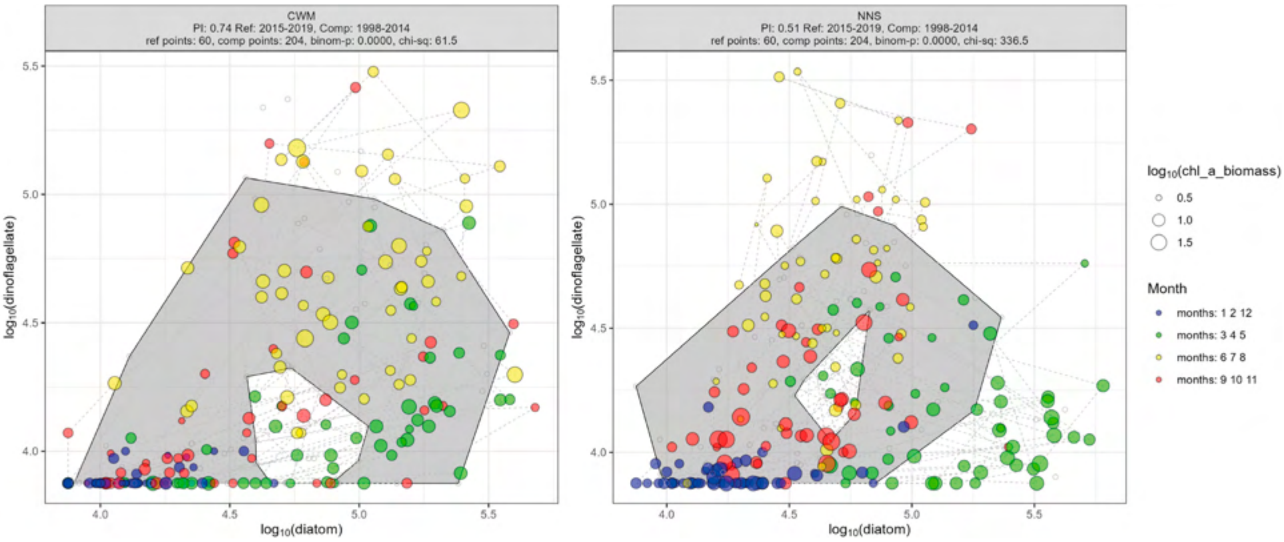

Figure 19. Lifeform pairs indicator output for diatoms and dinoflagellates in the Coastal Well Mixed (CWM) and Northern North Sea (NNS) COMP4 assessment units, overlaid with corresponding results from the chlorophyll-a biomass indicator, displayed as point size.

While it can be useful for more technical audiences to interpret indicator results at the level of the four distinct pelagic habitat types that make up each region, additional integration may be necessary if a single regional determination of GES is desired. Integration of indicator results is also an important requirement of the MSFD. To integrate results of multiple Pelagic Habitats indicators, we determined that the simplest approach was to extend the rules currently used for integrating results within the PH1/FW5 and PH2 indicators, by applying majority rules to GES results at the indicator level. We selected the One Out-All Out approach to automatically downgrade GES results to be more negative in the case of a tie.

An intermediate step is required to transition from multiple indicator results for each habitat type to a single regional determination of GES for the region; however, there were two logical approaches for this. The first approach would be to integrate the results of the common pelagic habitats indicators for each habitat type to determine an overall quality status result for each habitat (Figure 20a). The second approach would be to integrate the indicator results across habitat types to determine an overall quality status result for each indicator (Figure 20b). We concluded that integrating across indicators (i.e. PH1/FW5, PH2, and PH3 where it is accepted as a common indicator) to generate a single GES determination for each MSFD pelagic habitat type. This approach provides granular information on how anthropogenically linked changes vary with geography. Results generated using this approach can inform whether changes are mainly occurring close to the coast, and therefore possibly linked to direct anthropogenic pressures such as eutrophication, or whether they are occurring further offshore and more likely associated with broad scale processes like climate change. For the Pelagic Habitats Thematic Assessment (Deliverable D1.4b) we integrated across the three Pelagic Habitats indicators and developed a Coordinated Environmental Monitoring Programme (CEMP) guideline document to describe the integration methodology, which was approved by the OSPAR Biodiversity Committee (BDC) during their meeting in Berlin, Germany (12 to 15 December 2022).

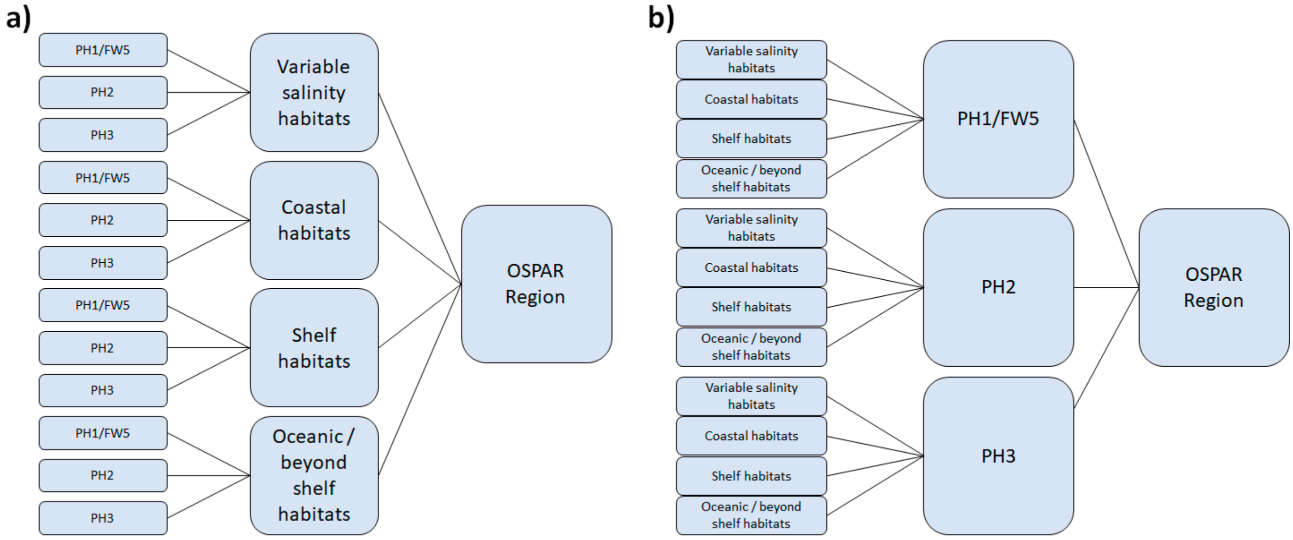

Figure 20. Conceptual flowchart diagram displaying two ways indicator results can be integrated to determine GES. Results can be integrated across the three indicators separately for each of the four pelagic habitat types within a region (a), or they can be integrated across the four pelagic habitat types separately for each of the three pelagic habitats indicators within a region (b).

Finally, regarding the setting of thresholds to determine GES, although pelagic habitats can in some cases be assessed for GES by evaluating and establishing threshold values based on primary productivity and chlorophyll-*a* (Heyden & Leujak, 2023; Tilstone et al., 2023), there is currently no scientific consensus on what represents GES when it comes to the abundance of lifeforms, copepods, or biodiversity. Further, determination of GES is further complicated by the fact that plankton data collection began after the North-East Atlantic was already heavily impacted by anthropogenic activities, thus there are no suitable data available to represent pristine conditions that would not be already adversely impacted by human activities.

The current methodology used to assess GES for pelagic habitats (and developed through the NEA PANACEA Project; Task 1.2) avoids the use of threshold values. Rather than testing whether a particular threshold value has been attained, the methodology for pelagic habitats indicators developed for the QSR 2023 evaluates three criteria to establish whether there is a suitable burden of evidence, including:

1. a sufficient level of spatial and temporal confidence among assessed time-series,
2. a sufficient level of spatial representation to assess each habitat type, and
3. the most important pressure being one that is linked to anthropogenic activity.

This methodology also evaluates whether the available evidence shows a suitable level of internal agreement to support determination of GES, including:

4. most assessment units showing the same direction of change, and
5. a sufficient mean rank for the most important pressure linked to changes in lifeform abundance).

It could be argued that the minimum levels applied to evidence and agreement criteria are themselves thresholds, however, these values only assess the burden of evidence for whether or not an important change may have occurred, rather than an indicator value above or below which GES is not achieved.

D1.4b Pelagic thematic assessment (Annexes I and J)

The Thematic Assessment of Pelagic Habitats for the OSPAR QSR 2023 was created to support EU MS MSFD reporting by determining the current state of Pelagic Habitats across the North-East Atlantic, the influence of humans on this component of the marine environment, and by determining if there are any management measures available within OSPAR to mitigate negative changes driven by human-linked pressures.

The document itself was written in consultation with members of the COBAM and UK Pelagic Habitats Expert Groups and underwent several periods of peer review and revision over the course of 2022. NEA PANACEA grant recipients were responsible for writing the State and Climate Change chapters, as well as curating all other sections written by other OSPAR expert groups and acting as primary editors of the overall document. The State chapter of the assessment was written as a summary of integrated indicator results at the level of MSFD pelagic habitats (i.e. variable salinity, coastal, shelf, and oceanic / beyond shelf habitats) and more generally at the level of the assessed regions (Figure 21). For all five OSPAR Regions (including unassessed Regions I and V) current literature on pelagic habitats was reviewed to create a regional summary narrative. The structure of the report followed the DAPSIR approach (Drivers, Activities, Pressures, State, Impacts, Response), which related changes in natural ecosystems with anthropogenic influences that drive them.

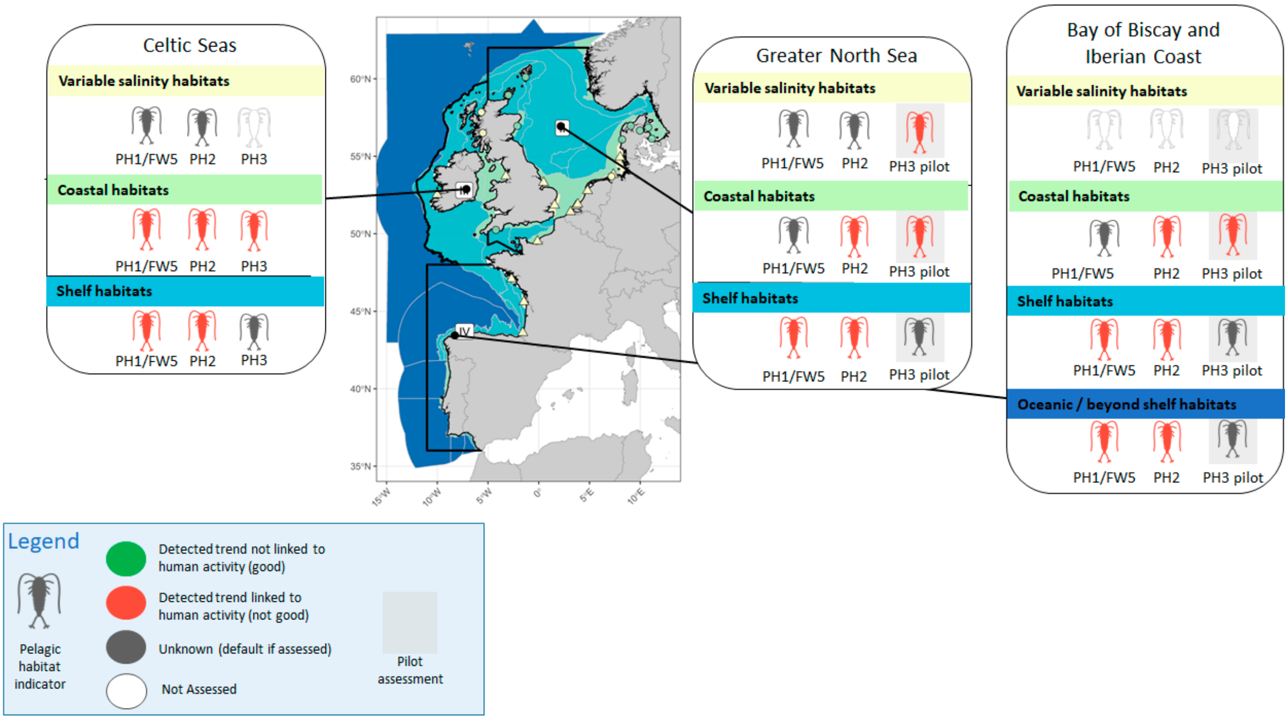

Figure 21. Indicator results schematic for pelagic habitat types (variable salinity, coastal, shelf, and oceanic / beyond shelf habitats) within the regions assessed for the Pelagic Habitats indicator assessments. This graphic has been designed following the format used and methodology described in McQuatters-Gollop et al (2022). For the OSPAR Pelagic Habitats biodiversity indicators there was variability among indicators, pelagic habitat types, and OSPAR/MSFD Regions. Icons have been coloured according to indicator status. Current integration methods for pelagic habitats do not allow for the determination of "Good" Environmental Status. Some indicators were not assessed in some Regions (grey) due to lack of data. Pelagic habitats without results displayed indicate that the particular habitat type is not present within the region. Grey background and "pilot" labelling display that an indicator has candidate status in the respective region and a pilot assessment has been prepared.

For this report, indicator results were summarised following methodology described in McQuatters-Gollop et al. (2022). Results were summarised in the form of graphical maps (Figure 21) which spatially link indicator results to geographic locations, and tables (Table 6), which clearly display the integration steps from indicator results at the level of pelagic habitat types, to a determination of GES for each pelagic habitat type, to determination of GES for each assessed region. For both figures and tables, we were sure to clearly differentiate results from common indicators and pilot assessments through the use of background shading and diagonal hatching, respectively.

Table 6. The status for each pelagic habitat type within each region, derived from integrating the status of common indicators for pelagic habitats. Uncoloured and diagonally hatched cells indicate that an indicator has candidate status in a particular region and a pilot assessment has been produced. As the PH3 indicator remains a candidate indicator for the Greater North Sea and the Bay of Biscay and Iberian Coast, the status of PH3 for these regions is given for information purposes only and was not considered in the integration of overall habitat or region status.

Region	**Habitat**	**PH1/FW5**	**PH2**	**PH3**	**Habitat status**	**Region status**
Greater North Sea (Region II)	Variable salinity	Unknown	Unknown	Not good	Unknown	Not good
	Coastal	Unknown	Not good	Not good	Not good	
	Shelf	Not good	Not good	Unknown	Not good	
	Oceanic	Not assessed	Not assessed	Not assessed	Not assessed	
Celtic Seas (Region III)	Variable salinity	Unknown	Unknown	Not assessed	Unknown	Not good
	Coastal	Not good	Not good	Not good	Not good	
	Shelf	Not good	Not good	Unknown	Not good	
	Oceanic	Not assessed	Not assessed	Not assessed	Not assessed	
Bay of Biscay and Iberian Coast (Region IV)	Variable salinity	Not assessed	Not assessed	Not assessed	Not assessed	Not good
	Coastal	Unknown	Not good	Not good	Not good	
	Shelf	Not good	Not good	Unknown	Not good	
	Oceanic	Not good	Not good	Unknown	Not good	

A confidence scoring methodology, based on an approach developed by ICG-Eut to validate the output from their COMPEAT Tool, was applied to evaluate the robustness of reported trends for each plankton dataset for each assessment unit it intersected. For each assessment unit or fixed-point station temporal confidence was evaluated by assessing the consistency of sampling throughout each time-series, integrating the consistency of sampling throughout each year (seasonal representation) and consistency of sampling across the entire time-series.

Spatial confidence was also evaluated for distributed datasets such as the CPR. For each COMP4 assessment unit spatial confidence was calculated based on the spatial distribution of samples relative to the boundaries of each assessment unit. This confidence scoring approach was incorporated into the assessments for all three Pelagic Habitats indicators (i.e. PH1/FW5, PH2, and PH3) and was further integrated in the Thematic Assessment of Pelagic Habitats, using the same integration rules which were applied to GES results (Table 7).

Table 7. Confidence assessment of the type, amount, quality, and consistency of evidence (i.e. Robust, Medium, or Limited), as well as the degree of agreement in the results (i.e. High, Medium, or Low) for the three pelagic habitats indicators across the assessed regions. Colours are used for interpretation. Uncoloured and diagonally hatched cells indicate that an indicator has candidate status in the region and while a pilot assessment has been conducted, a confidence assessment has not been produced.

Region	Criteria	PH1/FW5	PH2	PH3	Criteria status	Region status
Greater North Sea (Region II)	Agreement	Medium	Medium	Not assessed	Medium	Medium
	Evidence	Medium	Medium	Not assessed	Medium	
Celtic Seas (Region III)	Agreement	High	High	High	High	High
	Evidence	Medium	Medium	Medium	Medium	
Bay of Biscay and Iberian Coast (Region IV)	Agreement	High	High	Not assessed	High	Medium
	Evidence	Limited	Limited	Not assessed	Limited	

The general conclusions of the Thematic Assessment of Pelagic Habitats were that the growing global population has generated increasing demand for food production, waste disposal, coastal development, and energy systems, all of which contribute to human-induced climate change. Climate change is probably the greatest pressure currently impacting plankton communities across the OSPAR maritime area as a whole. These activities also influence the supply of nutrients entering coastal environments, which can generate eutrophication and impact the productivity of pelagic habitats.

Pelagic habitats in the OSPAR Maritime Area have experienced widespread changes over the past 60 years, with indicator assessments revealing a general pattern of decreasing phytoplankton and zooplankton abundance and/or biomass across the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast. Long-term trends have largely continued into the current assessment period, and are expected to continue into the future, eventually impacting higher food web levels. Due to widespread changes linked to pressures generated by human activities, the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast had "Not good" status, given the current definition and categorisation of quality status.

Global efforts to slow climate change are probably the best mechanism to counter widespread changes in plankton communities, although effective measures for reducing or preventing climate change mostly lie outside the remit of OSPAR. Regionally targeted management measures (e.g. controlling inputs of nutrients and organic matter) in coastal areas may affect pelagic habitats at the shelf and coastal scale. While these mitigation efforts are likely to only generate noticeable impact in coastal areas, they may also have some effect in areas where plankton communities are affected by the cumulative impacts of multiple pressures (i.e. both warming and eutrophication).

Task 1.4 knowledge gaps and next steps

- Future assessments need to include an assessment of the CPR Phytoplankton Colour Index (PCI) as an in situ direct estimate of phytoplankton biomass. This should run in parallel to the assessment of satellite data. There is much literature on this topic (e.g. McQuatters-Gollop et al., 2007; Raitsos et al., 2013).
- Integrate relevant Pelagic Habitats and Food Webs indicators for a better understanding of how changes in Pelagic Habitats indicators impact Food Webs.
- Improve coherence and integration between the PH2 indicator and relevant indicators within HASEC.
- Integrate datasets derived using different methods for measuring chlorophyll-*a*: continual assessment characterising the differences in chlorophyll-*a* methodologies is required, as well as for the PCI.

- Further develop the methodology for defining the natural annual cycle in the PH2 indicator and subsequently for the trend characterisation and assessing spatial and temporal confidence of the results for PH1/FW5 and PH2.
- Work to refine the use of remote sensing data to improve coherence with the OSPAR eutrophication assessments at different spatial and temporal scales.
- Refine the links between PH1/FW5 and PH2 indicators with pressures to identify the origin of the pressures.
- Appropriate training of taxonomists and ring testing as well as the integration of semi-automated sampling techniques
- Assessment of the whole size range of phytoplankton from flow cytometry and metabarcoding/metagenomics data.
- Assess spatial and temporal confidence to identify assessment areas in need of increased sampling effort.
- Develop a better understanding of the community structure of phytoplankton, particularly regarding synergies and antagonisms between Pelagic Habitats indicators.

Task 1.5: Linking pelagic indicators with food web indicators and their connection to other ecosystem components and MSFD-descriptors (Annexes K, L, M and N)

Task Lead: Felipe Artigas (CNRS, FR) (Partner)

Other involved: Arnaud Louchart (CNRS, FR) (Partner), Abigail McQuatters-Gollop (UoP, UK) (Partner), Matthew Holland (UoP, UK) (Partner), Birgit Heyden (AquaEcology, DE) (Partner), Anouk Blauw (Deltares, NL) (Sub-contractor), Gavin Tilstone (PML, UK) (Sub-contractor)

Other Activities involved: Activity 2 (Tasks 2.1, 2.2, 2.3 and 2.4)

Milestones: D5.2c UltraCOBAM workshop; identification of synergies

Deliverables: D1.5a First proposition of FW2/FW6 indicator assessment; D1.5b Options for integrating pelagic indicators with eutrophication indicators; D1.5c Options for integrating pelagic indicators with other ecosystem components

Task 1.5 summary

The current assessment of the ecological status of the North-East Atlantic has been conducted using a suite of indicators in a single metric approach. To better inform ecological status, however, the current best practice for the MSFD is to use the ecosystem approach as it provides a holistic view of the current state of environmental quality. To achieve this in the pelagic domain, NEA PANACEA Task 1.5 aimed to evaluate the FW2 "primary production" and the FW6 "biomass, species composition and spatial distribution of zooplankton" indicators and propose options for integrating the Pelagic Habitats indicators with relevant indicators from other MSFD descriptors D4 (Food Web) and D5 (Eutrophication). First, we conducted a pilot assessment of the FW2 candidate indicator for the upcoming assessment cycle and developed the methodology for the FW6 indicator (Deliverable D1.5a). Then, we provided options for integrating two of the Pelagic Habitats indicators and a related Food Webs indicator (PH2, PH3 and FW2) with eutrophication indicators (winter concentration of nutrients and concentration of chlorophyll-*a*). We provided detailed information on the impacts of the spatial resolution of the raw data as a source of difference between related indicators. We also offered two options for integrating Pelagic Habitats indicators with eutrophication indicators (D5C1 and D5C2) via the use of the One Out-All Out approach, widely used in WFD assessment, and via the use of the EQR approach, commonly used for the eutrophication MSFD descriptor (D5). Finally, we investigated synergies and antagonisms between Pelagic Habitats indicators (dedicated Pelagic Habitats indicators and de-facto pelagic Food Webs indicators) to conceptualise the integration of the Pelagic Habitats indicators with other ecosystem components.

D5.2c UltraCOBAM workshop

The purpose of the UltraCOBAM workshop and workshop outcomes for Pelagic Habitats assessment are described in detail under Task 1.4.

D1.5a First proposition of FW2/FW6 indicator assessment

FW2 Primary Production (Louchart et al., 2023c) (Annex K)

A pilot assessment of the FW2 candidate indicator was produced for the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast. The FW2 indicator provides a means of identifying changes (anomalies) in primary production (carbon fluxes in phytoplankton). Such changes represent deviations from the assumed natural variability in a plankton time-series. Changes in primary production are measured between a historic comparison period (prior to 2015) and a contemporary assessment period (2015 – 2019). The direction of change is statistically identified as either increasing, stable, or decreasing. This indicator has been assessed at the subregional scale, using COMP4 assessment units (Enserink et al., 2019) to subdivide data for samples collected within the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast. The FW2 indicator uses the same assessment method as the PH2 indicator. Satellite data covered years 2015 and 2016 of the assessment period, while fixed-point station data covered years 2015 to 2019 of the assessment period.

Indicator results revealed that anomalies in primary production exhibited decreasing trends across the majority of COMP4 units assessed (Figure 22). The assessment period for the COMP4 units (2015 to 2016 because of temporal limited coverage of satellite dataset) was characterised by strong and significant decreases in primary production in 84% of the assessment units studied, while primary production increased in only 5% of assessment units. There were no significant changes in primary production for 11% of the assessment units. In addition, long-term trends did not demonstrate net changes in primary production.

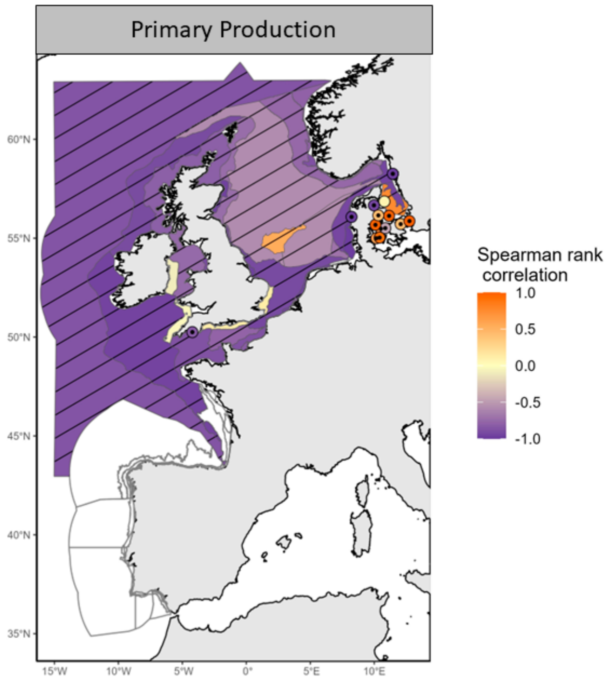

Figure 22. Trend in primary production between the assessment period (2015–2019; 2015-2016 for satellite data and 2015-2019 for fixed-point stations) and the comparison period (station data: 1992–2014; non-station data: 1997–2014). Hatched areas were characterised by significant changes in primary production between the reference and the assessment periods. Black dots represent significant trend for stations. White areas indicate no data or insufficient data to assess the area.

Changes in nutrient concentrations were the most important variables linked to changes in primary production (29% of COMP4 areas; Figure 23). Links between primary production and pressures affected by climate change were also evident in the Greater North Sea, the Celtic Seas, and Bay of Biscay and Iberian Coast (OSPAR Regions II, III and IV, respectively). Increasing mixed layer depth (16% of COMP4 assessment units), increasing SST (13%), decreasing pH (13%), and decreasing wind speed (11%) were among the most important variables linked to decreases in primary production. Changes in nutrient loadings can also be an indirect consequence of climate change, related to higher or lower continental inputs resulting from changes in the amount of precipitation during the autumn and winter. Other parameters linked to the decrease of primary production were decreases in salinity (8%), decreases in precipitation (5%) and increases in light attenuation (3%).

The quality status of food webs within the regions was addressed following the links between pressures and FW2 indicator results (Table 8) following the method used to determine the GES developed by McQuatters-Gollop et al. (2022). Regarding the relationships between the pressures and the primary production, quality status of most habitats within the OSPAR/MSFD Regions was "Not good". Only variable salinity habitat in the Greater North Sea (OSPAR Region II) had an "Unknown" quality status.

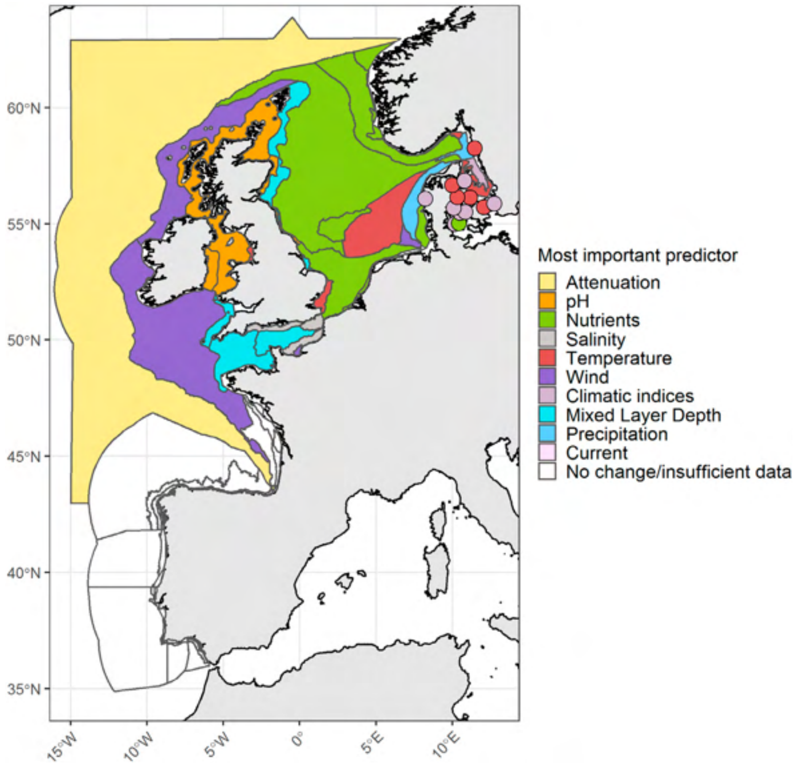

Figure 23. Most important variables addressing changes in primary production within the COMP4 assessment units.

Table 8. Integration of the indicator results of the Greater North Sea, the Celtic Seas and the Bay of Biscay and Iberian Coast (OSPAR Region II, III and IV respectively). Column names are described as follows: Dir: the net direction of change in the primary production (upward arrow: increasing trend, equality sign: no trend, downward arrow: decreasing trend), Trend: the percentage of assessment units exhibiting the respective trend (if no results were reported for assessment units, stations are used), Change: a logical variable (TRUE/FALSE) to report whether a net trend is likely given the significance of the results, Pressure: the environmental pressure with the greatest mean rank for the respective trend, Rank: the mean rank of the environmental pressure indicated under Pressure, nSt: the total number of fixed-point stations considered, nCOMP4: The total number of COMP4 assessment units considered, totCOMP4: The total number of potential COMP4 assessment units for the habitat category, spatialRep: the spatial representativeness score of the analysis.

OSPAR/MSFD Region	Habitat	Dir	Trend	Change	Pressure	Rank	nSt	nCOMP4	totCOMP4	Spatial Rep
The Greater North Sea	**Variable salinity**	↓	88%	TRUE	phosp	2,8	0	8	9	89%
	Coastal	↓	83%	TRUE	sst	4,2	12	12	12	100%
	Shelf	↓	88%	TRUE	np	4,1	1	8	11	72%
	Oceanic	NA								
The Celtic Seas	**Variable salinity**	↓	100%	TRUE	pH	2,0	0	2	2	100%
	Coastal	=	100%	FALSE	pH	2,3	0	3	3	100%
	Shelf	↓	100%	TRUE	mld	3,0	0	4	4	100%
	Oceanic	NA								
The Bay of Biscay and Iberian Coast	**Variable salinity**	NA								
	Coastal	NA								
	Shelf	↓	17%	TRUE	wspd	1,0	0	1	6	17%
	Oceanic	↓	17%	TRUE	attn	1,0	0	1	6	17%

FW6 Biomass, species composition and spatial distribution of zooplankton (Annex L)

The FW6 indicator was proposed to OSPAR as a candidate indicator for the first time for the QSR 2023. Several technical issues impeded the development of a pilot assessment for this indicator, including scarcity of biomass datasets, or the assessment period (2015 to 2019) not having coverage from available datasets. However, we have produced a case study for what the FW6 indicator assessment could look like in the future. Using a zooplankton biomass dataset we had available for 2008 to 2011, and based on the recommendations presented in the CEMP guidelines for the FW6 indicator (D3.4.1 of EcApRHA project; Padegimas et al., 2017), we created a masterlist of carbon content per taxon (linked to zooplankton groups with the WoRMS Aphia ID system) to calculate an estimate of zooplankton biomass per sample (Figure 24).

Matrix ***C***

Taxon	AphiaID	Carbon content
Sp_1	ID_{Sp1}	C_{Sp1}
Sp_2	ID_{Sp2}	C_{Sp2}
...	...	...
Sp_n	ID_{Spn}	C_{Spn}

×

Matrix ***A***

Taxon	AphiaID	Abundance
Sp_1	ID_{Sp1}	A_{Sp1}
Sp_2	ID_{Sp2}	A_{Sp2}
...	...	...
Sp_n	ID_{Spn}	A_{Spn}

Matrix ***B***

Taxon	AphiaID	Biomass
Sp_1	ID_{Sp1}	B_{Sp1}
Sp_2	ID_{Sp2}	B_{Sp2}
...	...	...
Sp_n	ID_{Spn}	B_{Spn}

Figure 24. Workflow to estimate zooplankton biomass per taxon using the abundance and carbon content per taxon. The carbon content per taxon is given by the matrix C and expressed in g C^{-1}. It corresponds to the masterlist. The abundance per taxon is given by the matrix A and expressed in ind m^{-3}. The matrix B corresponds to the biomass per taxon expressed in g C^{-1} m^{-3}. The matrix B is equal to matrix C multiplied by matrix A.

Spatial distribution at each year of zooplankton biomass samples from the Bundesamt für Seeschifffahrt und Hydrographie Institute (BSH; Germany) dataset for the Eastern North Sea and German Bight was represented (Figure 25). The figure revealed that the twelve stations were inconsistently sampled. This issue is commonly reported in each assessment realised for the upcoming assessment cycle. In this dataset, 2010 was the most sampled year with all stations sampled.

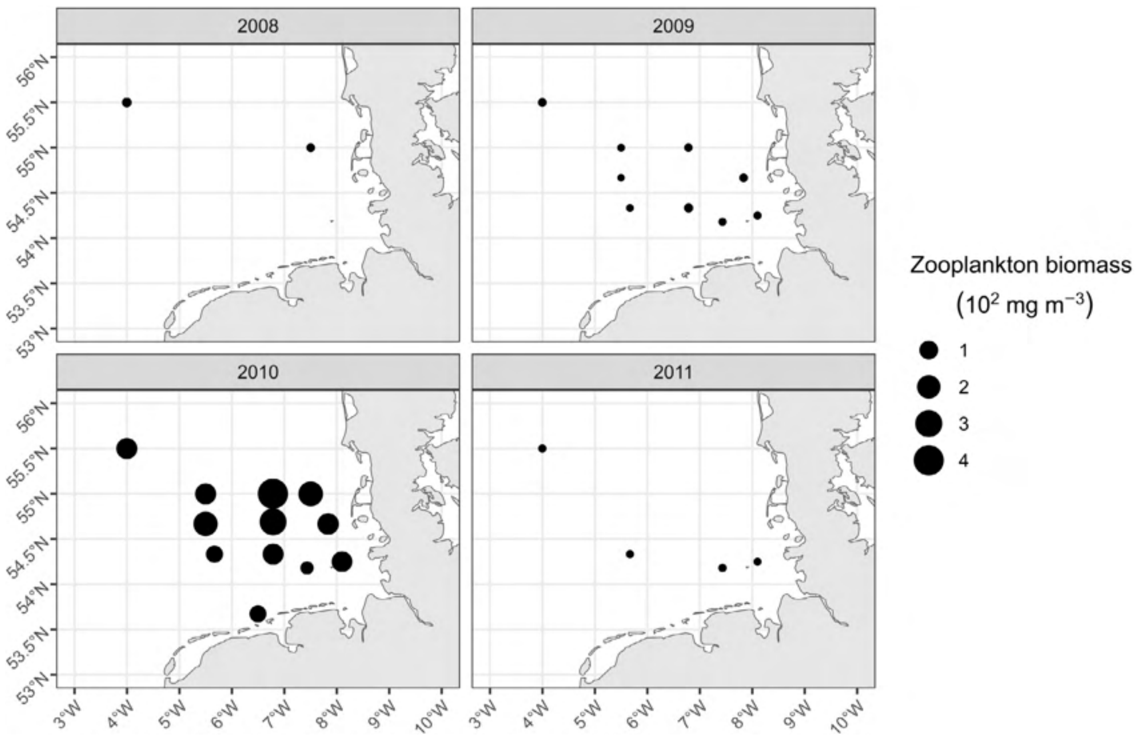

Figure 25. Annual Zooplankton biomass at the twelve monitoring sites of the Bundesamt für Seeschifffahrt und Hydrographie Institute (BSH; Germany).

Zooplankton biomass was also estimated from the masterlist of carbon content using abundance per taxon for few fixed-point monitoring stations. An example for the L4 station from Plymouth Marine Laboratory (PML, UK) in the Western English Channel from 1988 to 2021 is provided in Figure 26. A linear trendline was then plotted on the dataset to obtain the long-term trend in zooplankton biomass. To confirm whether these zooplankton biomass estimates were consistent with existing known values of zooplankton biomass, we pooled the monthly data at L4 to determine annual mean biomass and compared these values with data from BSH (Figure 26). We found that both datasets shared a similar range of biomass values, providing some validation of confidence for this methodology.

