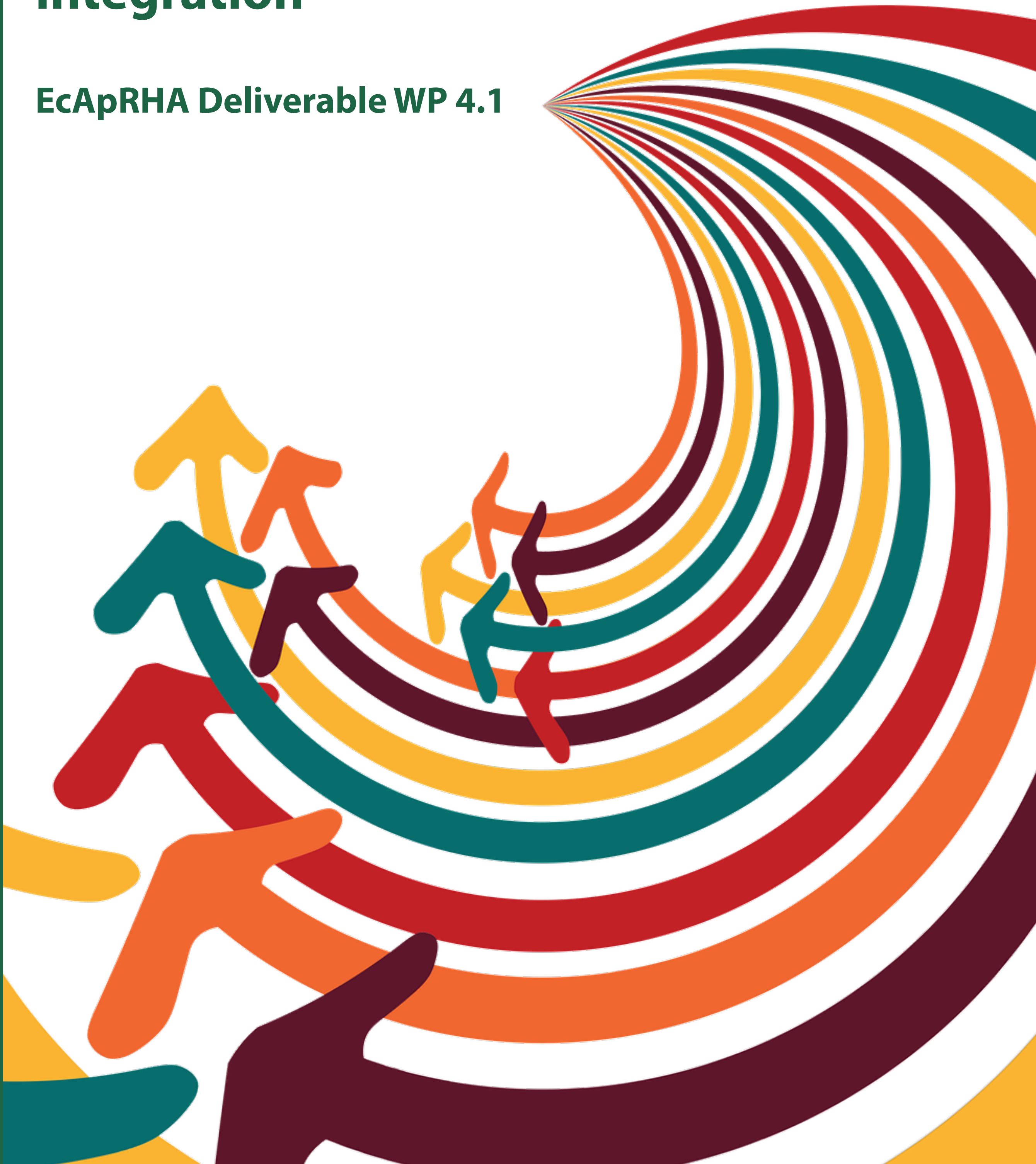
Proposed approaches for indicator integration

EcApRHA Deliverable WP 4.1



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EcApRHA an Ecosystem Approach to Regional Habitat Assessments

2017

Contents

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EcApRHA

The EcApRHA project (Applying an Ecosystem Approach to (sub) Regional Habitat Assessment) aims to address gaps in the development of biodiversity indicators for the OSPAR Regions. In particular, the project aims to overcome challenges in the development of indicators relating to the MSFD (Marine Strategy Framework Directive 56/2008/EU), such as Descriptor D1 (Biodiversity), D4 (Food webs) and D6 (Seafloor integrity), and to deliver an action plan to OSPAR that will enable monitoring and assessment at the (sub) regional scale, to contribute to OSPAR Intermediate Assessment 2017.

Indicators related to the benthic and pelagic habitats, as well as food webs, are investigated within the project at different levels (from data to indicator; from indicator to habitat assessment; from habitat to ecosystem assessment).

Acknowledgment

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Executive Summary

The Marine Strategy Framework Directive (MSFD) aims to achieve Good Environmental Status (GES) within European Commission waters through an ecosystem-based approach. The MSFD requires Member States sharing a marine region or sub-region to cooperate to ensure that the Directive's objectives are achieved and to coordinate their actions through Regional Seas Conventions e.g. the OSPAR Commission for the North-East Atlantic. As part of the 'applying an Ecosystem Approach to (sub) Regional Habitat Assessments' (EcApRHA) project, integration of indicators under Descriptor 1 (biodiversity), 4 (food webs) and 6 (seafloor integrity), relating to pelagic and benthic habitats and food webs have been forwarded to work towards an ecosystem's approach in assessing habitats regionally. The content of this report covers different approaches developed to integrate indicators forwarded within the project.

Five methods are described, four of which were developed to integrate indicators developed under the EcApRHA project. The fifth, OSPAR's cumulative effect approach has also been summarised as an additional approach to integrate indicators. For each method, management implications; the advantages and disadvantages in relation to being able to work toward assessment of GES; and the confidence in the assessments, are highlighted. The time it would take for the approach to become fully operational, its feasibility and costs are also discussed.

From the five methods described, three main approaches are discussed:

I. A quantitative method to draw links between indicators to assess pressures that have effects on the different aspects of the marine ecosystem (Chapters 3-4).

II. Use of the Nested Environmental status Assessment Tool (NEAT) to integrate different indicators to provide an overall assessment (Chapters 5 and 6).

III. Use of an industry led risk assessment tool (Bow-Ties) to assess cumulative effects (Chapter 7).

The integration approaches outlined within this document demonstrate the developments made within the EcApRHA project to ensure the various indicators under the different descriptors are not only operational, but also integrated in a way which permits a more holistic assessment of the marine environment. Using such a two-tiered approach of individual indicator and integrated analysis, will enable an understanding of why certain aspects of the marine environment may not be in good condition, and thereby recommend specific management measures to ameliorate them. Although the approaches forwarded have been initially trialled in the North-East Atlantic, they are able to be applied to other MSFD Regional seas areas. Each method addresses different levels of integration (indicator, habitat or ecosystem) and requires further development and testing. They should be thus considered as complementary and gaps should be progressed in parallel to ensure coherent progress towards an overall ecosystem approach. In addition, with some further comparative testing between the different methods outlined within this document, options to continue forwarding integrated assessment of OSPAR indicators could be proposed. The methods outlined within this document are a first step in applying an ecosystem's approach to assessing the state of our seas.

Acronyms

ActionMed	DG ENV/MSFD co-financed ‘Action Plans for Integrated Regional Monitoring Programmes, Coordinated Programmes of Measures and Addressing Data and Knowledge Gaps in Mediterranean Sea’
BalticBOOST	DG ENV/MSFD co-financed Baltic Sea project to boost regional coherence of marine strategies through improved data flow, assessments, and knowledge base for development of measures
BENTHIS	An EU funded FP7 project which developed two quantitative methods to determine the state of the seabed depending on trawling pressure and habitat sensitivity
BT	Bow-tie
CEMP	OSPAR’s Coordinated Environmental Monitoring Program: technical specifications report
DEVOTES	Development Of innovative Tools for understanding marine
DPSIR	Driving forces, pressures, State, Impacts and Responses
EcApRHA	OSPAR’s Ecosystem Approach to (sub) Regional Habitat Assessments project
EEA	European Environment Agency
EUNIS	European Nature Information System habitat classification
FAO	Food and Agriculture Organization of the United Nations
GES	Good Environmental Status
HELCOM	Baltic Marine Environment Protection Commission - Helsinki Commission
ICES	The International Council for the Exploration of the Sea
ICG COBAM	Intercessional Correspondence Group on the Coordination of Biodiversity and Monitoring
ICG-C	Intercessional Correspondence Group on cumulative effects
MTL	Mean Trophic Level
MSFD	Marine strategy Framework Directive
NEAT	Nested Environmental status Assessment Tool
NOAA	National Oceanic and Atmospheric Organization
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PP	Primary Production
RSC	Regional Sea Convention
TL	Trophic level
VMS	Vessel Monitoring System
WP	Work package

1 Introduction

The Marine Strategy Framework Directive (MSFD; 2008/56/EC) aims to achieve Good Environmental Status (GES) of all European marine waters by 2020 through 11 qualitative Descriptors which should be underpinned by numerous indicators to determine their status (CEC, 2008). Part of the MSFD's aim is to develop an "ecosystem's approach to the management of human activities" in the marine environment (CEC, 2008). A key component of the MSFD ecosystem approach is that it links the different European Directives together e.g. the Common fisheries Policy, the Habitats and Birds Directives (Natura2000), the Water Framework Directive, etc. This ecosystem approach is implemented through the use of indicators to assess the different Descriptors for the distinct ecosystems within the MSFD region (CEC, 2008,Painting et al. 2013). Under the MSFD, assessment of the marine environment is undertaken at regional and sub-regional seas level. Within the North-East Atlantic Region, the OSPAR Commission set up a framework through which Contracting Parties, who are also European Union (EU) Member States, can forward matters concerning environmental protection.

To help address some of the challenges identified in achieving regional application of the MSFD in the North-East Atlantic the EU co-financed Directorate-General Environment (DG ENV) 'Ecosystem Approach to (sub) Regional Habitat Assessments' (EcApRHA) project was formed. The EcApRHA project focuses on progressing indicator development under Descriptors 1 (biodiversity), 4 (food webs) and 6 (seafloor integrity) through three work packages (WP): WP1 Pelagic habitat, WP2 Benthic habitats, and WP3 Food webs. Indicators forwarded under the EcApRHA project are outlined within **Table 1**. The EcApRHA project also has the aim of working toward an ecosystem's approach for regional habitat assessment through WP4 and to contribute to address the gaps and shortcomings identified (COM, 2012) in national assessments of MSFD Article 12 reporting by EU Member States.

To undertake an ecosystem approach, information used to take decisions relating to the management of human activities should be integrated with information on relevant abiotic and biotic processes, to be able to achieve sustainable use of ecosystem services (Beaumont et al. 2007, Kenny et al. 2009, Sardà et al. 2014, OSPAR, 2016a). Ecosystem services are defined as the "direct and indirect benefits people obtain from ecosystems" (Beaumont et al. 2007). Examples include, vital source of food and materials, gas and climate regulation, the provision of leisure and recreation, etc. (Holmlund & Hammer 1999, Beaumont et al. 2007).

It is well recognised that forwarding an ecosystem approach to the management of human activities is essential to the safeguard the sustainability of the marine environment, given that different ecosystem components provide vital production, regulating, cultural and supporting services (Beaumont et al. 2007, Levin et al. 2009). Unsustainable use of one or more components of the marine environment could lead to declines in the ecosystem services it provides, with negative consequences on millions of people whose livelihoods depend on marine resources (Mee et al. 2008, Levin et al. 2009). An ecosystem approach therefore requires the consideration of societal, economic and environment effects to achieve balance and sustainable management (Beaumont et al. 2007).

To date (February 2017), within OSPAR, the regional indicators have been assessed on an individual basis. In this first phase of work, synergies between the different indicators were identified. For example, assessment of 'Typical species composition' (BH1) will be affected by the 'physical damage of predominant and special habitats' (BH3) due to the potentially damaging physical pressure on the communities. 'The condition of benthic habitats' (BH2) is equally likely to affect 'Mean trophic level' (FW4) of demersal species, through changes in possible food and refuge availability. Many of the indicators under the different descriptors are highly interrelated since they respond to similar (or the same) pressures types, and often in analogous ways.

Integrating related indicators together, will make it possible to determine a more holistic view of the environment enabling the environmental status of specific sub-regions to be understood (Borja et al. 2008, 2013, Painting et al. 2013; **Figure 1**). The latter will also enable significant risks to the marine environment to be determined. Undertaking an ecosystem's assessment of the marine environment will also enable co-occurring or the cumulative effect of anthropogenic activities to be assessed, facilitating changes to management to be prioritised in order to maintain GES.

Due to the remit (focus on pelagic and benthic habitats, and food webs), and the short duration of the EcApRHA project (15 months), the aim of this document is to propose options and examples of how to integrate those indicators developed within EcApRHA and the OSPAR framework to work toward an ecosystem perspective. Options for integration were undertaken by exploring potential cross overs between different indicators under the different work packages as an initial step to integration within the OSPAR region for the MSFD. In addition to proposals for integration of some of the indicators developed within the EcApRHA project, links to implications for understanding socio-economic aspects and implications for ecosystem services are outlined. An evaluation on the advantages and disadvantages of each proposal has also been summarised alongside a timeline of how long it would take for the approach to be up and running.

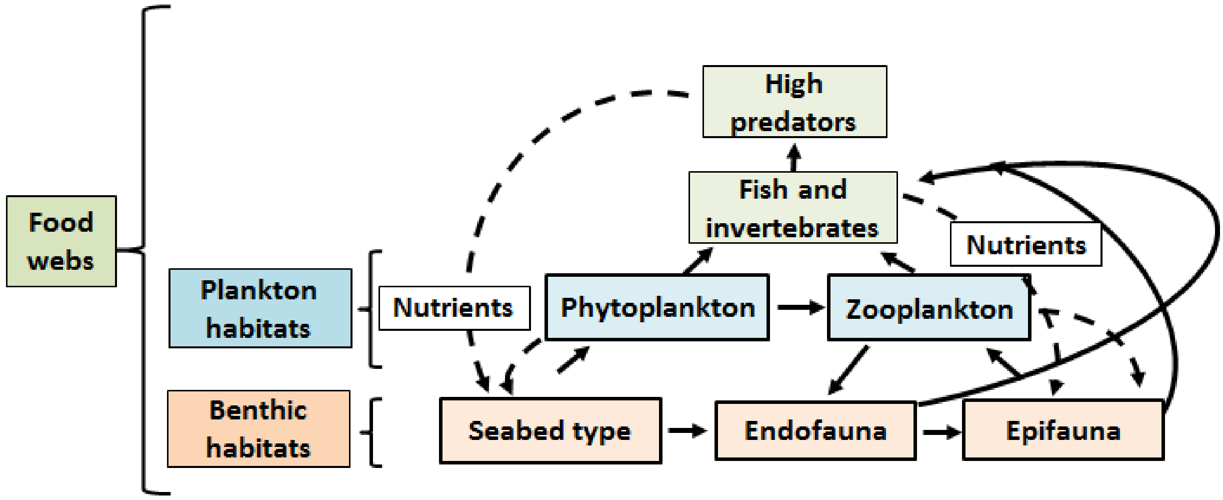

Figure 1: Links between the different components of the ecosystem relevant to pelagic and benthic habitats and food webs.

Table 1: Indicators considered under the EcApRHA project and their relations to MSFD GES (2012) criteria and OSPAR status.

OSPAR indicator name	Indicator acronym	MSFD GES (2012) criteria	OSPAR Status	Whether part of the EcApRHA project
Changes of plankton functional types (life form) index ratio	PH1/FW5	D1.4 - Habitat distribution D1.6 - Habitat condition D4.3 - Abundance/distribution of key trophic groups/species	Common	✓
Plankton biomass and/or abundance	PH2	D1.4 - Habitat distribution D1.6 - Habitat condition D1.7 - Ecosystem structure D4.1 - Productivity (production per unit biomass) of key species or trophic groups	Common	✓
Changes in biodiversity index (s)	PH3	D1.6 - Habitat condition D1.7 - Ecosystem structure	Common	✓
Typical species composition	BH1	D1.6 - Habitat condition D6.2 - Condition of benthic community	Candidate	✓
Condition of benthic habitat defining communities	BH2	D1.6 - Habitat condition D5.3 - Indirect effects of nutrient enrichment D6.2 - Condition of benthic community	Common	✓
Physical damage of predominant and special habitats	BH3	D1.4 - Habitat distribution D1.5 - Habitat extent D1.6 - Habitat condition D6.1 - Physical damage, having regard to substrate characteristics	Common	✓
Area of habitat loss	BH4	D1.5 - Habitat extent D6.1 - Physical damage, having regard to substrate	Candidate	✓

		characteristics		
Size-frequency distribution of bivalve or other sensitive/indicator species	BH5	D1.6 – Habitat condition D6.2 – Condition of benthic community	Candidate	✗
Reproductive success of marine birds in relation to food availability	FW1	D4.1 - Productivity of key species of trophic groups	Candidate	✗
Production of phytoplankton	FW2	D4.1 - Productivity of key species of trophic groups	Candidate	✓
Size composition in fish communities (TyL)	FW3	D4.2 - Proportion of selected species at the top of food webs	Common	✗
Changes in average trophic level of marine predators	FW4	D4.2 - Proportion of selected species at the top of food webs D4.3 - Abundance/distribution of key trophic groups/species	Common	✓
Biomass, species composition and spatial distribution of zooplankton	FW6	D4.3 - Abundance/distribution of key trophic groups/species	Candidate	✓
Fish biomass and abundance of dietary functional groups	FW7	D4.3 - Abundance/distribution of key trophic groups/species	Candidate	✓
Changes in the distribution of biomass and species over trophic levels and body size	FW8	D4.3 - Abundance/distribution of key trophic groups/species	Candidate	✗
Ecological Network Analysis diversity	FW9	Not directly related to an MSFD criteria. This is an additional indicator with a holistic approach	Candidate	✓

2 Integration of benthic habitat indicators

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2.1 Summary

The proposed method to integrate benthic habitat indicators brings together candidate and common OSPAR indicators to improve upon habitat assessment and overall confidence. The integrated cyclical approach is set up so that the indicators feed into one another improving upon best available information and facilitating quantitative thresholds and management measures for individual EUNIS level 4-6 and special habitats according to individual pressure types. The process has the potential to also be expanded to incorporate food web and pelagic indicators where links exist.

2.2 The approach

To undertake this integrative cyclical assessment the methodologies of the individual benthic habitat indicators are used and linked together, so that they feed into one another supporting cross-indicator assessment (**Figure 3.1**). For a more detailed method refer to Elliott et al, (2017).

Information is collected on anthropogenic activities and analysed according to the pressure exerted on the marine environment (BH3; **Figure 3.1.a and b**). Seabed sampling enables benthic habitat classification and habitat prediction models to be mapped (**Figure 3.1.c-e**). Benthic habitat classification and benthic sampling data also provides information on the 'Typical species composition' and 'benthic habitat communities' (BH1, BH2; **Figure 3.1.e-f**). This information is brought together to build a spatial understanding of habitat sensitivity (**Figure 3.1.f**). Combining pressure intensity and sensitivity for different benthic habitat and pressure types gives information on the 'Physical damage of predominant and special habitats' (BH3; **Figure 3.1.g-h**) and helps identify locations to monitor and assess benthic habitats along a pressure gradient (BH2; **Figure 3.1.i**). By analysing changes in typical species composition (BH1) or the condition of individual benthic communities (BH2), with increasing anthropogenic pressures, the point at which the benthic habitats can no longer resist pressure without a lasting detrimental effect on their condition will be possible to quantify (**Figure 3.1.j**).

Benthic monitoring can feed back and improve modelled benthic habitat mapping (**Figure 3.1.d-e**), and the pressure-state relationships can then provide a positive feedback loop and strengthen habitat sensitivity and disturbance calculations, and mapping (**Figure 3.1.e-h**). Given the fact that both benthic habitat community condition (BH2) and anthropogenic pressures (BH3) can have an effect on species which are dependent on certain benthic habitats (e.g. demersal fish and birds), links could also be made to food web and commercial fish and shellfish indicators (e.g. 'Mean Trophic Level' - FW4) (**Figure 3.1**; Chapter 4, Elliott et al. 2017, Elliott et al. In Press).

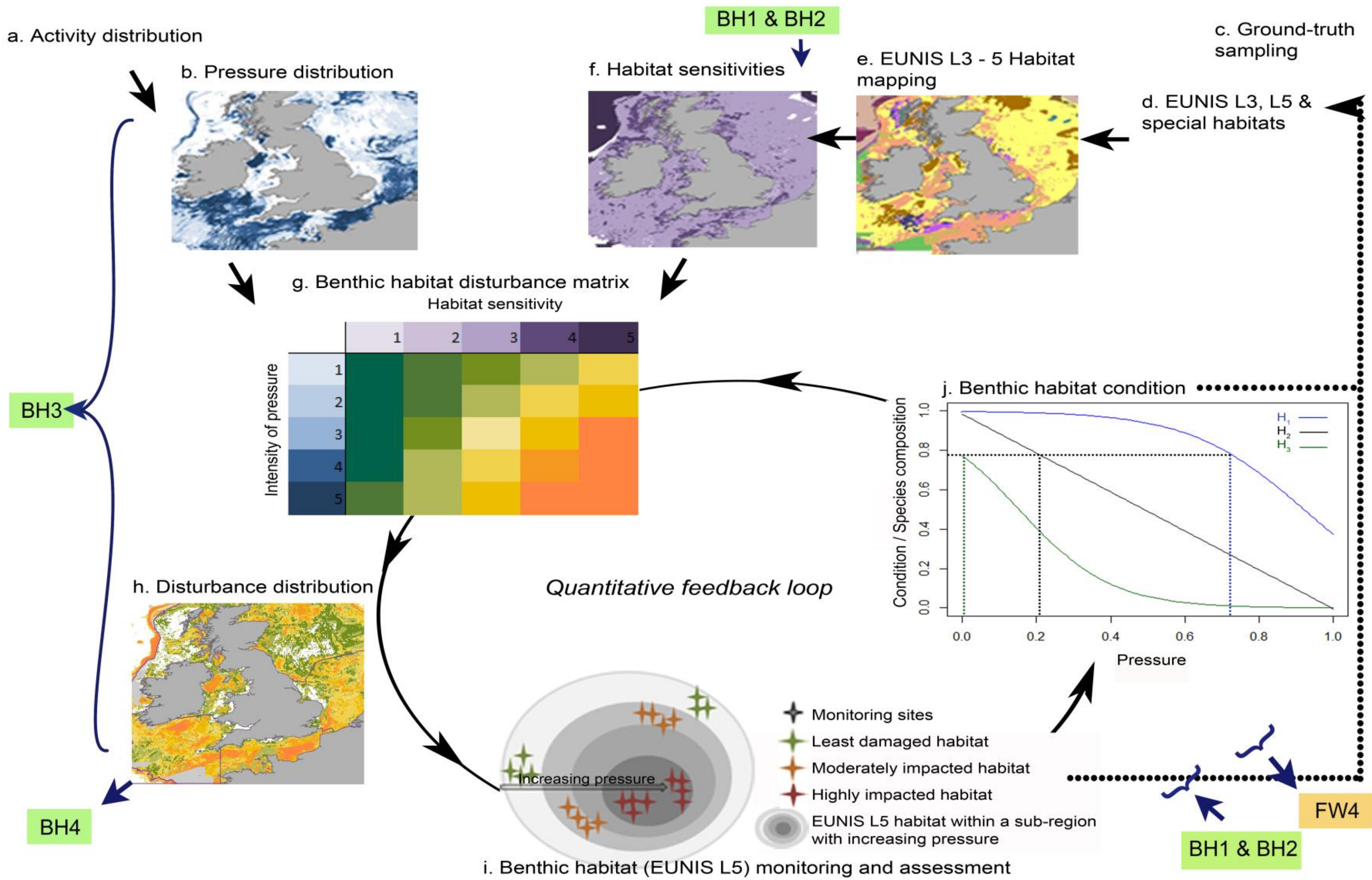

Figure 3.1: Overarching conceptual approach for an integrated assessment of benthic habitat indicators on a (sub) regional scale.

3 Overview of how indicators can be assessed to support management decisions

The proposed benthic habitat integration process strengthens benthic habitat models by feeding in new ground-truthed data. The process also facilitates direct links between benthic habitat condition and tipping points from a damaging anthropogenic pressure, through the analysis of pressure-state relationships. This integration approach therefore facilitates quantitative thresholds and management measures to be put in place through understanding pressure-state relationships, where benthic habitat (EUNIS level 4-6 and special habitats) and pressure data exists. The method also enables the individual benthic indicators to feed into one another strengthening the confidence in the overall assessment.