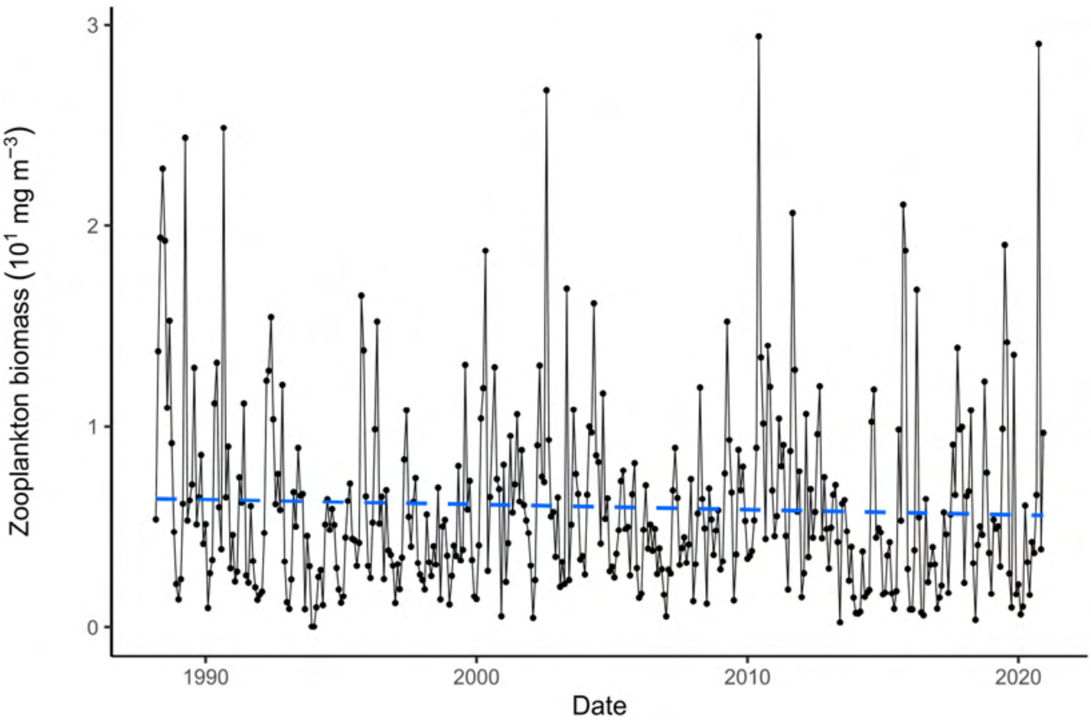

Figure 26. Zooplankton biomass at station L4 (UK-PML; western English Channel) calculated from abundance and carbon content.

D1.5b Options for integrating pelagic indicators with eutrophication indicators (Annex M)

The aim of this report was to provide elements of integration for Pelagic Habitats with relevant indicators to provide a holistic view of the current environmental quality status for plankton across MSFD D1 (Biological Diversity), D4 (Food Web), and D5 (Eutrophication). In this report, we presented two options for integrating the Changes in Plankton Diversity indicator (PH3; Louchart et al., 2023b), the phytoplankton biomass indicator (PH2; Louchart et al., 2023a), the primary production indicator (FW2; Louchart et al., 2023c), the winter nutrient concentration (HASEC; Heyden & Leujak, 2023) and the concentration of chlorophyll-*a* indicator (HASEC; Prins & Enserink, 2023), from the simplest (One Out, All Out approach) to the most elaborate (averaging weighted Ecological Quality Ratio) approach to assess the quality status of pelagic habitats.

The One Out, All Out approach resulted in an overall “not good” or “bad” environmental status from the GES determinations of the five indicators (Table 9). The One Out, All Out approach represented a fast and easy integration method and has the advantage that it can be performed even when different methodologies have been used for previous integration steps. It also has the benefit of being relatively simple since it avoids the need for any calculations. Nevertheless, One Out, All Out is the most rigid integration approach, which is known to regularly downgrade quality status to be more negative (Borja & German Rodriguez, 2010).

Table 9. Categorisation of the quality status and their associated narratives according to the One Out, All Out approach (OO-AO) for Phytoplankton biomass, Zooplankton abundance, Phytoplankton and zooplankton diversity, Primary Production, concentration of chlorophyll-a and Winter nutrient concentration for Plume, Coastal, Shelf and Oceanic habitats within the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast. The closer the colour coding is to red, the more "bad" the GES is. Pink colour coding was attributed for moderate GES. Colour coding for PH2, PH3, FW2 and Integrated quality status comes from (McQuatters-Gollop et al., 2022). For colour coding for Concentration of chlorophyll-a and winter concentration of nutrient, please refer to the NEA-PANACEA deliverable 1.5b 'Options for integrating pelagic indicators with eutrophication indicators'.

		OSPAR Indicator					**OO-AO**	**OO-AO**
OSPAR/ MSFD Region	Habitat	PH2	PH3	FW2	Concentration of chlorophyll-***a***	Winter concentration of nutrient	Integrated quality status (habitat)	Integrated quality status (Region)
Greater North Sea	Plume							
	Coastal							
	Shelf							
	Oceanic							
Celtic Seas	Plume							
	Coastal							
	Shelf							
	Oceanic							
Bay of Biscay and Iberian Coast	Plume							
	Coastal							
	Shelf							
	Oceanic							

The averaging weighted Ecological Quality Ratio (EQR) resulted in only 10% of the habitats being designated as having "moderate" Environmental Status, and 90% of the remaining habitats in "good" or "excellent" Environmental Status (Table 10). The averaging weighted Ecological Quality Ratio approach is less strict than the One Out, All Out approach and produced a more realistic and complete summary of the state of Pelagic Habitats. However, this latter approach also had the tendency to upgrade, rather than downgrade GES results.

Table 10. Categorisation of the quality status and their associated narratives according to averaging weighted Ecological Quality Ratio obtained for Phytoplankton biomass, Zooplankton abundance, Phytoplankton and zooplankton diversity, Primary Production, concentration of chlorophyll-a and Winter nutrient concentration for Plume, Coastal, Shelf and Oceanic habitats within the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast. The closer the colour coding is to dark green, the more "excellent" the GES is. The closer the colour coding is to red, the more "bad" the GES is. Pink colour coding was attributed for moderate GES.

		OSPAR indicator					**EQR**	**EQR**
OSPAR/MSFD Region	Habitat	PH2	PH3	FW2	Concentration of chlorophyll-***a***	Winter concentration of nutrient	Integrated quality status (habitat)	Integrated quality status (Region)
Greater North Sea	Plume	0.67	0.16	0.88	0.56	0.71	0.55	0.60
	Coastal	0.56	0.26	0.87	0.78	0.71	0.61	
	Shelf	0.52	0.27	0.76	0.93	0.86	0.63	
	Oceanic	-	-	-	-	-	-	
Celtic Seas	Plume	0.69	-	0.88	0.86	0.67	0.88	0.71
	Coastal	0.54	0.32	0.87	0.79	0.82	0.63	
	Shelf	0.45	0.29	0.68	0.98	0.96	0.63	
	Oceanic	-	-	-	-	-	-	
Bay of Biscay and Iberian Coast	Plume	-	-	-	0.92	-	0.92	0.75
	Coastal	0.46	-	-	1	0.89	0.76	
	Shelf	0.49	0.25	0.61	1	1	0.69	
	Oceanic	0.57	0.27	0.49	1	0.84	0.61	

D1.5c Options for integrating pelagic indicators with other ecosystem components (Annex N)

In order to get the best picture of the biodiversity and food webs descriptors, it is useful to integrate Pelagic Habitat indicators with other indicators of the MSFD D1 (Biological Diversity) and D4 (Food Web). The aim of this task was to provide elements of integration for Pelagic Habitats with Food Web, mammals, birds, and benthic habitats indicators through the FW9 'Ecological Network Analysis' indicator (FW9; Schückel et al., 2023). As it is crucial to understand exactly the relation and the mechanisms acting between the elements, the task D1.5b first focused on studying the *Synergies and antagonisms between Pelagic Habitat and Food Web Indicators.* Then, in a second step, we conceptualise the integration of Pelagic Habitat indicators with benthic habitat, food webs, birds, and mammals under the FW9 indicator.

In this part, we continued the comparisons made in task D1.4 and worked on the interaction between indicators in 3-dimensions (Figure 27). We also added the FW2 indicator 'primary production' to study the relationships between stocks and flows within planktonic compartments. Because biomass of zooplankton data are scarce, we decided to not include the FW6 indicator in the analysis at this stage. This part looked at interactions between PH1/FW5, PH2, PH3 and FW2 indicators for phytoplankton and between PH1/FW5, PH2 and PH3 indicators for zooplankton. Figure 27 displays an example of interaction between primary production, phytoplankton biomass and diatom abundance in the Channel Well Mixed (Figure 27A) and Southern North Sea (Figure 27B) assessment units. The models obtained revealed the ecosystem was more productive for intermediate values of biomass and abundance. However, the different models revealed that the pattern was specific to the location considered. Biological relationships (plankton stock versus turnover, most important lifeform responsible for primary production and/or biomass) may be responsible for driving these differences.

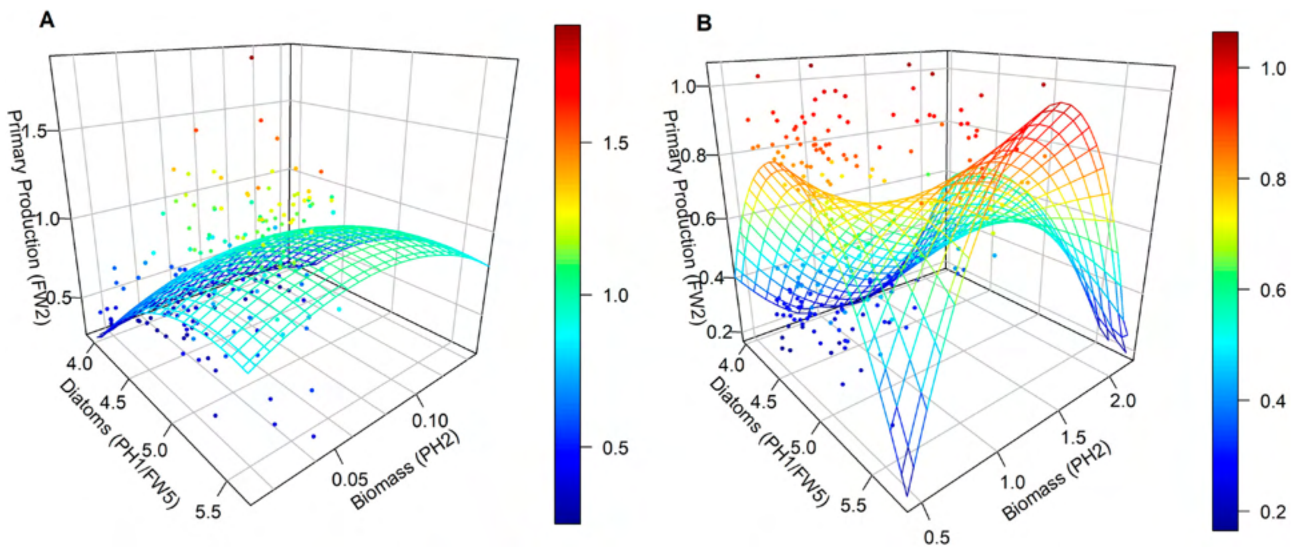

Figure 27. 3D scatter plot between diatoms abundance (PH1/FW5), phytoplankton biomass (PH2) and primary production (FW2) for Coastal Well Mixed (A) and Northern North Sea (B) assessment units. The grid represented the best fitting model explaining primary production.

We also conceptualised the connections between the Pelagic Habitats and related Food Webs indicators (Pelagic Habitats, FW2 and FW6 indicators). Figure 28 shows that the connection between most of the indicators is two-way (e.g. PH2 acting on FW6 and FW6 acting on PH2) although some of them are one-way (e.g. FW6 to benthos considering meroplankton, zooplankton becoming benthic). Therefore, this report essentially provides pathways of the pelagic indicators into the FW9 indicator. Because several issues identified in the knowledge gaps section have not yet been resolved, the integration of PH1/FW5, PH2, PH3, FW2, and FW6 indicators could not be completed within the timeframe of this project.

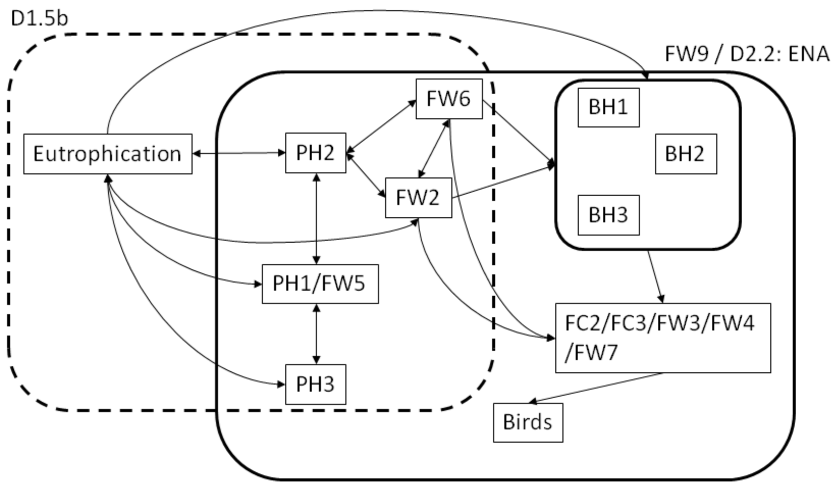

Figure 28. Conceptualisation of the integration of the Pelagic Habitats with Food webs, Benthic Habitats and birds within the FW9 'ENA' (NEA PANACEA Task 2.2). The relationships between the Pelagic Habitats indicators with eutrophication are also displayed (NEA PANACEA Task 1.5b).

Task 1.5 knowledge gaps and next steps

Knowledge gaps identified for the FW2 'Primary Production' indicator were as follow:

- Improvement of the methodology for defining the natural cycle and then for trend characterisation.
- Comparison to relevant Pelagic Habitat and Food Web indicators as well as relevant indicators within ICG-Eut.
- Reinforcement of *in situ* measurements of primary production, including direct (Carbon related) and physiological (variable fluorescence) approaches.
- Inclusion of additional datasets from field estimation
- Inclusion of additional datasets to improve the confidence of the indicator's result especially for the Bay of Biscay and Iberian Coast (OSPAR Region IV).
- Refinement of the use of remote sensing data within estuaries, plumes, and coastal habitats
- Improvement of the methodology for defining spatial and temporal confidence of the results
- Refinement of the links between FW2 and pressures to identify the origin of pressures.

Knowledge gaps identified for FW6 'Biomass, species composition and spatial distribution of zooplankton' were as follow:

- Adapt the sampling frequency to address marine policy issues
- Include additional datasets
- Consider sampling period and location
- Refinement of the methodology, including automated estimates of biovolumes through imaging approaches
- Definition of thresholds and/or reference conditions

Knowledge gaps identified for 'Options for integrating pelagic indicators with eutrophication indicators' were as follow:

- Improvement of the methodology for integration the Pelagic Habitats and FW2 indicators with eutrophication indicators
- More coherence of data availability between Pelagic Habitats and Eutrophication indicators: OSPAR QSR 2023 highlighted discrepancies between PH2 and Concentration of Chlorophyll-*a* indicator due to different spatial resolution of the datasets
- Incorporate spatial and temporal confidence to weight the determination of GES

Knowledge gaps identified for 'Options for integrating pelagic indicators with other ecosystem components' were as follow:

- Find appropriate temporal and spatial scale for integration of Pelagic Habitats. Plankton indicators require datasets at monthly resolution. The FW9 and most Food Web and Benthic Habitats indicators work at annual resolution.
- More information is needed about data availability across OSPAR Regions
- Lifeforms: importance of considering *Phaeocystis* genus (important in the Greater North Sea) and picophytoplankton size class, as diatoms and dinoflagellates are not always the lifeforms that contribute the most to biomass or primary production.
- Biodiversity: generalisation of the synergies and antagonisms between indicators to each assessment unit because plankton indicators do not respond linearly to each other.

Activity 1 cross-cutting and linkages to other activities

Work on progressing the development of Pelagic Habitats assessments is ongoing and future work should involve increased collaboration and cross-cutting between the COBAM Pelagic Habitats Expert Group and other relevant expert groups. The NEA PANACEA project has identified several overarching objectives for future cross-cutting work, including:

- Examining the Eutrophication indicator assessments to identify instances and assessment units where thresholds are regularly exceeded (i.e. problem areas) and examine the response of the Pelagic Habitats indicators for periods when an assessment units exceed thresholds. Compare these results to Pelagic Habitats indicator results in assessment units which have been determined to have good eutrophication status.
- Examining the response of Pelagic Habitats indicators in times of extreme events (e.g. heat waves, harmful algal blooms (HABs; occurrence information available from ICG-Eut), oxygen slumps etc.) using high temporal resolution Pelagic Habitats data. This form of analysis will likely be restricted to fixed-point station datasets with high temporal frequency (e.g. PML L4, Helgoland Roads).
- Further development of threshold values and determination of GES (e.g. using the EQR method or working with HASEC to better understand how their method could be applied to Pelagic Habitats assessment)
- Improving coordination with ICES for data storage and ingestion, as ICG-Eut currently uses ICES to provide the data required by their assessments. Data should be directly extractable from ICES and inserted into the online Plankton Lifeforms tool (PLET) to support all three Pelagic Habitats indicator assessments through automated aggregation to lifeforms (PH1/FW5) and raw data (PH2, PH3). To facilitate this, the PLET will need to be adapted to support storage and extraction of additional data types.
- Identifying consequences of change in indicators on other trophic levels (integration with Food Webs, Benthic Habitats, etc.).

Activity 1 knowledge gaps and next steps

The Thematic Assessment of Pelagic Habitats for the OSPAR QSR 2023 has identified several objectives for progressing the development of Pelagic Habitats assessments in the next assessment cycle. Future assessments must consider how to include plankton community indicators directly in the eutrophication assessment. The assessment needs to build the evidence of how nitrate and phosphate ratios lead to changes in phytoplankton communities (which negatively impact on the efficiency of the ecosystem services those communities provide).

Further to this, there may also be opportunities to explore how to consider plankton communities that form pelagic habitats within the Marine Protected Area (MPA) status assessment, and to consider the inclusion of plankton community dynamics in Environmental Impact Assessment (EIA) guidance. Considering the current scaling up of offshore renewable energy infrastructure, it is also important to consider the effects this will have on plankton dynamics.

Going forward, continuous work to improve understanding of linkages across trophic levels (top-down and bottom-up) should incorporate the concept of trophic cascades, particularly considering links to plankton health, food web function, and derived ecosystem services.

Finally, future assessments should aim to quantify the effects of plankton change on ecosystem services, and the effects of pressures on plankton as natural capital.

There are also more specific objectives for indicator development at the OSPAR regional scale, including further work on developing methods and threshold values, promoting indicator status from candidate indicator to common indicator, and introducing new pilot assessments in previously unassessed OSPAR regions (Table 13; colour key in Table 11 and text key in Table 12).

Table 11. Colour key for Table 13, indicating the current status of each indicator assessment within each OSPAR region.

(dark blue)	Common indicator assessment in the QSR 2023
(light blue)	Candidate indicator
(yellow)	Pilot assessment in the QSR 2023
(white)	No assessment included in the QSR 2023

Table 12. Text key for Table 13, indicating the development goals for each indicator assessment within each OSPAR region.

NEW	Expand Common indicator to new region (s)
COM	Seek promotion of Candidate indicator to a Common indicator in specified region(s)
NEW	Pilot assessment of a candidate in a new region(s)
TV	Threshold value development planned in specified region.
MD	Other method development planned in specified region

Table 13. Table outlining next steps for Pelagic Habitats indicator assessment, with colours representing the current status of indicator assessment methodology in each OSPAR region (defined in Table 11) and text to represent the development goals for indicator assessments in each OSPAR region for the next assessment cycle (defined in Table 12).

Code	**Indicator name**	**Lead country**	**Region** I	II	III	IV	V	**EU MSFD** Descriptor	**Criterion;** Relevant **primary,** secondary
PH1/ FW5	Changes of phytoplankton and zooplankton communities	UK	NEW MD	MD, TV	MD, TV	MD, TV	NEW MD	D1	**D1C6, D4C2,** D4C3
PH2	Plankton biomass and/or abundance	FR	NEW MD	MD, TV	MD, TV	MD, TV	NEW MD	D1	**D1C6, D4C2**
PH3	Changes in biodiversity index (s)	FR	NEW MD	COM MD	MD, TV	COM MD	NEW MD	D1	**D1C6, D4C1**
FW2	Production of phytoplankton	FR	NEW MD	COM MD	COM, MD, TV	COM MD	NEW MD	D4	**D4C4**
FW6	Biomass, species composition and spatial distribution of zooplankton	SE/FR	NEW MD	MD	MD	MD	NEW MD	D4	**D4C2, D4C3**

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ACTIVITY 2 – EUTROPHICATION AND PHYSICAL CONDITIONS

Activity 2 summary

Institutions involved:
The Netherlands: Rijkswaterstaat, Deltares
Germany: AquaEcology GmbH & Co. KG
United Kingdom: Plymouth Marine Laboratory (PML)

Main aims of Activity 2

Compared to the other Activities in the NEA PANACEA project, Activity 2 focused more on pressures, notably eutrophication, climate change and physical conditions. Next to modelled and observed data the Activity also introduced tools used in OSPAR's eutrophication assessment (and developed in the EU project JMP EUNOSAT) and in the MSFD CIS process. Together with the biodiversity experts working on Activities 1, 3 and 4 the Activity 2 team explored how these tools and data could improve the pelagic habitats, food web, benthic habitats and marine birds indicator assessments with regard to better understanding of ecosystem functioning and coherence between assessment frameworks.

The aim of Tasks 2.1 (*Model tool LiACAT linking eutrophication and climate scenarios to biodiversity and food web indicators*) was to set up an adaptation of the network model ACIM within the LiACAT tool and carrying out exemplary runs with benthos data on two different OSPAR regions. Through this setup the relationship between natural and anthropogenic pressures (including climate change effects) to changes in macrozoobenthos communities was to be explored. With literature input and use of measured and modelled data, cumulative stressor-effect relations were to be quantified and used to generate projections of how the population parameters reproductivity, growth, and mortality will change for selected macrozoobenthos species with varying environmental conditions. This kind of cumulative effect study has the potential to support further (future) developments of indicators for the MSFD state descriptors 1 (Biological Diversity) and 4 (Food Webs). Due to a combination of unfortunate circumstances outlined in the section on Task 2.1 below, this model study was not completed and the associated deliverable is not delivered, despite the fact that the team working on it has worked very hard to acquire the data and get the model operational. The task did deliver a desk study on the influence of climate change, current as well as future scenarios, on physical conditions affecting ecosystem functioning, which was to underpin the model runs. It involves regional aspects of climate change scenarios for the North Sea, possible temperature change (increase) scenarios of 1.5, 2.7 and 4 °C in subsurface temperatures (SST) showed increased periods of stratification in central North Sea. Furthermore, changes in net primary production dependent on nutrient reduction scenarios and a changed seasonality of the oxygen cycle is to be expected. Oxygen concentrations near the seabed are generally lower throughout the year, but the amplitude and timing changes. This will have significant implications for the reproduction and growth cycles of the benthic communities.

The implications of not delivering the main deliverable for Task 2.1 with respect to the project as a whole are minimal, fortunately. It did not represent an essential building block for other Tasks or Activities, and it is not a product that would have been of use in the EU MS MSFD reporting in 2024. It was rather a pilot study exploring an avenue for future modelling developments.

Ecosystem functioning was explored and quantified by Task 2.2 (*Operationalisation and assessment of OSPAR food web indicator FW9: Ecological Network Analysis (ENA)*) in areas where the available data and information allowed for those type of studies. The quantitative food web model ENA uses biomass data of all living components and related flow rates of organic and inorganic material, respiration, consumption, and egestion as well as import and export of material and energy. The model also integrates the trophic status, energy flows, and food chains of the system. In a pilot assessment of the Ecological Network Analysis Indices (FW9) developed under Task 2.2, ENA analysed interactions between all ecosystem components for four case studies. Different trends of indices were found over time and space, some linked to variability in primary production. Within the project period, the Ecological Network Analysis Indices (FW9) became an OSPAR candidate indicator as a Multitrophic Level Indicator.

Supported by Task 2.3 (*Identification of ecologically relevant scales and areas for assessment of pelagic and benthic habitats*), one of the tools used in OSPAR's eutrophication assessment, *ie.* ecologically coherent assessment areas/units, was successfully applied in the pelagic habitats and food web indicator assessments developed under Activity 1. This significantly enhanced combination/integration and comparison between these assessments, and with the eutrophication indicator assessments. The latter comparison did not only reveal options for mutual strengthening of the assessments, but also methodological differences that hamper comparison and integration. Furthermore, identification of relevant assessment areas was considered to be most important as shown by a study from Holland *et al*. (2023) produced within the NEA PANACEA framework. In the study, abundance trends revealed largely opposing trend direction between shelf and oceanic regions for most lifeforms: the North Sea areas showed increasing coastal abundance compared to decreasing abundances in North-East Atlantic areas. Within the phytoplankton lifeform assessment, similar abundance trends were observed, whereas taxa grouped within zooplankton lifeforms were more variable. The reasons for this unexpected contrast between the regions could not be unambiguously identified by the authors. This underlines the need for further research regarding the pelagic indicators. An initial analysis of spatial patterns in pelagic biodiversity indicators with the same variables that define the assessment areas for eutrophication (stratification, salinity and chlorophyll-a) was performed in Task 2.3. This confirmed that the eutrophication (so-called COMP4) assessment areas developed for eutrophication are also suitable for the biodiversity assessments of pelagic plankton lifeforms. Another part of this Task, *ie.* supply of quality-controlled satellite time series used in the eutrophication assessment (chlorophyll-a) and primary production for use in the pelagic habitats and food webs indicator assessments developed under Tasks 1.1, 1.3 and 1.5 significantly enhanced the information base for these assessments. Modelled physical parameters (3D) were also provided, but the Activity 1 team decided to use another model with matched better with their assessment period due to longer time series.

Finally, Task 2.4 (*Towards coherent threshold value setting methods and Activity 2 synthesis report*) investigated methods used in all OSPAR biodiversity indicator assessments, including those developed under NEA PANACEA, and the eutrophication assessments. Categories of threshold value setting methods developed in the MSFD CIS process were used here, to enable future comparisons in a pan-European context. Different solutions to the challenge of knowledge gaps on pristine or undisturbed conditions, pressure-state relationships and uncertainty on climate change impacts were applied, which hamper comparability. Taking into account these limitations, a pragmatic method to identify situations where lack of coherence might lead to conflicting management measures is proposed. We also suggest a number of feasible steps to improve coherence where action is needed.

This Chapter 3 functions as the Activity 2 synthesis report (Deliverable 2.4b). Figure 1 summarises the Activity 2 contributions to MSFD working themes.

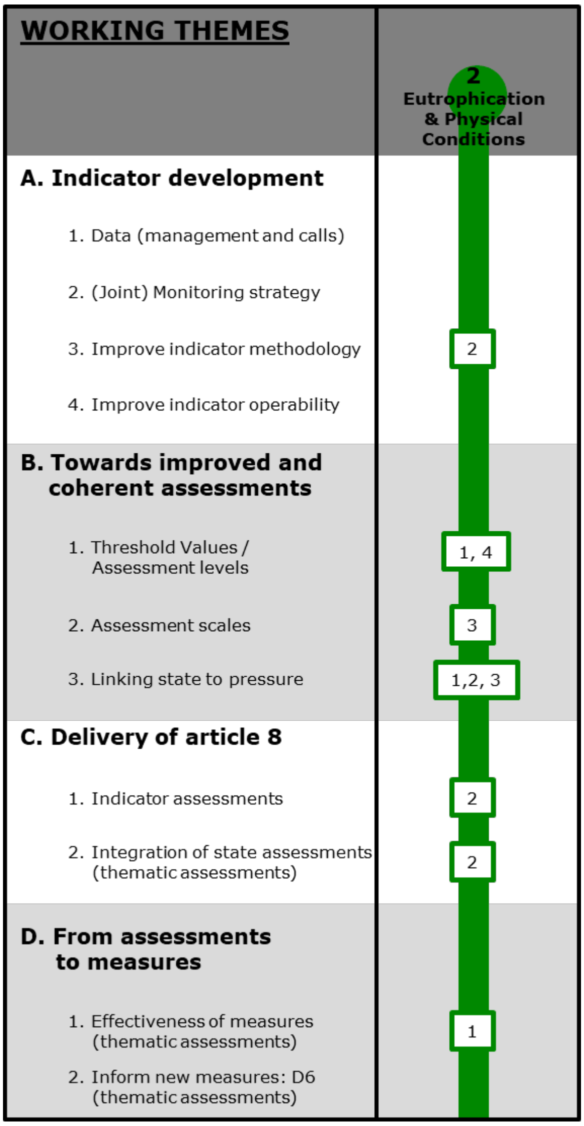

Figure 1. Activity 2 Tasks (in green boxes) in relation to the MSFD working themes.

Activity 2 working arrangements

The Activity 2 lead was Lisette Enserink (RWS, NL). The Activity 2 team further consisted of Thomas Raabe, Birgit Heyden, Hermann Lenhart, Silke Eilers, Hannah Schambil and Alexander Rahlf (AquaEcology, DE), Anouk Blauw and Theo Prins (Deltares, NL) (Subcontractor), Gavin Tilstone and Peter Land (PML, UK) (subcontractor) and Ulrike Schueckel (DE) (self-funded Advisor).

In order to coordinate the Tasks 2.1 to 2.4, investigate progress for the purpose of Action Management meetings, and to prepare for NEA PANACEA workshops, regular online meetings were organised. The Activity 2 team presented deliverables and intermediate products and liaised with the other Activities during all NEA PANACEA workshops and an intermediate in person workshop (MiniPANACEA) involving Activities 1 and 3. In this MiniPANACEA workshop the Activity 2 contribution focused on the tools used in the eutrophication assessments and provided results from model analyses, including climate change effects, and satellite observation of primary production to support the biodiversity and food web indicator assessments. In the in person Super- and UltraCOBAM meetings in October 2021 and June 2022, the Activity 2 team typically initiated and supported cross-cutting work, again to help the development of biodiversity indicator assessments and strengthen the links with eutrophication assessments. The SuperCOBAM workshop was also used to introduce the methods applied in Task 2.4 and initiate the investigation on threshold values setting methods, also involving indicator assessment leads outside of the NEA PANACEA consortium. Activity 2 contributions came as presentations, new methods, modelled and observed data and the FW9 pilot assessment of Ecological Network Analysis Indices. The Activity 2 team also ensured that relevant NEA PANACEA results were shared with the OSPAR eutrophication group ICG-Eut. The delivery of the Activity 2 products is reflected in Table 1. Due to multiple changes in staff at AquaEcology, responsible for Task 2.1, the results of this Task were delayed and therefore could not be presented in the Final meeting of the project, however, they are included in the set of Activity 2 products.

Table 1. Delivery timeline for Activity 2.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 2.1 preparation																								
Task 2.1 implementation																								a/b
Task 2.2 preparation																								
Task 2.2 implementation																						a/b		
Task 2.3 preparation																								
Task 2.3 implementation																								
Task 2.4 preparation																								
Task 2.4 implementation																								a/b

Task 2.1: Model tool LiACAT linking eutrophication and climate scenarios to biodiversity and food web indicators (Annexes O and P)

Task Lead: Thomas Raabe (AquaEcology, DE) (Partner)

Other involved: Anouk Blauw (Deltares, NL) (Subcontractor), Laurent Guérin (OFB, FR) (Partner), Megan Parry (JNCC, UK) (Partner), Hermann Lenhart (AquaEcology), Birgit Heyden (AquaEcology)

Other Activities involved: Activity 1 and 3

Milestones: D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D2.1a (at UltraCOBAM workshop) LiACAT ready for eutrophication analysis; D2.1b LiACAT analysis ready for target values under eutrophication

What we promised

Within Task 2.1, the mathematical network model ACIM (Automated Cumulative Impact Model) as part of the model frame the LiACAT (Literature-based Cumulative Assessment Tool) should be adapted and employed in the OSPAR assessment region to compare and analyse different datasets of human induced pressures and natural physical conditions with respect to their potential cumulative effects on higher trophic levels. Measured data, modelled data, and literature data was to be considered as input data. The different data types should be used to set up knowledge rules in the model to facilitate subsequent investigations, *e.g.* for estimating natural ranges of indicator values in the various assessment procedures.

Since geographical coverage and resolution of the output data strongly depended on the available input data, the LiACAT model aimed to make use of high-resolution data from Deltares generated in 3D physical-ecological model runs. For key parameters such as chlorophyll-*a*, primary production, oxygen depletion, temperature, shear stress and other physical parameters, Deltares intended to provide results with seasonal and spatial patterns for the different OSPAR regions.

Further data were to be provided by existing *in situ* measurements and validated satellite observations. The output of the model results (as biomass data) could partly feed into the ENA food web model (Task 2.2).

A further aspect of Task 2.1 was the consideration of climate change aspects. For this purpose, literature studies should be used to integrate the outcome of the climate scenarios. Especially for the North Sea, a series of model runs had been published with surprisingly different projections, *e.g*. on the stratification and the resulting projected oxygen depletion. For that reason, it seemed useful to provide a scope of possible projections which can be further investigated in their impact by applying the outcomes in the LiACAT and ENA models.

Since cumulative effects have important impacts on various MSFD descriptors such as biodiversity, food webs and sea-floor integrity and at the same time closely link “Pressure” descriptors with “State” descriptors, we aimed for giving an example on how a model based on the processing of data from literature and measurements as well as from (climate change) impact scenarios can give valuable information on the change in the macrozoobenthos community and thus, contribute to food web indicators, for example to FW9 via the ENA foodweb model.

What we delivered

As mentioned in the chapter summary, this Task did not deliver on the main product, the LiACAT and ACIM models that could be linked to future MSFD D1, D4 and D6 assessments (resulting in a missing Annex O), but the desk study on climate change impacts on the physicochemical environment was delivered (Annex P). The reason for not delivering on the main deliverable is threefold. Firstly, the expert that had the working knowledge and expertise on the LiACAT and ACIM models found a new position at an early stage in the project, and it has proven impossible to hire a new expert with the required expertise (the partner did, however, continue to invest time and effort into the project). Further, the data that was available to support the model turned out to be more limited than anticipated, constraining the work significantly. Combined with the first issue this has led to a situation in which the partner was unable to generate a properly operational model. Finally, the person responsible for writing up a report was faced with personal issues (which have been communicated to the European Commission) that prevented further work on the report. The coordinating team then decided that it was in the best interest of all parties to seize the work and hand in this project technical report without the main deliverable for Task 2.1.

As stated in the summary of this chapter, the implications of not delivering the main deliverable for Task 2.1 with respect to the project as a whole are minimal, fortunately. It did not represent an essential building block for other Tasks or Activities, and it did is not a product that would have been of use in the EU MS MSFD reporting in 2024. It was rather a pilot study exploring an avenue for future modelling developments.

As part of the efforts in delivering Task 2.1, more than 300 publications have been analysed semi-automatically by the LiACAT system in order to extract the information for quantitative relationships between the impact of external factors and stressors such as temperature, salinity, oxygen, nutrient, and chlorophyll-*a* content as well as pH values on one hand and the related changes in reproduction, growth, and mortality of selected macrozoobenthos species on the other hand. Figure 2 shows an exemplary output graph of LiACAT for the impact stressors influencing growth of benthos organisms. Input of the physical-chemical stressor values was generated from the Deltares model data (Task 2.3) that provided data on a high-resolution scale.:

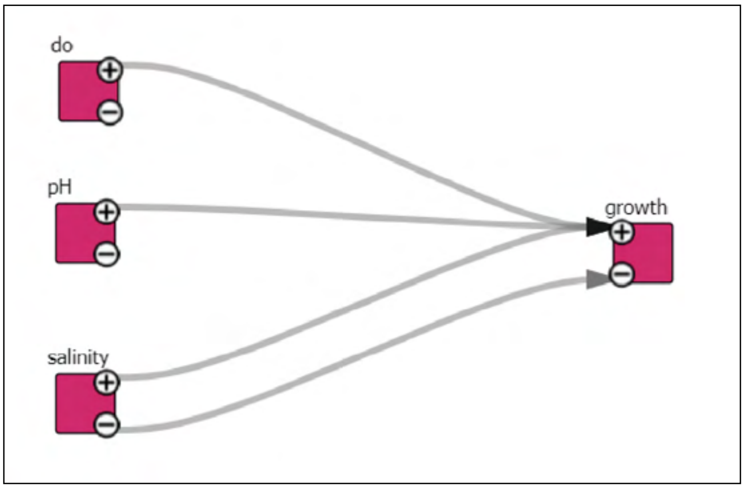

Figure 2. LiACAT: Assessment Relationship Editor with stressor impacts (dissolved oxygen, pH and salinity) on benthos growth

Looking at possible climate change processes, the possible temperature change (increase) scenarios of 1.5, 2.7 and 4 °C in subsurface temperatures (SST) result in increased periods of stratification in central North Sea, changes in net primary production dependent on nutrient reduction scenarios, and a changed seasonality of the oxygen cycle. Oxygen availability near the seabed is generally lower throughout the year, but the amplitude and timing changes.