3.1 Advantages and disadvantages of the approach

Advantages	**Disadvantages**	**Solutions**
Improves upon best available evidence.	Overall method not tested at (sub) regional scale.	Obtain access long-term datasets to test the process.
Provides quantitative analysis of benthic habitat assessment.	Requires detailed information on benthic habitat (EUNIS level 4-6 or special habitats) and pressure data	Obtain access to existing datasets. Where only modelled EUNIS level 3 habitats exist, more complex statistical analysis could be undertaken incorporating other environmental variables. However, results may be less reliable.
Enable benthic habitats to be analysed in the absence of pristine habitat information through analysing least damaged areas.	Co-occurring pressures (or cumulative effects) are not considered.	Improved methods to analyse co-occurring pressures and further work with OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C).
Provides links with D3 and D4.	Further integration with other food web and pelagic indicators required.	Develop methods, test and integrate other indicators.
Could be implemented in other MSFD regions.	The process for its implementation would need to be transposed within other Regional Seas.	Communication and exchange of knowledge between Regional Seas would need to be continued and coordinated.

3.2 Information on the confidence of the assessment

Given the overall method has not been tested at Regional scale, it is difficult to assess the confidence of this assessment. However, the method should improve the confidence of individual indicator assessment through the quantitative feedback loop. The individual parts of each benthic habitat indicator assessment (OSPAR, In Prep.a-d), and BH3 indicator integration with FW4 have been tested (refer to Chapter 4).

3.3 How far it goes to assessing thresholds and linking the results to policy requirements

Due to the nature of the proposed method (pressure-state relationships examined), it will be possible to assess the tipping point at which the condition of the benthic habitat deteriorates with increasing pressure, where pressure and benthic habitat (EUNIS level 4-6 and special habitats) data exist, enabling thresholds to be set according to habitat resistance. The latter will enable quantitative management measures to be recommended given the resistance of the benthic habitat and demersal food web species to different pressures will be better understood. Resilience over time could also be assessed if pressures were discontinued.

3.4 Added socio-economic and ecosystem services implications

Socio-economic and ecosystem services implications of benthic habitat indicator integration include, the ability to identify the point (or range of pressure) at which activities causing deterioration to a particular habitat takes place. The latter would help safeguard the benthic habitat from permanent loss and thereby avoiding loss of services it provides. Where sufficient data is available, this method could be implemented in a similar approach to BENTHIS (ICES, 2016). In the latter case, stakeholders and managers would need to come to an agreement on the level of pressure that can take place to ensure viability of anthropogenic activities, whilst minimising unsustainable damages to the seafloor.

3.5 Approach applicability to OSPAR sub-regions

Although the approach has been developed to work within the OSPAR region it could be applied to other MSFD sub-regions and regions supporting cross-region coherence. Benthic habitat and pressure maps at relevant scales would however be an essential building block for the approach. To facilitate the implementation of the approach into other regions, coordination with the relevant authorities would be required.

3.6 Links to other related projects

Similar work which has been forwarded parallel to this process, includes ICES advice on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats (ICES, 2016). The advice looks at different approaches to carry forward sea floor sensitivity mapping for MSFD. Nonetheless, the advice does not attempt to integrate the different indicators. To facilitate the implementation of the approach into other Regional Seas, where it should be conceptually applicable, coordination and exchange of knowledge with the relevant authorities would be required.

3.7 Timeline, feasibility and costs

Resource costs to implement this approach include, the need to forward an EcApRHA like project to provide enough time and resource to gather data at a (sub) regional scale and test this method for different habitat and presssure types. Links with other indicators (e.g. pelagic and food webs, commercial fish, mobile vertebrate species, etc.) could also be further investigated and integrated to this method to work towards a more ecosystem-based assessment. Resource costs could be adjusted in time according to habitat and pressure type prioritised, and depending on the level of integration desired (e.g. whether to just continue with benthic habitat integration or to include pelagic and food web indicators).

Figure 3.2 provides a timeline for how this integrative process could be put in place encompassing pelagic and food web indicators over the next MSFD and OSPAR reporting cycles (with the assumption of sufficient resources; OSPAR, 2017). If benthic habitat integration (or wider food web and pelagic indicators) is not undertaken, a quantitative ecosystem approach will not be possible to implement and therefore an assessment of GES for specific areas of sub-regions will not be possible.

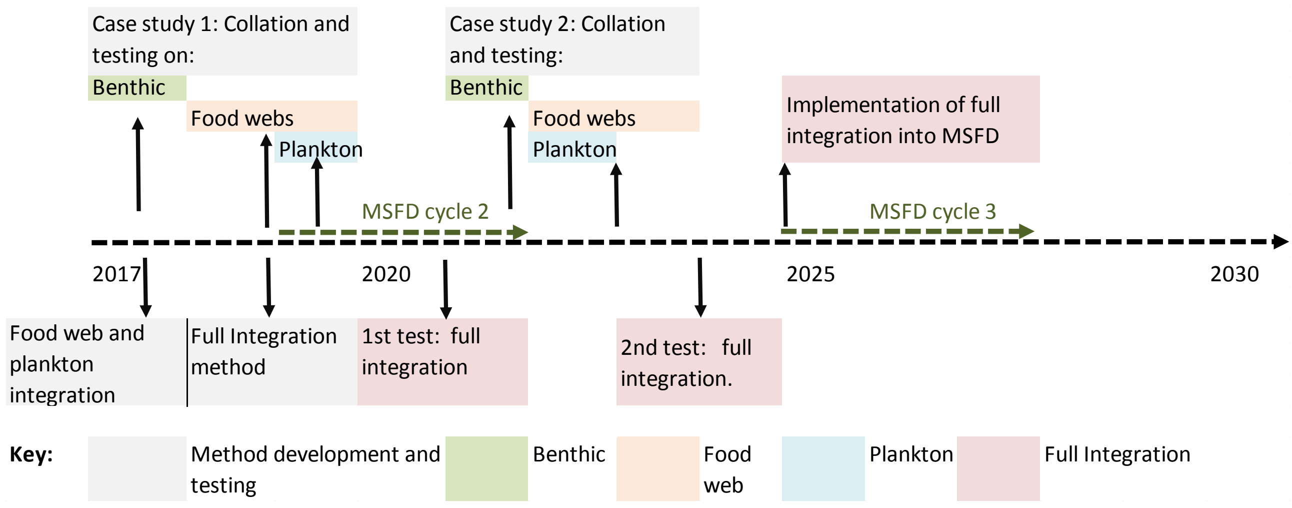

Figure 3.2: Timeline along which benthic habitat integration method could be implemented, incorporating food web and pelagic indicators (with the assumption of sufficient resources).

4 Integration of BH3 (Physical damage) and FW4 (Mean trophic level of marine predators) OSPAR indicators

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4.1 Summary

The health and sustainability of fisheries can be assessed by monitoring the trends in average Trophic Levels (TL) (Pauly & Watson, 2003). When TL values begin to drop, it indicates that fisheries are relying on ever smaller fish and that stocks of the larger predatory fish are beginning to collapse. TL-based indicators have been established as food web indicators capturing fishing impacts at community level of marine ecosystems (Shannon et al., 2014). Many studies have been conducted using landings, surveys and model estimations to capture the changes observed on mean trophic level of demersal communities in the last decades (Navarro et al., 2011, Bourdaud et al., 2016, Reed et al., 2016). Data sources and TL cut-offs arise as the main key questions on the trends observed in all TL-based indicators (Shannon et al., 2014). But, while all these studies prioritised a temporal approach, the spatial scale of these variations has hardly been considered. The relationship between fishing pressure and changes in the TL of demersal and benthic communities at specific and localised pressures is actually, virtually unknown. This approach is the first attempt to explore the direct impact of trawling on the mean trophic level of demersal communities using a spatial approach at local scale. The preliminary results obtained in the first steps of this integration (crossing mean trophic levels with Vessel Monitoring System (VMS) data using a spatial approach) corroborate the direct (and negative) relationship between fishing effort and Mean Trophic Level (MTL) of the demersal communities, and thus, convenience of FW4 (MTL) as a pressure indicator (**Figure 4.1**). One of the main contributions of this approach is the high resolution of the maps obtained, where highly impacted areas within "hotspots of fishing pressure" can be detected, thus helping in the implementation of specific management decisions at well-defined scales (refer to Arroyo et al, 2017 for more detail). The integration between these results and those obtained using BH3, will help to ascertain the relationship between damage to the seafloor caused by trawling and decreases in MTL of demersal populations in specific areas, further refining the spatial accuracy of these assessments and the associated management measures.

4.2 The approach

The relationship between MTL by haul and fishing disturbance was analysed using General Additive Models (GAMs). Sediment type and depth were also included as explanatory variables in the model. All the response variables were in a raster format which allows projecting the GAM results in a map and therefore predict the MTLs in space.

The final maps were computed using the real scenario (with real fishing effort values) and a no fishing scenario, where all the values in the VMS map were substituted by 0. The differences between both maps were computed and the percentage of change in the MTL produced by fishing was calculated as follows:

Percent change in MTL= ΔMTL between scenarios/MTL in real scenario.

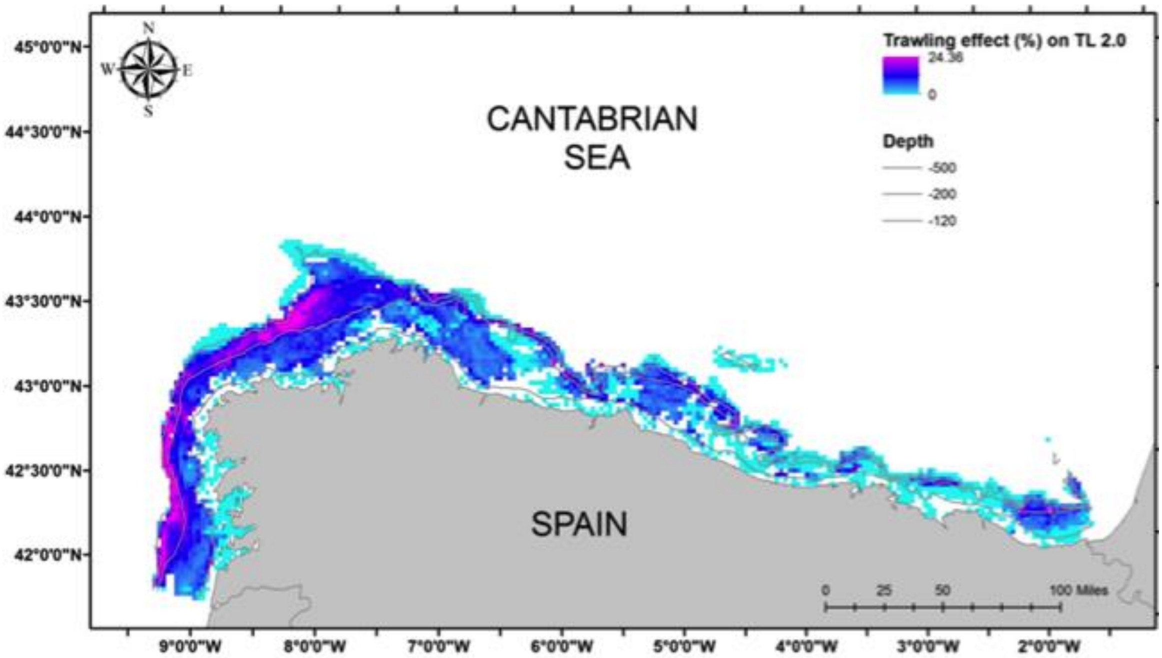

Figure 4.1: Statistically modelled trawling effect on Mean Trophic Level 2.0. Results from the predictions show the percentage of change between a non-fishing and a real scenario applying a threshold of Trophic Level >2 when including species (i.e. all consumers considered). The areas where the strongest effect (25% decrease in MTL) corresponded to those areas where trawling intensity is highest, at the Galician slope.

4.3 Overview of how indicators can be assessed to support management decisions

The combination of BH3 and FW4 indicators can help identify highly impacted areas, in terms of food web organisation, within hotspots of bottom contacting fishing gear impact. A decreasing trend in MTL values indicates that food webs are being deprived of the top predators. The resulting smaller food chains leave marine ecosystems increasingly vulnerable to natural and human induced stresses, as well as reducing the overall supply of fish for human consumption. The integration of this information with sensitivity maps resulting from the BH3 indicator may help to further link the effects of benthic habitat destruction as a result of bottom contacting fishing gear with the concomitant consequences in food web and thus, ecosystem population structure.

4.4 Advantages and disadvantages of the approach

Advantage	Disadvantage	Possible solution
Combination of these two indicators may help identify highly impacted areas by fishing.	More data requirements (VMS data need to be readily available)	Open access to VMS data.
It can help define more specific and accurate management measures from a spatial perspective.	TL values are not sufficiently accurate at regional level.	Stomach content or stable isotope analyses should be implemented in surveys to obtain accurate TL estimations.
When data are available, the approach can be easily applied at OSPAR and EU level.		

4.5 Information on the confidence of the assessment

The method is now being developed and will shortly be ready to test in order to produce an assessment. The confidence of the assessment would improve with better trophic level estimations and longer time series of VMS data. However, these improvements would have implications for the cost of monitoring.

4.6 How far it goes to assessing thresholds and linking the results to policy requirements

The establishment of thresholds for this integration approach is currently under development. However, the rationale behind this integration is to give a percentage of change in MTL (non-fishing versus fishing scenarios) based on model results. This percentage of change could be used as a proxy for a threshold.

4.7 Added socio-economic and ecosystem services implications

The socio-economic impact of fisheries and the importance of fish as a food source for humanity at a global scale are undisputed. However, growing evidence of fish depletion in the oceans calls for increased and ever-more accurate monitoring and assessment strategies to try to reach a compromise between securing the social and economic activities related to fisheries while at the same time preserving ecosystems services. The integration approach presented here permits the identification of impacted areas at very specific spatial scales, facilitating targeted management measures to be implemented if desired.

4.8 Approach applicability to OSPAR sub-regions

The applicability of the approach at an OSPAR level is dependent on the availability of VMS and log book data. Other data sources such as biomass and trophic levels are available or can be compiled for all regions.

4.9 Links to other related projects

To our knowledge, there hasn't been any similar attempt in any other region, nor is there any initiative to pursue it as a common target between Regional Seas Conventions. However, given the clear and sound results obtained in the Cantabrian Sea, it would be very interesting to extend this approach to other European regions and assess the generality of its applicability.

4.10 Timeline, feasibility and costs

The feasibility of the proposed timeline (**Figure 4.2**) will very much depend on the availability of resources, and specifically, of experts that can dedicate time to the development of case studies and analyses of the suitability of the indicators to the integration scheme. Preliminary analyses on the appropriateness of the indicators showed that there are some modifications that need to be performed to the way in which they are derived in order to make them spatially compliant, and thus, fit for integration. The costs would be thus related to the appointment of such experts.

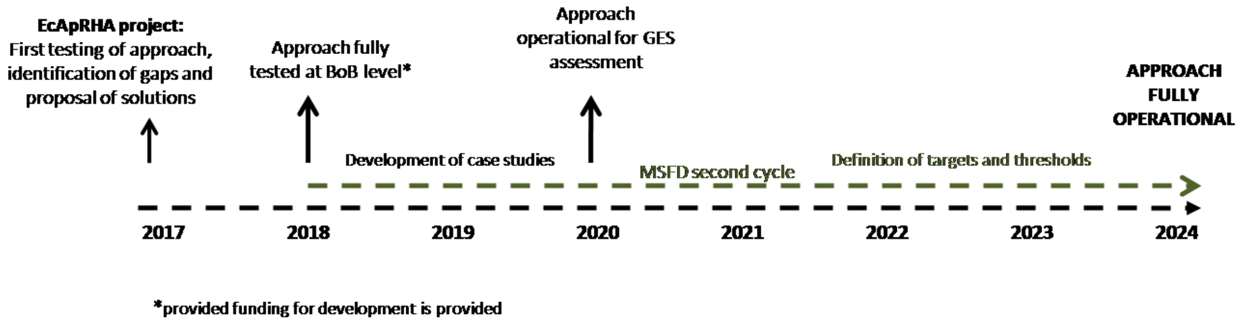

Figure 4.2: Timeline along which benthic habitat (BH3) and food web (FW4) integration could be implemented under the assumption of sufficient resources. The integration approach should be fully operational for 2024 and ready to use in the reporting of the next (third) cycle, once targets and thresholds are confidently set and contrasted with enough case-studies.

The feasibility of the integration is compromised by the limitations to the access of VMS data. Once these are made available, guidelines for a common structure and metadata format in order to create a common database for all Contracting Parties would be desirable, the costs being then, those of the maintenance of such a resource.

5 Integration of food webs indicators into the Nested Environmental status Assessment Tool (NEAT) tool

M. Haraldsson, N. L. Arroyo, E. Capuzzo, P. Claquin, J. Kromkamp, N. Niquil, C. Ostle, I. Preciado, G. Safi

5.1 Summary

OSPAR food webs indicators (**Table 1**) aim to capture the complexity of the food webs by assessing the status of their ecosystem components. Linking information between these indicators supports a holistic description of food webs. However, in the current state of knowledge, establishing relationships between all food webs indicators is a challenging issue as each of these indicators can be sensitive to a different kind of pressure. Integrative tools are hence needed to allow the integration of the information in a comparable and systematic way, to assess the food webs status. The Nested Environmental status Assessment Tool (NEAT) software is used here to implement a biodiversity assessment. The objective of the current work is to communicate and search for potential solutions on how to integrate information into the NEAT tool for food webs indicators. This involves identifying and addressing questions of both a methodological and ecological nature (refer to Haraldsson et al. (2017) for more detail). By illustrating how two different types of indicators (i.e. Phytoplankton Production (PP) and MTL) can be integrated into the NEAT tool, our aim is to share our experience with contracting parties and ICG-COBAM group and to propose a methodological framework on how to proceed in this work.

5.2 The approach

The NEAT tool is proposed here for a nested integrated assessment, ensuring clarity, transparency and easy handling of the indicators. In order to run an assessment using multiple indicators, the critical information needed for each indicator is the threshold values to define the boundaries between the various status classes (**Figure 5.1-A**).

Percentiles are used in EcApRHA project to set the threshold values and the surrounding class status (see examples of two case studies in **Figure 5.1-B**). For MTL_3.25, the reference period to define the threshold value is set on the most recent years where the indicator show the highest increase of the time series. This is in agreement with the current knowledge of the overall amelioration of the Bay of Biscay continental shelf food web. For Phytoplankton Production (PP), no trend is observed in PP over 20 years of survey in Sylt-Rømø Bight ecosystem (DE). The whole time series is used to define the threshold value (50th percentile) and the surrounding boundaries (i.e. Moderate, Poor, Bad) knowing that this ecosystem is known to be little impacted by human anthropogenic pressure.

Once threshold values and boundaries have been defined, the indicators' values and associated errors (i.e. field measures) are used to run the assessment. The NEAT values (i.e. the final assessment results) are given for each spatial assessment unit with an uncertainty/confidence around the values (**Figure 5-C**). The NEAT values can also be observed on the ecological components or habitats level. Finally, different assessment scenarios can be produced such as testing the influence of different threshold values (i.e. threshold values from literature versus local defined values) on the final assessment results (**Figure 5-D**).

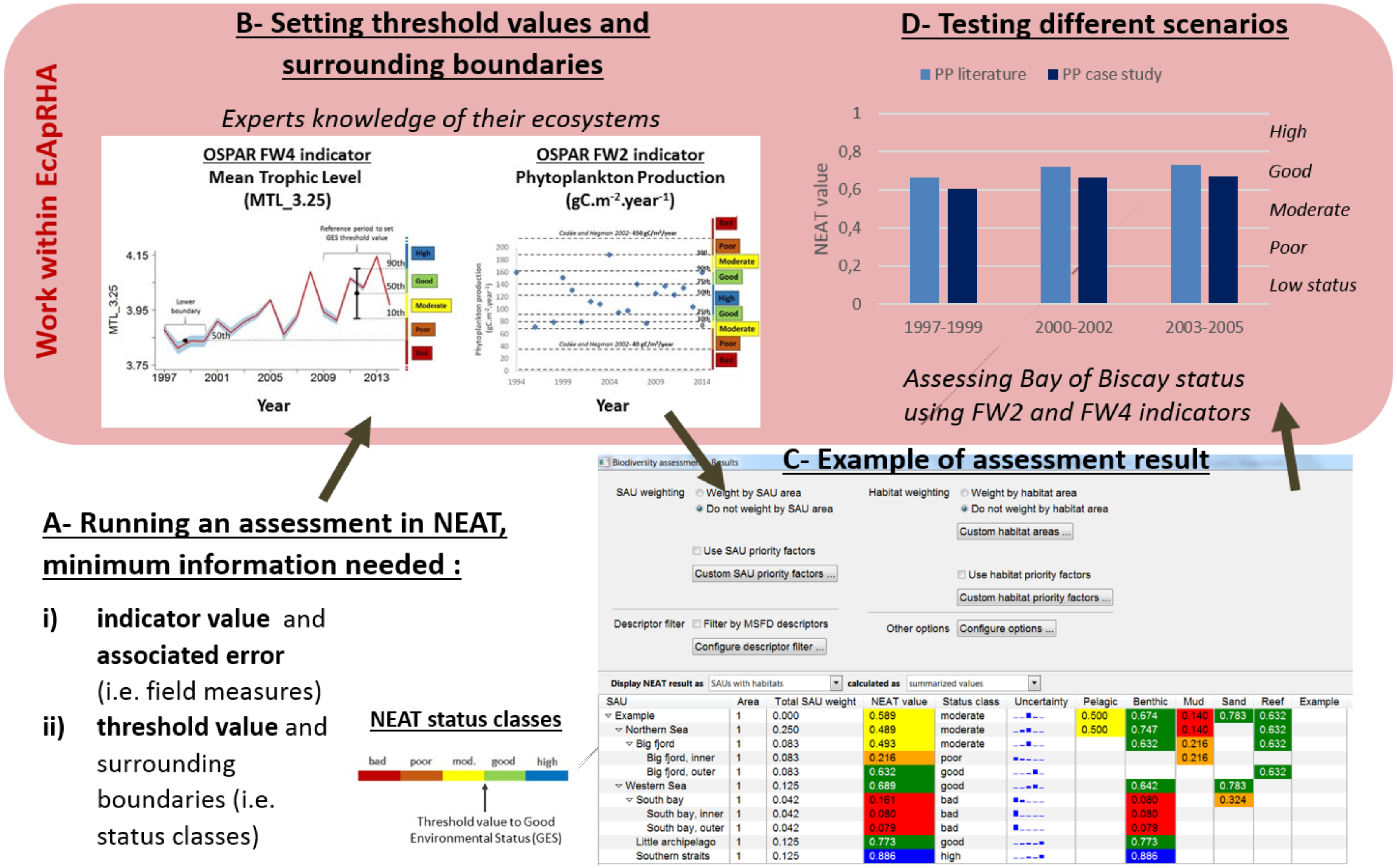

Figure 5.1: Schematic representation of the steps needed to produce different assessment scenarios using NEAT tool. **A.** The minimum information required to run an assessment with NEAT tool; **B.** Defining threshold values and surrounding boundaries based on expert knowledge of their ecosystems/case study; **C.** Example of the NEAT final assessment result in a table format; **D.** Testing different scenarios for assessment modifying threshold values for Phytoplankton Production (PP) which are either defined from literature or from local case study.

5.3 Overview of how indicators can be assessed to support management decisions

Given the tool setup, the indicators are integrated under a combination of a Spatial Assessment Unit (SAU) with its assigned habitats and ecological components (refer to Haraldsson (2017) for more detail).The final assessment result can be evaluated for each SAU, which is typically the unit of assessment. Within this area, the results of the underlying sub-SAU or sub-units (habitats) can be explored. It is also possible to explore the individual NEAT value for each ecological component. In this way, the policy makers can explore potential sensitive areas or components.

5.4 Advantages and disadvantages of approach

Advantages	**Disadvantages**	**Solutions**
NEAT structure is aligned with MSFD requirements	Cannot easily accommodate some indicators.	New NEAT version should address most of the technical issues allowing the inclusion of more indicators.
NEAT propose a nested approach where indicators are assigned to a combination of SAU with habitats and ecosystem components.	Lacks transparency in the mechanics behind NEAT.	The mechanics of NEAT should be made available in the future.
NEAT is applicable in all Regional Sea Conventions (RSCs) and includes RSCs' core and common indicators.	In the current NEAT version, the absence of threshold values and boundaries stop the possibility of running an assessment.	Proposition of common guidance for setting threshold values. This could imply additional resources for experts and stakeholders to work jointly towards defining common sub-regional threshold values for indicators

5.5 Information on the confidence of the assessment

The final NEAT assessment result includes a confidence around the assessment value in the form of a distribution of confidence over the five classes' status (see uncertainty bars in **Figure 5-C**). This is the result of a simulation based on the standard error of each indicator assessment value included in the analysis and also the weighing and priority factors that were applied on the spatial assessment units and habitats. Some additional confidence could be developed at the indicator level (refer to HELCOM BalticBOOST 2016b) which would be good to consider in future NEAT versions.