Considering these possible climate change processes, we used an early iteration of the model to calculate different scenarios on how and to what extent temperature and oxygen changes influenced the base of the food web (a preliminary model output is shown in Figure 3).

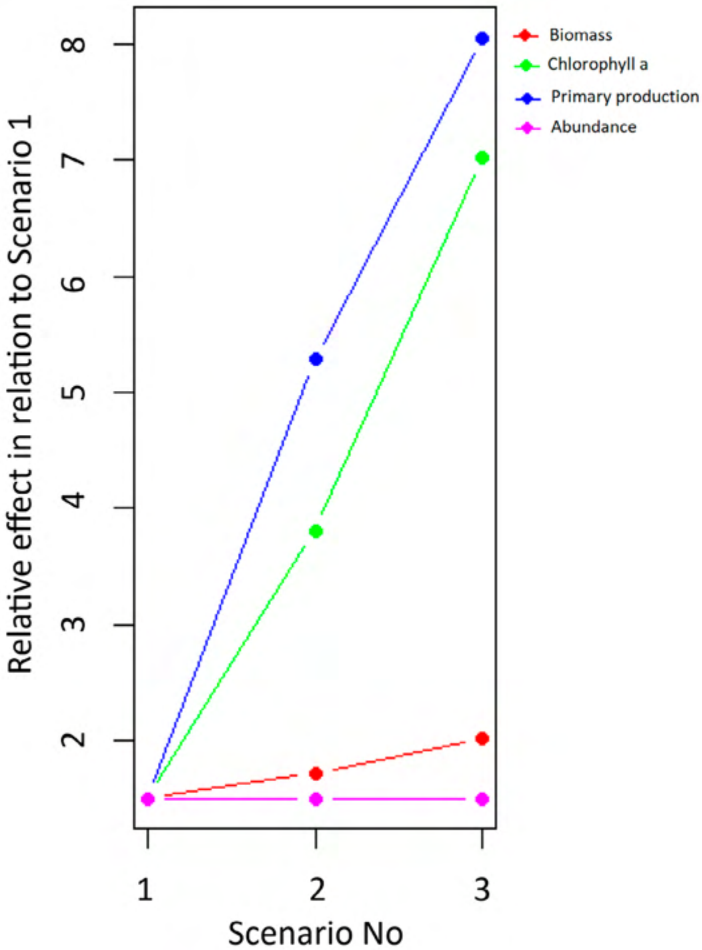

Figure 3. LiACAT: Output from preliminary ACIM simulations of the impact of different climate scenarios (temperature scenarios 1.5, 2.7, 4.0 °C increase) on base food web variables

These preliminary outcomes based on an early development stage of the model suggest that the methodology may be useable as input parameters by further biodiversity and food web models such as ENA.

How we delivered

We participated in all NEA PANACEA workshops as well as UltraCOBAM and SuperCOBAM meetings and presented our results. At these meetings, we had intensive discussions with partners from Tasks 1 and 3 about integrating assessment procedures in the COMP4 areas. Especially, the further intertwining of the pelagic habitats, eutrophication, and benthic assessments via model links and integration has been subject to discussions. A short compilation of the actual status of the climate change work is added as a separate document (Annex P).

Next Steps

While it unfortunately has proven impossible to deliver the LiACAT and ACIM models at a level where they are operational, we still think that there is scientific potential for this approach to underpin a more holistic approach to MSFD assessments, linking pressures to biodiversity through modeling. In the future, and in a different project context, we therefore see potential for carrying out this pilot study to deliver "proof of concept" for the methodology. One aspect of special attention would be the availability of biodiversity data to feed into the models, most notably at the proper spatial and temporal scales.

Task 2.2: Operationalisation and assessment of OSPAR food web indicator FW9: Ecological Network Analysis (ENA) (Annex Q)

Task Lead: Thomas Raabe (AquaEcology, DE) (Partner)

Other involved: Ulrike Schueckel (DE) (Self-funded), Birgit Heyden (AquaEcology, DE) (Partner)

Other Activities involved: Activity 1 and 3

Milestones: M2.2 ENA setting for eutrophication analysis ready; D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D2.2a (at Ultra COBAM workshop) ENA ready for eutrophication analysis; D2.2b ENA analysis ready for target values under eutrophication

What we promised

Task 2.2. was aimed at further developing and improving operability of the OSPAR food web candidate indicator FW9 and carrying out respective pilot studies. To reach that goal, the Ecological Network Analysis (ENA) model should be employed and contribute to the assessment of the MSFD D4C1, D4C2 and D4C4 criteria. ENA is a system-ecology oriented methodology to analyse the direct and indirect predator-prey (*e.g*. biomass carbon flow and energy transfer) interactions among its constituents in a food web and is established as a candidate indicator (FW9) in OSPAR. Since ENA allows assessing the functioning and status of food webs and analysing the effect of specific pressures on the biomass distribution of specific food web groups, it can also consider system responses to climate warming and anthropogenic stressors such as eutrophication.

For assessing OSPAR indicator FW9, required biomass data and information about predator-prey relationships should be compiled by conducting data calls in 2021 and be supported by data call activities in NEA PANACEA Task 1. In addition, the work of the EU-funded FishNet+ North Sea project should be explored as a possible data basis.

Based on this data, an FW9 assessment should be conducted in selected OSPAR COMP4 assessment areas. Furthermore, a pilot study was planned to process benthic output data (biomass fluxes) from the model system LiACAT within ENA and via this way, include different scenarios of modelled physical-chemical data as well as climate change data.

What we delivered

Within the project frame we have performed analyses in 4 different OSPAR eutrophication (COMP4) assessment areas: the Greater North Sea areas Elbe River Plume, the Kattegat (coastal and deep), the Bay of Seine, and near the Azores. These areas have also been included in the OSPAR FW2 indicator pilot assessment conducted within the NEA PANACEA project by Activity 1.

Prior to the analyses, we have collated various data sets from OSPAR data calls and other research projects. Data covered the years from 2009 to 2019.

Within the pilot assessment, consequences of changes in food web structure and functioning due to different pressures were successfully evaluated with Ecological Network Analysis Indices (FW9). We could show temporal trends in primary production and biomass of different trophic guilds. In the Greater North Sea coastal waters, *i.e.* the COMP4 areas Bay of Seine and Elbe Plume, several trophic guilds of the coastal food webs were very much linked to changes in primary production and phytoplankton biomass over time. We found that changes in the pelagic food web structure occurred in the Bay of Seine while the benthic trophic guilds showed changes in the Elbe Plume over time. As an example, Figure 4 shows the temporal variability of the biomass of the trophic guilds in the COMP4 area Elbe Plume:

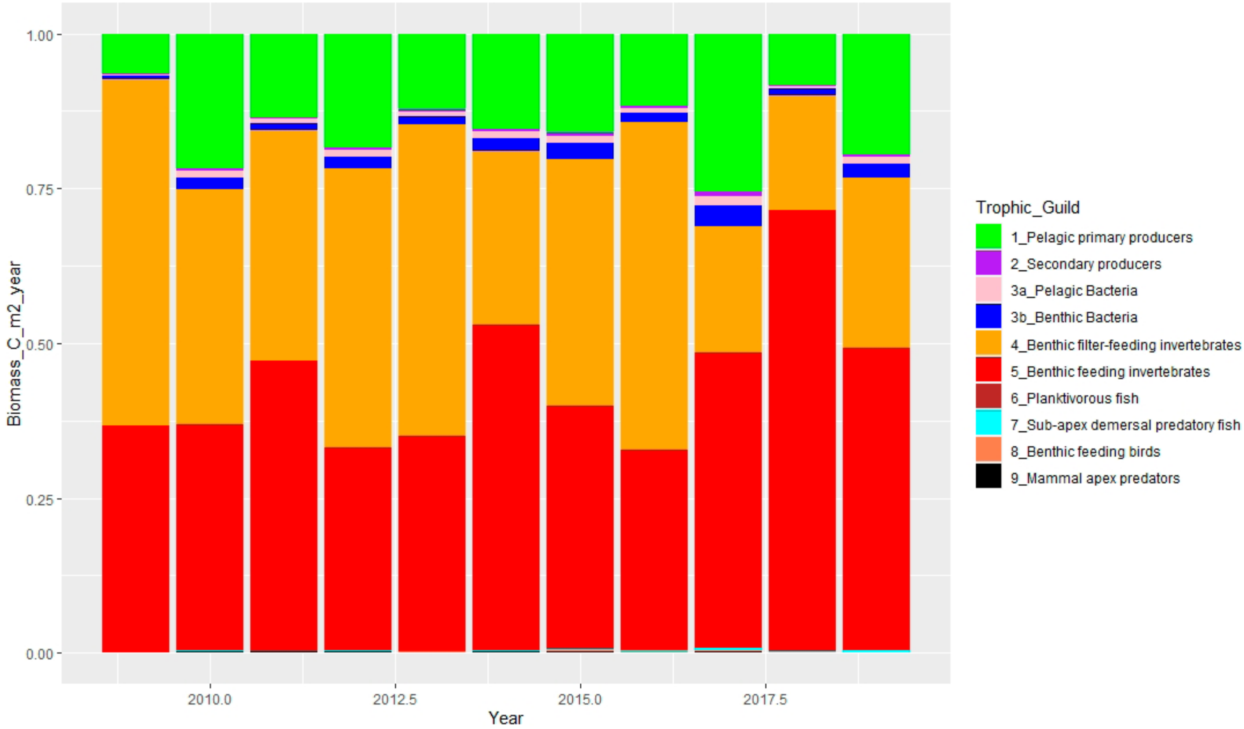

Figure 4. Temporal variability of biomass of trophic guilds between 2009 and 2019 in the COMP4 area Elbe Plume.

The most dominant trophic guilds (in terms of biomass as carbon) included the benthic invertebrates (meiofauna, invertebrate surface and subsurface deposit feeders, invertebrate filter feeders and invertebrate predators). Further important trophic guilds comprised bacteria and primary producers. The least abundant groups were marine birds (common scoter, eider duck) and marine mammals (porpoises, seals). This stressed the importance of the benthic invertebrate groups for the food web processes and clearly demonstrated the necessity to connect the ENA model to further ecological models like LiACAT in order to include simulations of scenarios with varying anthropogenically induced changes of physical-chemical conditions as well as climate change impacts.

The results of this pilot assessment clearly demonstrated the potential for the ENA indices indicator to show changes in the food web structure and functioning at regional (COMP4 assessment areas) scale and to provide information on the state of the food webs with special emphasis on the indicators of MSFD descriptor 4.

How we delivered

We participated in all NEA PANACEA workshops as well as UltraCOBAM and SuperCOBAM meetings and presented parts of our results. In addition, we had an intensive exchange of data and information with partners from Tasks 1 and 3 with regard to parallel assessment procedures in the COMP4 areas. A final compilation of our results can be found in Annex Q.

Next Steps

Within the NEA PANACEA project, an application of the ENA model regarding FW9 has been successfully demonstrated for selected areas. Further development of this indicator should include an increase of the spatial extent and the combination/coupling with existing food web and ecosystem models. An open question remains how to deal with ecosystem components that were not regularly monitored but were important food resources in the food web (e.g., bacteria, meiofauna). Furthermore, harmonisation of functional groups among food webs, determination of appropriate thresholds and assessment values, identification pressure-state relationships, and comparison of other relevant food web and biodiversity indicators with FW9 should be taken into focus.

Task 2.3: Identification of ecologically relevant scales and areas for assessment of pelagic and benthic habitats (Annex R)

Task Lead: Anouk Blauw (Deltares, NL) (Sub-contractor)

Other involved: Lisette Enserink (RWS, NL) (Partner), Matt Holland (MBA, UK) (Partner), Gavin Tilstone (PML, UK) (subcontractor)

Other Activities involved: Activity 1 and 3

Milestones: M2.3 Receive draft pelagic and benthic indicator assessments; D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D2.3: Evaluation of assessment scales for pelagic and benthic indicators.

What we promised

This Task evaluates the suitability of the assessment areas used for eutrophication - as part of OSPAR's revised Common Procedure (COMP) - for other pelagic and benthic biodiversity indicators. The eutrophication assessment areas are based on areas with similar environmental conditions such as hydrological characteristics (depth, stratification, salinity), freshwater inputs and seasonal patterns of chlorophyll a, derived from satellite data. We will test to which extent these environmental conditions are also important drivers for spatial variability of other biodiversity indicators. Using the same assessment areas for different, but related, MSFD and OSPAR assessments will contribute to enhanced coherence in assessments within and between Descriptors. This should ultimately lead to enhanced understanding of the response of biodiversity to anthropogenic pressures.

Furthermore, this Task would provide validated primary production satellite and *in situ* observations as input for Task 2.1 and Task 1.1 that supports *e.g*. the foodweb FW2 indicator assessment (Task 1.5) and to validate modelled primary production, used in several Tasks.

What we delivered

We made an analysis of spatial patterns in pelagic biodiversity indicators with the variables underlying the definition of the assessment areas for eutrophication: stratification, salinity and chlorophyll-*a*. We used model data of stratification and salinity and satellite data for chlorophyll-*a*. We focused on the lifeform abundance data from the Continuous Plankton Recorder (CPR) dataset, that was also used for the assessment of biodiversity indicator PH1/FW5 (see Task 1.2). The abundance of many plankton lifeforms showed abrupt changes in transition zones between different stratification regimes: permanently stratified (PS), seasonally (or intermittent salinity) stratified (SS) and permanently mixed (PM) (Table 2). Interestingly, satellite-derived chlorophyll-*a* data did not show strong gradients in these transition zones, even if the phytoplankton lifeforms (diatoms and dinoflagellates) showed strong gradients. The spatial resolution of the CPR data was insufficient to assess changes in plankton lifeform abundance between river plumes (salinity lower than 32 psu) and coastal waters. The width of the river plume assessment areas was too small compared to the spatial resolution of the CPR data. The benthic assessment indicator for nutrient enrichment (BH2a) had only assessment results for WFD assessment areas, which do not overlap with the COMP4 assessment areas for eutrophication. Therefore, we could not evaluate the suitability of the COMP4 assessment areas for this benthic indicator.
We concluded that the COMP4 assessment areas developed for eutrophication are also suitable for the biodiversity assessments of pelagic plankton lifeforms. This provides scientific support for their use in the biodiversity assessments of OSPAR and later on for MSFD descriptor D1: biodiversity.

Table 2. Overview of elevated (red), reduced (blue) and unaffected (black) abundance under different stratification regimes: permanently mixed (PM), seasonally or salinity stratified (SS) and permanently stratified (PS) for all categories of lifeforms.

Lifeform	Channel	Celtic	SNS	Atlantic	NorTrench
diatoms	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
dinoflagellates	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
lg-copepods	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
sm-copepods	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
fish larvae	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
holoplankton	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
meroplankton	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS
chlorophyll-*a*	PM SS	PM SS PM SS	PM SS	PS SS	SS PM SS PS

Next to the evaluation above we also provided primary production time series (notably satellite and also *in situ* in the period 1997-2019), which significantly contributed to the data used in four indicator assessments developed in this project:

- PH1/FW5 Changes in Plankton communities (Task 1.2);
- PH2 Plankton biomass and abundance (Task 1.3);
- PH3 Changes in biodiversity index (Task 1.3);
- FW2 Primary production (Task 1.5).

Notably the satellite time series (1997-2019) supported the OSPAR area-wide assessments, especially in the more offshore areas where data were previously lacking. Furthermore, these data were used to validate primary production model outcomes in the present Task.

How we delivered

We joined the NEA PANACEA workshops and discussed with other partners about the background of the COMP4 assessment areas for eutrophication and their suitability for other biodiversity indicators. Matt Holland (Activity 1) shared his dataset of CPR plankton lifeform abundance, used for the PH1/FW5 assessment, with us for an analysis of spatial patterns. After the analysis, the draft report was written by Deltares and reviewed by Matt Holland and Lisette Enserink. The resulting final report was delivered as deliverable D2.3 (Annex R).

We also stimulated the use of (validated) primary production data observed with satellites through presentations and discussions in the NEA PANACEA workshops and meetings. The results of an example assessment of primary production in the North-East Atlantic (not the OSPAR FW2 assessment) was published in a peer-reviewed journal (Tilstone *et al*., 2023).

Next Steps

The NEA PANACEA project allowed for a preliminary data analysis only. Further elaboration of this research is required to enable more robust conclusions. This would include statistical testing of the significance of the observed patterns, comparison with more environmental variables (including turbidity and primary production) and more detailed characterization of the plankton composition across gradients to understand the causes of the observed patterns. Furthermore, this type of analysis, using information in the MSFD/QSR 2023 indicator assessments and combining this information with oceanographic data, is a valuable starting point for further interaction and collaboration between the eutrophication and pelagic habitats and food web expert groups in OSPAR.

Task 2.4: Towards coherent threshold value setting methods (Annex S)

Task Lead: Lisette Enserink (RWS, NL)
Other involved: Thomas Raabe (AquaEcology, DE), Anouk Blauw (Deltares, NL), Laurent Guérin (OFB, FR), Abigail McQuatters-Gollop (UoP, UK), Ian Mitchell and Stefano Marra (JNCC, UK)
Other Activities involved: Activity 1, 3, 4 and 5 (Tasks 1.4, 2.1, 3.1, 3.4, 3.6, 4.1, 5.2)
Milestones: M2.4 Inventory of baseline and threshold value setting methods used or considered in D1/D6 (pelagic and benthic habitats, birds), D4 and D5 assessments
Deliverables: D2.4a Joint list of feasible options to improve coherence of baseline and threshold value setting methods for (future) D1/D6 (pelagic and benthic habitats, birds), D4 and D5 assessments; D2.4b Final Activity 2 synthesis report in discussion with activities 1 and 3

What we promised

Task 2.4 aimed at supporting the development of a coherent assessment framework in line with the requirements of the MSFD. Coherence is important for management measures and would prevent assessment outcomes that call for conflicting measures, *eg.* reducing or increasing the productivity of an ecosystem by reducing or increasing nutrient inputs from rivers. This Task would investigate and compare the threshold value setting experiences in OSPAR for MSFD Descriptors D1/D6 (pelagic and benthic habitats, birds, mammals, fish and NIS), D4 and D5.

We would also use the background documents and outcomes of the *MSFD Workshop on Horizontal issues* (30 September 2020) in order to facilitate exchange with the MSFD CIS process. This included a set of categories of threshold setting methods/narratives. A number of steps were proposed for this Task, ranging from sharing and explaining the MSFD categories and investigating the threshold value setting methods used in OSPAR's biodiversity assessments to identifying incoherent methods and discussing whether and how these should be adapted. This would lead to a list or approach to determine feasible options for improving coherence. This approach would be submitted to relevant OSPAR meetings and the MSFD CIS network for inspiration and discussion.

What we delivered

Annex S contains the results of the inventory of threshold setting methods used in all 29 OSPAR biodiversity and eutrophication indicator assessments, also beyond the set that was developed in the NEA PANACEA project. A matrix (Appendix in Annex S) was produced that includes information on:

- the parameters used;
- season (if applicable/known);
- the MSFD/OSPAR region the indicator applies;
- the threshold value setting method used;
- the category it fits in;
- whether threshold values indeed have been used and how 'good' or 'not good' status has been defined;
- whether these threshold values are area-specific;
- (where relevant) comments on coherence between indicators.

Furthermore, the development stage and policy acceptance of the threshold values used was investigated.

This information was summarized and further analysed with regard to coherence between indicators related to the same ecosystem component (pelagic and benthic habitats, food webs, seabirds, marine mammals, fish and non-indigenous species), and within the set of eutrophication indicators. In addition, an initial analysis of relationships between indicators and a comparison of threshold value setting methods between these related indicators was made. Two examples were analysed in more detail, providing an estimate of the need for further harmonisation and options for improvement of coherence. Finally, a pragmatic decision tree was proposed, to determine when incoherence between threshold value setting methods and assessment outcomes may become a problem for effective management measures (Figure 5).

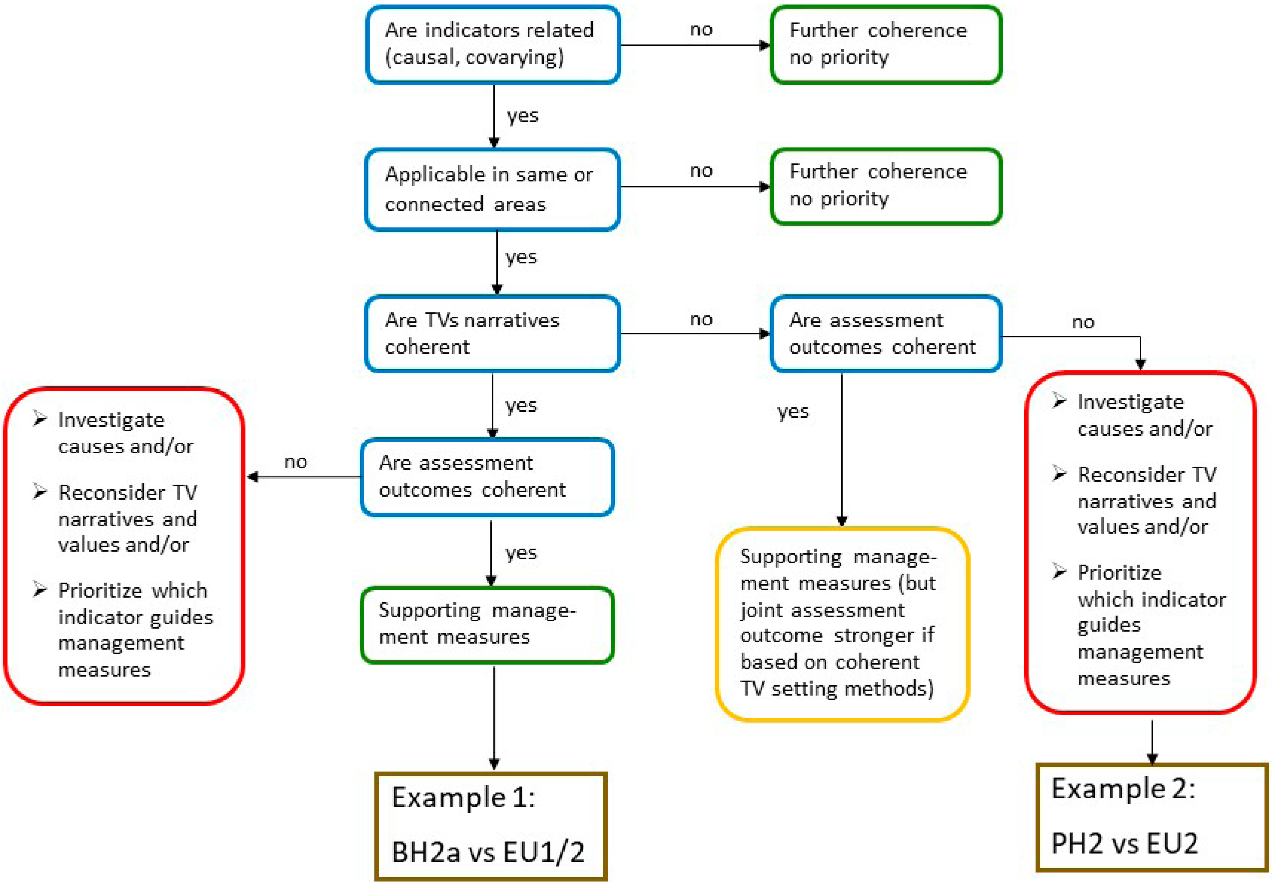

Figure 5. (In)coherence between threshold value setting narratives or assessment outcomes - problem or not? Successive questions (blue boxes) lead to either acceptable situations (green boxes) or need for further work to improve the coherence (red and orange boxes). The examples are described in section 3.2.3 of Annex S.

If action is needed, suggested options are:

- Further investigation of TV narratives and values, involving relevant expert groups in OSPAR or other Regional Sea Conventions, ICES and JRC expert networks. This may lead to adjustments and improvements;
- Investigation of potential issues with conflicting messages to policy makers and areas where these occur;
- In areas where a management decision needs to be taken in the short term: decide which indicator guides these management measures, using transparent criteria;
- Pragmatic approach:
    - In case measures are already in place, continue these measures to improve the status of at least one of the indicators and where possible monitor the effects on related indicators;
    - Be transparent about the (potential) inconsistencies to policy makers in OSPAR, and – where applicable – MSFD CIS;
    - In the meantime develop a plan to address important incoherencies, involving relevant expert groups and policy makers (OSPAR Committees).

How we delivered

The inventory, classification of threshold value setting methods and level of development and policy acceptance was based on information gathered during and after the SuperCOBAM workshop. The discussion in the workshop was prepared by sharing the documentation developed for the MSFD Horizontal issues workshop as homework, in order to enable participants to familiarize themselves with the approach and threshold value setting categories. Subsequently, the completed indicator assessments developed for the OSPAR Quality Status Report 2023, that will form the basis for EU member states' Article 8 reporting under the MSFD (2024 cycle), were analysed thereby completing the inventory. The outcome of the analysis and the examples of comparisons between related indicator assessments were presented and discussed in the NEA PANACEA Final meeting. The Task 2.4 report was finalised after that meeting, with no further input from the other Activity leads.

Next steps

Threshold value setting is a sensitive process. There is common understanding in OSPAR and MSFD CIS that threshold setting methods and threshold values essentially should be based on science. However, knowledge gaps hamper development of threshold values in many indicator assessments and the methods/narratives chosen in many cases are pragmatic and not the scientifically 'ideal' approach. These knowledge gaps have been identified in the OSPAR indicator assessments supporting MSFD reporting and will be included in the 2024 update of the OSPAR Science Agenda. In all cases policy decisions are needed to decide on the distinction between 'good' and 'not good' status. The biodiversity and eutrophication threshold values considered in this study are clearly at different phases of development and policy acceptance. There is still room for adjustment of approaches to improve coherence, where assessments, for instance of indicators that are related in terms of ecosystem functioning, or pressure-state relationships, may lead to conflicting management measures.

This type of discussion is only starting. The NEA PANACEA results are expected to provide a useful input for discussions in the OSPAR Biodiversity Committee and the Hazardous Substances and Eutrophication Committee, and in the relevant working groups thereunder. Furthermore, the NEA PANACEA coordinators will provide input in the MSFD Working Group GES and will make an effort to liaise with other European Regional Sea Conventions, via this Working Group and OSPAR. In this way, the NEA PANACEA project can contribute to the process of improving coherence between threshold value approaches that was started in the MSFD Horizontal Issues workshop of 30 September 2020.

References

Matthew M. Holland *et al.*, Major declines in NE Atlantic plankton contrast with more stable populations in the rapidly warming North Sea, Science of The Total Environment, Volume 898, 2023, 165505, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.165505.

Gavin H. Tilstone, *et al.*, Threshold indicators of primary productivity in the north-east Atlantic for assessing environmental disturbances using 21 years of satellite ocean colour, Science of the Total Environment, Volume 854, 2023, 158757. https://doi.org/10.1016/j.scitotenv.2022.158757

ACTIVITY 3 – BENTHIC HABITATS

Activity 3 summary

Institutions involved:
France: Office Français de la Biodiversité
Germany: BioConsult Schuchardt & Scholle GbR, Bundesamt für Naturschutz
Spain: Consejo Superior de Investigaciones Científicas
The Netherlands: EcoAuthor
United Kingdom: JNCC Support Co

Activity 3 contains a total of 7 Tasks, each of which supports the delivery of the Action and working themes (Figure 1) and is summarised in numerical order below; Task-specific realised timelines are provided, summarizing concrete outcomes from the grant proposal, notably deliverables and new (North-East Atlantic) benthic habitats standards for EU MS MSFD reporting through OSPAR's QSR 2023, or other regional Sea scales assessments.

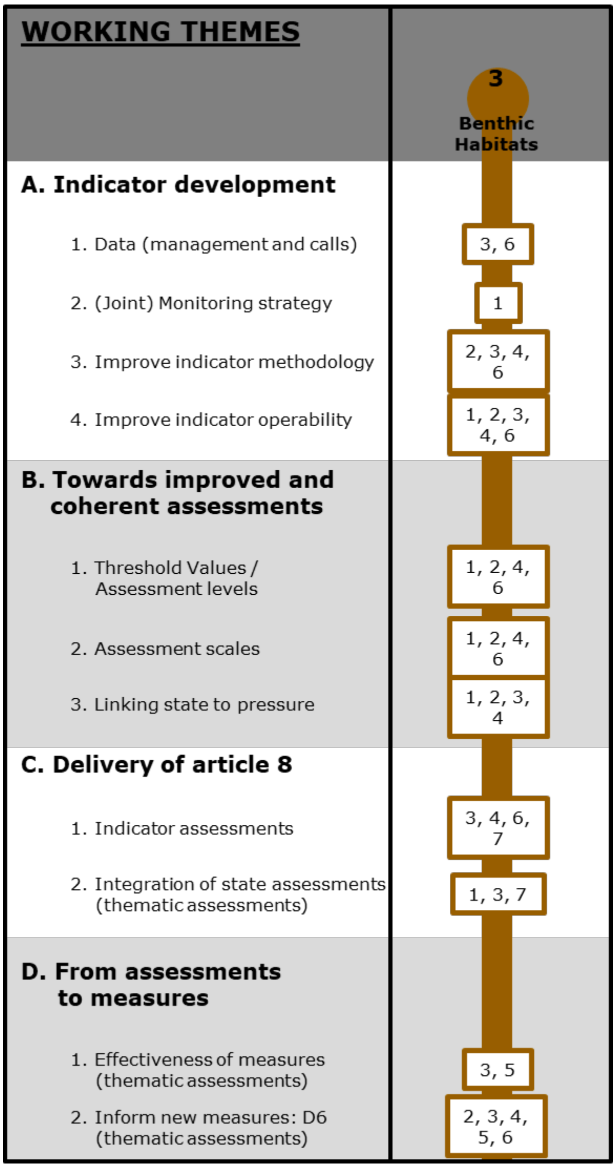

Figure 1. Activity 3 tasks (in brown boxes) and MSFD working themes.

The partners in this Benthic Habitats Activity are also OSPAR benthic habitat indicator leads, ensuring that products from this project complemented the ongoing work in OSPAR and that the products fed into the OSPAR process (from scientific technical proposals to policy buy-in and implementation of action plans). This project supported MSFD assessment work through OSPAR and increased efforts on indicators and thematic assessment to directly contribute to the MSFD North East Atlantic benthic habitats assessments. Additional dedicated meetings, expert and post-doctoral time and travel resources enabled to have mid-term dedicated workshops in addition to the annual benthic and COBAM expert groups (See Activity 5). Post-doctoral researchers, alongside dedicated expert time, as well as travel and subsistence funding enabled more intensive inter-sessional and online works. All the work proposed in this Activity was reviewed in the OSPAR Benthic Habitats Expert Group (OBHEG) and forwarded through the OSPAR process for reviews and adoptions as updated methods, new standards and evidence products for the OSPAR Quality Status Report 2023, also relevant and available for MSFD articles 8 (assessment) and 9 (GES standards) 2024 reporting. Figure 2 shows the timeline along which the Activity's work was planned.

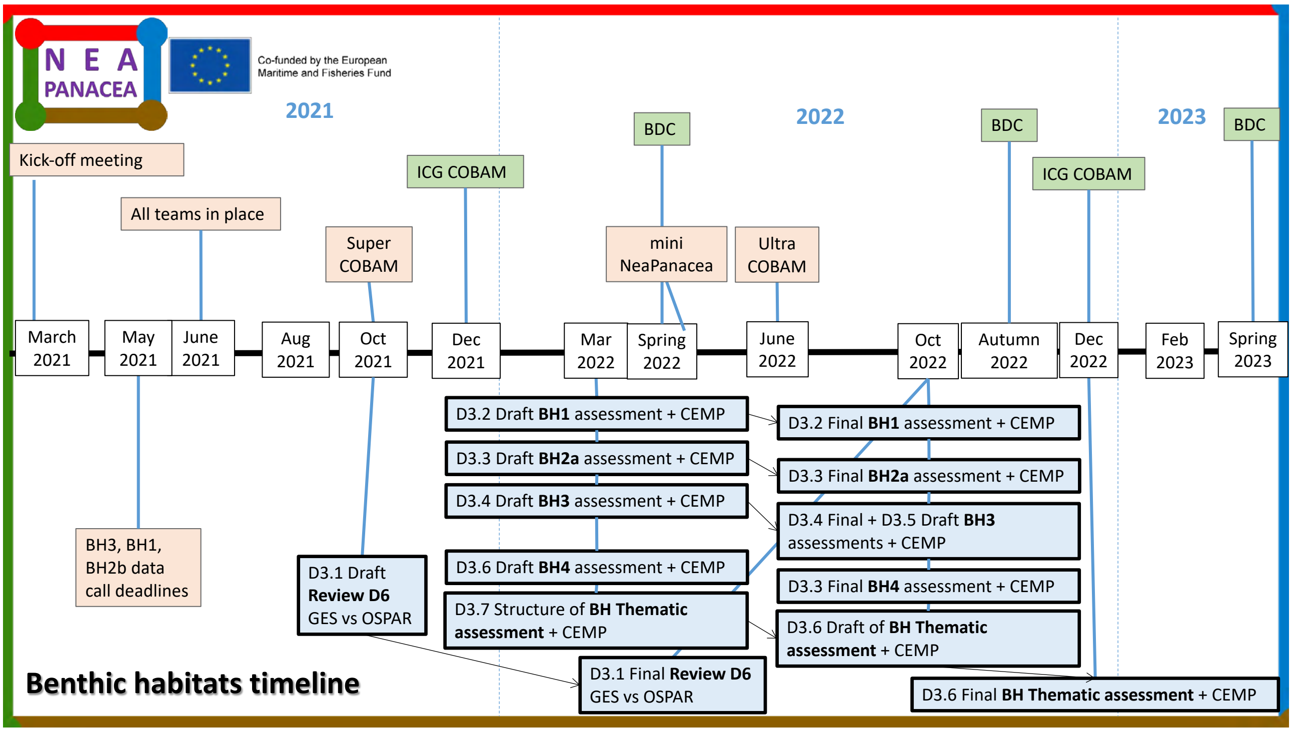

Figure 2. Delivery timeline for each milestone and deliverable under Activity 2 of the NEA PANACEA project.

Task 3.1: Review of MSFD GES national reporting for D6 versus OSPAR indicators and relationships with D4 and D5 (Annex T)

Task Lead: Laurent Guérin (OFB, FR) (Partner)
Other involved: Anna Lizińska (OFB, FR) (Partner)
Other Activities involved: Activity 2
Milestones: M3.1 post-doc recruited
Deliverable: D3.1 Review D6, in link with D4 and D5

Summary

This Task identify commonalities and gaps (or discrepancies) in reporting on MSFD for benthic habitats for D1 and D6, in links with D4, D5 and European Regional Seas standards, to establish a common understanding and baseline on the elements of the definition of GES for benthic habitats in EU member states. This report (Guérin and Lizińska, 2022; Figure 3) was already disseminated through this project partners and contacts of several European working groups on benthic habitats (OSPAR, Barcelona Convention, HELCOM, ICES, JRC).

Table 1. Task 3.1 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey) and letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.1 preparation																								
Task 3.1 implementation																								

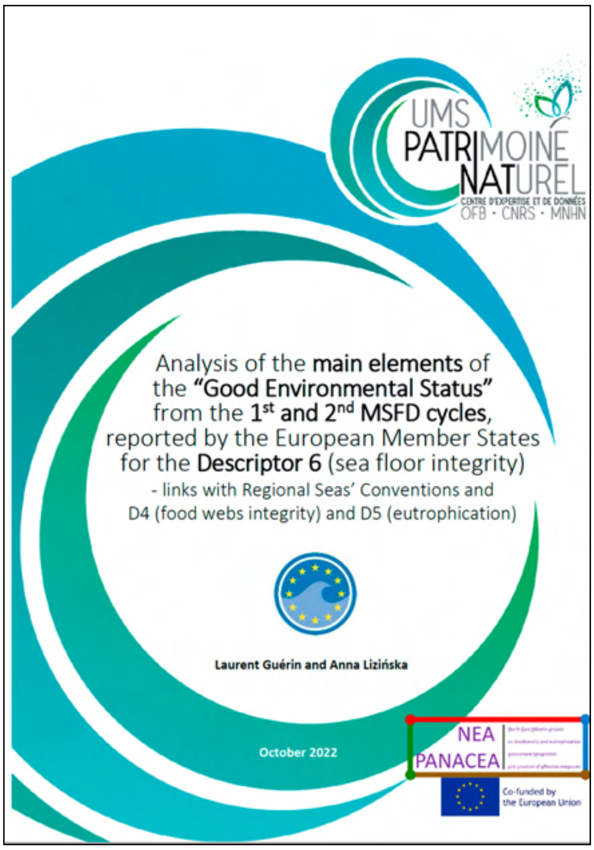

Figure 3. Task 3.1 report cover, see also Annex T.