5.6 How far it goes to assessing thresholds and linking the results to policy requirements

The work described here proposes a way of assessing threshold values to be used in integrative tools such as NEAT. Threshold values defined are based on European experts' knowledge of their shared sub-region ecosystems. The best available information is used, either by setting thresholds on sub regional case studies (**Figure 5-B**) or by referring to scientific published work to set theoretical thresholds (**Figure 6.2**). For a precautionary approach, the threshold values should be revised at each MSFD cycle (i.e. every six years) considering knowledge progress on each ecosystem. It is worth noting that the threshold values that are proposed here are calculated for the purposes of demonstrating the NEAT tool. They do not represent any agreement by European Member States that are OSPAR Contracting Parties. The establishment of threshold values, where appropriate, is outlined for indicators within the current revised Commission

Decision (2010/477/EU) under its Article 4 (https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2016-5301702_en).

5.7 Added socio-economic and ecosystem services implications

The NEAT tool provides integrated information with several layers (i.e. indicators) of socio-economic and ecosystem goods and services implications. Phytoplankton production (PP) and the Mean Trophic level indicator (MTL) were integrated into NEAT tool to test it within EcApRHA project. With no PP, marine ecosystems would collapse. PP plays a major role in reducing the green-house effect which influences climate change. MTL indicator describes the structure of the food web. A reduction of MTL could be related to the loss of high predators impacting thus ecosystem goods with an important socio-economic value.

5.8 Approach applicability to OSPAR sub-regions

The NEAT software is preconfigured for the use in the four European Regional Seas with their assigned indicators according to Texeira et al. (2014)

5.9 Links to other related projects

The BalticBOOST project is working on an integrative tool (HELCOM biodiversity assessment tool BEAT), making ameliorations after an initial review that they conducted on existing integrative tools including NEAT tool (HELCOM BalticBOOST 2016a) and considering outcomes of various workshops and relevant meetings (e.g. HELCOM HOLAS II 2016, HELCOM 2016, HELCOM BalticBOOST 2016c).

5.10 Timeline, feasibility and costs

The feasibility of the proposed timeline (**Figure 5.2**) depends on the availability of resources, and experts that can dedicate time to the development of case studies and comparison of NEAT with other existing integration tools. Preliminary analyses, within EcApRHA, of the integration using NEAT tool showed that there are some technical issues that need to be addressed for the developers of the tool. However, most of these technical issues should be considered in the upcoming NEAT version. The NEAT tool is ready to be used for assessment purposes. The timeline suggests complementary analyses in order to test a more complex nested assessment, than the one achieved within EcApRHA project, by increasing the number of indicators used and by assessing different nested spatial assessment units. Parallel assessments can be conducted, on a case study region or sub-region, using NEAT tool and other existing assessment methods. This would allow to establish the pros and cons of using NEAT and would help policy makers in selecting the appropriate method for future national and OSPAR assessments.

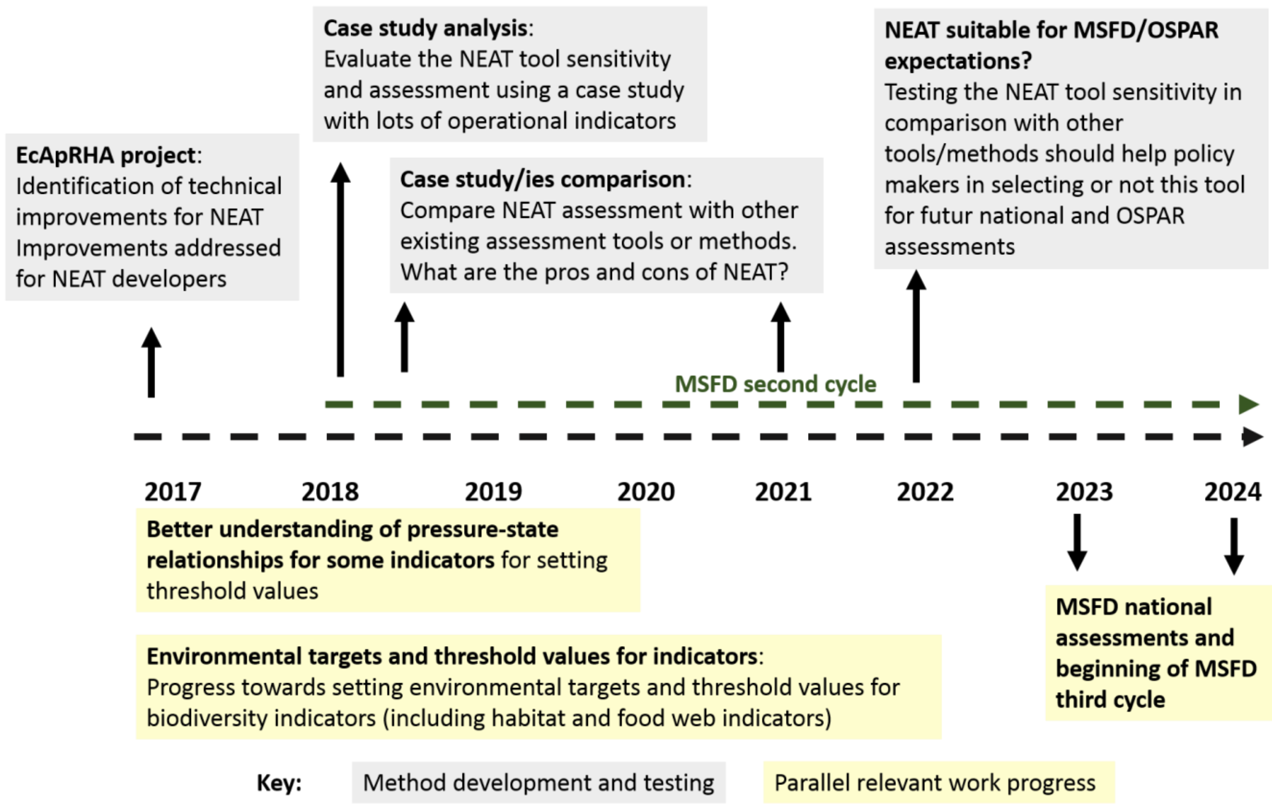

Figure 5.2: Timeline along which food web integration using the NEAT tool could be further tested and implemented with the assumption of sufficient resource.

6 Integration of pelagic habitats and Food web indicators

A. Aubert, C. Ostle, G. Safi, A. Budria, I. Rombouts, F. Artigas, A. McQuatters-Gollop

6.1 Summary

OSPAR pelagic habitat and food webs indicators (**Table 1**) use plankton, which forms the base of marine food webs to assess the state of the ecosystem and therefore flow of energy through it. The integration of such indicators is difficult due to differences in their defined spatio-temporal resolution and because of potential differences in their responses to pressures (for the moment the indicators are state indicators not assessed against pressures). Since further development is needed for the integration of the pelagic indicators (allowing a more holistic pelagic approach), we propose to start considering the pelagic indicator integration with food web indicators by using only those pelagic indicators that represent the clearest and more direct link to an ecological function in food webs. Two common indicators, PH1/FW5 and PH2/FW6 (not official approved yet if it will be PH2/FW6 or FW6 alone), represent the most relevant indicator to start with for this integration approach.

6.2 The approach

Three common OSPAR indicators for pelagic habitats are currently under development: PH1/FW5, PH2 and PH3. These indicators are currently state indicators which assess changes in the plankton community at different levels of organisation. They do not currently assess GES in relation to environmental changes or anthropogenic pressures. It was decided to use these indicators are used as a suite:

- PH2 considers plankton at the broadest level, using a proxy of phytoplankton biomass (chl *a* and Plankton Colour Index, PCI) and total copepod abundance.
- PH1/FW5 considers plankton at an intermediate level, using plankton grouping into ecologically-relevant lifeform pairs.
- PH3 considers plankton at the finest level of organisation, down to the genus or species level where possible, using diversity indices such as species evenness, dominance and beta diversity indices.

An approach for the integration of PH1/FW5, PH2 and PH3 indicators is proposed to address the plankton community as a whole, rather than through specific components (Budria et al, 2017), in accordance with the ecosystem approach inherent to the implementation of MSFD. Considering the three indicators together will allow to understand plankton dynamics in a more holistic way, and to better understand the links in the future with environmental changes and anthropogenic pressures. However, the integration of these three indicators has just been initiated and is, hence, still under development. So far, the pelagic indicators remain state indicators and it is not possible to anticipate potential links between an unachieved pelagic multi-metric index and the food web indicators. In order to make integration between pelagic and food web indicators, pelagic indicators based on pelagic metrics are clearly important to the food web have to be selected first. For instance, the importance of plankton diversity (especially pure diversity, cf. PH3 indicator) for food web functioning (thus including food web's health and productivity) should be further investigated. Plankton is however at the base of food-webs, providing a valuable food resource for higher trophic levels (both benthic and pelagic), such as bivalves (shellfish), fish of commercial interest and even whales. Indicators based on plankton productivity metrics are the most straightforward indicators to relate to food-web indicators (as it is done for phytoplankton production indicator and MTL when tested in NEAT (Haraldsson et al, 2017). Additionally, plankton can impact other important ecosystem processes such as nutrient recycling, which should hence, be considered in order to follow an ecosystem approach. Two indicators are based on metrics which have clear links with such other food-web components and/or processes: PH1/FW5 with some lifeform pairs such as meroplankton/holoplankton, and the food web indicator FW6 (Aubert et al, 2017) which considers zooplankton productivity estimation. There is currently no indicator fully considering phytoplankton productivity (Production: Biomass ratio) within the pelagic indicators. In the future, links between phytoplankton biomass (PH2) and phytoplankton primary production (FW2) should be explored and potential proposition of a PH2/FW2 indicator could be made. This will have to consider improvements of the PH2 indicator for phytoplankton, since only proxies of biomass (chl *a* and Plankton Colour Index, PCI) are currently considered. We address separately below the integration with food web indicators of the two pelagic indicators mentioned, PH1/FW5 and FW6 (potentially also going to be called PH2/FW6).

The lifeform pairs (PH1/FW5) were identified and built for their ecological relevance related to the food web concept. Some lifeform pairs have a clearer "trophic status" compared to others. Among them, the meroplankton/holoplankton pair is an indicator of benthic/pelagic coupling in the food web, the large copepods/small copepods pair is an indicator of food transfer in the food web, and the pelagic diatoms/tychopelagic diatoms pair is an indicator of benthic disturbance and frequency of re-suspension events. Such lifeform pairs can thus be initially considered in the process of integrating pelagic indicators with food web ones. The first testing of pelagic integration with food webs can be conducted with the Nested Environmental status Assessment Tool (NEAT). This first work, thus, will investigate how to integrate information into the NEAT tool from two indicators, a pelagic and a food web one. This work notably implies identifying and addressing both methodological and ecological questions (Haraldsson et al, 2017 for more detail). The example of the integration in NEAT between Phytoplankton Production ('PP') and the 'MTL' (presented in this report in part 5.1 as an example) can be followed for the pelagic indicator PH1/FW5. Potential changes on the methodology of the PH1/FW5 indicator should be addressed. For instance, methods based on percentiles as used for the phytoplankton production indicator (FW2; OSPAR, In Prep.e) could be used for PH1/FW5, although time-series instead of PI annual values should be considered (Tett et al, 2008). In order to integrate the PH1/FW5 indicator with food web indicator into NEAT, threshold values and surrounding boundaries should first be defined, based on experts' knowledge of their ecosystems/case study.

This work will require human resources in term of time and involvement with the other compartment experts.

6.2.1 Integration of FW6 (or FW6/PH2) and food web indicators

An important differentiation has to be done between the concepts of the PH2 indicator and FW6 (which will potentially become PH2/FW6, cf. Aubert et al, 2017). PH2 is not considering primary and secondary production because it only considers chl *a* or PCI for phytoplankton (which are not proxies of primary production, but just proxies of the phytoplankton bulk biomass) and total copepod abundance for zooplankton. PH2 only depicts a broad organisational level of the plankton community and cannot be considered as an indicator of production for these plankton compartments (phytoplankton and zooplankton). For this reason, an adaptation of PH2 has been proposed in the development of FW6. The concept and proposed methodological development of this indicator are available in the EcApRHA deliverable report 3.4.1 (the main adaptation will consist in transforming the zooplankton abundance data into biomass data to produce a better proxy of secondary compartment production). A biomass per size spectra indicator for zooplankton should, hence, become available in the future. Since each biomass per size spectra represents a different food source which can be related to higher trophic levels (notably zooplanktivorous fish), these are highly relevant in the food web approach. As for PH1/FW5, the NEAT tool is potentially usable for integrating both indicators. This will need further methodological work when the FW6 indicator will be available for case studies or for some assessment scale unit. This will then allow the integration testing with food web indicators. Moreover, work is needed to transform phytoplankton abundance per taxa (or size class) into biomass as well, in order to be able to build a FW indicator complementary to FW6, for the phytoplankton part. Phytoplankton real biomass could then also be used for estimating real P/B ratios (instead as P/chl a ratios).

6.3 Overview of how indicators can be assessed to support management decisions

Since some lifeforms (PH1/FW5), but also zooplankton production (FW6), are clearly connected to other trophic levels or trophic processes, it will be possible to relate them to the anthropogenic pressures that affect the food web components or to processes they are related to. This step will necessitate further development for both pelagic and food web indicators currently developed. Indeed, no thresholds values related to environmental changes or anthropogenic pressures have been clearly set. However their integration might render easier this step. Ideally, the integration with the food web indicators will permit to identify highly impacted area (in term of mismatch between the presence of some important functioning life forms, and dependant higher trophic levels for instance, due to environmental changes or pressures). Another example is the potential identification of zones where increases in zooplankton production are linked to decreased fish stock due to fishing pressure. These examples illustrate how the integration will allow a better cross-cutting of issues, by relating different components of the food-web that can be impacted by similar anthropogenic pressures. This is of high interest for future management actions because it will allow identifying zones where potential management actions are needed (as pressures are affecting several component of the ecosystem and not a single component). The integration will also provide an assessment at a common scale between food web component and pelagic organisms, rendering easier the future link with other compartments, and thus management.

6.4 Advantage and disadvantages of approach

Advantages	**Disadvantages**	**Solutions**
Use of the same reference period gives more ecological meaning	Difficult to define a reference period, especially for pelagic habitats	Use/Develop standardised methodology to define GES for the pelagic – food web indicators integration (to potentially define reference period in relation to identified pressures impacting the trophic relationships)
NEAT structure is aligned with MSFD requirements	Cannot easily accommodate some indicators in its current methodology (PH1/FW5 for instance)	New NEAT version should address most of the technical issues allowing the inclusion of more indicators/ PH1/FW5 methodology could be revised in order to keep the monthly information
NEAT is applicable in all RSCs and includes RSCs' core and common indicators.	In the current NEAT version, the absence of threshold values and boundaries stop the possibility of running an assessment.	Propose a common guidance for setting threshold values. This could imply additional resources for experts and stakeholders in order to work jointly towards defining common sub-regional threshold values for indicators
Allow to assess link with pressures	The link with pressures is made indirectly (through pressures affecting trophic relationships)	Pressures identified through the most relevant trophic relationship between pelagic indicator and food web ones

In addition to these points mentioned in the table, it has to be highlight that extra work is needed to go deep into the ecological meaning of the combination of indicators as well as on the improvement of the meaning of each indicator (by improving their definition and by including new types of data in order to complete the assessment of both diversity and food web state).

6.5 Information on the confidence of the assessment

At the current stage, it is not possible to speak about confidence of assessment since no testing is currently made. The integration of pelagic indicators with food web indicators is promising and will allow setting references period more easily as explained previously. It will give to the plankton compartment more weight since it is now difficult to relate them to any pressure, despite their huge importance as a food base in the marine ecosystem. For future assessments, the definition of local boundaries in order to refine the class boundaries in relation to local specifications and human-induced pressures, will be an important step. This can be limited by the knowledge of an area, and the data that are available within that area.

6.6 How far the assessment goes to assessing thresholds and linking the results to policy requirements

Currently this analysis is conceptual and needs further development and testing. However, the potential to link pelagic indicators to identified pressures and/or environmental changes through their integration with food web indicators is promising for future policy requirements.

6.7 Added socio-economic and ecosystem services implications

By incorporating the plankton in the food web approach there is a strong socio-economic benefit for assessing changes in the food source of many marine birds, bivalves (shellfish), fisheries, and mammals. The bottom of the food-web is clearly vital for maintaining these ecosystem services and assessing their health. Changes in the plankton community composition not only have implications for the flow of energy through a range of different food webs and thus its productivity and services, but also for the storage of anthropogenic carbon via the biological carbon pump. This has large socio-economic value from a carbon-sequestration perspective, and should be continually monitored and assessed.

6.8 Approach applicability to OSPAR sub-regions

The data have been divided using ecohydrodynamic areas within OSPAR regions (**Figure 6.3**). For the PH1/FW5 indicator and for the FW6, the first work will consist in assessing if an adaptive scale can be developed for the use within the NEAT tool. In order to be able to use this state-space plankton indicator (OSPAR, In Prep.f), the scale of good to bad (used within NEAT) would indeed need to be changed to a scale of significance (proportion of points outside of the state-space plot for instance). This scale could go from 0 to 1 for instance and will need a colour scheme, which is not based on subjective quality such as good/bad since (it is not possible to assess if a change is actually good or bad for plankton indicators in general). The scale will thus need to be neutral. We propose an example of 0-1 range scale for all the lifeform pairs in the **Figure 6.3** following. Further work would be required however to know how to potentially use several lifeforms together or rather if they should be used separately and combined with different food web indicators of relevance depending on which trophic relationship they are linked to.

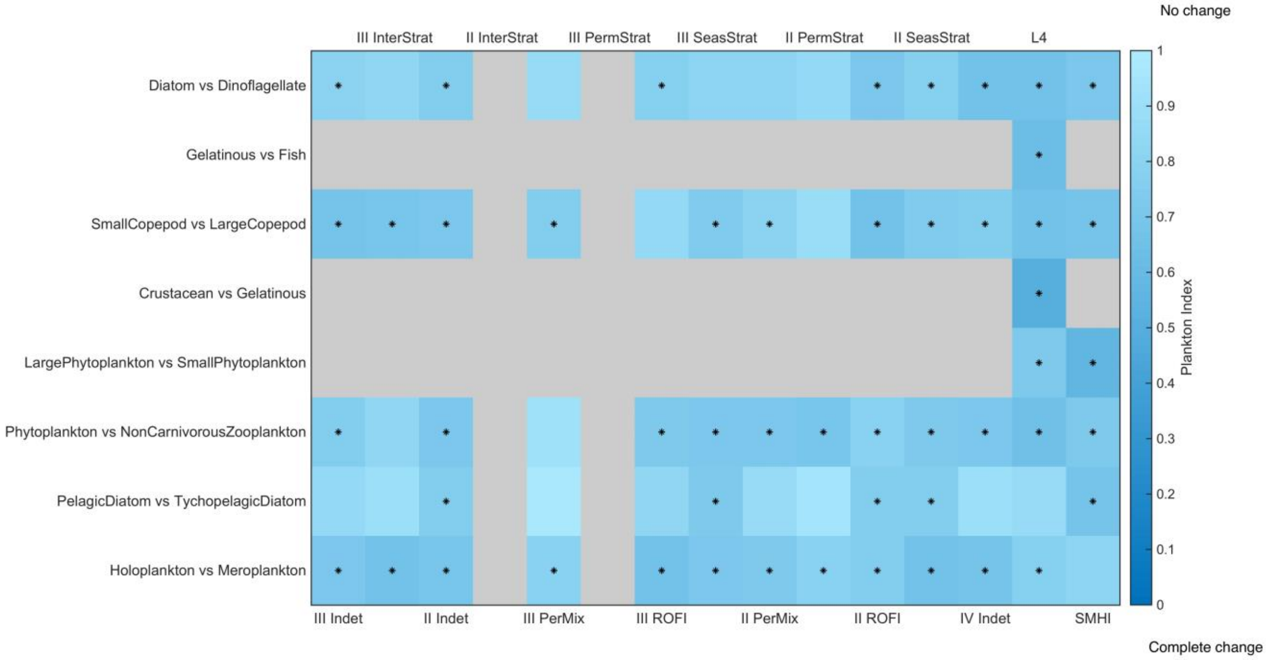

Figure 6.1: Change in Plankton Index for the period 2009 - 2014 from starting conditions (2004 to 2008) for each lifeform pair. The x-axis labels correspond to the region or station, while the y-axis is the lifeform pair. Darker blue indicates a more pronounced change. Grey shading represents where there were not enough/well-represented data to determine a Plankton Index. Starred cells indicate significant change ($p < 0.01$) from starting conditions. Changes in the Plankton Index do not necessarily indicate a deterioration of environmental condition; it does however, indicate change from starting conditions.

For the FW6 indicator, the methodology of the indicator itself needs to be defined to propose further integration into the Neat tool. However, the advantage is since this indicator methodology is not yet set up, the integration approach within Neat tool can be already taken into account within the indicator development. The assessment will be done considering the ecohydrodynamic areas.

6.9 Links to other related projects

The work on FW6 is considering the methodology of the HELCOM Core Indicator Zooplankton mean size and total abundance (Gorokhova et al. 2013). It will potentially involve experts from HELCOM, and thus from BalticBOOST. The development of this indicator should be clearly also associated with the ActionMed project since it will propose strategies/methodologies for ongoing assessment of Biodiversity indicators for the plankton part and also basis for coherent design and implementation of MSFD monitoring programs, which are two important aims of the ActionMed project.

6.10 Timeline, feasibility and costs

The feasibility of the proposed timeline (**Figure 6.4**) is dependent on the availability of resources. Investigation is required to determine periods of reference condition for the pelagic indicators which are considered for the food web integration. While currently this, period is defined by when there are adequate data, it should be defined by when an area is in GES according to ecological relevance. A pelagic and a food web full time scientist would be required, for 2 years, to assess GES and further development of the two indicators (PH1/FW5 and FW6) and of other combinations and improvements of PH/FW indicators, through case studies (if not possible for each assessment unit at the OSPAR level). These positions would indeed require a close collaboration between pelagic and food web groups of experts for an ecosystem perspective to work towards NEAT integration of the indicators. 2 workshops of 1 week each with pelagic experts will be required to confirm the integration techniques.

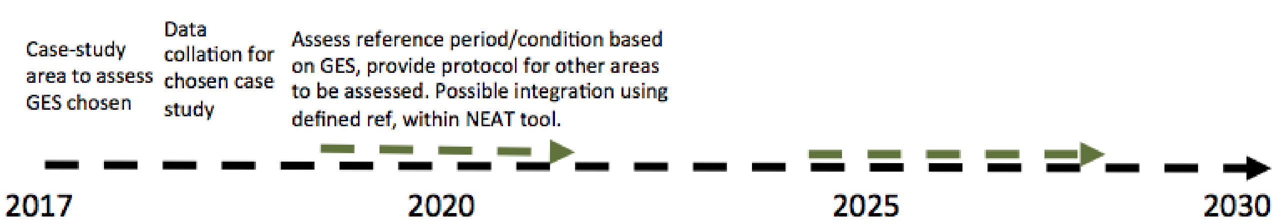

Figure 6.2: Timeline along which PH1-3 integration could be implemented with the assumption of sufficient resources.

7 The Bow-Tie approach used to assess cumulative effects

S. A. M. Elliott, A. Judd, G. Safi, L. Arroyo, C. Ostle

7.1 Summary

Cumulative effect assessment is being undertaken under OSPAR ICG-C through the use of Bow-Ties on individual OSPAR Common indicators. This approach enables links between the risks of activities on different ecosystem components to be easily visualised where they exist. Bow-Ties also highlight potential management measures that can be put in place to avoid risk of deterioration of different ecosystem components.

7.2 The approach

The BT approach is centred on a critical event, where possible causes to the critical event are established on one side (the left), and possible scenarios from the event are listed on the right-hand side highlighting the possible consequences of the critical event (**Figure 7.1**) (Khakzad et al. 2012, Ferdous et al. 2013). Quantitative analysis can be implemented through the use of probabilities of possible causes of the event occurring and scenarios which can be used to avoid the consequences (Khakzad et al. 2012). BTs are an expanded visualisation of Driving forces, pressures, State, Impacts and Responses (DPSIR) enabling an easier method to track potential cause-effect pathways cumulatively and how these might be controlled. BTs can be as simple or extensive as the scenario required which allows for flexibility in its application to the different methods and data for which it is applied. Ferdous et al. 2013, Pitbladoa & Weijand 2014 provide reviews of how to set up and use Bow-tie risk analysis.