This published and publicly available report (Figure 2) compares, synthesizes and analyses the main elements reported by the 23 European Union Member States (Table 2) for the MSFD under article 9 (determination of GES) to guide the assessment of environmental quality status for benthic habitats through Descriptor 6 (sea-floor integrity). It also includes and considers the most recent outcomes from MSFD, TG Seabed and ICES guidance (International Council for the Exploration of the Sea). Moreover, in the context of the NEA PANACEA project, potential links with MSFD Descriptor 4 (food webs), Descriptor 5 (eutrophication) and Regional Sea Conventions' methodological standards, notably from OSPAR, were scrutinized, to conclude on current gaps and guide future progress to reinforce cooperation and coherence in next MSFD, Regional Sea Convention and national reporting cycles. This report also reviewed and digested the main previous related analyses and documentation, but it is NOT an MSFD article 12 assessment (technical assessment of countries reporting obligations under MSFD). The initial timeline was a bit delayed to enable to include late national reports which were not available in the initial planned timeline (Table 2), and enable to analyses all national reports in the submitted languages. This study, conducted under a scientific project, focuses on analysing technically the GES elements, to provide guidance on technical assessment methods, but not on the reporting process itself. After the conclusions of this analysis, some key recommendations and views are provided, also including personal views from experienced authors, to guide and encourage technical ways to progress towards a better harmonisation of GES elements and to guide future assessments of benthic habitats at European, regional and national scales. The proposed links between MSFD Descriptor 6 and some other related Descriptors (both for state and pressures aspects), with the most recent OSPAR methodological standards, for which technical documentation will be published in 2023, are proposed in two summary tables (for benthic habitat aspects in Descriptors 1, 2, 4, 5, 6 and 7). All results data are included in this report as an embedded file, and main related documentation as references and hyperlinks.

Table 2. GES determination reporting dates for the 2nd MSFD cycle for Descriptor 6, and codes of the EU Member States (None = not available before May 2022).

		EU MSFD Good Environmental Status (Art 9)		
		First text report or XML data	**Last update of the text report**	**Last update of the XML data**
Belgium	**BE**	15/10/2018	21/11/2019	14/01/2020
Bulgaria	**BG**	23/12/2021	23/12/2021	31/03/2022
Croatia	**HR**	30/09/2019	11/12/2019	31/10/2019
Cyprus	**CY**	09/01/2020	13/05/2020	12/08/2020
Denmark	**DK**	05/07/2019	05/07/2019	30/08/2019
Estonia	**EE**	12/02/2019	14/02/2019	06/04/2020
Finland	**FI**	09/01/2019	16/01/2019	10/04/2019
France	**FR**	30/09/2019	15/10/2019	19/02/2020
Germany	**DE**	14/12/2018	14/12/2018	17/02/2020
Greece	**EL**	31/12/2018	31/12/2018	None
Ireland	**IE**	25/06/2020	26/06/2020	31/08/2020
Italy	**IT**	22/01/2019	22/01/2019	01/10/2020
Latvia	**LV**	21/06/2018	26/02/2019	08/05/2019
Lithuania	**LT**	31/03/2020	09/06/2020	09/06/2020
Malta	**MT**	23/03/2020	26/06/2020	16/04/2020

Table 2. Continued.

		EU MSFD Good Environmental Status (Art 9)		
		First text report or XML data	**Last update of the text report**	**Last update of the XML data**
Netherlands	**NL**	01/10/2018	13/02/2019	15/04/2019
Poland	**PL**	04/04/2019	04/04/2019	28/01/2020
Portugal	**PT**	23/03/2020	19/06/2020	03/03/2021
Romania	**RO**	19/12/2018	30/09/2019	06/04/2020
Slovenia	**SI**	06/08/2019	09/01/2020	13/08/2020
Spain	**ES**	09/07/2019	11/07/2019	03/02/2020
Sweden	**SE**	27/12/2018	29/06/2020	06/07/2020
United-Kingdom	**UK**	23/10/2019	information was also obtained here from the official website https://moat.cefas.co.uk/	

Next steps

Depending on the resources and data available in the future, this analysis could be re-conducted and completed by the 3rd MSFD cycle reports, and the next Regional Seas Quality Status Reports, as the method, references and source data are publicly available in this deliverable. A scientific publication of this report and/or the next steps are planned to be submitted to a scientific journal by this task lead and involved experts.

Reference

Guérin L. and Lizińska A., (2022). Analysis of the main elements of the “Good Environmental Status” from the 1st and 2nd MSFD cycles, reported by the European Member States for the Descriptor 6 (sea floor integrity), and links with Regional Seas’ Conventions and D4 (food webs integrity) and D5 (eutrophication). August 2022. Nea Panacea European project. PatriNat joint unit (OFB, MNHN, CNRS). Station marine de Dinard. http://dx.doi.org/10.13140/RG.2.2.16732.46728

Task 3.2: Final development and first assessment of the Sentinels of Seabed indicator (BH1) (Annexes U and V)

Task Lead: José Manuel González Irusta (IEO, ES) (Partner)

Other involved: Maider Plaza Morlote (IEO, ES) (Partner), Alberto Serrano (IEO, ES) (Partner), Antonio Punzón (IEO, ES) (Partner), Liam Matear (JNCC, UK) (Partner), Stefano Marra (JNCC, UK) (Partner) Cristina Vina-Herbon (JNCC, UK) (Partner)

Other Activities involved: None

Milestones: M3.2a post-doc recruited; D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D3.2 BH1 2022 indicator assessment plus CEMP (Coordinated Environmental Monitoring Programme) update

Summary

This Task involves the adaptation of the OSPAR Sentinels of Seabed benthic habitats indicator (BH1) to the 2017/848 GES decision and its development towards a simpler and easier use across regional and subregional assessments. The BH1 assessment results and annexes (including BH1-BH3 pilot integration method), the technical specification (OSPAR Coordinated Environmental Monitoring Programme guidelines) and related MSFD table (linking to MSFD reporting criteria and elements) were technically finalised and are proposed for adoption to OSPAR commission (June 2023), to be made available notably for MSFD reporting considerations.

Table 3. Task 3.2 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.2 preparation																								
Task 3.2 implementation																								

The overall objective of this task was to (1) adapt the BH1 indicator (also called Sentinel of the Seabed, SoS) to the MSFD revised Decision on GES (Commission Decision 2017/848/E.U.) and (2) improve its operability.

The BH1 indicator was conceptually developed in the frame of the Benthic Habitats Expert Group of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) under the EU-funded EcApRHA project. However, its conceptual adaptation to fulfil the requirements for descriptor 6, seafloor integrity, of the second commission decision on GES (2017/848/E.U.), its complete methodological development, and the improvement of its friendly use was executed under the NEA-PANACEA project. This indicator is one of the five OSPAR standards developed to monitor and assess the benthic habitats' quality status within the OSPAR Maritime Area according to the Marine Strategy Framework Directive (MSFD; Directive 2008/56/E.C.); specifically, the BH1 is common for the assessment units Gulf of Biscay, North Iberian Atlantic, South Iberian Atlantic and Gulf of Cadiz (Figure 1), previously named OSPAR region IV. The BH1 indicator was initially developed as BH1-typical species composition- following the OSPAR requirements and the corresponding criteria from the EU Commission Decision to achieve a Good Environmental Status (GES; 2010/77/E.U.). Afterwards, the indicator name and methodology were updated to their current form to fulfil better the revised Decision's requirements to achieve GES (2017/848/E.U.; Serrano et al., 2022, CEMP guidelines document).

Achievement of aims (1) and (2) involved the obtainment of **deliverable 3.2** promised within this task, the CEMP (Coordinated Environmental Monitoring Programme) update (Deliverable 3.2a, Annex U), plus the BH1 indicator assessment (Deliverable 3.2b, Annex V).
The general objective was developed based on the achievement following specific objectives:

(a) Definition of sensitivity/fragility
As part of the BH1 indicator, species were listed according to their sensitivity to the pressure. Two main pressures were tested (trawling disturbance and chemical pollution) using the BESITO index (BEnthos Sensitivity Index to Trawling Operations; González-Irusta et al., 2018) and the AMBI groups (AZTI's Marine Biotic Index; Borja et al., 2000) respectively. The suitability of these indices was tested and reviewed in different forums for different regions and specificities (e.g., different sampling gears): The indicator was analysed, and the indices tested in: (i) six different cases of study, located in different areas of the Atlantic and the Mediterranean; using different sampling method for data acquisition (otter trawl, Remote Operate Vehicle- ROV-, and box-corer) as well as different pressure type (trawling vs pollution). This test of the BH1 methodology was scientifically peer-reviewed and published in Ecological Indicators (Serrano et al., 2022). (ii) Seventeen benthic datasets, located in different areas of the Atlantic and Mediterranean, using different combinations of broad habitat types and three different pressure types (trawling, pollution, and eutrophication). This testing and review were carried out by ICES experts through the Workshop on assessment methods to set thresholds and assess adverse effects on seabed habitats (WKBENTH2 & WKBENTH3 October 2022), being the BH1 the most sensitivity indicator to trawling and one of the few indicators which showed a significant response to more than one pressure. The analyses culminated in the publication of the ICES WKBENTH2 & WKBENTH3 reports (ICES, 2022a; ICES, 2022b). (iii) Four benthic datasets, located in four of the Spanish Marine Demarcation, using the same sampling method for data acquisition (otter trawl) and the primary pressure type in these areas (trawling). This work is in progress and is being developed within the monitoring programs for Spanish marine strategies in response to the Framework Directive on Marine Strategy (Dir 2008/56/C.E.) in compliance with the Regional Seas Conventions (e.g., OSPAR). (iv) Four benthic datasets, located in the four MSFD Marine Reporting Units (Gulf of Biscay, North-Iberian Atlantic, South-Iberian Atlantic, and Gulf of Cadiz) where BH1 is an agreed OSPAR Common Indicator using the same sampling method for data acquisition (otter trawl) and the primary pressure type in these areas (trawling). The analyses were developed in the assessment units where BH1 is an agreed OSPAR Common Indicator: Gulf of Biscay, North-Iberian Atlantic, South-Iberian Atlantic, and Gulf of Biscay. The OSPAR Benthic Habitats expert group conducted this testing and review before supplying deliverable 3.2.

(b) Development of a user-friendly indicator
With the final aim of facilitating the BH1 applicability in a wide range of regions and subregions: (i) BH1 was summarised in an R function published in GitHub (https://github.com/Gonzalez-Irusta/SoS). This function provides the list of sentinel species straightforwardly. The R function was tested across countries and regions (e.g., Serrano et al., 2022; ICES, 2022a; ICES, 2022b) to optimise the code behind the function regarding functioning and geographical coverage. (ii) An updated generic guidelines for Coordinated Environmental Monitoring Programme (CEMP, deliverable 3.2a) was obtained for BH1 being approved by OSPAR's Biodiversity Committee (BDC). (iii) BH1 methodology was published in Ecological Indicators (Serrano et al., 2022), in which its operability is tested and confirmed.

(c) Setting thresholds for BH1.
In previous MSFD cycles, no thresholds for BH1 were set. Previous results in BH1-testing for the Bay of Biscay and Iberian Coast showed different responses across habitats and pressures. During this task, a method for

setting quality thresholds with ecological meaning was developed, called distance to degradation. Each habitat's threshold value is specific and determines the minimum proportion of sentinel species acceptable to keep ecosystem processes. This threshold methodology was: (i) presented and valued in the WKBENTH2 of ICES (ICES, 2022a). (ii) Successfully applied and approved in the BH1 assessment supporting MSFD reporting for EU MS. (iii) The method is critical for the BH1/ BH3 integration (Task 3.7). The methodological and operational development of BH1, as well as its application and revision in different forums during this task, support that BH1: (i) Is potentially applicable based on all standardised benthic community monitoring data in case of the presence of no-/low-pressure situations or reference has been defined before. (ii) Is very sensitive in clear pressure gradients and single/dominant pressure situations. (iii) Is a suitable indicator to respond to D6C3 MSFD criteria with valuable input to D6C5 MSFD criteria. (iv) Provides consistent results regarding specific disturbances, as it targets the community's most' sensitive' fraction. (v) The model's confidence is good, and the reliability of assessment results is high in case results are based on clear (dominant) pressure gradients, including the presence of reference areas. (vi) provide threshold values specific for each habitat which allows classifying the degree of disturbance. (vi) The uncertainty is taken into account as the standard error when classifying the areas into disturbance categories disturbance. For all of that, this task has supposed a substantial step forward in our assessment capabilities within the BH1 Common Indicator Assessment Units -Gulf of Biscay, North Iberian Atlantic, South Iberian Atlantic, and Gulf of Cadiz- for the QSR 2023 as well as for the assessment of the MSFD for the descriptor 6.

Deliverable 3.2. OSPAR BH1 Common Indicator

The commitment established in the NEA-PANACEA grant proposal for this task was to obtain Deliverable 3.2, which is made up of two documents: the Coordinated Environmental Monitoring Programme update (Derivable 3.2a) plus BH1 2022 indicator assessment (Derivable 3.2b).

Deliverable 3.2a. BH1 CEMP guideline (Annex U)

This document is an OSPAR Guideline for the Coordinated Environmental Monitoring and Assessment Programme (CEMP) specific and exclusive of the BH1 indicator. This derivable exhaustively described the updated methodology for the Sentinels of the Seabed indicator (BH1), tested its applicability in different marine habitats under different pressures and provided a methodological proposal to integrate the BH1 and BH3 OSPAR indicators.

The BH1 assessment method and application detailed in CEMP were scientific peer-reviewed being published in Ecological Indicators (Serrano et al., 2022). They were also tested and reviewed by national, OSPAR and ICES experts through focus workshops, and it represents a realistic approach to assess the impact of a specific pressure across the benthic BHTs based on current knowledge and using all evidence available. This document's format and content update was also supervised and reviewed by ICG-COBAM through its expert groups and with the oversight, steer and agreement of OSPAR's BDC, (2) 2022.

The BH1 CEMP guideline provided all the necessary documentation for the methodological development and the application of the BH1 indicator. The document specified that the BH1 uses three types of information: (i) the distribution of benthic BHTs, (ii) the distribution and intensity of pressures that disturb these BHTs and (iii) biological sampled data of the abundance (preferably biomass, although also works with density) of benthic species from each BHT across a pressure gradient (including no pressure/low-pressure areas). These three sources of information (Figure 4) allow the BH1 to detect changes in the community composition of marine habitats produced by any disturbance, physical or chemical if the species' sensitivity to these disturbances is known.

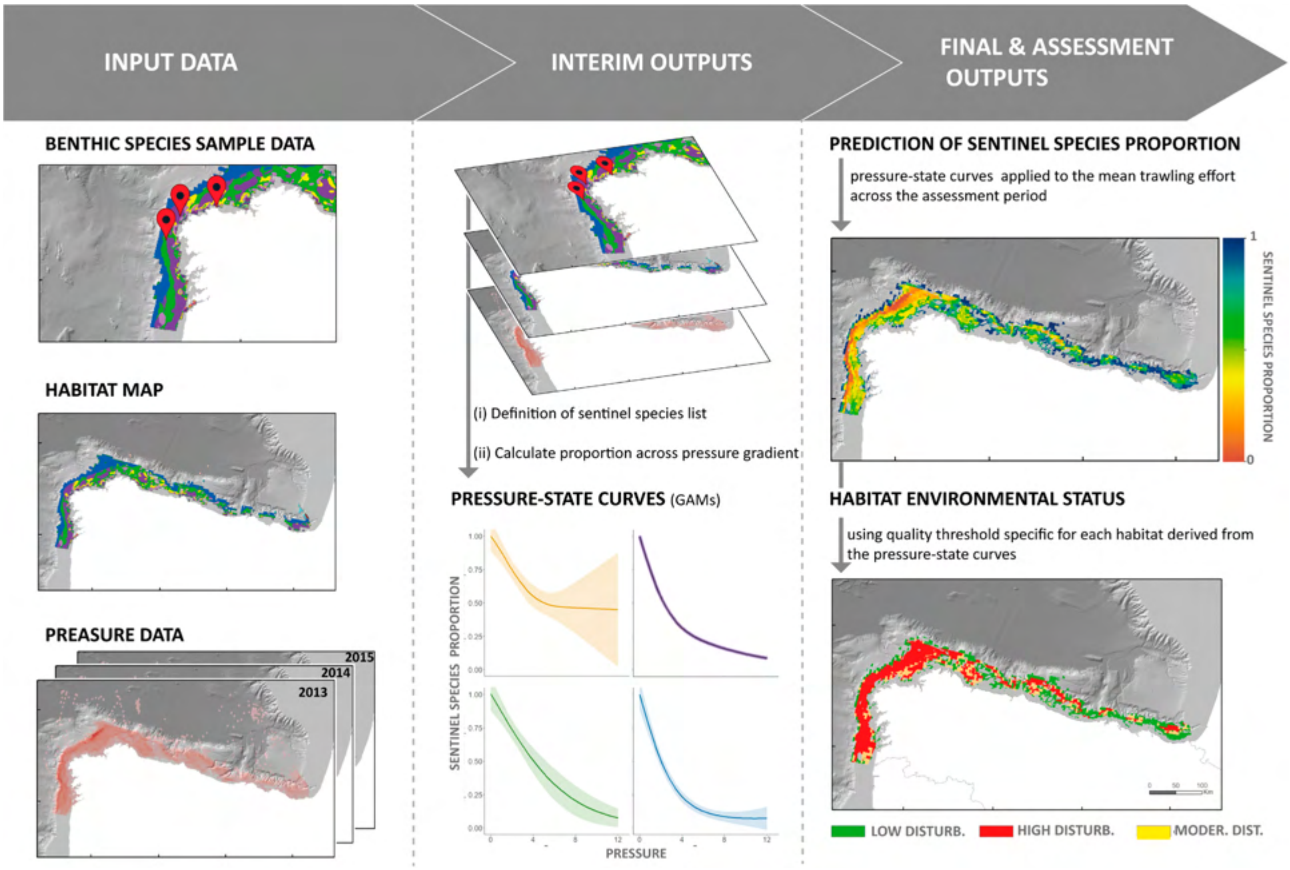

Figure 4. BH1 methodology update. Interlinkage between data inputs, processes, and outputs for the BH1 indicator.

Specifically, BH1: (i) is adapted to each BHT by selecting a set of typical species from each habitat in areas with no pressure; and (ii) is responsive to any stressor type as long as there is an index available to evaluate species sensitivity to that pressure since these sensitivity indexes filter the previously selected typical species (e.g., BESITO index for trawling, González-Irusta et al., 2018). Once the final set of sentinel species has been selected (Figure 5), changes in the proportion of these species across a pressure gradient can be computed to generate the pressure-state curves (Elliott et al., 2018). These curves are used in this assessment for three primary purposes: (i) to directly evaluate the status of habitat by transforming pressure units (e.g., swept area) into the proportion of sentinel species (using correlative models, e.g. GAMs), allowing to evaluate the status of the habitat across its extent (Figure 4); (ii) to calculate the habitat sensitivity by comparing the curve for each habitat with five theoretical models using an R function developed for this purpose (see https://github.com/Gonzalez-Irusta/SoS). (iii) to compute quality thresholds based on pressure state curves following the most recent recommendation of the E.U. Technical Group on Seabed Habitats (TGSEABED group) as well as previous works of OBHEG experts (Elliot et al., 2018); The threshold must be defined based on the specific sensitivity of the habitats to guarantee the habitat quality (Figure 6). Finally, these values are converted into habitat status maps showing high, moderate, and low disturbance areas (Figure 7) using quality thresholds previously computed based on the pressure-state curves (minimum proportion of sentinel species acceptable to keep ecosystem processes) specific for each habitat (for detailed information, see CEMP guidelines and its annexes).

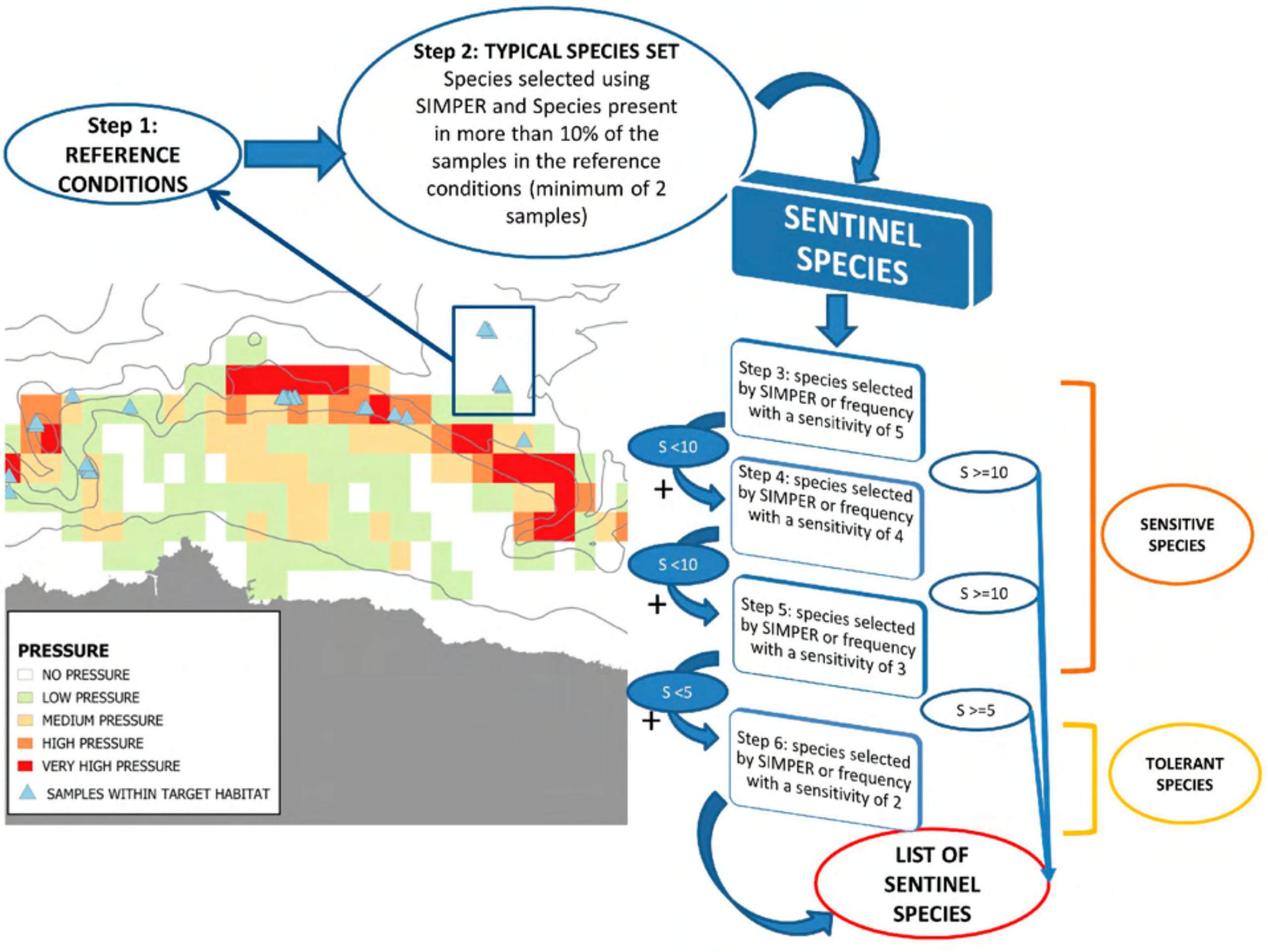

Figure 5. Diagram explaining the methodology to determine the sentinel species list. All these steps have been included in an R function publically available at https://github.com/Gonzalez-Irusta/SoS*.*

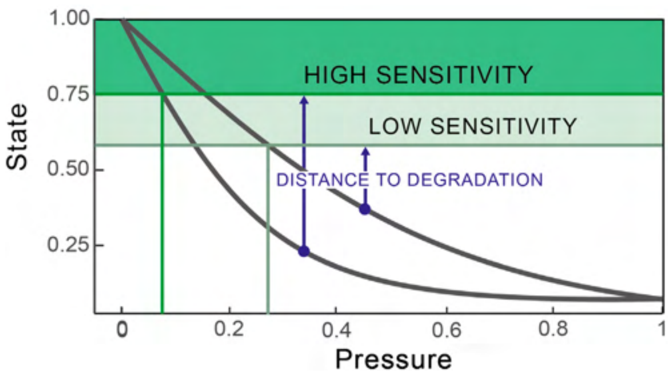

Figure 6. Illustrative examples of the derivation of BH1 thresholds. The solid green line indicates the threshold between the good state and the degraded, and the green polygon indicates the region above the threshold (where present).

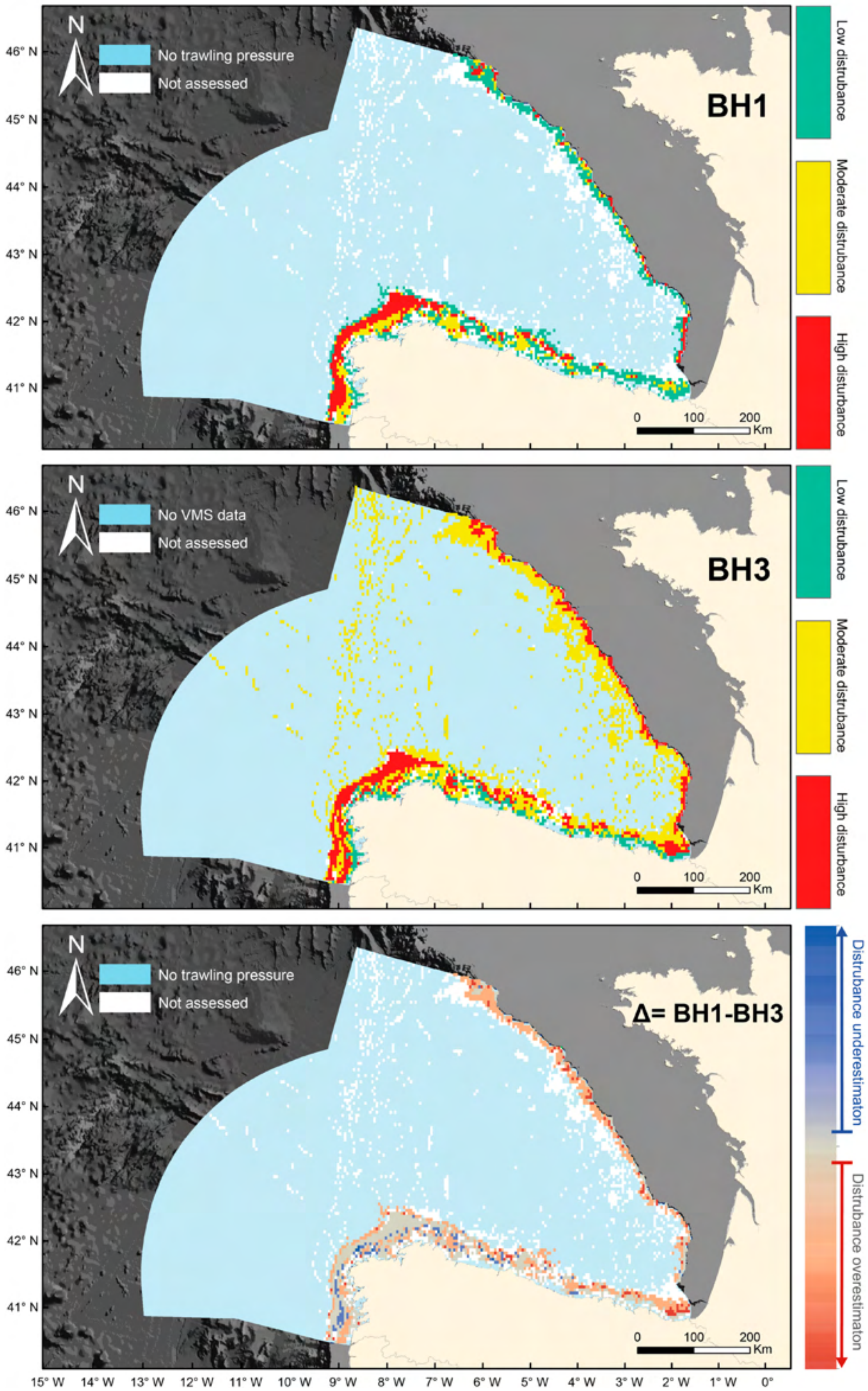

Figure 7. Risk-based benthic level of disturbance estimations determined by BH1 and BH3 indicators and their differences for the North Iberian Atlantic assessment unit.

In addition, in this delivery, the indicator was tested in different benthic BHTs, using endobenthos and epibenthos communities and with two different pressures (pollution and trawling disturbance) to show the full potential of the indicator, its sensitivity and its high plasticity. Further testing in other biogeographic regions was carried out by Serrano et al. (2022).

Finally, this document includes a proposal to integrate the BH1 and BH3 indicators via a pilot study in the North Iberian Atlantic assessment unit. The proposal can be found in annex 4 of the BH1 CEMP guidance (Annex U of this report). This annex proposes combining both indicators in future assessments as a method of integration or using BH1 curves to calibrate and improve BH3 disturbance values.

This section of the document is part of the work developed in Task 3.7 of the NEA-PANACEA grant proposal, specifically with the work related to the development and testing of approaches to integrating common indicators BH1, BH2, BH3 and BH4, building on already published results from EcApRHA EU EMFF funded project (2015-2017; Elliott et al., 2017). Therefore, this document also directly contributes to producing an integrated assessment by proposing the complementarity of the BH1 and BH3 indicators, nested by types of methods (BH3- risk indicator calibrated or ground-truthed with BH1-sample-based indicator), what would improve in the future the OSPAR's capabilities to assess the benthic habitats under D6.

The integration of both indicators arises from the lack of specific monitoring requirements associated with BH3 and, therefore, the need for the BH3 to use data from monitoring programmes, in particular those associated with BH1, but also with BH2 – Condition of Benthic habitat communities (Elliot et al., 2017; ICES, 2022b), to improve the evidence base and algorithms underpinning the metrics and concepts, and to calibrate and ground-truth the results.

The document shows that despite apparent differences in the methods and philosophy of both indicators (BH3 is a risk indicator, and BH1 is a quality/status indicator), there was certain consensus in their results, especially in terms of relative values, which has its reflection in the high level of correlation observed between the outputs of both indicators. This correlation is also high when the comparison is made habitat by habitat, although with a higher level of variation.

Unfortunately, this high level of agreement disappears when the outputs of both models are used to determine the proportion of each habitat exposed to a low, moderate or high level of disturbance (so when the quality threshold starts to be applied). BH3 overestimates the disturbance level compared to BH1, determining that nearly 90% of the total extent of the studied area is exposed to moderate or high disturbance compared to the nearly 50% obtained when BH1 was used (Figure 7). BH3 matrix disturbance categories (Figure 6; see BH3 CEMP Guidelines for further information) for habitats with a sensitivity of 3 (0.66 SAR) or 4 (0.33 SAR) were lower than the thresholds determined using the BH1 methodology.

In order to help to reduce these differences (derived from the lack of inclusion of quality indicator inputs in the disturbance matrix) (Figure 8), the document proposes a method to inform the disturbance matrix with information from BH1 and other quality indicators is proposed in this pilot study (Figure 9). The proposal defines each quality category of the disturbance matrix according to its ecological meaning and uses the values from the BH1 quality thresholds to define the boundaries when possible. To maximise BH3 utility, the pressure categories must agree with the BH1 quality threshold defined for each benthic habitat.

Although the numerical values suggested in this pilot study for each category are not final of each category and may be modified once more data and other indicators can be used to define quality thresholds, it is more crucial than the theoretical approach developed in this section of the BH1 CEMP, and previously delineated by Elliot et al. (2018), can be adopted for BH3 methodology, as well as serve as inspiration for the integration of other indicators.

Therefore, deliverable 3.2a represents substantial methodological progress in improving the OSPAR's benthic habitats assessment capabilities under D6 to support EU MS MSFD reporting through the QSR 2023.

Disturbance matrix		Sensitivity				
		1	2	3	4	5
Pressure	0 - ≤0.33	1	2	3	4	6
	>0.33-≤0.66	1	2	4	6	7
	>0.66-≤1	1	3	5	7	9
	>1.00-≤3	1	4	6	8	9
	>3	2	4	7	9	9

Figure 8. BH3 disturbance matrix (BH3 CEMP OSPAR, 2022).

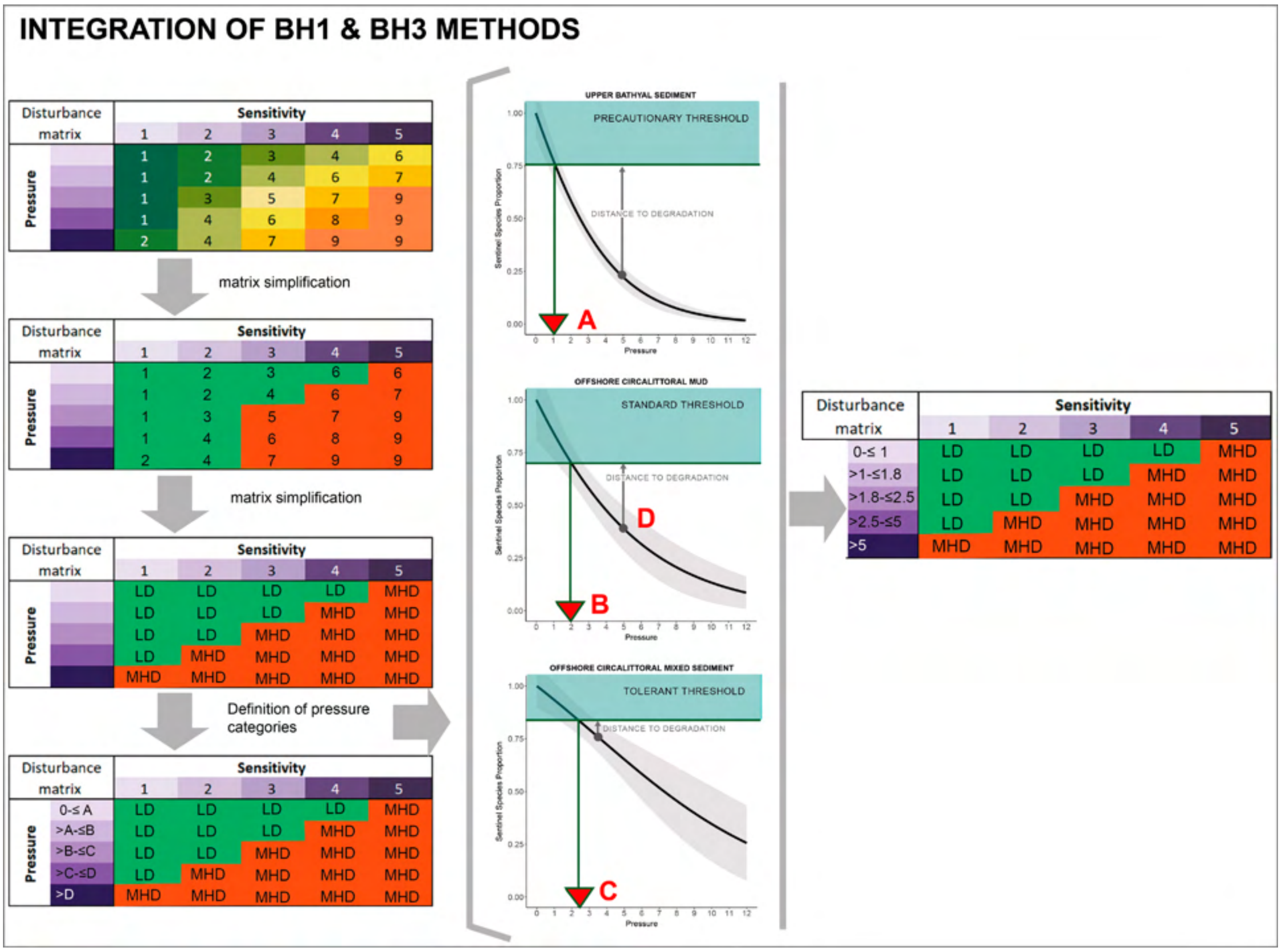

Figure 9. Scheme of the indicators methods integration that is proposed.
L.D.: Low disturbance. MHD. Moderate/high disturbance.

Deliverable 3.2b. BH1 assessment (Annex V)

This document, the BH1 OSPAR Common Indicator Assessment, evaluates the level of disturbance of the main benthic habitats affected by bottom-contact fishing within the Common Indicator Assessment Units-Gulf of Biscay, North Iberian Atlantic, South Iberian Atlantic and Gulf of Cadiz- for the QSR 2023. The assessment was run from 2009 to 2020 (QSR), the timeframe established for the QSR 2023 to identify and analyse information using long-term trends, and from 2016 to 2020 (MSFD), the six years used by European Union Member States to assess progress from the second EU MSFD Article 8 reporting. The format and content of this assessment were supervised and reviewed by ICG-COBAM through its expert groups and were agreed upon during BDC (2) 2022.

This delivery is the first quantitative assessment of the extent of benthic habitats' level of disturbance in response to bottom-contact fishing within the Common Indicator Assessment area (Figure 10) using BH1, which allow to (i) provide a map with continued values of the proportion of sentinel species for each evaluated benthic BHTs (ii) determine the extent of the habitat affected by trawling, predicting and mapping disturbed areas by converting these values into three disturbance categories using quality thresholds obtained from the pressure-state curves (following EU MSFD article 8 guidelines, European Commission, 2022), providing values of low, moderate and high disturbance areas.

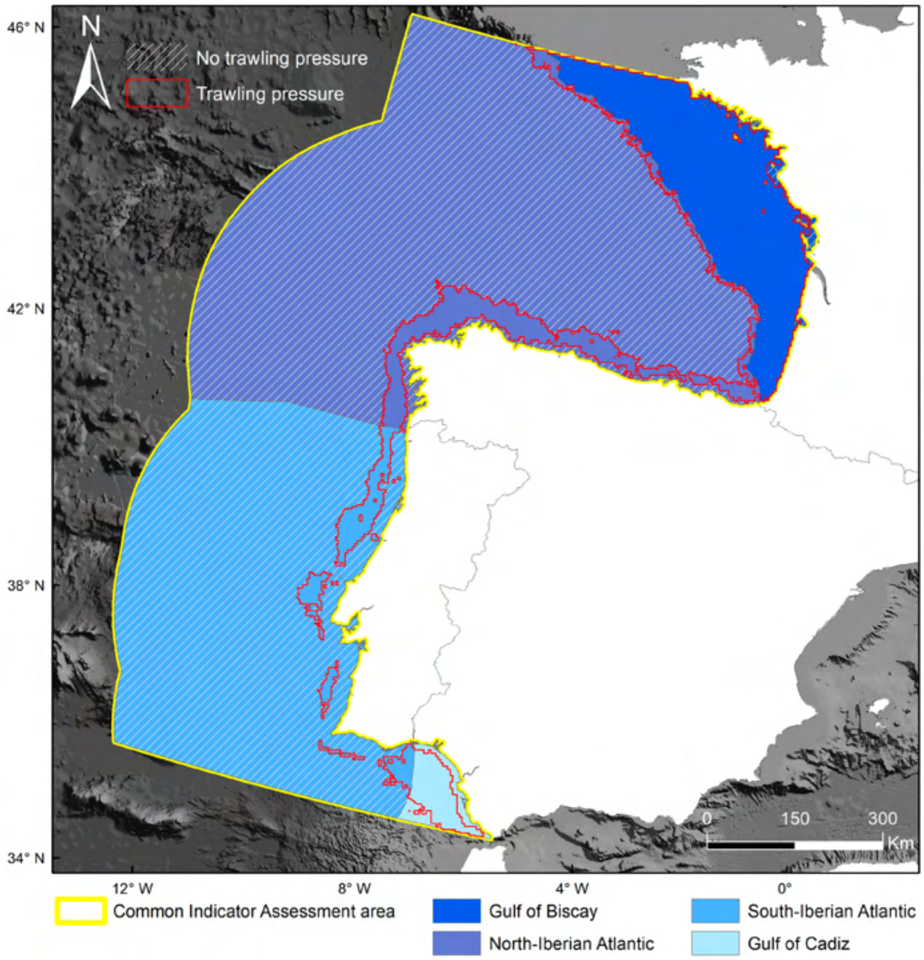

Figure 10. BH1 Common Indicator Assessment Units, the extent of the trawling footprint (bordered in red) and the area without bottom-trawling pressure (grey hatched area).

The BH1 assessment method and application were detailed in CEMP (Deliverable 3.2a) and were scientific peer-reviewed being published in Ecological Indicators (Serrano et al., 2022). They were also tested and revised by the OSPAR Benthic Habitats expert group and by ICES experts through the Workshop on assessment methods to set thresholds and assess adverse effects on seabed habitats (WKBENTH2 & WKBENTH3 which occurred in October 2022). These revisions supported that the indicator accurately and explicitly represents the benthic BHTs' disturbance.

The assessment showed that 17,51% of the total area had disturbance in the QSR timeframe and 16,9% in the MSFD period (Figure 11 and Figure 12). The extent and distribution of bottom trawling were widely distributed over the continental shelf of the BH1 Common Indicator Area. This geographical distribution results in the intensity of fishing effort primarily concentrated at depths shallower than 500 m and mainly shallower than 200 m. This explains that the most significant proportions of disturbance were found in the Gulf of Biscay (QSR: 96,47%; MSFD: 96,07%), followed by the Gulf of Cadiz (QSR: 67,84%; MSFD: 64,14%) assessment units, since they presented the greatest trawled extents as a consequence that their continental shelves constitute most of their extents (Figure 11 and Figure 12).

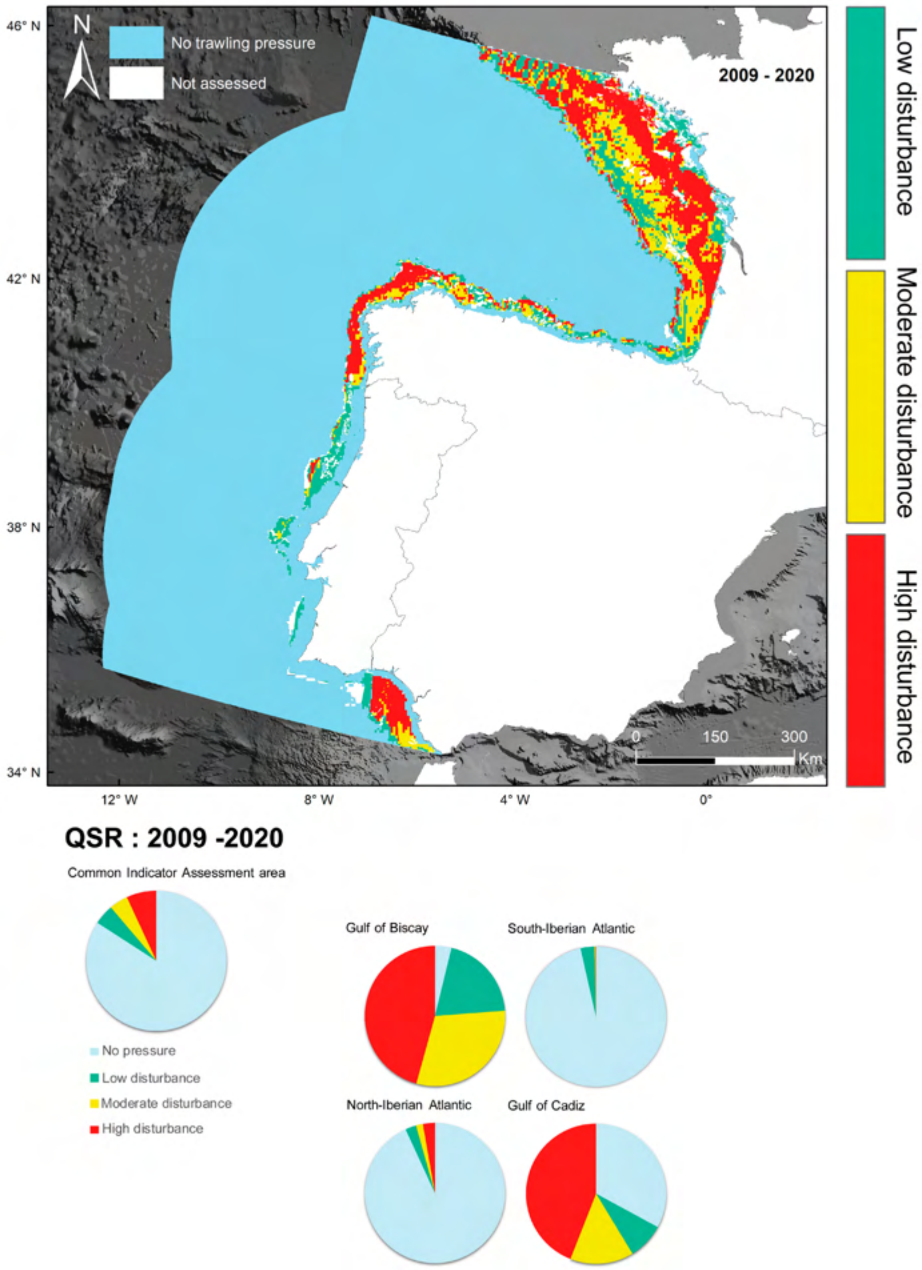

Figure 11. Disturbance spatial distribution across the Common Indicator Assessment Units over the QSR time frame. Pie chart plots show the percentage of the assessment unit area under each disturbance level.

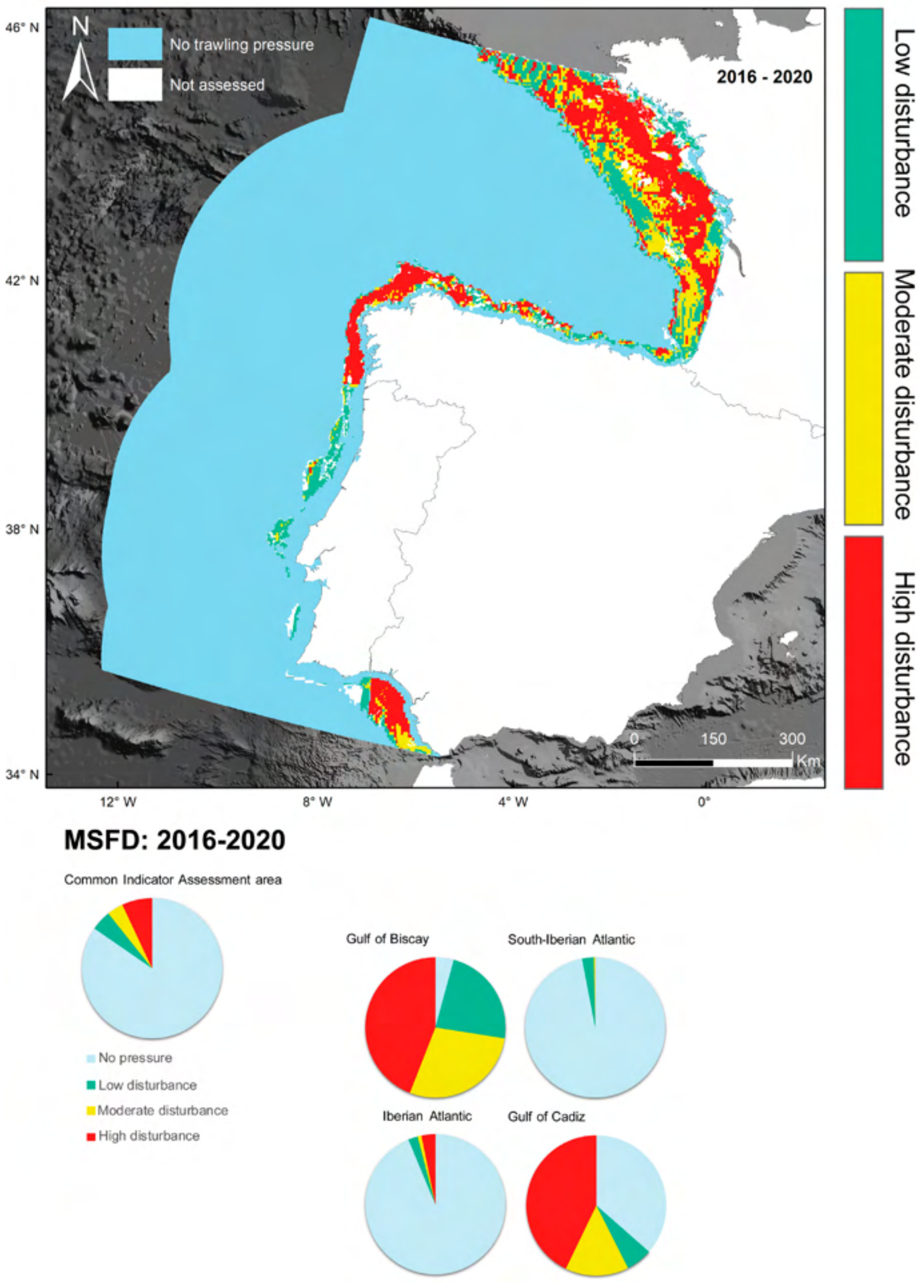

Figure 12. Disturbance spatial distribution across the Common Indicator Assessment Units over the MSFD time frame. Pie chart plots show the percentage of the assessment unit area under each disturbance level.

The level of disturbance was derived from the interaction between the trawling intensities distribution and the sensitivity of the benthic BHTs (in the form of specific response curves for each habitat). In the QSR assessment, 6,78% of the evaluated area had high disturbance, 4,55% low and 4,22 moderate disturbances being similar percentages for the MSFD assessment, with high disturbance in 6,86% and low and moderate disturbances in 4,57% and 3,68 % of the total area respectively (Figure 11 and Figure 12). However, it drew attention to the fact that all the offshore and circalittoral benthic BHTs had areas with a high disturbance which manifests very high intensities of trawling efforts in the area, which produced high disturbance regardless of sensitivity.

Regarding the disturbance, within the assessment units, offshore circalittoral mud had the largest or one of the largest proportions of high disturbance in most of the units, whilst one of the greatest proportions of low disturbance was founded in the offshore circalittoral coarse sediment. These results are not only a consequence of trawling distribution but also the result of habitat sensitivity to trawling, which is low for this habitat.

This BH1 assessment tried to maximise regionally-specific accuracy with the available data, generating a map of distribution and extent of uncertainties (Figure 13) associated with the results derived from the data quality.

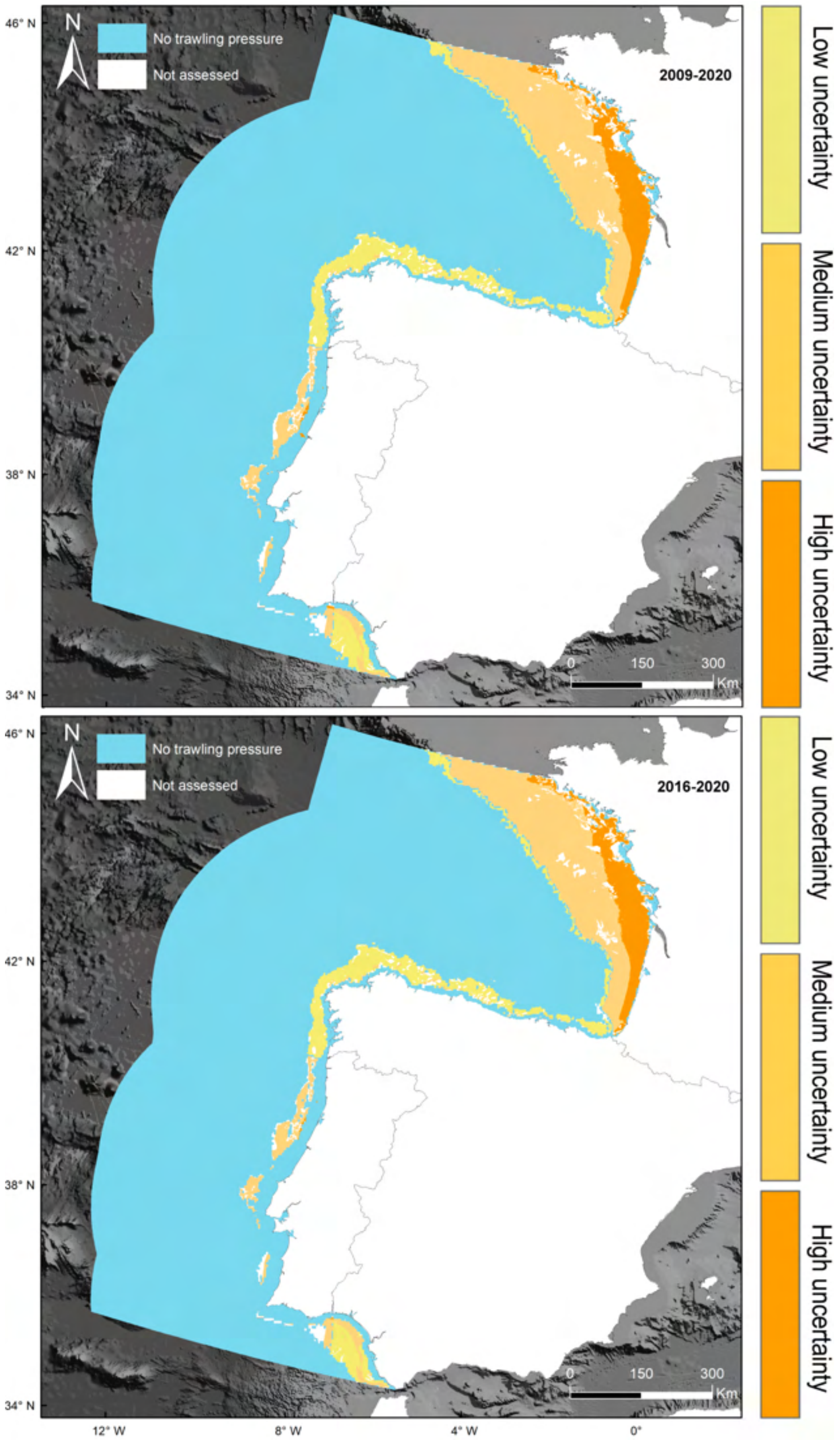

Figure 13. Uncertainty spatial distribution associated with the BH1 assessment across the Common Indicator Assessment Units over (top) QSR time frame (bottom) MSFD period.

This assessment represents a substantial step forward in assessing the impact on benthic BHTs from bottom-contacting fishing in our assessment capabilities in the assessment units where BH1 is an agreed OSPAR Common Indicator for the QSR 2023.

Knowledge gaps and next steps

The BH1 indicator is sensitive to data quality, which will dictate the power and utility of the resultant information. Access to more data with high accuracy will improve the confidence and coherence in BH1 assessment results. In this sense, the critical gaps that need to be addressed are:

(i) The distribution of benthic habitats
This assessment used the composite habitat map (EMODnet, 2021) that EMODnet Seabed Habitat prepared for OSPAR. Despite that, this EUSeMap is the only pan-European cartographic product that provides a standardised transboundary overview of the spatial distribution of seabed habitats across Europe, which makes it tremendously helpful for this assessment; it presents uncertainties derived from the level of detail of some areas from its habitats descriptors maps (Vasquez et al., 2021) which can be regionally significant. A detailed habitat map with low uncertainties is key to obtaining quality results in the common BH1 assessment units.

(ii) The distribution and intensity of pressures that disturb these habitats
The spatial resolution of the VMS data (0,05° × 0,05° grid cells) with a pressure intensity homogeneous over each c-square (ICES, 2021) leads to trawling pressure underestimation or overestimation. Increasing the resolution of the VMS data would improve the confidence in BH1 assessment results, especially in areas geomorphologically complex such as the Iberian Peninsula. In addition, the trawling effort may have been overestimated in some areas where slow vessel speeds were reduced during manoeuvres not linked to commercial bottom fishing (such as entrances and exits to port and adverse weather conditions), which erroneously are attributed to trawling. Finally, including Inshore Vessel Monitoring Systems (I-VMS) data as bottom-contacting fishing pressure would increase the confidence of the BH1 assessments in shallow waters, where smaller vessels are most likely to operate.

(iii) Biological sampled data of the abundance (biomass or number) of benthic species from each habitat across a pressure gradient (including no pressure/low-pressure areas).
The BH1 was designed to feed on empirical data; it is based on monitoring data with a broad time perspective. Specifically, BH1 needs samples with biological information on species abundance across the pressure gradient within each benthic BHTs (e.g., data from IBTS with invertebrates abundances) to have data on the proportion of sentinel species at different levels of disturbance. Increasing monitoring of benthic species in terms of biomass and abundance in the common Indicator Assessment units, specifically in the Gulf of Biscay and South Iberian Atlantic, from surveys would improve the confidence and accuracy of BH1. The creation of standardised Benthic Monitoring Programmes would help increase data coverage and, therefore, achieve the purposes of this type of assessment.

BH1 should move towards a quantitative and integrated assessment with low uncertainties for the next assessment cycle. To reach this goal, in addition to all the points previously discussed, the indicator would need to explore the incorporation into its analyses: (a) evidence-based proposals for Threshold values, (b) environmental variables and (c) testing/optimising applications in multi-pressure situations (including the need for data from reference areas).

(a) Agreed upon criteria to define the suitability of quality thresholds values
Effective thresholds must be ecologically meaningful and separate good and degraded states based on each benthic BHT. Deciding how much change is compatible with a “good” state has proven difficult, but this is vital

for understanding the assessment. This cannot be determined subjectively by each work team and for each indicator but must be a consensus and consistent Decision for all indicators. OSPAR has to agree on common criteria for defining quality thresholds for all the indicators that assess the impact on the benthic BHTs.

(b) Environmental variables

The BH1 assessment method and application have been tested and revised, showing that the sentinel species assessed are sensitive to the pressure studied. However, environmental variables may also affect their proportional abundance, especially in habitats with a wide variability of the environmental variables that define them, such as the Upper Bathyal Sediment. Because of the correlative approach used in applying BH1 to convert the pressure layer into a layer with values of the proportion of sentinel species, other environmental layers can be included as covariates in the correlative approach. Considering the underlying environmental variation, this twist to the methodology could increase the model's accuracy, substantially improving the prediction models.

(c) Testing/optimising applications in multi-pressure situations

BH1 has demonstrated the ability to analyse the seafloor impact in response to two pressures: eutrophication and pollution and bottom trawling effort. Of course, although it is impossible to know if the values of each pressure are comparable, under the assumption that both pressures cover a range of disturbances from low to high, the presented method allows comparing the effect of both pressures on the proportion of sentinel species. In this sense, the BH1 indicator could offer the opportunity to develop new methods to assess the cumulative effects of multiple pressures acting simultaneously, an aspect of great importance, especially in the frame of D6C5.

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Task 3.3: Update the OSPAR BH2a benthic habitats indicator assessment (Annexes W and X) and explore how it can inform or be integrated with other assessments linked to eutrophication or coastal habitats

Task Lead: Laurent Guérin (OFB, FR) (Partner)

Other involved: Anna Lizińska (OFB, FR) (Partner), Petra Schmitt (BioConsult, DE) (Partner), Sander Wijnhoven (EcoAuthor, NL) (external expert)

Other Activities involved: Activity 2

Milestones: M3.3 Data call; D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D3.3 BH2a 2022 indicator assessment

Summary

This Task updated the previous assessment cycle's assessment of BH2a (assessment of coastal habitats exposed to nutrient and organic enrichment) with the most recently available data formally reported from quality elements of the Water Framework Directive (WFD). The results for the elements invertebrates, macroalgae and phanerogams enable direct comparison of the BH2a state assessments between WFD cycles and to other assessments linked to eutrophication (e.g. coastal pelagic habitats, eutrophication and food web assessments). Formal OSPAR data calls were launched mid 2021 and early 2022, mainly to encourage countries to make available their reported data on these quality elements available through dedicated national programmes and WFD databases (WISE database). Data extraction was made in links with the Joint Research Council (JRC) and the European Environmental Agency (EEA) to ensure that the formal and most relevant and quality-insurance based data were provided. The BH2a assessment results (Lizińska & Guérin, 2023; Annex W), the technical specification (OSPAR Coordinated Environmental Monitoring Programme guidelines; Guérin et al, 2023; Annex X) and related MSFD table (linking to MSFD reporting criteria and elements) were technically finalised and are proposed for adoption to OSPAR commission (June 2023), to be made available notably for MSFD reporting considerations. These results were already communicated at a conference (Guérin et al., 2023).

Table 4. Task 3.3 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.3 preparation																								
Task 3.3 implementation																								

From the results, coastal water bodies were assessed for only 72% (invertebrates), and 59% (vegetation) of the total area of 3 MSFD/OSPAR regions (Figure 14). From those, the Water Framework Directive quality status was good or high for 79% (invertebrates) and for 86% (vegetation). However, local eutrophic impacted areas were highlighted for 2010 and 2016 reporting cycles.

These results indicate that most of the water bodies for which data were provided, in the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast, have benthic habitats classified as good biological status, according to the European Union WFD. However, despite the data gaps for many water bodies, this fine-scale assessment (sub-regions and coastal water bodies) enabled the identification of regional variations and the main locally impacted areas for benthic invertebrates and vegetation communities. The main impacted areas, notably on the benthic vegetation, are persistent between 2010 and 2016, all along the Dutch and Danish coasts, and on the North-West coasts of France. The total area of assessed/reported water bodies increased significantly between 2010 and 2016 in most regions (except the Northern Iberian Atlantic) and led to better representativity, with both new good and bad WFD quality status areas.

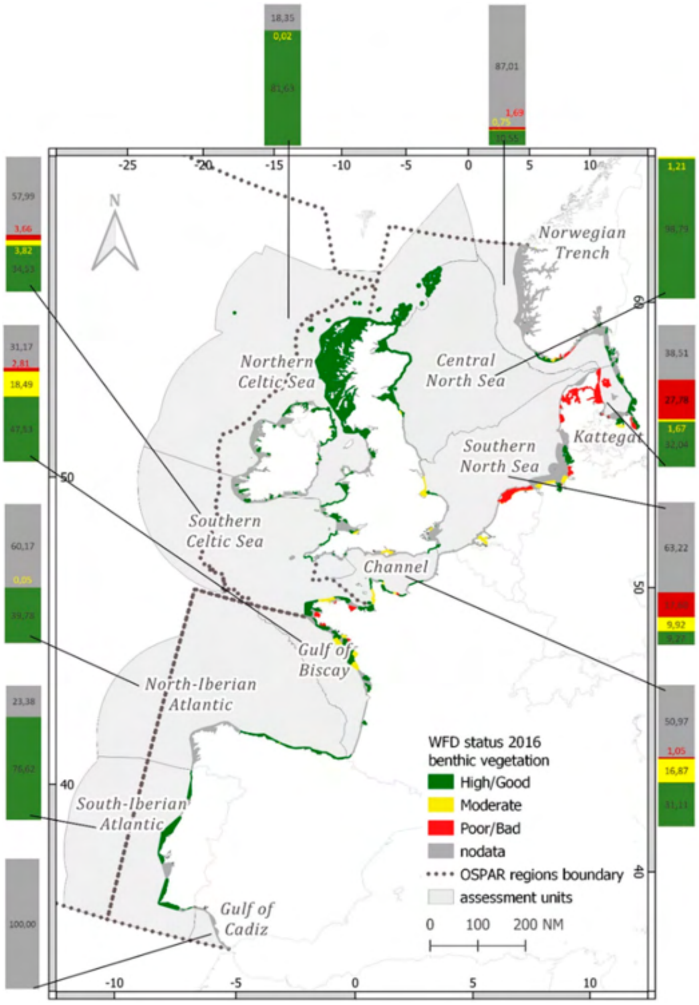

Figure 14. Distribution of 2016 Water Framework Directive (WFD) quality status (condition) for benthic vegetation (common indicator BH2a) in intertidal and subtidal sediments, in response to the (direct or indirect) effects of nutrient and /or organic enrichment, and proportion (area) of the quality status of coastal water bodies for each benthic habitat assessment unit in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast.

Next steps

The extension and standardisation of the assessed and reported coastal water bodies' WFD quality status should be further encouraged for the next assessment cycles, as this provides important and relevant information to guide measures and notably identify their effects on targeted areas. This information can successfully be used for several policies, notably OSPAR, MSFD and the Habitat Directive (HD), for the coastal habitats exposed to nutrients and/or organic enrichments. For OSPAR assessment of coastal benthic habitats in relation to nutrient and/or organic enrichment, the use of the already implemented WFD monitoring and assessment programme is relevant and improves coherence and data flow.

However, even with this already implemented regional scale monitoring programme, some issues with the coherence and exhaustivity of data were highlighted. Data flow and availability have been improved since the 2017 OSPAR intermediate assessment, including quality assurance and quality control, as data were downloaded easily from a unique and certified European database.

Most OSPAR Contracting Parties undertake large-scale marine benthic monitoring, at least for the European Union Water Framework Directive (WFD) and other national programmes. Finer-scale networks of state-pressure relationship assessment areas are more heterogeneous and should be further investigated. Developing coordinated monitoring (or even better, joint monitoring) would be more cost-efficient and would ensure coherence and robustness for an assessment at (sub)regional scale. Each country currently stores its monitoring data and common methodology (and tools), but improvement to achieve coherence and data availability is still needed. Development of data flow arrangements to access and analyse data has improved since 2017, but heterogeneities between indicators and assessment methods limits inter-calibration and comparison of results at wider regional and European scales. The need for these steps should be anticipated and relevant work should be coordinated at a (sub)-regional scale to ensure coherence and facilitate the data flow for this OSPAR specific assessment to be used also for EU Member States' reporting requirements (WFD, MSFD and HD). By targeting an increased coherence and complementarity between the different indices used, the development of methods, monitoring and data flow to assess other pressures types, and ultimately the cumulative effect of pressures, should facilitate interpretation of results and guidance for targeted response measures (notably through Regional Seas Conventions and EU policies; see Carvalho et al., 2019; Lizińska & Guérin 2022). Until then and after, the use of experts' judgment is recommended with adapted methods and scales (McQuatters-Gollop et al., 2022)

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Task 3.4: Expansion and operationalisation of the OSPAR Extent of Physical Disturbance to Benthic Habitats indicator (BH3) (Annexes Y, Z, AA and AB)

Task Lead: Liam Matear (JNCC, UK) (Partner)

Other involved: Cristina Vina-Herbon, Kirsty Woodcock, Stephen Duncombe-Smith, Adam Smith (JNCC, UK) (Partner), Petra Schmitt (BioConsult, DE) (Partner)

Other Activities involved: None

Milestones: M3.4 Addition of new activities, threshold setting, improved tool; D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D3.4 BH3 2022 Indicator assessment; D3.5a Reports and maps on scenarios according to various options of thresholds and disturbance categories for BH3 indicator

Summary

Task 3.4 involved the further development and operationalisation of the OSPAR Extent of Physical Disturbance to Benthic Habitats indicator (BH3) to build on the assessment produced for the previous MSFD assessment cycle. Task 3.4 involved one identified milestone and several deliverables, carried out by BH3 indicator leads from the UK and Germany between March 2021 to February 2023 (Table 5). The BH3 assessment results and annexes (including BH1-BH3 pilot integration method), the technical specification (OSPAR Coordinated Environmental Monitoring Programme guidelines) and related MSFD table (linking to MSFD reporting criteria and elements) were technically finalised and are proposed for adoption to OSPAR commission (June 2023), to be made available notably for MSFD reporting considerations.

Table 5. Task 3.4 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.4 preparation																								
Task 3.4 implementation																								

Addition of new activities for BH3 assessment and CEMP update (Annex Y, M3.4; D3.4)

It was outlined in the Grant Proposal that funds would be used to develop the BH3 indicator to assess new human activities, specifically, commercial aggregate extraction. The development of a BH3 assessment for commercial aggregate extraction was achieved through collaboration with the Environmental Impacts of Human Activities Committee (EIHA), International Council for the Exploration of the Sea's Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (ICES-WGEXT) and Bioconsult. Furthermore, a BH3 assessment for commercial aggregate extraction would feed into ongoing work to produce an updated BH3 assessment for the upcoming MSFD assessment cycle. NEA PANACEA facilitated the integration of the new activity into the indicator, furthering our understanding from previous assessments that only considered the impacts of bottom-contact fishing on Seafloor Integrity at a North-East Atlantic-scale.

Funding contributed to the development of an OSPAR-wide data call that was circulated to OSPAR Heads of Delegation, requesting commercial aggregate extraction data from across the OSPAR Maritime Area, and confirmation of where the activity did not occur. This process was the first OSPAR-scale collation of commercial aggregate extraction data for an assessment, helping to set a new basis for future work and collaboration between OSPAR and those working directly on the extraction of non-living resources and aggregates. Data were acquired from a range of Contracting Parties and representatives from ICES-WGEXT. The most commonly available data was boundary polygons of areas licensed for aggregate extraction (Table 6). The data call also facilitated the acquisition of annual statistics, representative of national dredging activities and extraction footprint data, within licensed areas, from the UK and Denmark (Table 6).

Table 6. Summary of data received from OSPAR aggregates data call. Spatial data used in the BHb assessment is highlighted in purple. 1 Preliminary data or a database that is still under construction; 2 The temporal range is applicable to the dataset and not necessarily all individual Contracting Parties within the dataset; 3 Conventional sea not provided in attribute table but spatial analyses indicated that licensed areas were outside the OSPAR Maritime Area; 4 The years 2016, 2018 and 2019 were missing; 5 Only data from 2017 was present for Belgium;' 6 Convention area not supplied within dataset these countries are known to not contain extraction activity within the OSPAR Maritime Area; 7 Temporal range and Contracting Parties summarised in the table were for the OSPAR Maritime Area only; 8 Extraction volumes in IE and SE were zero indicative that there is no aggregate extraction activity from these countries in the OSPAR Maritime Area.

Data Type	Format	Data Provider	Contents	Temporal Range	OSPAR Regions Covered	OSPAR Contracting Parties Covered
Licensed area polygons	Spatial	ICES[1]	Polygons by year and country	1998-2020[2]	I, II, III, IV, V	BE, DK, FI[3], FR, IS, NE, NO, PT, ES, SE[3], UK
		DE	Polygons for two known active licensed areas for sand and gravel extraction: Westerland III, OAM III	N/A	II	DE
		FR	Polygon layer	N/A	II, IV	FR
		NIBIS portal	Polygon for licensed marine and terrestrial extraction sites for a variety of extraction activities.	N/A	II	DE
		MST portal	Four polygon layers as follows: • Fællesområder: Common sites (with multiple license holders) • Auktionstilladelser: Exclusive sites with a single user (won on at auction) • Bygherretilladelser: Exclusive sites, connected to a specific large building project • Efterforskningsområder: sites where exploration and EIA is occurring in preparation for license application	N/A	II	DK
		EMODnet portal[1]	Polygon layers by year by country	Unknown: database still under construction		
Area extracted polygons	Spatial	ICES[1]	Polygons by year and country	1993-2024	II, III	BE[5], UK
Area extracted values	Tabular	ICES[1]	Annual values for total area licensed and total area dredged per country	2006-2018	Unknown	BE, DK, FI[6], FR, IS, NE, SE[6], UK
Extraction volume (national statistic)	Tabular	ICES[1]	Annual records by country, convention area and extraction type[7]	2005-2020[2]	I, II, III, IV, V	BE, DK, FR, DE, IS, IE[8], NE, NO, PT, ES, SE[8], UK
Extraction volume (licensed area)	Tabular	DE	Annual records for the following licensed areas: Westerland III, OAM III	2010-2020	II	DE
Extraction duration	Spatial	The Crown Estate and Royal Haskoning	Annual duration of extraction within 50 x 50 m polygons derived from EMS	2009-2020	II, III	UK
Extraction polylines	Spatial	MST	Annual extraction polylines derived from AIS with associated start and end times and start and end speeds from extraction activity	2015-2020	II	DK

Furthermore, funding from NEA PANACEA facilitated a series of online and in-person workshops, as well as regional review meetings, to focus on comments and issues raised by experts from specific assessment units. These workshops included, but were not limited to, additional meetings between members of OSPAR's Intersessional Correspondence Group on the Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM), termed "SuperCOBAM" (D5.2a) and "UltraCOBAM" (D5.2c). The aforementioned workshops enabled collaboration and stakeholder engagement with data providers to jointly develop assessment methods and review draft outputs. The relationships established through online and in-person workshops between OSPAR and national data providers, will help facilitate future assessments through established rapport that can assist with future collaboration, join-up, and cross-sectoral integration (e.g., amongst industry experts, regulators and those assessing biodiversity).

Key outputs from the addition of M3.4; D3.4 included newly developed methods, with associated CEMP Guidelines (Annex Y), alongside the first OSPAR-scale assessment of seafloor disturbance associated with commercial aggregate extraction. Assessments were delivered in spatial formats and as a suite of statistical and reporting products that contributed to the OSPAR QSR 2023, supporting EU MS MSFD reporting and within this, the Benthic Thematic Assessment; outputs will also facilitate reporting against Good Environmental Status (GES) for the Marine Strategy Framework Directive (MSFD) and the UK Marine Strategy (UK MS) in 2024. Next steps will include future assessments that incorporate improved data quality (establishment of standardised data resolution and formatting); improvements to methods for extraction-related disturbance calculations (e.g., pressure-sensitivity-disturbance matrices); and continued liaison with stakeholders within the North-East Atlantic marine aggregates sector.