Within the context of OSPAR the BT approach is being used to assess cumulative effects by identifying significant risks, causes, pathways and consequences of the effects on ecosystem components (OSPAR, In Prep.g; **Figure 7.2**). BTs for each OSPAR common indicator have been developed, highlighting activities exerting pressure on the ecosystem component, and management frameworks in place to mitigate impacts and consequences. The approach also provides links between indicators which may cause cumulative effects on a particular ecosystem component (e.g. **Figure 7.2**). Refer to OSPAR (In Prep.g) and ICES (2014) for detailed explanations of incorporating the BT approach to the assessment of cumulative effects.

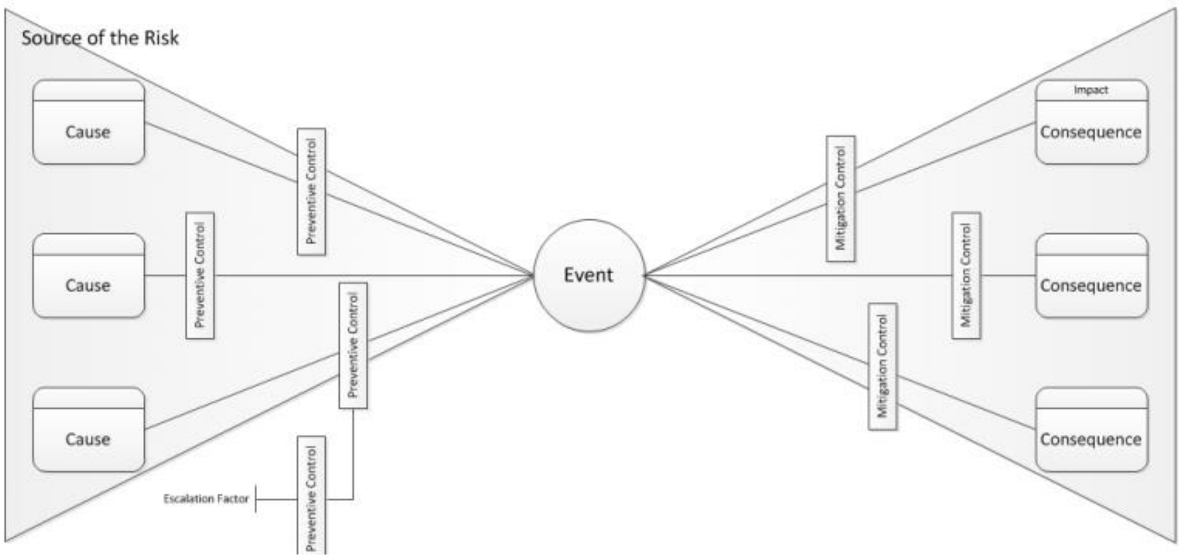

Figure 7.1: Bow-tie analysis conceptual diagram (from ICES. 2014)

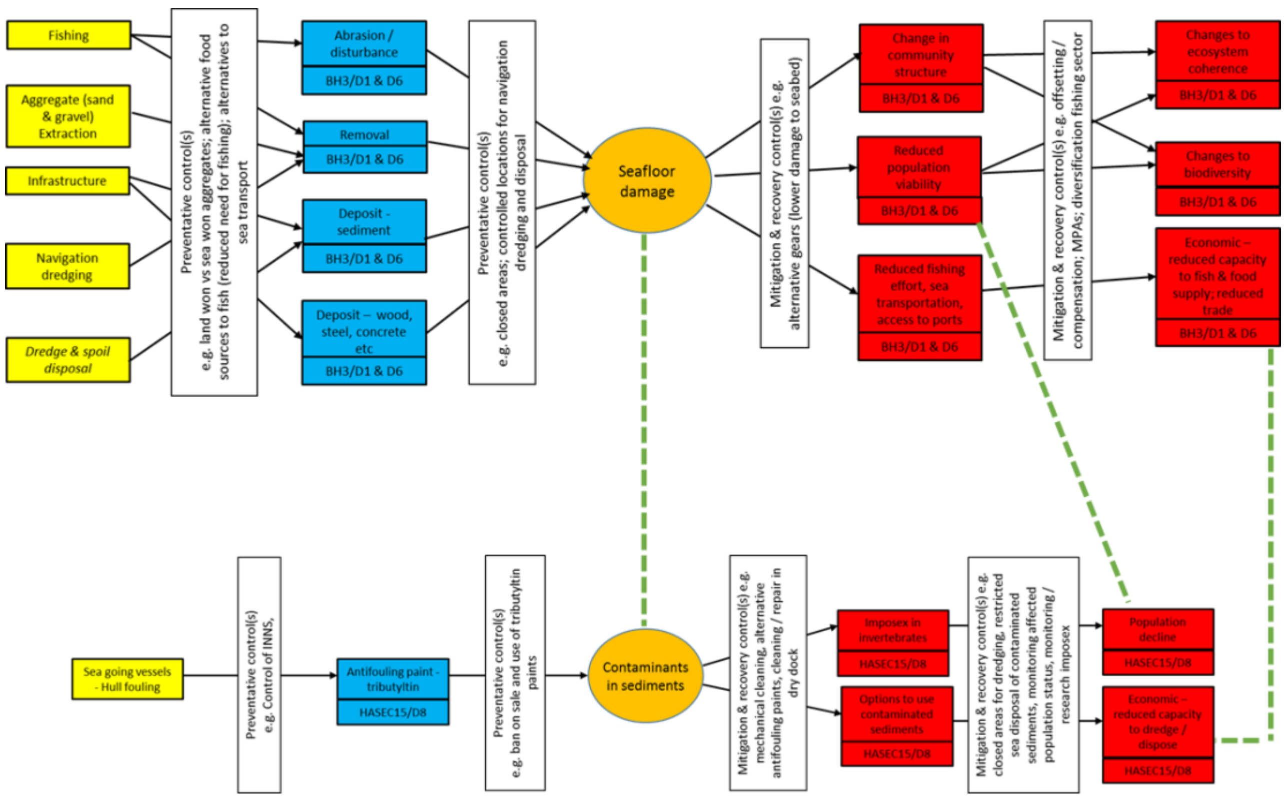

Figure 7.2: An example of building up assessment of cumulative effects from OSPAR common indicators using the Bow-tie (BT) approach on seafloor damage (BH3) and contaminants in sediment (from OSPAR, In Prep.g). The diagram gives a simplified representation of a cumulative effect assessment using the BT approach. "The diagram identifies potential cumulation points between BT for two indicators associated with marine sediments (organotinin sediment and seafloor damage)" (from OSPAR, In Prep.g). Green dashed lines represent links between indicator BT steps.

7.3 Overview of how the approach can be assessed to support management decisions

The Bow-tie (BT) analysis enables risks of activities to be examined in a visual format that is easy to communicate (Khakzad et al. 2012, Pitbladoa & Weijand 2014). BT analysis is frequently used as a risk management standard in industry related activities but to date has not been used in ecological contexts (ICES, 2014, Judd et al. 2015). Within OSPAR's remit, the BT approach is being trialled in the assessment of cumulative effects based on the OSPAR suite of common indicators (OSPAR, In Prep.g; **Figure 7.1** and **7.2**). This approach therefore brings together risks from multiple components of the ecosystem enabling evaluation of management options to be proposed to avoid detrimental effects. It can therefore be used to understand issues associated with the achievement of GES by establishing route causes and highlighting potential measures to avoid and manage risks. Furthermore, use of the BT tool to assess cumulative effects can be applied across the different Descriptors under the MSFD and thereby supporting an ecosystem's approach (ICES, 2014, Judd et al. 2015, OSPAR, In Prep.g). Even though the theoretical BT analysis is relevant to bridge science and management in a clear framework (ICES, 2014), its applicability to biodiversity indicators is still being tested.

7.4 Advantages and disadvantages of approach

Advantages	Disadvantage	Solution
Illustrates simply the relationship between cause and effect.	The BT approach is a static.	Methods can be adapted to enable BTs to be a less static processes.
Highlights gaps and causes of not achieving GES.	BTs can become overly complex leading to conflicting goals and possible misleading decisions.	Care should be taken when building and describing BT diagrams to highlight possible weaknesses in the approach e.g. insufficient data in the system, uncertainty, etc.
Focuses on the principal problem inhibiting GES.	Possible confusion can arise with regard to the spatial scale to be used and lack of alignment with individual indicators.	Meetings are planned during 2017 to ensure BTs align with common OSPAR indicator methods.
Facilitates management implications to be taken on board at high levels for individual indicators.	Further research and testing to understand cumulative effects assessment methods is required.	Further research is planned for 2017 to improve cumulative effect methods.
Supports visualisation and understanding of multiple pressures which may have effects on different ecosystem components or cumulative effects on individual ecosystem component, by integrating cause and consequences and thereby supporting management across multiple components.		
Builds upon mutual understanding between different disciplines.		
Helps forward the understanding of cumulative effects on ecosystem components.		

7.5 Information on the confidence of the assessment

Due to the nature of the BT approach, the confidence of the assessment is not entirely relevant to this approach. However, use of the BT approach to illustrate cumulative effects, is a clear and easy to follow method to understand the root causes of risks inhibiting attainment of GES and possible methods to avoid risks which may damage the marine environment.

7.6 How far the assessment goes to assessing thresholds and linking the results to policy requirements

In collaboration with individual and proposed integrative indicator assessments, use of the BT approach could help assess thresholds at which certain activities can take place. However, on its own it will be difficult to understand thresholds for damaging pressures. The approach enables key risks to be highlighted so management decisions can be made to avoid them. With the support of individual indicator analysis, the identification of thresholds at which a certain or cumulative pressures can take place can be calculated.

7.7 Added socio-economic and ecosystem services implications

Socio-economic and ecosystem services implications of using the BT approach to assess cumulative effects revolve around societal goals and the potential regulation of activities causing damaging pressures on the different parts of the ecosystem. If ecosystem components are damaged beyond a certain point, that particular ecosystem component may no longer be able to provide ecosystem services.

7.8 Approach applicability to OSPAR sub regions

Although using the BT analysis to assess cumulative effects has been developed within the OSPAR region, it could be applied to other MSFD regions supporting cross-region coherence. The approach is applicable to other MSFD regions given its generic nature (i.e. not being specific to a particular region). To undertake analysis, detailed knowledge of activities occurring in the region would be essential, in addition to details on condition related indicators.

7.9 Links to other related projects

The BT approach to assess cumulative effects has been presented and discussed at a joint Rijkswaterstaat, Fisheries and oceans Canada and ICES Workshop on risk assessment for Spatial Management (ICES 2014). The BT approach is also linked to the following two projects: Marine Ecosystems Research Programme, WP3 Topic 2 – Cumulative Impacts and the Management of Marine Ecosystems (www.marine-ecosystems.org.uk), and the Climate Change and European Aquatic Resources (CERES) project (www.ceresproject.eu/).

7.10 Timeline, feasibility and costs

Figure 7.3 provides a timeline through which cumulative effect assessment can be implemented using the BT approach. The implementation of the process is currently being led by CEFAS (Adrian Judd) as part of the OSPAR ICG-C. Possible costs include continued staff resource costs, with continued input from COBAM and other relevant meetings to support alignment with Common indicators since the approach is based around working with the data that already exists.

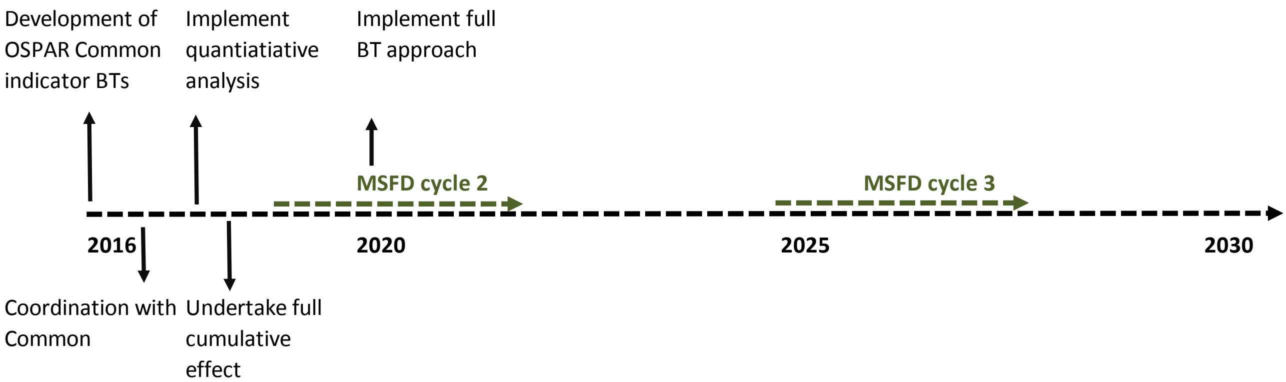

Figure 7.3: Timeline along which the Bow-Tie cumulative effects approach will be implemented

8 Summary

To undertake an assessment of the status of the marine environment, an understanding of the state of individual ecosystem components, in addition to a more integrative analysis at ecosystem level, is essential. Using such a two-tiered approach will enable a detailed analysis of why certain aspects of the marine environment may not be in good condition and thereby recommend specific management measures to ameliorate them. In addition, an assessment of individual and co-occurring pressures (or cumulative effects) on the marine environment is essential to ensure that the threshold of resistance to a particular or multiple ecosystem components is not surpassed. Resilience over time could also be assessed if pressures were discontinued. Examining benthic, pelagic and trophic interactions demonstrates just how complex the marine environment is and how depleting one resource can have knock-on effects on other resources.