Expansion of BH3 to deliver an updated assessment for the OSPAR QSR 2023 and a Candidate Indicator Assessment for Region I and V (D3.4, Annexes Z and AA)

The BH3 indicator is currently agreed as an OSPAR Common Indicator the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast. In the previous assessment cycle, a BH3 assessment was conducted in the Greater North Sea, the Celtic Seas, and the Bay of Biscay and Iberian Coast for the assessment period of 2010 to 2015. To facilitate an updated assessment, the NEA PANACEA Grant Proposal stated that the BH3 OSPAR QSR 2023 assessment would be expanded to include OSPAR regions I and V (Arctic Waters and Wider Atlantic), if agreed by the OSPAR Biodiversity Committee (BDC), and be updated to include a new assessment period.

Ahead of this assessment cycle, it was proposed that all benthic indicators should use the same assessment units during discussions within the OSPAR Benthic Habitats Expert Group (OBHEG). Assessment units were defined as the spatial area for which assessment results should be calculated. Assessment units were proposed based on regionally and ecologically relevant boundaries and, through NEA PANACEA (discussions initiated at D5.2a SuperCOBAM workshop) and submitted to ICG-COBAM 2021 for sign-off prior to submission to BDC. Following national consultations, final assessment units were agreed at BDC 2022. BH3 was agreed to be assessed as a Common Indicator in Faroe Shetland Waters, Central North Sea, Southern North Sea, Channel, Kattegat, Norwegian Trench, Northern Celtic, Southern Celtic Sea, Gulf of Biscay, North-Iberian Atlantic, South-Iberian Atlantic, and Gulf of Cadiz (assessment units overlapping OSPAR Region II, III, and IV; Figure 15); and assessed as a Candidate Indicator in Atlantic Projection (area within Region V; Figure 15). However, it should be noted that BH3 assessments in the Northern Celtic Sea, Southern Celtic, North-Iberian Atlantic and South-Iberian Atlantic also encompassed areas within Region V. Furthermore, the Northern Celtic Sea partially overlapped a small proportion of Region I.

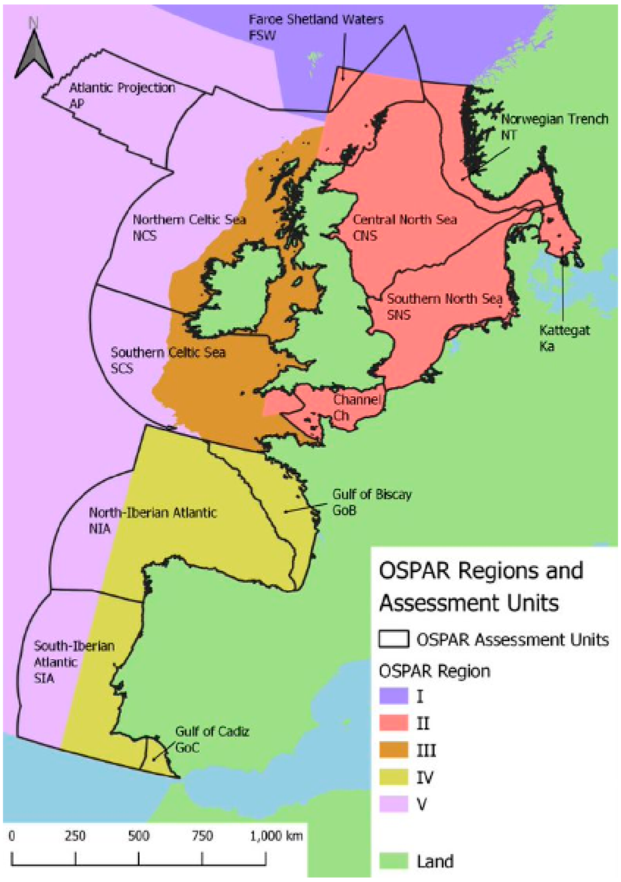

Figure 15. OSPAR Regions with MSFD/OSPAR benthic assessment units where BH3 was assessed as a Common and Candidate Indicator overlaid.

In addition to the spatial expansion of the BH3 indicator assessment, NEA PANCEA facilitated a temporal expansion of the indicator for the updated assessment period. Work undertaken through NEA PANACEA enabled the inclusion of updated bottom-contact fishing data (obtained from ICES) and new commercial aggregate extraction data (see "*Addition of new activities for BH3 assessment (M3.4; D3.4)"* section above) which were both available from 2009 to 2020 at the time of assessment. Therefore, for the QSR 2023, BH3 assessments comprised individual years between 2009 to 2020 (to investigate possible trends), an aggregated assessment for the QSR reporting Period (2009 to 2020) and an aggregated assessment that aligned with the MSFD / UK MS reporting period (2016 to 2020).

NEA PANACEA successfully facilitated the spatial and temporal expansion of the BH3 indicator assessment to include a new assessment period and additional MSFD/OSPAR Regions for the QSR 2023. In addition, outputs from M3.4; D3.4 will facilitate forthcoming assessments for the MSFD and UK MS in 2024, that cover new areas of interest and temporal ranges. Furthermore, the pilot BH3 assessment in the Atlantic Projection (Region V) and the small proportion of Region I that was assessed within the Northern Celtic Sea will also support further developments of the BH3 indicator in these Regions for future assessments. Future work will include additional trialling of BH3 across wider areas of OSPAR, where agreed, and necessary data are available.

Improvements to the operability of the BH3 method (semi-automated assessment methods) (Annex Y, M3.4; D3.4)

It was outlined in the Grant Proposal that funds would be used to develop BH3 to become a semi-automated method, reducing the human capital and time required to analyse large-scale, complex datasets. Building on initial automation trials undertaken prior to project initiation, BH3 was updated to use novel and innovative technologies and automation thereby, creating a more accurate, transparent, and efficient methodology that can be easily repeated in future assessments. Due to the scale of data needed for a cross-Regional assessment and the resource required for manual computations/analyses, automation through open-source software was deemed to be the most appropriate way of improving the indicator within the scope of the project. A range of prospective open-source software were considered, with options presented to the OSPAR Benthic Habitats Expert Group. Through participatory planning, NEA PANACEA helped stakeholders reach consensus on the most effective and appropriate changes to assessment methods (engagement included, but was not limited to, D5.2a SuperCOBAM & D5.2c UltraCOBAM workshops).

Python and R were selected as both were freely accessible to the public, which not only improved accessibility for end users (previous iterations of BH3 used proprietary technologies), but also created clear and understandable methods that could be documented in public computer code repositories (e.g., GitHub). Once developed, automated scripts could be re-run easily, reducing time and therefore, costs to undertake future BH3 assessments. In addition, open-source code could be readily accessed by experts within the OSPAR framework, helping to improve quality assurance checks, and facilitate knowledge exchange for wider knowledge exchange and indicator development.

BH3 is a multifaceted indicator, with diverse components relevant to habitats, species, pressure and disturbance data. Automated processes were developed for each component separately, with additional scripts for data management and visualisation in computer languages that were appropriate for each component of the assessment (Table 7). Methods were developed as individual scripts to enable sections to be run and repeated as appropriate (e.g., drafting required e pressure maps to be rebuilt, to accommodate for expert feedback).

Table 7. Computer languages used for each component of the BH3 indicator assessment.

Assessment Component	Computer Language Used
MarESA sensitivity aggregations	Python
Habitat classification translations	Python & R
Fishing & aggregate extraction pressure assessments	R
Fishing & aggregate extraction disturbance assessments	R
BH3 confidence assessments	R
Summary statistics	R
Output graphs & figures	R

Automated improvements delivered through NEA PANACEA created a cost-effective and repeatable approach to undertaking assessments for key international legislative drivers, delivering the BH3 QSR 2023 assessment and forthcoming reporting obligations in 2024 for Good Environmental Status under the MSFD and UK Marine Strategy. Improvements to the method and use of automation were documented through the development of revised CEMP Guideline documents (Annex Y), including the addition of new annexes to account for the newly assessed activity, commercial aggregate extraction. NEA PANACEA funds directly contributed to updates to all CEMP Guidelines/Annexes (Annex 1-7), and the development of a suite of computer scripts in various computing languages that will be published via OSPAR, alongside the QSR 2023.

Moving forward, future work will be undertaken to strengthen the improvements made through NEA PANACEA. Methods will be made faster and more streamlined through increased computation accuracy and speed. In addition, BH3 will be developed to analyse new activities, to help meet emerging policy and science needs, such as understanding Seafloor Integrity in relation to forthcoming offshore wind developments. All future improvements and changes to the indicator will be reflected in updates to CEMP Guidelines to ensure that methods are clear, coherent and transparent.

Setting thresholds for BH3 (M3.4; D3.5a, Annex AB)

In the previous assessment cycle, thresholds for Good Environmental Status (GES) using the BH3 indicator assessment outputs were not set. Consequently, to meet national reporting requirements, OSPAR Contracting Parties previously set their own thresholds, that differed, when using the BH3 indicator to assess the status of benthic habitats. To improve consistency of determination of GES across Contracting Parties, Task 3.4 aimed to facilitate discussions on BH3 threshold values for this assessment cycle. Therefore, the Grant Proposal outlined that that Task 3.4 would: compare national thresholds reported for BH3 to give an overview of regional variation (outputs of Task 3.1); test various threshold scenarios for potential use in the QSR 2023; and submit proposals for discussion within OSPAR. Furthermore, the work undertaken to discuss, test, and set thresholds would be guided by the EU technical group on seabed habitat and seafloor integrity (TG Seabed).

The NEA PANACEA project facilitated three online workshops between members of OBHEG and policy experts in 2021 to discuss possible thresholds for the BH3 indicator. Throughout these workshops, the UK and Germany presented possible threshold options, based on their own thresholds used for previous national reporting, and their scientific rational and policy applications were discussed. As a result of workshop discussions, the BH3 indicator leads tested three possible thresholds on four broad-scale habitats in the Greater North Sea and the Celtic Seas. The testing of these thresholds was facilitated by NEA PANACEA and the results were presented at ICG-COBAM 2021 (D3.5a), for further discussion by Contracting Parties. The proposed thresholds were as follows:

- **Option 1:** At least 10% of the area of a broad habitat type is under low disturbance (categories 0-4).
- **Option 2:** At least 10% of the area of a broad habitat type is permanently without anthropogenic physical disturbance (category 0).
- **Option 3:** The area which is highly disturbed (categories 5-9) is less than 25% of the total habitat area.

The aforementioned threshold testing facilitated productive discussions at ICG-COBAM 2021. However, through discussions, it was decided further work was still required and, to meet the requirements of all Contracting Parties, any final threshold agreements would need to align with thresholds set by TG Seabed – which had not been set in 2021. Consequently, further work on BH3 thresholds was not possible within the timeframe of the project. TG Seabed also subsequently concluded that further work was still required to set thresholds for the MSFD Criterion D6C3: “Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance”. Therefore, the agreement that threshold setting for an indicator, such as BH3, was a complex task that required time for further discussions within OSPAR aligned with the findings of TG Seabed.

Nevertheless, the discussions and testing undertaken through NEA PANACEA successfully progressed the work on setting standardised thresholds for BH3. Three possible threshold options, with international policy links and scientific rational were proposed, tested, and discussed with relevant scientific and policy experts. These discussions identified valuable next steps, such as considering the socio-economic impacts of thresholds, and the need to meet the various reporting requirements of both EU and non-EU member states. The discussions and threshold testing facilitated through NEA PANCEA can provide a valuable contribution to future work on setting thresholds for physical disturbance, and the BH3 indicator specifically.

In addition to threshold setting, NEA PANACEA facilitated an OBHEG workshop in May 2022, where disturbance groups for communicating BH3 indicator results were discussed and agreed (D3.5a). Although these groups were not thresholds, the identification of 'Zero', 'Low', 'Moderate' and 'High' disturbance groups (Table 8) enhanced the communicability of the BH3 indicator assessment for end users in the QSR 2023; the disturbance groups were used to create graphical summaries of the percentage of assessment unit area, and broad habitat area within each disturbance group. Furthermore, the agreement of disturbance groups enabled possible trends in different disturbance levels over time to be easily analysed and communicated, which was an alternative approach to setting thresholds discussed in the various threshold workshops.

Table 8. Disturbance matrix with summary groups; 'Zero' (0), 'Low' (1-4), 'Moderate' (5-7), and 'High' (8-9).

Disturbance matrix		**Sensitivity**				
		1	2	3	4	5
	Null / 0*	0	0	0	0	0
Pressure	1	1	2	3	4	6
	2	1	2	4	6	7
	3	1	3	5	7	9
	4	1	4	6	8	9
	5	2	4	7	9	9

Task 3.5: Evaluate the use of the Extent of Physical Disturbance indicator BH3 and other OSPAR information to guide assessment of effectiveness of management measures (Annex AC)

Task Lead: Cristina Vina-Herbon (JNCC, UK) (Partner)

Other involved: Liam Matear, Cristina Vina-Herbon, Kirsty Woodcock, Stephen Duncombe-Smith, Adam Smith (JNCC, UK) (Partner), Petra Schmitt (BioConsult, DE) (Partner)

Other Activities involved: None

Milestones: M3.5 Receive draft BH3 assessment; D5.2c UltraCOBAM workshop

Deliverables: D3.5a Reports and maps on scenarios according to various options of thresholds and disturbance categories for BH3 indicator; D3.5b Contributions to D3.7b Benthic habitat 2022 advanced draft thematic assessment

Summary

BH3 estimates the extent of physical disturbance from anthropogenic activities (including bottom-contact fisheries). Consequently, BH3 was identified as an indicator that could facilitate the assessment of links between spatial fisheries management measures and the extent and distribution of physical disturbance to seabed habitats. Therefore, Task 3.5 aimed to analyse disturbance results from the BH3 indicator assessment over time, in conjunction with the location of Marine Protected Areas (MPAs) designated for benthic features and / or MPAs with established management measures. It was proposed that Task 3.5 would build upon the operationalisation of BH3 in the QSR 2023 (Task 3.4) and incorporate information from the OSPAR MPA Network to establish whether disturbance had decreased within MPAs with benthic features and /or within MPAs with established management measures.

Table 9. Task 3.5 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.5 preparation																								
Task 3.5 implementation																								

The expansion and operationalisation of the BH3 indicator in the OSPAR QSR 2023 (Task 3.4) resulted in two separate BH3 indicator assessments for bottom-contact fisheries (BH3a) and commercial aggregate extraction (BH3b). Both BH3 indicator assessments for the upcoming MSFD assessment cycle contained annual assessments of disturbance between 2009 and 2020 that enabled temporal assessments of disturbance in MPAs. However, disturbance from bottom-contact fisheries remained one of the most widespread human activities responsible for physical disturbance to the seabed. Therefore, Task 3.5 utilised the outputs from the BH3a indicator assessment, following the initial Task 3.5 proposal to assess disturbance from bottom-contact fisheries within MPAs.

Following consultation with the OSPAR Secretariat, information on the spatial extent of MPAs within the OSPAR maritime area, their designated features, and associated management measures were obtained. The spatial extent of the OSPAR MPA Network (as of July 2021) was obtained from the OSPAR Data and Information Management System (ODIMS) in the form of a Shapefile. The Shapefile contained polygons for 551 MPAs submitted to OSPAR by Contracting Parties before or in the year 2020. Metadata on designated features or management measures present within OSPAR MPAs were obtained separately from the OSPAR MPA database.

Within the MPA metadata, MPA features were grouped by habitat features and species features. Habitat features were used as a proxy for benthic features and species features (which were typically mobile and not necessarily seafloor dwelling, e.g., marine birds and pelagic fish species not typically assessed by BH3) were used as a proxy for non-benthic features.

Funding from the NEA PANACEA project enabled analyses of disturbance within and outside MPAs in the OSPAR framework using the aforementioned data sources (Figure 16). An initial comparison of the distribution of disturbance in 2020, in conjunction with the location of MPAs, indicated some differences in the distribution and intensity of disturbance between areas within MPAs and outside MPAs, and between areas with designated habitat features and areas without designated habitat features. These differences appeared to align with exploratory analysis of trends in the distribution and intensity of disturbance observed over time. However, an assessment of potential management drivers for differences in the distribution and intensity of disturbance was not possible due to data paucity on the presence of MPA management measures to regulate specific human activities. The aforementioned results were presented at the final NEA PANACEA meeting in April 2023, and a draft version of the written report deliverable, with associated figures, was circulated to members of the OSPAR Benthic Habitat Expert Group (OBHEG) and the International Correspondence Group for Marine Protected Areas (ICG-MPA) to seek feedback and sense-check regional results. Furthermore, the final report will be made available to other expert groups such as the Helsinki Commission (HELCOM) and the EU Technical Group on seabed habitats and sea-floor integrity (TG Seabed).

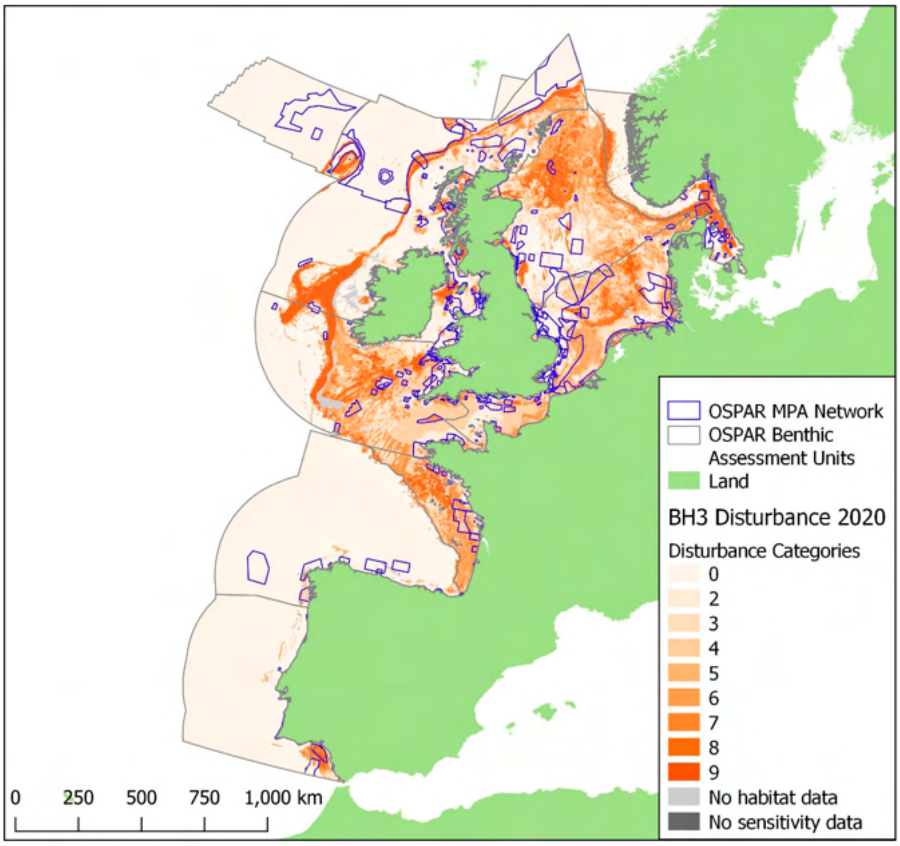

Figure 16. Spatial distribution of disturbance using VMS abrasion pressure data from 2020, with the OSPAR MPA Network overlaid. Disturbance categories ranged from "0" (0 SAR values or no reported VMS data), to "9" (most disturbed). In some instances, disturbance could not be assessed due to i) no habitat data, or ii) no sensitivity assessments for underlying habitat.

In conclusion, for the first time within the OSPAR framework, analyses undertaken through NEA PANACEA demonstrated that indicator assessments, such as BH3a, can be useful tools to evaluate possible differences in the disturbance from bottom-contact fisheries within and outside of MPAs. Additionally, work undertaken through the NEA PANACEA highlighted knowledge gaps and possible next steps to further improve understanding of the relationships between disturbance from bottom-contact fisheries and the presence of established fisheries management measures. Future work would benefit from more detailed information on established MPA management measures, and the specific human activities they regulate, to enable a full assessment of possible drivers for change in disturbance associated with bottom-contact fisheries. Exploratory findings from Task 3.5 of the NEA PANACEA project could potentially guide future assessments, should the required data on MPA-specific management measures become available and help facilitate discussions on the development of the OSPAR MPA Network, including its contribution to the reduction of seafloor disturbance.

Task 3.6: Development and first assessment of OSPAR indicator Area of habitat loss (BH4): Case study of OSPAR region II (Greater North Sea) (Annexes AD and AE)

Task Lead: Petra Schmitt (BioConsult, DE) (Partner)

Other involved: Axel Kreutle, (BfN, DE), Liam Matear, Cristina Vina-Herbon, Kirsty Woodcock, Stephen Duncombe-Smith, Adam Smith (JNCC, UK) (Partner)

Other Activities involved: None

Milestones: D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop

Deliverables: D3.6 BH4 pilot assessment and CEMP update

Summary

The OSPAR benthic habitats indicator 'Area of habitat loss' (BH4) assesses the proportion of habitat area that is subject to a permanent change of substrate or morphology due to anthropogenic pressures. Indicator BH4 together with benthic habitat indicator BH3 on 'physical disturbance to benthic habitats' completes the assessment of physical pressures on benthic habitats. BH4 can be used to assess MSFD criteria D6C1 on physical loss and D6C4 on the extent of habitat loss. The BH4 pilot assessment results and the technical specification (OSPAR Coordinated Environmental Monitoring Programme guidelines) were technically finalised and are proposed for consideration to OSPAR commission (June 2023).

Table 10. Task 3.6 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.6 preparation																								
Task 3.6 implementation																								

During the NEA PANACEA project term, the BH4 methodology to assess sealed loss by offshore structures and unsealed loss by bottom trawling and aggregate extraction was developed and a pilot assessment for the Greater North Sea was produced. Data on the distribution of offshore structures (oil and gas platforms, pipelines, offshore wind farms) were readily available from ODIMS and EMODnet. For bottom trawling the spatial layers produced by ICES could be used, while the data on aggregate extraction delivered by Contracting Parties in response to an OSPAR data call was not sufficient to conduct a spatial assessment of loss by extraction. Therefore, only the assessment methodology was outlined and a general evaluation of risk factors by aggregate extraction could be presented. For the methodology and assessment of loss by the placement of infrastructure, a literature research was carried out and based on these results the extent of loss by offshore structures in the Greater North Sea was assessed. The risk assessment of loss by bottom trawling included the development of a completely new methodology to highlight risk factors and varying degrees of the probability of substrate changes. The indicator method is outlined in the BH4 CEMP guideline (Annex AD).

The pilot assessment of habitat loss in the Greater North Sea (Annex AE) was agreed by OSPAR in December 2022. The main outcomes of the indicator are an inventory of the habitat area lost due to the placement of offshore structures per habitat type and assessment unit. A risk assessment highlights areas and habitat types most at risk from bottom trawling during the assessment periods 2009-2014 and 2015-2020 (Figure 17). Not all structures and activities contributing to loss are covered in the assessment due to lack of data. Threshold values were not discussed and set, as a simultaneous process took place at EU level in TG Seabed to agree a threshold value for the corresponding criterion D6C4. However, the newly developed BH4 indicator was acknowledged by the TG Seabed chair and considered valuable for further EU work on the assessment of loss under D6C4.

Further work on this indicator could include the assessment of other activities like dredging and disposal of sediments or coastal defence structures. Methodological improvements could include the calibration of categories proposed for trawling and dredging intensities by ground truthing. Depending on data availability, the indicator could be extended to other MSFD/OSPAR regions.

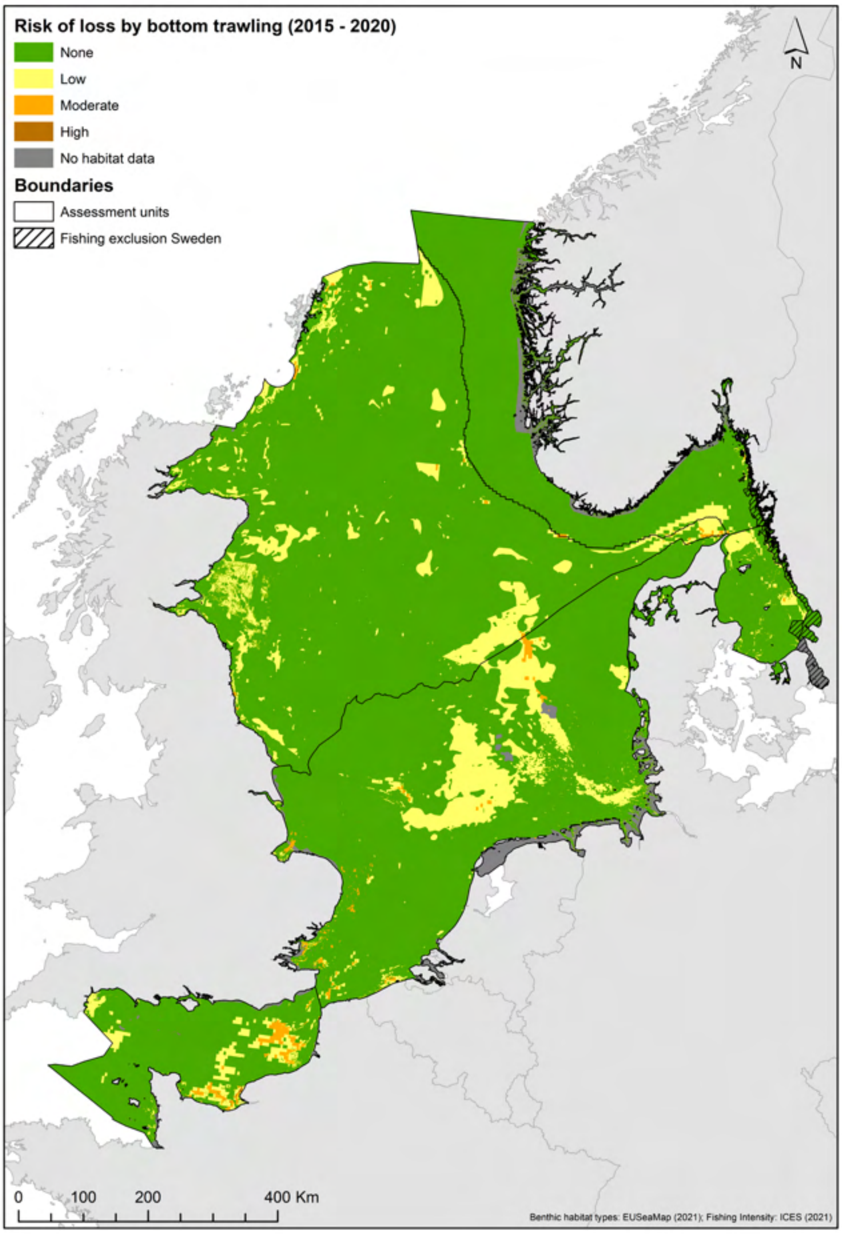

Figure 17. Distribution of risk of habitat loss by bottom trawling in the Greater North Sea for the assessment period 2015-2020.

Task 3.7: Production of the North-East Atlantic benthic habitat's thematic assessment (Annex AF)

Task Lead: Laurent Guérin (OFB, FR) (Partner), Cristina Vina-Herbon (JNCC, UK) (Partner)
Other involved: Anna Lizińska (OFB, FR) (Partner), José Manuel González Irusta (IEO, ES) (Partner), Maider Plaza Morlote (IEO, ES) (Partner), Alberto Serrano (IEO, ES) (Partner), Antonio Punzón (IEO, ES) (Partner), Liam Matear (JNCC, UK) (Partner), Stefano Marra (JNCC, UK) (Partner), Petra Schmitt (BioConsult, DE) (Partner), Sander Wijnhoven (EcoAuthor, NL) (external expert), Kirsty Woodcock (JNCC, UK) (Partner), Stephen Duncombe-Smith (JNCC, UK) (Partner), Adam Smith (JNCC, UK) (Partner), Axel Kreutle, (BfN, DE)
Other Activities involved: Activities 1, 2, 4 and 5
Milestones: D5.2a SuperCOBAM workshop; D5.2c UltraCOBAM workshop
Deliverables: D3.7 Benthic habitat thematic assessment

Summary

This Task involved the collation of evidence from all other tasks 3.1 to 3.6, notably OSPAR benthic habitat indicators BH1 to BH4 and testing integration method (Elliot et al, 2017a, 2017b, 2018) from previous EcApRHA project, to undertake a qualitative and quantitative evaluation of the overall status or health of marine benthic ecosystems. Furthermore, existing regional measures agreed upon through OSPAR are summarised and evaluated to identify geographic differences across OSPAR regions. Knowledge gaps are highlighted and lessons learned are to be communicated with other regional seas conventions, specifically HELCOM and BARCON, ICES (Benthic Ecology Working Group, in May 2023) and TG Seabed (dedicated workshop planned in October 2023). OSPAR benthic habitats thematic assessment, based on these works submitted end of 2022 (Guérin and Vina-Herbon (coord), in press), was scientifically and technically finalised and validated by lead authors in early June 2023 after several reviews by science-policy committees and processes (including European Commission representatives) and is now proposed for adoption by OSPAR commission (June 2023) to be made available notably for MSFD reporting considerations. Some innovative elements (notably synthetic integration and climate change methods, figures and tables) which were not included in the final OSPAR products, were already published and communicated at a conference (McQuatters-Gollop et al, 2022; Guérin et al., 2023a, 2023b, in prep) and will be submitted for science articles publications by the expert lead and involved experts, notably from other biodiversity components with similar approaches resulting from NEA PANACEA and OSPAR workshops.

Table 10. Task 3.7 specific deliverable timeline. Deliverables are marked in black (draft deliverables in grey), letters in each column indicate the month from March 2021 to February 2023.

Semester	Semester 1						Semester 2						Semester 3						Semester 4					
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Task 3.7 preparation																								
Task 3.7 implementation																								

Many benthic habitats within the OSPAR Maritime Area are under threat from various pressures. These include physical disturbance, modification of substrate or loss (such as abrasion by bottom-trawling, sediment extraction or man-made structures) and chemical (by nutrients enrichment or contaminants) and biological impacts (e.g. spread of non-indigenous species or native species exploitation). From these works under OSPAR and NEA PANACEA, we assessed that their impact is not uniform, and thus the state of benthic habitats and the level of threat varies across the OSPAR Regions. The indicators, data and methodology that support this thematic assessment also differ across the regions. The results of this thematic assessment should therefore be considered on Region by Region and cannot be directly compared.

This assessment, both for broad-scale habitats and those identified as threatened and declining, shows that many are in poor status, although some areas also show good status for a specific pressure and impact (eutrophication). All but one of the 18 benthic habitats that OSPAR has identified as “threatened and/or declining” show no signs of improvement in the regions where they occur. Some habitats (e.g. oyster beds and seagrass beds) also show a decrease in distribution and extent in some Regions.

In those areas where the OSPAR Common Indicators were applied, physical disturbance remains the main pressure contributing to a widespread reduction in diversity and changes in sensitive benthic communities. The Common Indicators assessing physical disturbance to the seabed by bottom trawling (BH3a) and changes to sensitive species (BH1) showed that most benthic habitats in areas where such fishing activities take place are under significant threat or impact. The diversity of benthic communities (BH2b) is particularly poor in inshore habitats of the Greater North Sea Region (the only one assessed with this indicator). Coastal waters show mainly high/good status for benthic vegetation and invertebrates with regard to eutrophication, but this remains an issue in the eastern part of the Greater North Sea, including Kattegat, and the English Channel (BH2a). However, in the Arctic Waters Region, climatic factors are the most significant variables driving the trends detected in benthic habitats.

In the face of climate change and ocean acidification, as well as increasing production of food and energy there is more than ever an urgent need to lower the pressures on benthic habitats. This can be achieved through a combination of responses including effective area-based management, sustainable use and other regulation of human activities and innovations. Where they are assessed, (i.e. in the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast), benthic habitats are already impacted by human activities.

It is difficult to assess the effectiveness of measures to improve the status of benthic habitats, due to the multiple activities and pressures involved. In addition, the effects of measures on the recovery of habitats may take a long time to become evident. However, the lack of clear signs of improvement reported here suggests that current measures have been inadequate or ineffective. This assessment provides an evidence base to help develop future response measures, for example, targeted action plans. These need to be supported by improved monitoring and access to data alongside better resolution and geographic coverage in the next iteration of assessments and measures.

Next steps

Even if the full integration method is not yet agreed or complete for the benthic thematic assessment, several “pieces of this puzzle” have already been developed and further progressed under the EcApRHA and NEA PANACEA projects, with contributions and review from the whole OSPAR Benthic Habitat Expert Group.

The indicators are being developed by the experts who lead the different work areas, using since a decade a complementary approach to ensure that indicators can be operationalised as a set and integrated in the future. There are **2 main types of OSPAR benthic indicators**:

- **Station sample-based**, used to quantify specific state-pressure relationship curves at fine scale: **BH1, BH2a and BH2b**.

- **Area and model-based**, used to estimate the impacts from pressures at wider scales, based on sensitivity values and state-pressure relationships, on broader habitat types and the OSPAR List of threatened and declining habitats: **BH3a, BH3b and BH4**.

BH2a is already **extrapolating the station results for each assessed coastal water body**, which is the relevant scale for benthic quality elements under the EU Water Framework Directive, the corresponding Norwegian water regulations (Vannforskriften) and the Water Environment Regulations and Water Environment Water and Services Act for United Kingdom waters.

The BH2 "**common approach**", a precursor of this thematic assessment, was developed as a separate "chapeau" concerning the use of several multi-metric indices to address different pressure types, but involving common requirements in terms of sampling at similar biological and geographical scales, and data requirements in terms of parameters and taxonomical referencing. The more recent **BH1** indicator, focusing on sensitivities at the species biological scale and more pressure-specific sensitivities (González-Irusta et al, 2018), is also included with these types of indicators.

More recently, BH3 was also applied to two different types of physical pressure, leading to two separate and specific assessments: BH3a considered physical disturbance by bottom-contacting fisheries, while BH3b looked at physical disturbance by aggregate extraction. Although this area- and model-based type of indicator is different from the previously mentioned BH1 and BH2, its approach and conceptual chapeau are similar, and it aims to use similar methods to assess different pressure types and thus **facilitate comparison and further methodological development** under the "common approach".

At a more advanced integration level, the **conceptual approach to link and combine (data and methods) these 2 types of indicators** has been published as a detailed deliverable of the EcApRHA project (Elliott et al., 2017a) and summarised as an article in a peer-reviewed international scientific journal (Elliott et al., 2018). Under the NEA PANACEA project, this common approach was successfully tested and published both as a CEMP appendix of BH1, also referred to in BH3 and in a pilot assessment in the Bay of Biscay and Iberian Coast. Even if there are still data and methodological limitations, this new recent step forward will help the progress **towards a more integrated method** which combines these two types of indicators to help improve methodologies and confidence in the overall assessment of benthic habitat quality status.

Despite this recent significant progress, **more working and scientific policy interactions** are still needed, at both regional-sea and European levels. In line with the steps described above, the **coordination and additional resources shared through common projects** are key to enabling this work to proceed under commonly agreed and defined timelines and priorities.

In the near future, significant progress is urgently needed to greatly improve **the monitoring that supplies the required data**, and the **scientific policy process itself,** to enable sufficient technical, methodological and management progress towards a more integrated assessment, as well as provide information and evidence to **support the evaluation of the efficiency of management measures**. This needs to happen both within and between benthic and biodiversity assessments (Elliott et al., 2017b; Padegimas et al., 2017), considering also the most recent progress made nationally and through the MSFD (Lizińska and Guérin, 2021; Guérin and Lizińska, 2022), and in wider socio-economic areas (Révelard et al., 2022).

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ACTIVITY 4 – MARINE BIRDS

Activity 4 summary

Institutions involved:

Denmark : Aarhus University
Germany: Gavia EcoResearch
Sweden: Lund University
United Kingdom: JNCC Support Co

Main Aims of Activity 4

The aim of Activity 4 was to produce an integrated thematic assessment of marine birds in the North-East Atlantic, through the delivery of four tasks covering 4 working themes (Figure 1): the development of a new indicator of breeding productivity (D1C3) and the production of the relevant indicator assessment (Task 4.1); the first application of an integrated assessment of marine birds based on a methodology developed by the European Commission's Joint Research Centre (JRC) and recommended in the Article 8 MSFD Assessment Guidance (Task 4.2), the analysis of main pressures and management responses affecting marine birds in the North East Atlantic (Task 4.3). All these deliverables were successfully delivered and fed into the thematic assessment of biodiversity for OSPAR QSR 2023 to inform EU MS MSFD reporting. In addition, Activity 4 delivered a workshop with marine birds' experts from the 4 European Regional Seas Convention during which approaches to Good Environmental Status (GES) and future collaboration were discussed (Task 4.4).

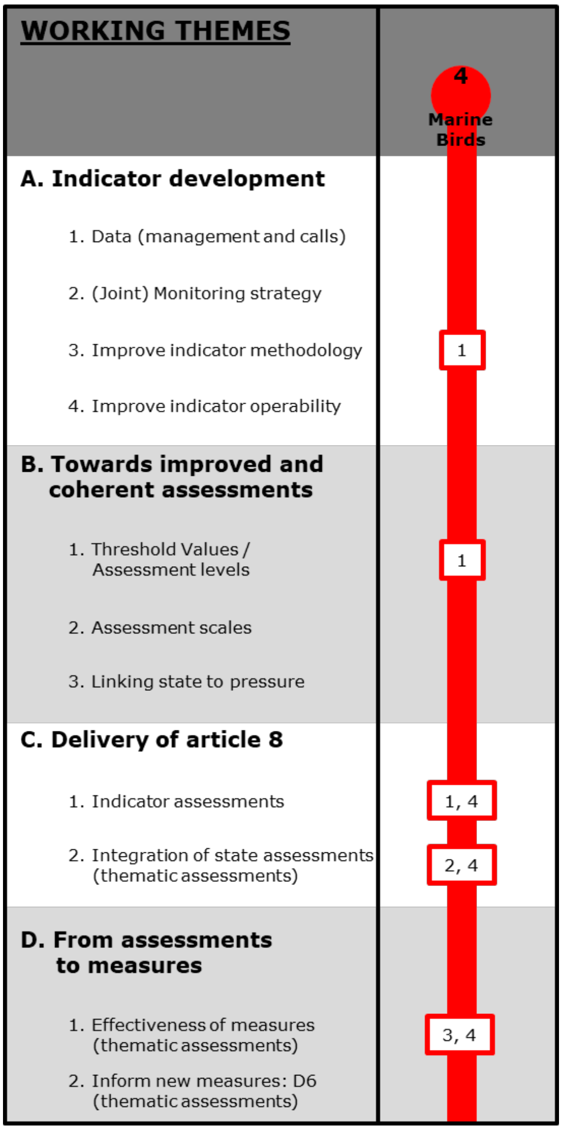

Figure 1. Activity 4 tasks (in red boxes) in relation to the MSFD working themes.

Activity 4 working arrangements

The Activity 4 leads were Stefano Marra, Matt Parsons (JNCC, UK) and Volker Dierschke (Gavia EcoResearch, DE) that jointly coordinated the delivery of the work.

The Activity 4 team included additional colleagues from JNCC (UK) and from Aarhus University (DK), the latter leading on the analyses for task 4.1 and contributing to the revision of deliverables of tasks 4.2, 4.3 and 4.4

At the start of the project, the Activity 4 team agreed a set of online meetings to update on the progress of the work and ensure task delivery remained on track. Additional ad-hoc meetings were set up throughout the project, to discuss and address any challenges that arose. At each meeting a detailed list of actions was produced with a clear allocation of actions to individuals.

The Activity 4 team used an MS Teams site set up by JNCC to share files and resources needed to produce the required deliverables.

The delivery of Activity 4 was significantly affected by long delays in the submission of the data by OSPAR contracting parties. As a result, the abundance indicator (D1C2, worked on outside the NEA PANACEA project) could only be processed with a very long delay. The same was true for the breeding success indicator (delivered under Task 4.1), as it depends on results from the abundance indicator. Consequently, the integrated assessment and the thematic assessment (Task 4.2) were completed later than planned (Figure 2).

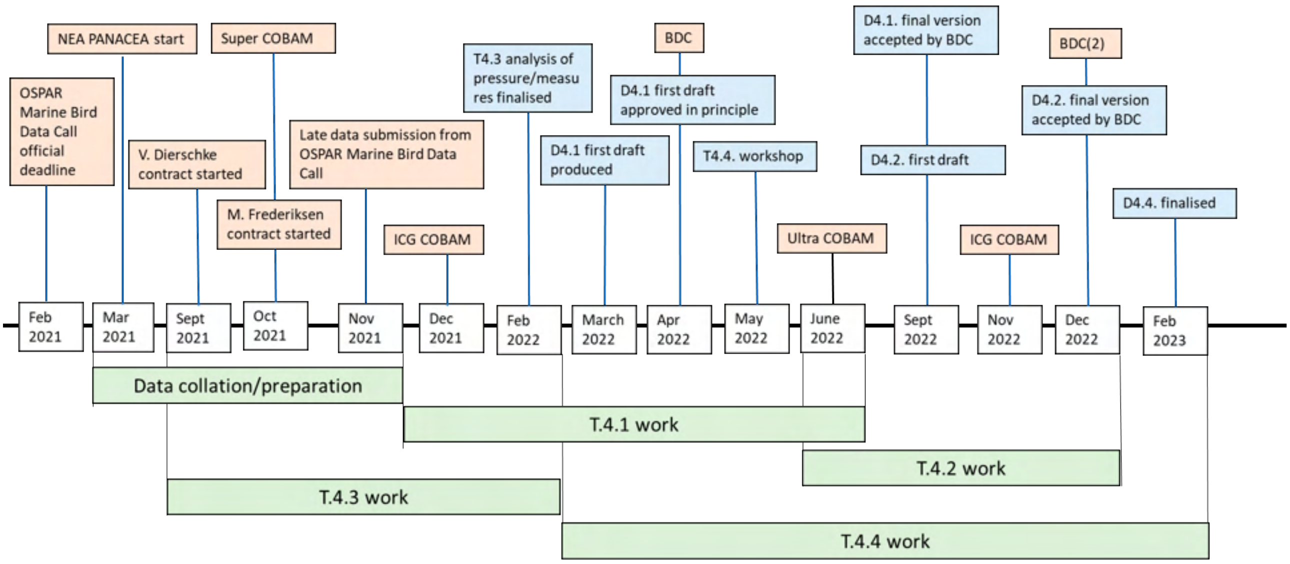

Figure 2. Delivery timeline for Activity 4.

Task 4.1: Breeding productivity indicator (Annexes AG and AH)

Task Lead: Stefano Marra, Matt Parsons (JNCC, UK) (Partner), Volker Dierschke (Gavia EcoResearch, DE) (sub-contractor)
Others involved: Morten Frederiksen (Aarhus University, DK) (Sub-contractor)
Other Activities involved: None
Milestones: D5.2a SuperCOBAM, D5.2c UltraCOBAM workshop
Deliverables: D4.1 Indicator assessment of bird breeding productivity indicator

What we promised

The aims of Task 4.1 were to support the co-ordinated regional assessment of GES in marine birds by completing development of an enhanced threshold-setting method for marine bird breeding productivity (D1C3). As long-lived species with delayed maturity, changes in the productivity of seabirds and other marine birds are expected to reflect changes in environmental conditions long before these are evident as changes in population size (D1C2). Breeding productivity in marine birds can, therefore, be a valuable indicator of population health. Consequently, an indicator of breeding productivity can add value to assessments of the status of species by helping to identify possible causes of population decline and by acting as an early warning of possible future declines and of changes in the marine environment. This Task will use the improved method to update the assessment of the OSPAR Common Indicator on marine bird breeding productivity (D1C3) in three sub-regions of the Northeast Atlantic. In doing so it will demonstrate how the method can be applied to other sub-regions or regions where assessments of marine bird breeding productivity are required as an indicator of population health.

What we delivered

Task 4.1 successfully delivered an indicator assessment of bird breeding productivity. The full assessment was agreed and published by the OSPAR Commission in the QSR2023 (see Annex AG). The new methodology for the indicator that was developed by NEA-PANACEA has also been agreed and published by the OSPAR Commission (see CEMP guideline, Annex AH). This task also produced the Addendum 1 MSFD results table, required by the OSPAR Commission as part of the indicator assessment package of the indicator. All outputs produced under Task 4.1 completed the deliverable D4.1 (Indicator assessment of bird breeding productivity indicator).

This assessment was conducted in three of the NE Atlantic sub-regions: Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast; plus the OSPAR Region I: Arctic Waters. The assessments of Greater North Sea and Celtic Seas include UK waters. The assessment can be used by EU Member States to assess the condition of marine birds against criterion D1C3 when assessing whether GES has been achieved for marine bird groups. The assessment includes species of surface feeders, water columns feeders and wading feeders, depending on the sub-region.

Under task 4.1, a sophisticated indicator of marine bird breeding productivity was developed. This indicator replaces the indicator of breeding success/failure that was used for the previous assessment cycle. The new indicator addresses some of the limitations of the previous indicator. By focusing on the extreme event of colony failure, the indicator of breeding success/failure did not identify other years where poor breeding productivity could still have significant negative impacts on the population in the long-term.

The new approach predicts how observed levels of breeding productivity may impact on the long-term population growth rate of a species.

This indicator derives from time series of mean breeding productivity for each species and sub-region with sufficient data. Through a demographic modelling approach, the expected impact of the observed level of breeding productivity on population growth rate is estimated. Species-specific thresholds for expected growth rates are derived from the criteria used by the International Union for the Conservation of Nature (IUCN) to establish species conservation status. The frequency of failure to pass these thresholds is aggregated for MSFD/OSPAR regions and for functional groups of marine birds (Figure 3).

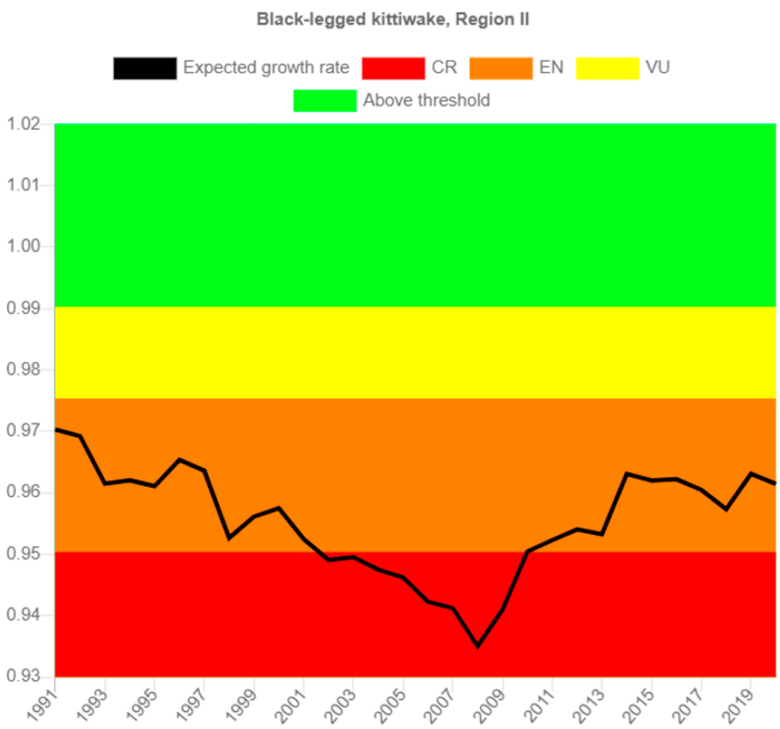

Figure 3. Expected annual population growth rate of black-legged kittiwake in the Greater North Sea, 1991 to 2020 (black line) (Source: Frederiksen et al., 2022).

Breeding productivity is one of the demographic determinants of population growth rate. Therefore, results of this assessment should be viewed as an early warning of changes in population status, and thus complement the assessment of marine bird abundance. At the same time, annual breeding productivity of marine birds is a sensitive indicator of the ability of marine ecosystems to support higher trophic level predators.

The assessment for Marine Bird Breeding Productivity produced under task 4.1 showed that across Arctic Waters (OSPAR Region I) and in the Greater North Sea and Celtic Seas, for most marine bird species breeding productivity was so poor that future population size declines are likely. Breeding productivity was above threshold for the two species assessed in Bay of Biscay and Iberian coast (Table 1, Table 2).

Table 1. Predicted future conservation status for marine bird species in the North-East Atlantic based on the expected growth rate observed in the last year of the time series within each sub-region and in Arctic Waters (OSPAR Region I). (Source: Frederiksen et al., 2022*)*

Insufficient data / Not breeding
Breeding productivity too low to sustain population
Breeding productivity sufficient to sustain population

Feeding guild	Species (common name)	Arctic Waters	Greater North Sea	Celtic Seas	Bay of Biscay and Iberian Coast
Surface Feeders	Northern fulmar		EN	CR	
	Great skua		EN		
	Arctic skua		CR		
	Herring gull		CR ↓	EN	
	Common gull		CR ↓		
	Lesser black-backed gull	↑	EN ↓	↑	
	Great black-backed gull		EN	↑	
	Black-headed gull		CR ↓		
	Black-legged kittiwake	CR	EN	EN	
	Roseate tern				
	Common tern		CR ↓	VU ↑	
	Arctic tern		CR ↓	EN ↓	
	Little tern		↑		
	Sandwich tern		↑		
Wading Feeders	Eurasian spoonbill				
	Eurasian oystercatcher		CR		
	Pied avocet		EN ↑		
Water column Feeders	Great cormorant			EN	
	European shag	↑			
	Northern gannet				
	Razorbill	EN		VU ↑	
	Black guillemot	EN ↓			
	Atlantic puffin	VU	VU ↑		
	Common guillemot		↑		
	Brünnich's guillemot	EN			

Table 2. The proportion of all marine bird species for which breeding productivity is sufficient to avoid population declines, per species group in each sub-region and in Arctic Waters (OSPAR Region I). (Source: Frederiksen et al., 2022*)*

Threshold achieved (≥75%)
Threshold failed (<75%)

	Percentage of species above assessment threshold value for breeding productivity			
Functional group	Arctic Waters	Greater North Sea	Celtic Seas	Bay of Biscay and Iberian coast
Wading feeders		33% (3)		
Surface feeders	80% (5)	21% (14)	58% (12)	100% (2)
Water column feeders	43% (7)	83% (6)	60% (5)	
All	58% (12)	39% (23)	59% (17)	100% (2)

How we delivered

- Data for this task were obtained from OSPAR Contracting Parties via a data call that was issued in November 2020 by the OSPAR Secretariat for marine bird data in order to update bird assessments in QSR2023. Data consisted of annual estimates of breeding success (i.e. the average number of chicks fledged per breeding pair) for each seabird colony or waterbird breeding site during the period 1990-2020.
- JNCC undertook additional checking, cleaning and gap-filling of the breeding success data sourced from the data call. Additionally, JNCC provided time series of relative breeding abundance that were required to produce species specific models of breeding productivity, obtained from the analyses of Marine Bird Abundance indicator (produced outside of the NEA PANACEA project).
- The models and analyses for the breeding productivity assessment were produced by Dr Morten Frederiksen (Aarhus University, DK) who was contracted for this task under the NEA PANACEA project.
- The outputs of the analyses were used by JNCC to produce the indicator assessment and Morten Frederiksen reviewed and checked drafts versions.
- Morten Frederiksen updated the Marine Bird Breeding Productivity CEMP Guidelines and supported the completion of the Addendum 1 MSFD results table required as part of the assessment package of the indicator.
- Interim results and draft assessments of the Breeding Productivity indicator were shared with the OSPAR-HELCOM-ICES Joint Working Group on Marine Birds (JWGBIRD) for revision and quality assurance.
- Updates with the progress of this task, draft versions of the Breeding Productivity indicator assessment and final outcomes were presented at OSPAR ICG-COBAM and BiTA meetings, including the SuperCOBAM and UltraCOBAM workshops organised under Activity 5 of NEA PANACEA
- A first full draft of the Breeding Productivity indicator was presented at OSPAR BDC and agreed in principle in April 2021. A final version of the assessment that included refined outputs was delivered on September 2022 and agreed by OSPAR Contracting Parties following a written procedure.
- The methodology for the Breeding Productivity indicator resulting from the work conducted under Task 4.1. has also been described in a peer-reviewed paper accepted, subject to revisions, for publication in IBIS: *Frederiksen et al* "*Model-based assessment of marine bird population status using monitoring of breeding productivity and abundance*"

Next steps

The breeding productivity indicator has the potential to integrate other demographic parameters beyond those used in this assessment. Therefore, this indicator has opened the door to a more comprehensive seabird assessment, potentially via a sophisticated Integrated Population Modelling approach.

Task 4.2: An integrated assessment of marine birds in the Northeast Atlantic (Annexes AI and AJ)

Task Lead: Stefano Marra, Matt Parsons (JNCC, UK) (Partner), Volker Dierschke (Gavia EcoResearch, DE) (sub-contractor)

Other involved: Ian Mitchell (JNCC, UK) (Partner), Fredrik Haas (Lund University, SE) (invited expert to provide support for D5.2c UltraCOBAM workshop)

Other Activities involved: None

Milestones: D5.2a SuperCOBAM, M4.2a Integration method for marine bird indicators, D5.2c UltraCOBAM workshop

Deliverables: D4.2 OSPAR Thematic Assessment of marine birds

What we promised

Task 4.2 will support the co-ordinated regional assessment of GES in marine birds by integrating the results on marine bird productivity (D1C3) from task 4.1 with other OSPAR indicator assessments (covering D1C1, D1C2 and D1C5), conducted within the OSPAR QSR process, but outside this Action. It will test integration methods under development by the Commission at a regional scale. In doing so it will demonstrate how these methods can be applied to other sub-regions or regions where assessments of GES in marine birds are required. The task outputs on regional integration methods for birds will be of interest to groups such as WG-GES and others connected with the MSFD Common Implementation Strategy. It will also deliver an assessment of GES of marine bird species and species groups in three subregions of the Northeast Atlantic: Greater North Sea, Celtic Seas and Bay of Biscay & Iberian Coast. The assessment of GES can be used by Member States for their reporting of progress under Article 8 MSFD in 2024. We will also carry out an integrated assessment of the state of marine bird populations in parts of OSPAR Region I - Arctic Waters, where data are available.

What we delivered

Task 4.2 successfully delivered an integrated assessment of marine birds for the Northeast Atlantic (Annex AI) applying for the first time an integration methodology developed by JRC (Dierschke et al. 2021) and followed the latest Article 8 MSFD Assessment Guidance (European Commission 2022). The integrated assessment of marine birds was agreed by the OSPAR Commission and permitted the delivery of the "State" chapter of the Marine Bird Thematic Assessment in the OSR 2023. The methodology to produce an integrated assessment for marine birds was also summarised in a CEMP guideline (Annex AJ), as required by the OSPAR Secretariat for the submission of the Marine Bird Thematic assessment. The outputs produced under Task 4.2 completed the deliverable D4.2 (OSPAR Thematic Assessment of marine birds).

The integrated assessment was conducted in three Northeast Atlantic sub-regions (Greater North Sea, Celtic Seas and Bay of Biscay & Iberian Coast) plus the OSPAR Region I: Arctic Waters. The integrated assessment of the Greater North Sea and Celtic Seas included data from UK waters.

The integrated assessment was based on the common indicator on marine bird abundance (D1C2), delivered outside of the NEAPANACEA project) and the common indicator on marine bird breeding productivity (D1C3) delivered as part of Task 4.1. Other OSPAR indicators (covering D1C1, D1C2 and D1C5) were not included in the integration process following the decision of OSPAR Contracting Parties not to include candidate indicators (BDC 22/9/1 decision 3.7.a). Assessments of three OSPAR Threatened and/or Declining Species of bird (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/) were also included in the integration process, because there were insufficient data for these species to conduct common indicator assessments.

Status assessments were conducted for each element (i.e. marine bird species or breeding/non-breeding population) and feature (i.e. functional species group). Marine birds are allocated to five functional groups:

i. surface-feeding birds
ii. water-column-feeding birds
iii. benthic-feeding birds
iv. wading birds
v. grazing birds

The status of a marine bird species (or population) is derived from the integration of the outcomes of different indicators which represent different MSFD criteria. If a species occurs in an assessment area with two or more populations, e.g. when breeding birds and wintering birds from the same species do not belong to the same population, these are assessed separately.

The schematic in Figure 4 shows the integration approach applied in task 4.2: The status of a species group can be found by the integration of the status of the associated species. The approach for integration is based on two steps:

1) from criteria results to individual species / population status (conditional rule)
2) from individual species / population status to species group status (proportional rule).

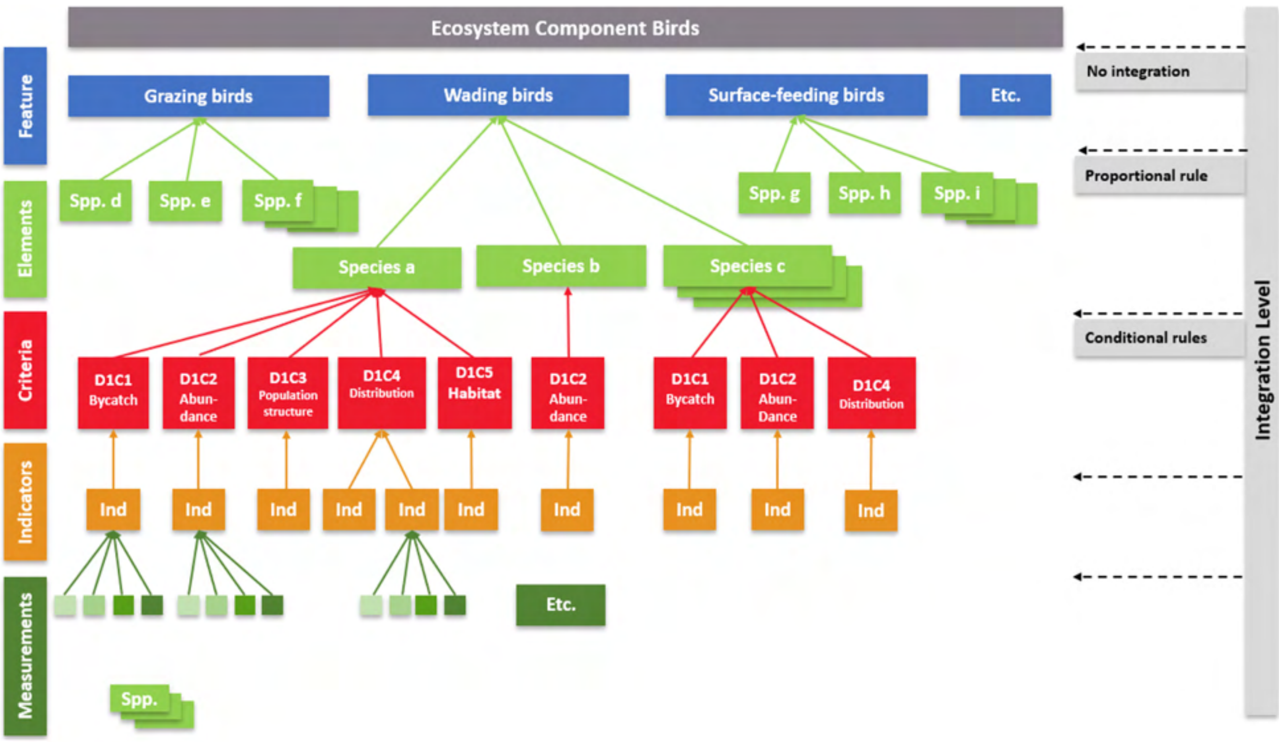

Figure 4. schematic of the integrated assessment method for marine birds. (Source: OSPAR QSR 2023)

The conditional rules acknowledge the high informative value of the criteria of by-catch, abundance and demography, which are directly informative of the prospects of a population, and use the criteria of distribution and habitat for the species as additional decision support factors (as these criteria reflect the environmental conditions for a population) (Figure 5).

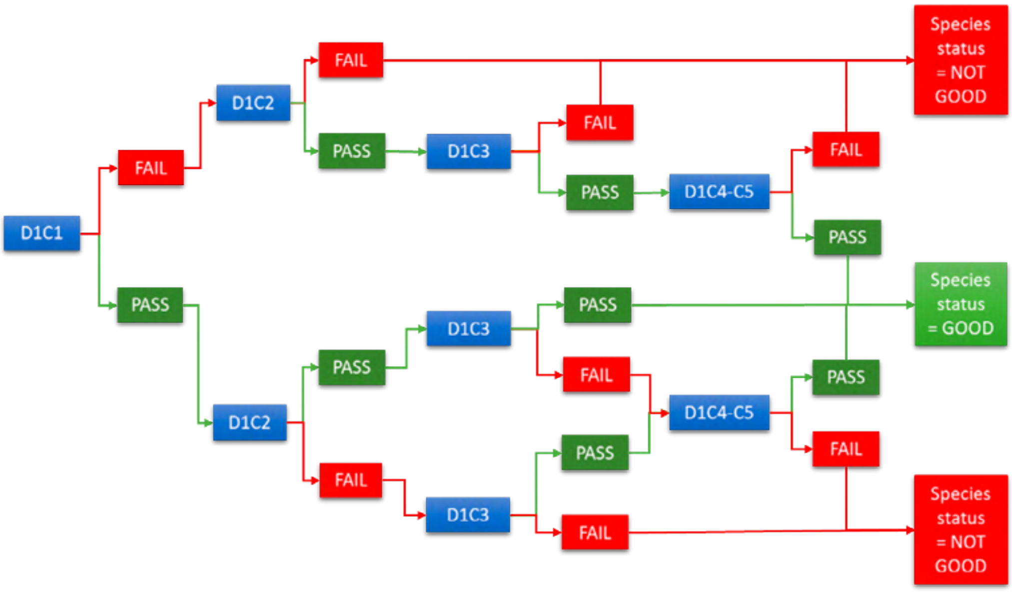

Figure 5. Conditional rule in the scenario of all criteria available. (Source: OSPAR QSR 2023)

The rationale behind these rules is described in Dierschke et al. (2021). If at least five species (or populations) of a species group can be assessed, the following proportional rule shall be applied: If 75 % of all species (or populations) are in good status then the species group is considered to be in good status. Following OSPAR BDC decision not to include candidate indicators in the integration, the QSR 2023 integrated assessment can only build on two OSPAR Common Indicators: Marine Bird Abundance (D1C2) and Marine Bird Breeding Productivity (D1C3).

Where data were insufficient for indicator assessments, they were supplemented for by OSPAR Threatened and Declining Species of bird status assessments – for the *fuscus* subspecies of lesser black-backed gull, Iberian guillemot (Iberian population of common guillemot) and Balearic shearwater.

Table 3 provides an example of how results for integrated status assessment are presented in the QSR 2023 thematic assessment for Marine Birds. Similar tables are produced for the other functional groups in the State chapter of the thematic assessment.

*Table 3[1]. Example of an integrated status assessment of marine bird features (e.g. Surface feeding species/populations) using OSPAR common indicators to assess criteria: D1C2 - marine bird abundance and D1C3 – marine bird breeding productivity. Breeding populations (B) and non-breeding populations (NB) are assessed separately. Green: indicator threshold achieved or status good; Red: indicator threshold not achieved or status not good; OSPAR Threatened and Declining Species are shown in italics; * status solely derived from status assessment. (Source: OSPAR QSR 2023)*

		Arctic Waters (OSPAR Region I)			Greater North Sea			Celtic Seas			Bay of Biscay and Iberian Coast		
	Surface feeders	D1C2	D1C3	Status	D1C2	D1C3	Status	D1C2	D1C3	Status	D1C2	D1C3	Status
B	*Black-legged kittiwake*			not good			not good			not good			not good
B	Black-headed gull						not good			not good			good
NB	Black-headed gull						good						
B	Mediterranean gull												good
B	Common gull						not good			good			
NB	Common gull			good			good						
B	Great black-backed gull			good			not good			good			good
NB	Great black-backed gull			not good			not good						
B	European herring gull			good			not good			not good			not good
NB	European herring gull			good			not good						
B	Lesser black-backed gull			good			not good			not good			good
NB	Lesser black-backed gull						good						
B	*Lesser black-backed gull (subspecies fuscus)*			not good*									
B	Sandwich tern						good			good			good
B	Little tern						good			good			
B	*Roseate tern*						good						
B	Common tern						not good			not good			good
B	Arctic tern						not good			not good			
B	Great skua			good			not good			good			
B	Arctic skua						not good						
B	Northern fulmar			not good			not good			not good			
NB	*Balearic Shearwater*						not good*			not good*			not good*
	Number of species in good status			**6**			**6**			**5**			**6**
	Number of species not in good status			**4**			**14**			**8**			**3**
	Proportion of species in good status			**60%**			**30%**			**38%**			**67%**
	State of species group			**not good**			**not good**			**not good**			**not good**

1 Note that the assessments of Greater North Sea and Celtic Seas include UK waters.

The integrated status of marine bird elements (i.e. species/population) was assessed using indicators of (a): breeding and non-breeding abundance (D1C2) and (b): breeding productivity (D1C3) for five features or species groups in three sub-regions and OSPAR Region I – Arctic Waters. Good environmental status was not achieved for surface-feeding birds, water column-feeding birds, benthic-feeding birds and wading feeding birds in all areas in which these group could be assessed. Good status was achieved by grazing feeding birds in the Celtic Seas and Greater North Sea sub regions and in OSPAR Region I – Arctic Waters. The overall status is "not good" for marine birds in three sub-regions and OSPAR Region I – Arctic Waters. No assessment could be made of the Wider Atlantic (corresponding to the sub-region Macaronesia) (Figure 6) The assessments of Greater North Sea and Celtic Seas include UK waters.

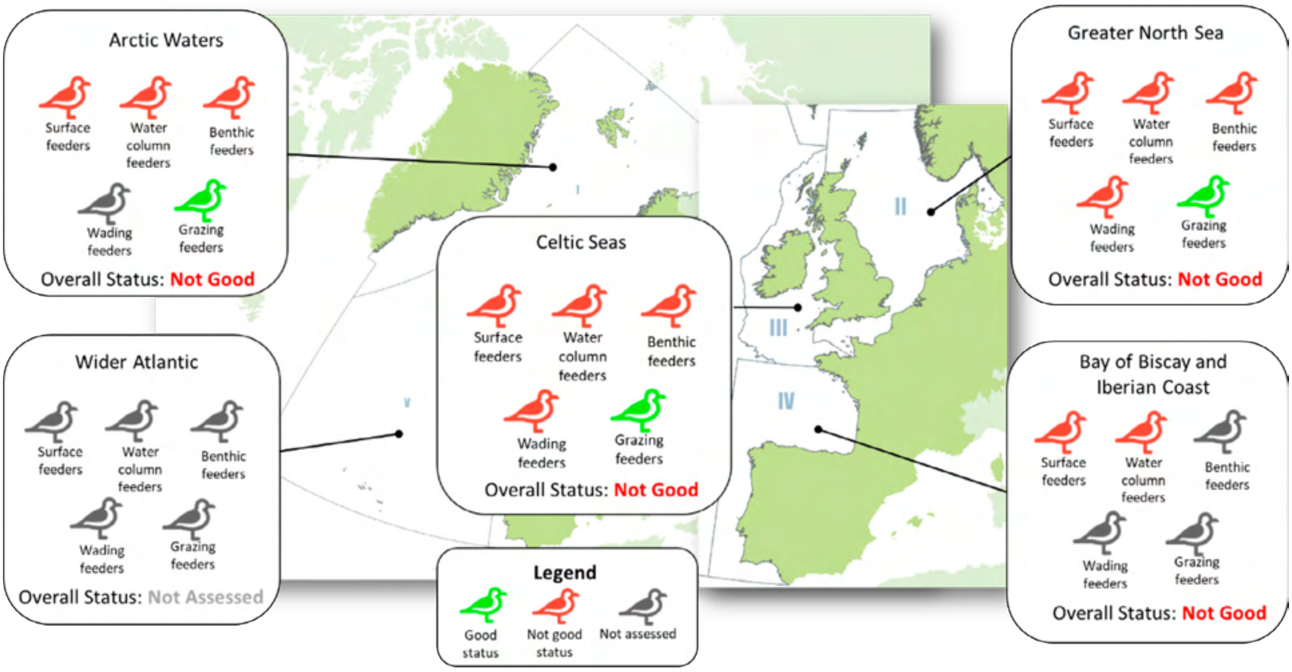

Figure 6. The integrated assessment of Marine Birds. (Source: OSPAR QSR 2023, Annex AI)

Retrospective assessments based on the integration methodology were also run to identify changes in state since 2010 and thus compare the latest QSR with the results that would have been presented in QSR 2010 if the same method was applied. The comparison 2010-2020 gave no evidence for improvement in the situation for marine birds (i.e. poor status was maintained or even became worse for some species).

How we delivered

- Volker Dierschke produced the integrated assessment for Marine Birds once the final results of the common indicator assessments (bird abundance, breeding productivity) became available in September 2022.
- The Activity 4 leads jointly produced the integration CEMP guidelines, which summarised the steps required to produce an integrated assessment of marine birds.
- The Task 4.2 team jointly updated the State chapter of the Marine Bird Thematic assessment, describing the results of the integration method and including additional information from candidate indicators and OSPAR Threatened and Declining Species of bird assessments.
- Updates with the progress of this task, draft versions of the integrated assessment and final outcomes of this task were presented at OSPAR ICG-COBAM and BiTA meetings, including the SuperCOBAM and UltraCOBAM workshops organised under Activity 5 of NEA PANACEA

- Interim results and draft assessments of the Marine Bird Thematic Assessment were shared with the OSPAR-HELCOM-ICES Joint Working Group on Marine Birds (JWGBIRD) for revision and quality assurance.
- The finalised version of the Marine Birds Thematic Assessment was agreed by Contracting Parties at BDC(2) meeting in December 2022

Next Steps

Future assessments would benefit from the inclusion of additional indicators covering more MSFD criteria in the integration rules.

Task 4.3: Pressure impacts on birds and management responses (Annexes AI, AK, AL and AM)

Task Lead: Stefano Marra, Matt Parsons (JNCC, UK) (Partner), Volker Dierschke (Gavia EcoResearch, DE) (sub-contractor)

Other involved: Marco Fusi, Hannah Wheatley, Holly Baigent (JNCC, UK)

Other Activities involved: None

Milestones: D5.2a SuperCOBAM, M4.3a Draft overview of pressures on marine birds, M4.3b Draft overview of measures for marine birds, D5.2c UltraCOBAM workshop, M4.3c Completed overview of pressures on marine birds, M4.3d Completed overview measures for marine birds

Deliverables: D4.2 OSPAR Thematic Assessment of marine birds

What we promised

This Task will identify the main pressures impacting marine birds (including climate change) in the North East Atlantic and will assess the effectiveness of measures that have been put in place to reduce these pressures. This assessment will support EU Member States to review and revise their definitions of GES (Article 9 MSFD) and their environmental targets (Article 10 MSFD) in 2024 and allows them to adjust and update their programmes of measures (Article 13 MSFD) in 2026. This task will also support the compilation of a marine bird thematic assessment as part of the OSPAR QSR 2023.

The main pressures impacting on marine birds within the North Atlantic will be identified using mainly existing reports from EU member States under MSFD Art 8 reporting in 2018 and Birds Directive Art 12 reports in 2019. The aim will be to identify the main threats on marine birds in each sub-region. The next step will look at whether current measures are being directed effectively to reduce the impacts of these pressures. The analysis of measures will be validated by experts from JWGBIRD and from other regions at the workshop under Task 4.4. The results will feed into the Thematic Assessment of biodiversity in the OSPAR QSR2023.

What we delivered

Under Task 4.3 an analysis of main reporting sources was conducted to identify key pressures and management responses affecting marine birds in the OSPAR maritime area. This exercise contributed to the “Pressure” and “Response” chapters of the Marine Birds Thematic Assessment. The details of the analyses conducted under this task were summarised in a short document hyperlinked to the Pressure chapter of the Marine Bird Thematic Assessment as a supplementary material. Additional documents detailing the steps taken to summarise information from main reporting sources on management measures were also produced but these documents were not included as supplementary material in the thematic assessment due to large data gaps encountered. Key information (with relevant caveats) from the analyses of management measures was however included in the ”Response” chapter of the thematic assessment.

All outputs produced under Task 4.3 contributed to the finalisation of the deliverable D4.2 (OSPAR Thematic Assessment for marine birds, Annex AI)

- *TA Birds Pressures – Supplementary Material* (Annex AK)
- *Measures MSFD* (Annex AL)
- *Responses_BirdDirectiveArticle12* (Annex AM)

For the analyses of pressures and management measures related to marine birds, the following reporting sources were investigated:

- OSPAR MPA database
- MSFD Art 8 reporting
- MSFD Art 16 reporting
- Birds Directive Reporting Art 12

After extracting information about pressures from the available sources with the highest spatial and temporal resolution possible, the relative importance of the individual pressures was evaluated. First, for each source it was quantified how often the individual pressures were mentioned or occurring per species group and per region. Considering that the type of information extracted by each reporting source is different (e.g. number of reports for MSFD Art 8, number of species exposed to pressure for the OSPAR MPA database), a scoring system was developed to rank the relative importance of individual pressures and make results comparable across reporting sources.

From the results of this investigation, it was generally apparent that disturbance and additive mortality are the most important pressures (**Table 4**)

However, the overall confidence in the assessment of relative importance of individual pressures was considered low: various gaps were highlighted in the four reporting sources analysed, spanning from (often severe) uncertainties regarding the pressure categories used, incomplete coverage of regions to limited details/coverage of the bird species reported.