To date, assessment of the marine environment at an OSPAR level has taken place on an individual indicator approach. This in itself is an achievement, given the work which has been undertaken to enable working indicators under the different descriptors to be assessed. Nonetheless, individual indicator assessments do not consider how damage on one component of the ecosystem may have an effect on another. At the same time methods developed to integrate indicators, need to ensure that holistic assessments of the marine environment can be dis-integrated to analyse the different parts of the ecosystem which may be receiving anthropogenic pressure.

This is a first attempt, at OSPAR Regional scale, to integrate various OSPAR indicators at different levels (indicator, habitat or ecosystem). Work was conducted to ensure that the methods developed are based on existing MSFD and Regional Seas works and processes, and other related projects. This report uses methods developed by indicator leads and outlines a series of different methods to begin integrating biodiversity, food web and seafloor integrity related indicators, to undertake a more holistic approach to ecosystem assessment and inform management requirements. The report also considers work being forwarded within OSPAR to analyse cumulative effects through a risk-based method. The approaches developed and outlined within this report vary from:

- Developing methods to draw links between different indicators and ecosystem components to quantitatively determine how different pressures affect different aspect of the marine ecosystem (Chapter 3 and 4).
- The testing of the NEAT tool to integrate different indicators to provide an overall assessment (Chapter 5 and 6).
- The use of an industry led risk assessment tool (the Bow-tie approach) to begin assessing cumulative effects (Chapter 7).

Each method address different levels of integration (indicator, habitat or ecosystem) and they each require further development and testing. They should be thus considered as complementary and gaps should be progressed in parallel to ensure coherent progress towards an overall ecosystem approach. It is also advised to be able to assess which method to forward, a cross-comparison testing should be undertaken, using the same set of indicators and data for the three main approaches. The latter would enable comparison of results, the identification of differences between the approaches, and facilitate the recommendation of a way forward for an integrated assessment.

As it stands it may seem to be quickest to implement NEAT (Chapters 5 and 6) to integrate indicators. However, this methodology is limited by the need to define threshold values for indicators in order to run an assessment. Furthermore, some gaps exist within this approach and certain aspects still lack transparency. Extra work would also be required to fully understand the ecological meaning of integrating these indicators as well as on the improvement of the meaning of each indicator (by improving their definition and by including new types of data in order to complete the assessment of biodiversity). Undertaking quantitative assessment of indicators where overlaps exist (Chapters 3 and 4) will enable a better understanding of how ecosystem components react to varying pressures ensuring natural links between ecosystem components for each indicator. However, this method may take more time and would have to be progressively implemented according to resources available. The use of this latter mechanism, in combination with the bow-tie approach, should enable cumulative effects (or co-occurring pressures) to be assessed. The combined use of the quantitative assessment in combination with the bow-tie approach will also facilitate a mechanism to communicate to managers and policy makers the state of the marine environment more clearly and efficiently.

In summary, further work is required to undertake full integration of the indicators developed under the EcApRHA project and compare the different methods developed. The approaches outlined within this report are a first and successful step, showing the advantages and disadvantages of their implementation to begin undertaking a more holistic assessment of the marine environment under the co-ordination of OSPAR or other Regional Seas processes.

9 Glossary

Term	Description	Source
Anthropogenic pressure	The mechanism through which a human activity causes an effect on any part of the ecosystem and that may change the environmental state or condition of that part of the ecosystem over a given period of time. A pressure can be of physical, chemical or biological nature. A list of defined pressures has been formally agreed by the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C).	Foden et al. 2011, Goodsir et al. 2015, Oesterwind et al. 2016
Baseline condition	The qualitative or quantitative description of the state a EUNIS level habitat type against which subsequent values of state are compared. A baseline condition can be set at different levels (e.g. pristine, least damaged, or to be maintained in its current state) according to the management objective for that particular habitat.	OSPAR 2012, Elliott et al. In Review
Benthic Habitat	The place where benthic species occupy. Characterised by the physico- chemical (e.g. sediment, depth, salinity, temperature, etc.) and biological conditions (fauna, flora, algae). Benthic habitats may comprise of one or several biological communities depending on the European Nature Information System (EUNIS) habitat classification level. EUNIS is a system to classify benthic habitats on different nested scales. The higher the level, the more detail and sub-types of habitats are included.	Davies et al. 2004, Elliott et al. 2016
Biota/ Biome	The living parts of the environment, including the association of a lot of interrelated populations that belong to different species inhabiting a common environment. An organised community of biota forms a biome.	Ramade 1994, Patricio et al. 2014, Leeuwen et al. 2015
Biological community	Assemblage or association of populations of two or more different species occupying the same geographical area and in a particular time.	Verhoef & Morin 2010
Coastal waters	Marine waters, the seabed and subsoil on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured.	CEC 2000, 2008
Criteria	A particular aspect of biodiversity that requires their status to be assessed e.g. population size.	OSPAR 2012
Cumulative effects or co-occurring pressures	The size and location of multiple anthropogenic pressures, which overlap in an area or on a habitat. These pressures may be additive, synergetic or antagonistic. This term is also referred to as co-occurring to avoid this confusion.	Foden et al. 2011, Judd et al. 2015
Descriptor	Qualitative features which are used to assess GES. 11 are described within the MSFD, three of which (biological diversity, seafloor integrity and food webs) relate to the EcApRHA project.	CEC. 2008
Driving forces,	A causal framework for describing the interaction between	Borja et al. 2006,

pressures, State, Impacts and Responses (DPSIR)	society and the environment to evaluate pressure-state changes.	Nobre 2009
Ecohydrodynamic region	Bio-physically defined areas, constructed using density stratification, the most important large-scale physical feature in shallow shelf seas. Density stratification occurs when the buoyancy of surface waters (influenced by fresh-water input or solar heating) is stronger than turbulence and vertical mixing, which limits vertical exchange across the pycnocline.	van Leeuwen et al. 2015
Ecosystem	An ecosystem consists of biotic (community of organisms) and abiotic (physical, chemical and biogeochemical) features, processes and interactions in a defined space at a given time.	Dauvin et al. 2008, Curtin & Prellezo 2010
Ecosystem approach	The comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity.	OSPAR, 2016d
Ecosystem components	The term ecosystem component (mentioned in Annex VI of the Directive 2008/56/EC: 'measures that influence the degree of perturbation of an ecosystem component' and 'tools which guide human activities to restore damaged components of marine ecosystems') includes both biota and habitats as parts of the ecosystem. With regard to the NEAT tool, different ecosystem components have been defined such as birds, fish, benthic vegetation or pelagic organisms.	Patricio et al. 2014, Berg et al. 2016
Ecosystem perspective:	The EcApRHA project draws from the OSPAR definition of the ecosystem approach. However, within the frame of the project, an ecosystem perspective refers to the exploration of potential cross-overs between the different indicators of descriptors 1, 4 and 6 developed by each of the EcApRHA work packages. By identifying cross-overs between the different indicators and descriptors of the three work packages it is hoped to be able to integrate where possible, the assessment of the different indicators. In identifying links between the indicators and the state of the marine environment it is hoped that management options can be proposed based on pressures exerted on the marine environment.	
Environmental Status	Refers to the overall state of the environment in marine waters, taking into account the structure, function and processes of the constituent marine ecosystems together with natural physiographic, geographic, biological,	CEC. 2008

	geological and climatic factors, as well as physical, acoustic and chemical conditions, including those resulting from human activities inside or outside the area concerned.	
Good Environmental Status	Refers to the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.	CEC. 2008
Ground-truth	*In situ* sampling to verify a marine habitat type and its condition.	EMODnet 2016
Habitat	The term 'habitat' has several meanings in common usage linked to the biotic and abiotic environment. The use of the term 'habitat' in the EcApRHA project, taking into account food webs, pelagic and benthic habitat work package indicators developed, refers to the environment a species or community of species inhabit/occupy at a particular stage in its life cycle. In the NEAT tool, the habitat (e.g. pelagic, reef) is hierarchically defined under a spatial assessment unit (SAU). These habitats are nested and hierarchically structured so an indicator can be assigned to one or more SAU.	OSPAR 2016, Patricio et al. 2014, Berg et al. 2016
Holoplankton	Planktonic lifeforms that spend their whole lifecycle as plankton.	
Indicator	Are distinct features that help quantify descriptors outlined within the MSFD.	CEC. 2008
Integrated approach	The combining of information from different (scientific) indicators into one higher-level indicator or to criterion-level, or the combining of information from two or more criteria to descriptor level or to an alternative grouping of criteria (e.g. for an ecosystem component, or for a grouping of criteria below descriptor level).	Borja et al. 2014
Least damaged habitats or condition	The state of a habitat that may have been subject to some anthropogenic impacts or disturbance, but whose structure and functions are not adversely modified. The latter will need a certain level of expert judgment. However, through exploring anthropogenic pressure-state relationships, it will be possible to determine whether the least damaged habitat's structure and function are not adversely modified.	Elliott et al. In Review
Log book	A detailed, usually official, record of a vessel's fishing activity registered systematically on board the fishing vessel, usually including information on catch and its species composition, the corresponding fishing effort and location. Completion of logbooks may be a compulsory requirement for a fishing license.	NOAA fisheries glossary 2006
Meroplankton	Planktonic lifeforms that only spend part of their lifecycle	

	as plankton.	
Metadata	The data helping to define or to understand other data. For example, date of sampling and geographical location of a station which is associated with biological data such as species abundance and environmental data such as substrate characteristics.	FGDC Content Standard for Digital Geospatial Metadata Workbook, Ver2.0, May 1, 2000 within OSPAR In Prep.c
Monitoring	The different observatory methods to survey species, habitats, ecosystems, etc. in time.	Schmitt et al. 1996
Pelagic habitat	Environmental (i.e. physico-chemical and biological) conditions that support biological communities in the water column of shallow or deep sea, or enclosed coastal waters. Because of the strong temporal nature of the pelagic environment, the water column at a given location will be classified differently at different times of the year (EUNIS habitat type code A7).	EEA 2016
Predominant species and habitat	Habitat category referred to in **Table 1** of Annex III to the Directive. Widely occurring and broadly defined habitat types (e.g. shelf sublittoral sand or mud) that are typically not covered by other legislation (see 'special habitat types').	OSPAR 2012
Pristine reference state/ condition/ area	The mean value or the ranges of values which define a pristine or best environmental state which has not been subject to anthropogenic impacts or only minor disturbance has been undertaken in the area.	CEC. 2008, Borja et al. 2010
Region	The MSFD derestriction is split into four marine regions (Baltic sea, the North East Atlantic Ocean, the Mediterranean Sea and the Black Sea) to facilitate implementation of the Directive, taking into account hydrological, oceanographic and biogeographic features.	CEC. 2008
Sensitivity	The ability of a habitat to tolerate pressure and the time the habitat needs to recover following removal of the pressure.	Aish et al. In Review.
Special habitat	Habitat which have a specific management concern, especially those recognised or identified under Community legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest.	CEC. 2008
Sub-region	An area within EU regional seas which has similar range of benthic habitats and oceanic conditions. Within OSPAR's mandate, the North East Atlantic Ocean, this includes the Celtic seas, Greater North Sea, Bay of Biscay and the Iberian Coast, Macaronesian biogeographic region.	CEC. 2008

Threshold	For management purposes, thresholds are used as the value or range of values to describe the quality of a particular habitat before it changes state from increased pressure	Samhouri et al. 2010, OSPAR, 2012
Vessel Monitoring System (VMS)	VMS is a general term to describe a satellite communications system used to monitor fishing activities. The system is based on electronic devices (transceivers), which are installed on board vessels and automatically send data to a shore-based "satellite" monitoring system. VMS provides monitoring agencies with accurate locations of where fishing vessels are and where they were at periodic time intervals. The position information can be provided to the monitoring agency in near real time (less than 30 minutes), regardless of the location of the vessel.	NOAA fisheries glossary 2006, FAO, 2016

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