Table 4. Overall assessment of importance of pressures on marine birds in the OSPAR Maritime Area. (Source: OSPAR QSR 2023)

	Overall Assessment	Birds Directive Art. 12 Reporting	MSFD Art. 8 Reporting	MSFD Art. 16 Assessments	OSPAR MPA database
Physical loss	**medium**	medium		low	high
Physical disturbance to seabed	**medium**	high	low	medium	high
Changes to hydrological conditions	**medium**	medium	low	low	medium
Input of anthropogenic sound	**medium**	high	low		high
Input of other forms of energy	**low**	low	low	low	medium
Input of litter	**medium**	medium	medium	low	medium
Input of nutrients	**medium**	medium	low	low	medium
Input of organic matter	**low**	low	low		medium
Input of other substances	**medium**	medium	medium	low	medium
Input of water	**no importance**				
Input of genetically modified species and translocation of native species	**low**				medium
Input of microbial pathogens	**low**			low	medium
Input or spread of non-indigenous species	**medium**	medium	low	low	high
Selective extraction of species, including non-target catches	*				high
Loss of, or change to, natural biological communities due to cultivation of animal or plant species	**low**	low	low		
Disturbance of species	**high**	high	high	low	high
Extraction of, or mortality/injury to, wild species	**high**	high	medium	high	high

The level of information available on management measures affecting marine birds was scarce. It has become apparent that the measures are very general and the reporting on them is not detailed enough to evaluate the success of these measures.

How we delivered

- The Task 4.3 team divided the screening of the 4 reporting sources among members.
- The steps taken to screen each reporting source were detailed in the following documents:
  - TA Birds Pressures – Supplementary Material: this document focused on the results of the screening for the main pressures affecting marine birds. The document was included as supplementary material in the "Pressure" section of the Marine Birds Thematic Assessment. For each reporting source, there is a section detailing the steps taken to conduct the screening, a summary of the results and a confidence assessment of the information obtained. A final section summarises the key findings from all reporting sources, providing an overall assessment of relative importance of pressures in the OSPAR Maritime Area
  - Measures MSFD: this document details the results of the screening of key management measures from MSFD Article 8 and 16 reports.
  - Responses_BirdDirectiveArticle12: this document details the results of the screening of key management measures from Birds Directive Article 12 reports.
- The analyses for Task 4.3 were finalised in February 2022
- Updates with the progress of this task, draft versions of the Thematic Assessment and final outcomes of this task were presented at OSPAR ICG-COBAM and BiTA meetings, including the SuperCOBAM and UltraCOBAM workshops organised under Activity 5 of NEA PANACEA
- Interim results and draft assessments of the Marine Bird Thematic Assessment were shared with the OSPAR-HELCOM-ICES Joint Working Group on Marine Birds (JWGBIRD) for revision and quality assurance.
- The finalised version of the Marine Birds Thematic Assessment was agreed by Contracting Parties at BDC(2) meeting in December 2022

Next Steps

Future assessments would benefit from more detailed information available from the sources used for this assessment. This includes stronger linkage between pressures/impacts, marine bird species and marine (sub) regions.

Task 4.4: JWGBIRD-plus workshop (Annex AN)

Task Lead: Stefano Marra, Matt Parsons (JNCC, UK) (Partner), Volker Dierschke (Gavia EcoResearch, DE) (sub-contractor)
Other involved: Ian Mitchell, Hannah Wheatley (JNCC, UK), Morten Frederiksen (Aarhus University, DK)
Other Activities involved: None
Milestones: M4.4 Marine bird expert workshop, D5.2c UltraCOBAM workshop
Deliverables: D4.4 Action plan for marine bird assessments in OSPAR Region

What we promised

Task 4.4 will contribute to the regional assessment of GES in marine birds in other marine regions by delivering the outputs of this activity to a specially convened workshop of seabird experts from all four European Regions. The workshop will be hosted by the Task lead in Aberdeen UK in Spring 2022. It will comprise the membership of JWGBIRD nominated by ICES, OSPAR and HELCOM, plus specially invited experts from Macaronesia (e.g. affiliated with the MISTIC Seas projects), the Mediterranean (affiliated with the Barcelona Convention) and the Black Sea.

The aims of the workshop will be to share approaches to GES assessments of marine birds in the four Regional Seas Convention (RSC) areas to identify regional synergies and differences. The workshop will also help to validate and refine the outputs from the other tasks in this activity. The main output from JWGBIRD-plus will be an Action plan detailing priorities for future co-working and establishing best practice for assessing GES in marine birds across the four regions.

What we delivered

Task 4.4. successfully delivered a hybrid workshop called "*NEA-PANACEA: From Assessment to Action*" that was held in the UK in May 2022. The workshop included attendees from OSPAR, HELCOM and UNEP-MAP conventions with 24 experts on marine birds joining in person and/or online from various European and African countries of the North-East Atlantic Ocean, the Baltic Sea and the Mediterranean Sea regions. The workshop enabled the sharing of experiences of GES assessment and efforts to restore and maintain marine birds across Europe's Regional Seas- and to map future collaboration. The workshop report (Annex AN) completed the deliverable D4.4 (Action plan for marine bird assessments in OSPAR Region).

During the 3 days of the workshop, the following themes were discussed:
- Approaches to GES
- interpreting and communicating assessments
- policy responses to declines in marine bird populations
- ways forward

A workshop report was produced detailing the key messages for each of the themes discussed. The last session of the report consists of an Action Plan for future collaboration on GES assessment. This section includes:
- Priorities that could be addressed through increased future collaboration between RSCs
- Options to maintain engagement for future collaboration
- Options for funding opportunities

The workshop identified a need for and a desire among participants to maintain and develop collaboration between RSCs, both for future assessment and reporting of GES but also to share best practice and collaborate on future action on seabird recovery. Participants discussed the possible existing fora that might be used as a basis for taking forward such collaborations. The two that received most discussion were JWGBIRD and the African-Eurasian Migratory Waterbird Agreement technical committee (AEWA); BirdLife International was also suggested as a possibility.

Figure 7. Workshop attendees.

How we delivered

- Task 4.4 leads developed and agreed the 4 themes to discuss at the workshop and prepared the agenda around these themes. Each theme included an introduction session in which presentations were provided for the different RSC, followed by a discussion session.
- JNCC coordinated the logistic for the workshop and assisted participants who were less able to fund attendance by coordinating the expenses reimbursement using funds available for this task
- In advance of the workshop, attendees were provided with background material and with the list of questions that would have been discussed for each theme. By doing so, it was ensured that attendees came prepared and informed on the aims of the discussion maximising their input.
- A sharepoint site was set up for the workshop, were notes and background material was accessible for all attendees.
- The outcomes of the workshop were summarised in a report by the Task 4.4 leads. The final section of report defines an Action Plan for future collaboration on GES assessment and action planning in the four Regional Seas areas, thus delivering D4.4.
- The draft version of the report was shared with the workshop attendees for revision and comments received addressed to produce the final version in February 2023.

Next Steps

The outputs of the workshop will be used as a basis for further discussion on the development of an Action Plan detailing priorities for future co-working and establishing best practice for assessing GES in marine birds across the four regions.

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Robson, L.M., Fincham, J., Peckett, F.J., Frost, N., Jackson, C., Carter, A.J. & Matear, L. 2018. UK Marine Pressures-Activities Database "PAD": Methods Report, JNCC Report No. 624, JNCC, Peterborough.

ACTIVITY 5 – COORDINATION

Activity 5 summary

Institutions involved:

The Netherlands: Rijkswaterstaat

Activity 5 was centered around communication, coordination, the organization of Action-wide meetings, and reporting. Using the excellent facilities and the experience with project management Rijkswaterstaat has to offer this Activity team ensured communication channels between the Action partners were always open and in use, interacted with other (e.g. EU, OSPAR) bodies and organized workshops and meetings to kickstart and/or enhance Action elements. OSPAR kindly hosted a Sharepoint site for NEA PANACEA to use for internal collaboration and communication (the deliverables directly related to assessments for the QSR were developed on the OSPAR QSR Sharepoint). Further, a project website was set up, supported by the OSPAR secretariat.

The Activity 5 team met online on a weekly basis to discuss developments and progress in the Action, make the necessary arrangements for reporting by the partners and to prepare the various workshops and meetings. In addition, the team organized so-called Action Management meetings every 4 to 6 weeks. During these meetings the coordinating team met with the leads of the other Activities to discuss scientific progress, ensure cross-cutting work between the Activities was carried out, offer support on e.g. financial and administrative issues, and inventory the needs and wishes of the various Action members with regards to the timing, content and format of the workshops and meetings. During the summer of 2022 the focus of the Action turned increasingly to the delivery of the integrated State assessments in the Thematic Assessments. OSPAR's Biodiversity Committee had installed BiTA (Biodiversity Thematic Assessment steering group), and given the overlap in topic, people involved and frequency it was decided to lower the frequency of the Action Management meetings and have the associated discussions in the BiTA context. This allowed the Activity 5 lead to support the preparation and chairing of BiTA meetings, making it so that experts from ecosystem components not directly involved in NEA PANACEA could also benefit from the impulse the EU funding offered, which was one of the explicit aims of the Action (see for example the UltraCOBAM meeting).

NEA PANACEA was planned and (for a good share) executed during the Covid-19 pandemic. The number of meetings organized in the MSFD CIS framework and in OSPAR was therefore relatively low and typically meeting agendas were reduced to necessary elements to accommodate the fairly inefficient way of meeting (most notably in the earlier days when online meeting procedures were being developed). The degree of outreach to these meeting platforms was therefore not optimal, though we have been able to bring NEA PANACEA and the products to the attention of OSPAR bodies on various occasions. The pandemic also made it so that there was less travelling during the Action. This freed up resources for the final meeting of the Action to be a physical meeting rather than an online meeting.

Task 5.1: Coordination (Annexes AO and AP)

Task Lead: Jos Schilder (RWS, NL) (Partner)
Other involved: Lisette Enserink, Lyke Bosma, Evert Jan van den Berg (all RWS, NL) (Partner)
Other Activites involved: All Activities
Milestones: M5.1a NEA PANACEA Kickoff meeting, M5.1b NEA PANACEA Final meeting
Deliverables: D5.1 periodic financial, administrative and scientific reporting

Kickoff meeting

Due to the pandemic the Action kickoff meeting was an online event, spread out over two days (March 1 and 4 of 2021). The first day (see Figure 1) was dedicated to introducing the Action and presenting the aims of the Activities, not just to the other Action members, but also to representatives of sister-projects under the same funding call (QUIETSEAS, HELCOM BLUES, HARMONIZE and ABIOMMED). These sister projects were also provided an opportunity to present their project and aims.

Figure 1. Programme of day 1 of the NEA PANACEA kickoff meeting

The second day of the kickoff meeting was open to Action members only. One of the aims was to have some degree of team building, despite the fact that travel restrictions were limiting the meeting to an online event. Time was spent to get to know each other, especially also on a more personal level. All participants were asked to present themselves in a tour-de-table using the following questions:

- My name is:
- I am from (country):
- I work at (Institute):
- I am involved in Activity:
- My hobbies are (max. 2):
- My favourite food is:
- When the borders open, ________ is the country that I'd like to visit first.

On closing, we enjoyed beverages-at-distance while discussing the NEA PANACEA Spotify playlist that was created by having every Action member add a song they favoured or felt was appropriate for the science NEA PANACEA delivers. Despite the hindrance of not being able to meet in person, this setup allowed for at least some team building.

In terms of scientific content, day 2 of the kickoff meeting featured a breakout session in which each Activity could make initial planning and arrangements, and we held 3 breakout sessions in which every combination of 2 Activities was to discuss cross-cutting issues, identify areas where collaboration was necessary and how this could be achieved.

Final meeting

As mentioned above, having reduced traveling activity due to the pandemic allowed for resources to be allocated to having a physical final meeting rather than an online event. During this 3-day event we presented the Action deliverables to each other and to online representatives of EU's DG ENV, the OSPAR secretariat and representatives of the sister projects CetAMBicion, QUIETSEAS, HELCOM BLUES and ABIOMMED. The sister project representatives then presented the outcomes of their projects. After a day full of interesting and exciting marine science, the physical participants enjoyed a closing dinner together.

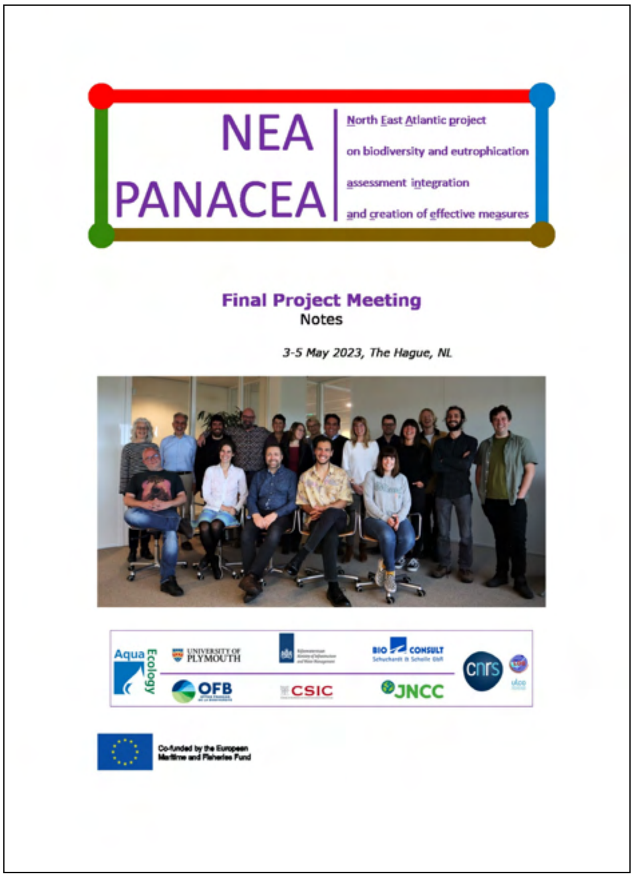

Figure 2. Final meeting notes front page, see also Annex AO.

Day 2 and 3 were attended by Action members physically present only. In an informal workshop setting the participants discussed first the outline of this final technical report and then had discussions and brainstorming sessions on future science needs, the future organization of biodiversity assessment work in the North-East Atlantic, and maintaining the dialogue between the biodiversity and eutrophication communities in OSPAR. The outcome of these discussions and brainstorming sessions are recorded in the "Final Project Meeting notes" (Figure 2, Annex AO). Note that this report is not mentioned as a deliverable in the Action proposal because the meeting was initially not planned to extend beyond online sharing of results.

Technical reporting

Both an interim (Annex AP) and a final (this report) technical report was delivered as part of the coordinating work of this Task. In both cases, the structure and guidance on the content was discussed and agreed upon with the Activity and Task leads, during Action management meetings for the interim report and during the final project meeting for the final report. Within the agreed framework, the Activity leads were tasked to coordinate their section of the report with some degree of freedom to accommodate the variety in products, group composition and working arrangements. Activity 5 was tasked with collating the various subsections and producing a coherent report, as well as with the production of general sections (such as the summary).

Finances summary and reporting

The total budget for the Action NEA PANACEA was € 1.211.352,35, of which € 1.134.235,27 has been used (94% of the budget). In the interim financial report, on the period 1st of March 2021 until 28th of February 2022, expenses of 35% of the total budget were claimed. In the final financial report, on the period 1st of March 2022 until 31st of May 2023 another 59% of the budget was claimed on expenses.

University of Plymouth and AquaEcology have slightly overspend their beneficiary's budget with 103% and 106% respectively. AquaEcology has spent much effort in retrieving suitable data for the North Sea regions of interest, working up this data to make it usable, and in getting the proposed model system LiACAT operational. By the end of the project, it turned out that the models and their outputs were not at a level that they produced output of sufficient quality. Although further efforts have been made to adapt and adjust the system accordingly, this has proven to be unsuccessful. This explains why, despite the deliverable was not finalized, AquaEcology did spend its budget. Other beneficiaries have underspend their budget. For Rijkswaterstaat the renting of the venues for both planned meetings were in house and free of charge to the Action.

During the lifetime of the Action minor shifts have occurred. For beneficiary Office Français de la Biodiversité (OFB) budget from travel costs to personnel was shifted, because the recruited postdoc costed more than anticipated. This shift was approved by DG ENV (20-04-2021), with the remark that for minor changes no formal approval is needed. Other minor shifts occurred for beneficiaries JNCC, University of Plymouth and AquaEcology. JNCC was able to host an additional workshop on birds, because the covid-19 restrictions were lifted and a physical meeting was possible and deemed more fruitful. With the extension of 3 months University of Plymouth, Centre National de la Recherce Scientifique (CNRS) and Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC) were able to extend the contract of temporary staff to fulfill the final activities for NEA PANACEA.

For subcontracting costs no other costs than foreseen in the application annex III were claimed. The expenses for University of Plymouth and JNCC for subcontracting costs are slightly over budget (117% and 106% respectively), which is caused by variations in the exchange rate.

During the lifetime of the Action beneficiary Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC) went through a reorganization and its name was changed from Instituto Español de Oceanografía (IEO) in April 2021. This was formalized for NEA PANACEA in July 2021.

As coordinating partner, Rijkswaterstaat oversaw the financial overviews and statements, offered guidance to the partners on financial matters when required and when needed interacted with DG ENV on behalf of the partners. The financial administration for all partners was collated in both an interim and final financial report.

Task 5.2: Super- and UltraCOBAM workshops (Annexes AQ and AR)

Task Lead: Jos Schilder (RWS, NL) (Partner)
Other involved: Lisette Enserink, Lyke Bosma, Evert Jan van den Berg (all RWS, Partner)
Other Activites involved: All Activities
Milestones: M5.2a, M5.2b UltraCOBAM workshop
Deliverables: D5.2a SuperCOBAM workshop; D5.2b UltraCOBAM workshop programme; D5.2c UltraCOBAM workshop; D5.2d UltraCOBAM workshop report

SuperCOBAM

The first large workshop organized by Activity 5 was SuperCOBAM (see Annex AQ for the workshop programme and report). It was held 20-22 October 2021 in Utrecht, the Netherlands. Rijkswaterstaat offered their in-house LEF Future Centre as a venue, including lunch, drinks and snacks, as well as a professional moderator. The moderator helped out with the planning, organizing the technical facilities on-site and running of the workshop.

The aim of the meeting was to support early alignment of indicator and thematic assessments within and between D1, D4, D5 and D6 and to prevent expert groups working in isolation (including ecosystem component expert groups not directly involved in the project). The uncertainty around travel restrictions because of the pandemic complicated the planning of the workshop. In early stages planning was done along 3 tracks: An online meeting, a physical meeting or a hybrid meeting. SuperCOBAM ended up being a hybrid meeting, where NEA PANACEA members (25) participated live in Utrecht and experts not involved in the project joined virtually (40).

For all involved, participants, organizers and the venue, holding an interactive hybrid workshop entailed venturing into unexplored territory. In order to capitalize on the benefits of having in-person discussions while keeping the online community involved and giving them an opportunity to input to the discussion the following setup was designed (see also Figure 3). On each of the 3 main themes of the workshop (assessment scales and spatial integration, integration of indicator results and threshold values) we started with an in-person discussion among expert group leads to align discussion topics, aims and approach. Each expert group then had an online meeting on the theme to produce a common view and understanding. Following this online discussion the physically present experts shared the output between different expert groups in “mixed group” meetings, after which we held a plenary discussion to harvest the views and ideas that were produced. The online component of the workshop also featured presentations by e.g. the OSPAR secretariat and the lead of the expert group on cumulative impacts (ICG-EcoC), as well as a recap of the findings of the day before by the workshop organizer.

Despite some technical difficulties and everyone involved needing to adjust to this new mode of working, SuperCOBAM turned out to be a productive and useful workshop. Having project members meeting face-to-face again after such a long time was a great positive impulse for the work NEA PANACEA set out to do. A large amount of information was exchanged, also to non-project members, setting the stage for the process to deliver biodiversity assessments for the OSPAR QSR and EU Member State MSFD reporting.

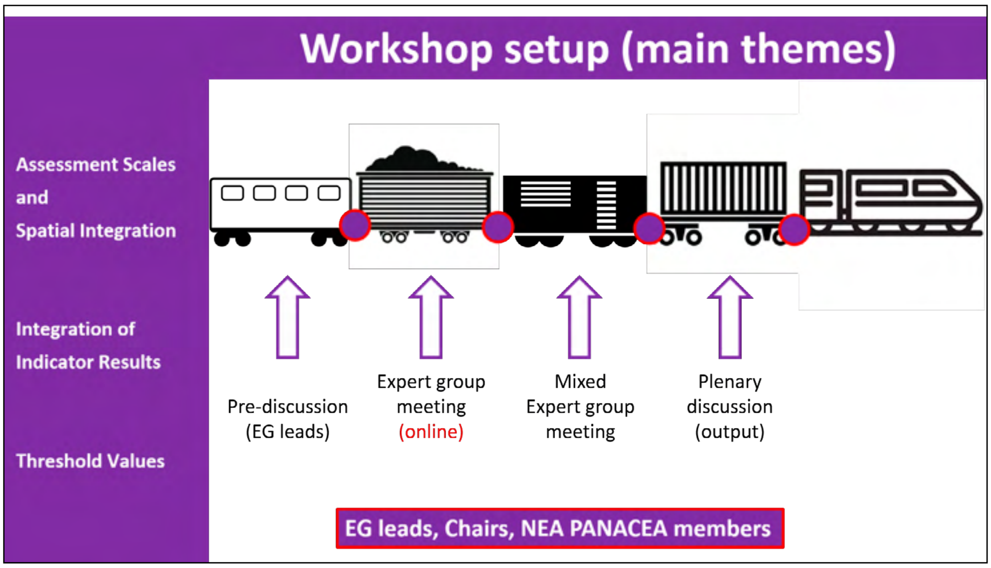

Figure 3. All 3 main cross-cutting themes of SuperCOBAM were addressed through a "train" of sub-meetings, where the expert groups leads and those physically present were responsible for bringing information from one "coach or car" to the next (see text above for more information).

UltraCOBAM

On 14-16 June 2022, NEA PANACEA hosted its second large workshop, UltraCOBAM (see Annex AR for the workshop programme and report). As with the SuperCOBAM workshop, Rijkswaterstaat offered the venue and a moderator to help plan and run the workshop. This workshop was attended physically by 50 persons, with 6 persons that attended selected elements virtually. UltraCOBAM was aimed at the delivery of the seven biodiversity Thematic Assessments (TA) for the QSR2023. These TAs not only contain an integrated assessment of the state of each ecosystem component, allowing EU Member States to report on the "feature level" of the biodiversity-related descriptors, but they also tie biodiversity (State) in with societal Drivers, associated Activities, resulting Pressures, Impacts on ecosystem services and policy Response (the DAPSIR framework) and with climate change. Delivery of these TAs required on one hand discussions and work to integrate the various indicator assessments and on the other hand interaction with experts that deal with climate, relevant pressures, socio-economical aspects and cumulative impact assessments.

Many of the experts from the different "silo's" had never met each other and would normally not convene in the same forum. In order to get the most out of the 3 days in terms of interaction, all experts were housed in the same hotel and lunches and dinners were enjoyed together. Figure 4 shows the workshop programme to illustrate the number of targeted interactions. With so many meetings, topics and work to discuss and perform UltraCOBAM was a very intensive workshop. It was recognized by many as pivotal in the delivery of the biodiversity TAs for the QSR2023. It built relationships and opened up communication channels for collaboration between "silo's" leading up to delivery of the QSR and beyond.

ULTRACOBAM WORKSHOP — **NEA PANACEA**

North East Atlantic project on biodiversity and eutrophication assessment integration and creation of effective measures

From		To	Benthos	Pelagic	Food webs	Fish	Mammals	Birds	Activity 2	Others
1800	to	2000	Everyone invited to have dinner in the hotel restaurant at time that suits them							
1900	to	2200	Opening mixer / drinks in the hotel bar							

Day 1 (14 June)

From		To	Benthos	Pelagic	Food webs	Fish	Mammals	Birds	Activity 2	Others
830	to	900	Participants arrive and get their entry passess for the building							
900	to	930	Plenary welcome, go through practicalities, schedule, discuss the aims and desired outcome and products							
930	to	1000								
1000	to	1030	All teams find their room, get installed and plan their workshop (use Padlet!)							
1030	to	1100	Coffee break							
1100	to	1130		HA TA: Terence Ilot			Gro / NO: Region I			
1130	to	1200								
1200	to	1230								
1230	to	1300	Lunch							
1300	to	1330								
1330	to	1400	Climate TA: Bee Berx		HA TA: Terence Ilot	DAP / ICG-EcoC	Noise TA: Niels Kinneging	Litter TA: Lex Oosterbaa		
1400	to	1430								
1430	to	1500								
1500	to	1530	Coffee break							
1530	to	1600		Climate TA: Bee Berx		Impact: Rob Federico	HAZ TA: Marianna			
1600	to	1630								
1630	to	1700								
1700	to	1730	Groups to wrap up and prepare for the next day (use Padlet!)							
1900	to	2300	Food and drinks at Restaurant Oudean, Oudegracht 99 (on foot from station/hotel area)							

Day 2 (15 June)

From		To	Benthos	Pelagic	Food webs	Fish	Mammals	Birds	Activity 2	Others
830	to	900	Participants arrive and get their entry passess for the building							
900	to	930	HA TA: Terence Ilot		Climate TA: Bee Berx	Gro / NO: Region I	Impact: Rob Federico			
930	to	1000								
1000	to	1030								
1030	to	1100	Coffee break							
1100	to	1130	EUT TA / Act 2		DAP / ICG-EcoC			Impact: Rob Federico		
1130	to	1200								
1200	to	1230								
1230	to	1300	Lunch							
1300	to	1330	with plenary presentation on EMODNET resources by Gert van Hoey (room 13)							
1330	to	1400	Impact: Rob Federico	EUT TA / Act 2		Climate TA: Bee Berx	DAP / ICG-EcoC			
1400	to	1430								
1430	to	1500								
1500	to	1530	Coffee break							
1530	to	1600		Impact: Rob Federico	EUT TA / Act 2		Climate TA: Bee Berx	DAP / ICG-EcoC		
1600	to	1630								
1630	to	1700								
1700	to	1730	Groups to wrap up and prepare for the next day (use Padlet!)							
1900	to	2300	Food and drinks at LE:EN (Heuveloord 140, bus 6 to Galgenwaard, stop at Vaartsche Rijn)							

Day 3 (16 June)

From		To	Benthos	Pelagic	Food webs	Fish	Mammals	Birds	Activity 2	Others
830	to	900	Participants arrive and get their entry passess for the building							
900	to	930		DAP / ICG-EcoC	Impact: Rob Federico	HA TA: Terence Ilot		Climate TA: Bee Berx		
930	to	1000								
1000	to	1030								
1030	to	1100	Coffee break							
1100	to	1130	DAP / ICG-EcoC		Gro / NO: Region I		HA TA: Terence Ilot			
1130	to	1200								
1200	to	1230								
1230	to	1300	Lunch							
1300	to	1330	BiTA meeting during lunch: stocktaking and strategy until september meeting							
1330	to	1400						HA TA: Terence Ilot		
1400	to	1430								
1430	to	1500								
1500	to	1530	Coffee break							
1530	to	1600	Plenary wrap-up. Did we achieve our aims, what is still left to do? (use Padlet!)							
1600	to	1630								
1630	to	1700	Groups to wrap up internally, make provisions for next steps, pack up stuff (use Padlet!)							
1700	to	1730								

HA: Human Activites
TA: Thematic Assessment
NO: Norway

HAZ: Hazardous substances
EUT: Eutrophication
DAP: Drivers, Activites & Pressures

Green blocks are in the video conferencing room

Figure 4. UltraCOBAM workshop programme illustrating the number of targeted interactions between experts of different relevant to the biodiversity TAs. White boxes provided the biodiversity expert groups with time to prepare and to work on indicator integration.

Task 5.3: Outreach and dissemination

Task Lead: Jos Schilder (RWS, NL) (Partner)
Other involved: Lisette Enserink, Lyke Bosma, Evert Jan van den Berg (all RWS, Partner)
Milestones: M5.3 Exchanges with similar Actions under this call (to be determined)
Deliverables: D5.3 Written and/or oral presentations to relevant groups and committees

As mentioned in the introduction of this chapter, the frequency and length (and consequently the agenda) of meetings in the CIS process was strongly reduced during NEA PANACEA (due to COVID-19). Activity 5 was therefore never in a position to present the Action's plans, progress or results in the MSFD CIS process. Activity 5 members that also participate in WG GES have identified this as a missed opportunity during WG GES meetings, but it has not (yet) led to a central session around the various projects under this MSFD-specific call for funding.

Some communication between project coordinators of the projects under this call was had on organizing a joint event to inform and exchange. It was concluded, however, that this was not opportune. This was related to the starting times of the projects being very much unaligned, to general difficulties and uncertainties in organizing and traveling for events under the pandemic-related restrictions, and to doubts whether we would, from a practical and planning point of view, be able to gather such a large and geographically diverse group of experts in one place. Recognizing the value of exchange, we decided to, where possible, have coordinators attend each other's kick-off and final meetings to present.

A presentation by NEA PANACEA's Activity 5 on the plans, progress and products was given at the kick-off meeting of HELCOM BLUES and ABIOMMED, the two projects with the greatest overlap in research topics with NEA PANACEA. Outcomes were also presented at the QUIETSEAS final meeting. In return, representatives of QUIETSEAS, ABIOMMED, HELCOM BLUES, HARMONIZE and CetAMBicion presented at NEA PANACEA's kick-off and/or final meeting. Further, Activity 5 motivated NEA PANACEA experts to interact with experts from these other projects, for example by sharing current standards and practices in OSPAR with pelagic habitats experts in the Mediterranean and by participating in HELCOM workshops on food webs.

In order to embed NEA PANACEA's work as well as possible into the QSR2023 process and products, to highlight the importance of the project's work for delivery of the QSR, frequent presentations were given in OSPAR meetings. OSPAR groups that were informed (usually more than once) in this way are the Coordination Group (CoG), the Biodiversity Committee (BDC), the Hazardous Substances and Eutrophication Committee (HASEC), the Intersessional Correspondence Group (ICG) on Eutrophication (ICG-EUT), the ICG Quality Status Report (ICG-QSR), the ICG on Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM) and the Biodiversity Thematic Assessment group (BiTA).

In addition to the dissemination activities undertaken by Activity 5, experts involved in NEA PANACEA have been working on peer-reviewed publications, some of which are in preparation and few have already been published and are listed below.

- Matthew M. Holland *et al.*, Major declines in NE Atlantic plankton contrast with more stable populations in the rapidly warming North Sea, Science of The Total Environment, Volume 898, 2023, 165505, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.165505.
- Alberto Serrano *et al.*, Sentinels of Seabed (SoS) indicator: Assessing benthic habitats condition using typical and sensitive species, Ecological Indicators, Volume 140, 2022, 108979.
- Gavin H. Tilstone *et al.*, Threshold indicators of primary production in the north-east Atlantic for assessing environmental disturbances using 21 years of satellite ocean colour, Science of the Total Environment, Volume 854, 2023, 158757.

OUTLOOK

NEA PANACEA has built upon the achievements of previous projects in the North-East Atlantic, such as EcApRHA and JMP EUNOSAT, and reflecting on the achievements of this project also offers views on and avenues for future research on the themes of biodiversity, pelagic and benthic habitats, food webs and the coherence between state and pressure assessments. Knowledge gaps and next steps are detailed in the sections describing the Activity Tasks in chapter 2 to 5. A fair share of them involves development at the indicator, MSFD Criterion or MSFD Descriptor level, but many touch on topics of a more cross-cutting nature. As society's attention turns more and more towards the seas and oceans as a source of food (aquaculture and fisheries), energy (wind farms and tidal energy) and climate adaptation and mitigation (defensive structures or carbon sequestration or storage), the need for a better understanding of interactions and connectivity between ecosystem components and of ecosystem components with the environment is higher than ever. This makes the MSFD, with its integrated and holistic ambitions, an important tool for marine management and continued scientific work to support the MSFD is therefore important and relevant.

There is a number of important recurring themes and emerging issues in these lists of knowledge gaps. For example:

- The inclusion of more data (e.g. geographical scope or higher resolution) but especially also different types of data are mentioned, including using non-microscopy data in pelagic assessments (e.g. satellite, flow cytometry), using the full suite of sources of disturbance of the seabed and/or loss of benthic habitat, and using more demographic parameters in the marine birds breeding success assessment.
- General improvements to indicator methodology and operability are always in order. For example, knowledge on biological response under multi-stressor conditions needs to be expanded.
- The identification of mechanical links between environmental parameters and ecological indicator species (including relevant spatial and temporal scales) is of importance.
- Insight into the impact of (changes in) lower trophic levels on organisms at higher trophic levels is crucial to properly assess food webs and the potential impact of human activities.
- Coherence in monitoring methodologies and reporting requires continued attention. This is not just between CPs or Member States, but also between directives where relevant (such as Water Framework Directive, Birds and Habitats Directive en Marine Strategy Framework Directive).
- Given the scale of the environment we typically assess, models (if well informed and validated) can be a valuable addition to biological monitoring and assessment. It can especially be useful in investigating trophic interactions (food webs) and (multi)stressor impacts on ecosystems. Implementing them at scale in a way that is synergetic with biological monitoring and assessment requires much further work, however.
- Making assessment methodologies (and underlying data sources) and definitions of GES (and the narratives behind the Threshold Values being developed) coherent between state and pressure MSFD Descriptors where this is relevant (for example between eutrophication and pelagic and benthic habitats, which has gotten attention in NEA PANACEA, but for example also between noise pollution and biodiversity).
- It is of importance to start the discussion on Threshold Value between scientific experts and policy makers timely. There needs to be consensus on the narrative and methodology, and policy consequences need to be made clear at an early stage in order to increase the chance of adoption at the end of the process. Moreover, coherence (where applicable) with other indicators or MSFD criteria needs to be considered and taken into account in these discussion.

LIST OF ANNEXES

Annex	Description and link
A	Protocol for pelagic data ingestion
B	CEMP PH1/FW5: Changes in Phytoplankton and Zooplankton Communities
C	PH1/FW5: Changes in Phytoplankton and Zooplankton Communities
D	PH2: Changes in Phytoplankton Biomass and Zooplankton Abundance
E	CEMP PH2: Changes in Phytoplankton Biomass and Zooplankton Abundance
F	PH3: Changes in Plankton Diversity
G	CEMP PH3: Changes in Plankton Diversity
H	Options for integration within and across pelagic habitats indicators
I	Pelagic Habitats Thematic Assessment
J	CEMP integrated Pelagic Habitats assessment
K	FW2: Pilot Assessment of Primary Productivity
L	Case study for FW6 - Biomass, species composition and spatial distribution of zooplankton
M	Options for integration between Pelagic habitats diversity, Biomass, PP and eutrophication
N	Options for integration of pelagic habitats indicators with indicators for benthic habitats, marine birds, marine mammals and food webs within the FW9 indicator
O	Not delivered (see technical report)
P	Changes in North Sea stratification and primary production in climate change scenarios
Q	FW9: Pilot Assessment of Ecological Network Analysis Indices
R	Spatial scales for OSPAR biodiversity assessments
S	Towards coherent threshold value setting methods
T	Review of MSFD GES national reporting for D6 versus OSPAR indicators and relationships with D4 and D5
U	CEMP BH1: Sentinels of the Seabed

Annex	Description and link
V	BH1: Sentinels of the Seabed
W	BH2a: Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment
X	CEMP BH2a: Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment
Y	CEMP BH3: Extent of Physical Disturbance to Benthic Habitats
Z	BH3a: Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears
AA	BH3b: Extent of Physical Disturbance to Benthic Habitats: Aggregate Extraction
AB	ICG-COBAM discussion document with proposed sea floor disturbance threshold values for regions II and III
AC	Exploring the use of the BH3 indicator to evaluate effectiveness of MPA management
AD	Draft BH4 CEMP Guidelines
AE	BH4: Pilot Assessment of Area of Habitat Loss
AF	Benthic Habitats Thematic Assessment
AG	B3: Marine Bird Breeding Productivity
AH	CEMP B3: Marine Bird Breeding Productivity
AI	Marine Birds Thematic Assessment
AJ	CEMP integrated Marine Birds assessment
AK	Supplementary Material Thematic Assessment Marine Birds_Pressures
AL	Supplementary Material Thematic Assessment Marine Birds_Measures MSFD
AM	Supplementary Material Thematic Assessment Marine Birds_Responses_BirdDirectiveArticle12
AN	Marine Birds Workshop Report and Action Plan
AO	Final project meeting notes
AP	Interim technical report NEA PANACEA
AQ	SuperCOBAM Workshop Report and Annexes
AR	UltraCOBAM meeting summary