



OSPAR CEMP Guideline

Cumulative effects assessment for the QSR 2023 (Bow Tie Analysis)

OSPAR Agreement 2023-01¹

North-East Atlantic Environment Strategy 2030, Strategic Objective 7: Ensure that uses of the marine environment are sustainable, through the integrated management of current and emerging human activities, including addressing their cumulative impacts.

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1. Introduction to cumulative effects assessment in the QSR 2023

The marine environment is a complex system of interacting organisms (including humans), their ecological traits, their physical environment and societal benefits. Understanding these interactions and the collective / cumulative effects of human activities on them is critical for effective management. Article 6 of the OSPAR Convention (OSPAR, 1992) requires Contracting Parties to undertake and publish at regular intervals joint assessments of the quality status of the North-East Atlantic marine environment and of its development. Quality Status Reports have been undertaken and published in 2000 (OSPAR, 2000); 2010 (OSPAR, 2010) with an Intermediate Assessment in 2017 (OSPAR, 2017).

The OSPAR Commission applies the ecosystem approach to work coherently and holistically to meet conservation and management objectives. OSPAR defines the ecosystem approach as “... *the comprehensive integrated management of human activities based on the best available scientific knowledge of the ecosystem and its dynamics, in order to identify and take action on drivers, activities and pressures that adversely affect the health of marine ecosystems. The ecosystem approach thereby*

¹ English only

achieves the sustainable use of ecosystem goods and services and the maintenance of ecosystem integrity.” (OSPAR, 2021).

The OSPAR North-East Atlantic Environment Strategy 2030 (OSPAR, 2021) describes that “... the ecosystem approach takes into consideration cumulative effects and is implemented through a continuous cycle of (i) setting and coordinating ecological objectives and associated targets and indicators, (ii) ongoing management and (iii) regular updates of ecosystem knowledge, research and advice. Monitoring, assessment and adaptive management are essential elements for implementing the ecosystem approach.”

Patricio et al., 2016 undertook a comprehensive review of the history, evolution and wide adoption of the DPSIR (Drivers-Pressures-State-Impact-Response) conceptual framework for determining and assessing the links between human pressures and state changes in marine and coastal ecosystems. Elliot et al., 2017 expanded the framework to describe how **Drivers** of basic human needs require **Activities**, which lead to **Pressures**, which can lead to changes in **State** (environmental impacts on the natural system), which lead to **Impacts** on Ecosystem Services, which in turn influence the Drivers. These interrelationships require **Responses** (as Measures). The complexity of any managed sea area in terms of multiple interlinked drivers, activities, pressures, receptors and impacts requires an understanding and analyses of the connectivity between these parameters. Judd and Lonsdale (2021) describe how a DAPSIR (Drivers-Activities-Pressures-State-Impact-Response) framework embodies all components and provides a practical construct to apply the ecosystem approach.

For the Quality Status Report 2023, OSPAR has introduced a series of thematic assessments which are intended to explicitly apply the ecosystem approach through a DAPSIR framework (OSPAR, 2019). A schema is applied (OSPAR, 2019) to guide practical application of the DAPSIR framework in the thematic assessments (Figure 1). Applying the DAPSIR framework ensures that the thematic assessments coherently, consistently and holistically consider the interrelationships between environmental, social, economic, management (policy, regulatory, voluntary) causes and consequences of change.

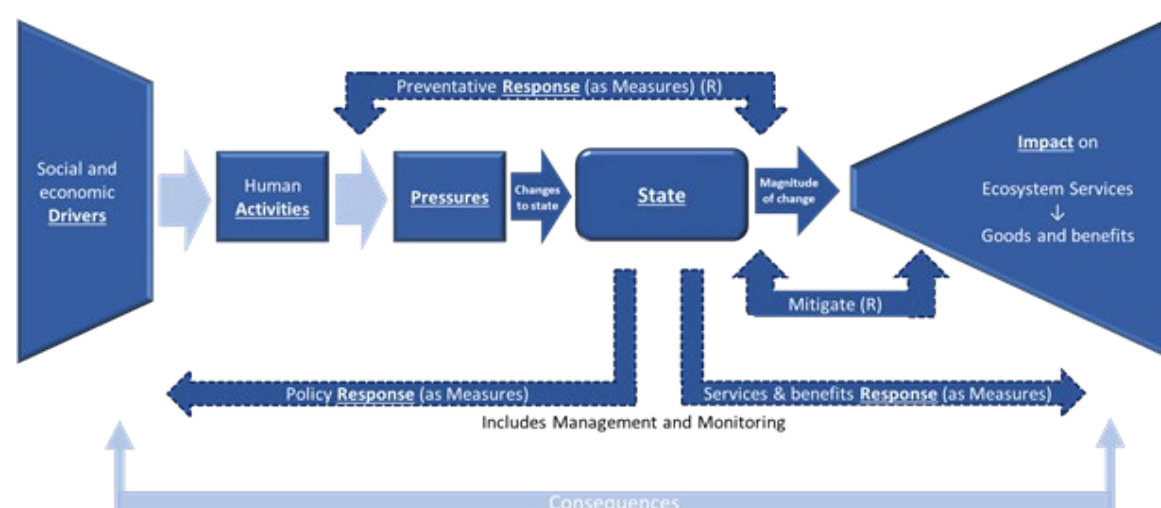


Figure 1. Schema describing the framework to underpin thematic assessments, using DAPSIR (adapted from Judd and Lonsdale, 2021). The structure of the schema reflects the Bow Tie Analyses embodying the components of the ecosystem approach.

OSPAR defines cumulative effects assessment (CEA) as “a systematic procedure for identifying and evaluating the significance of effects from multiple pressures and/or activities on single or multiple

receptors. CEA provides management options, by quantifying the overall expected effect caused by multiple pressures and by identifying critical pressures or pressure combinations and vulnerable receptors. The analysis of the causes (source of pressures), pathways, interactions and consequences of these effects on receptors is an essential and integral part of the process.” (Judd et al., 2015, adapted from Cooper, 2003).

The cumulative effects assessment for the OSPAR QSR 2023 describes these cumulative effects for each biodiversity theme: pelagic habitats ([<hyperlink to TA>](#)); benthic habitats ([<hyperlink to TA>](#)); fish ([<hyperlink to TA>](#)); marine birds ([<hyperlink to TA>](#)) and marine mammals ([<hyperlink to TA>](#)).

2. Bow Tie Analysis

The DAPSIR details set out in Figure 1 have been collated and assessed in a Bow Tie Analysis (Cormier *et al* 2018, Cormier *et al* 2019) for each thematic assessment to establish the linkages between the causes of change (the left-hand side of the bow tie comprising DAP) to ecosystem state (the knot of the bow tie comprising S) and the consequences of change (the right-hand side of the bow tie comprising I). The responses were inserted as preventative (left-hand side of the bow tie) or mitigation management measures (right-hand side of the bow tie).

An advantage of applying Bow Tie Analysis is the identification and integration of management measures (responses) into the diagrams where they have effect, i.e., in the prevention of impacts through managing human activities (left-hand side of the bow tie) or pressures or in mitigating impacts (centre or right-hand side of the bow tie). It was not possible to fully implement this aspect of the analyses for the QSR 2023 but this should be a core focus for the ongoing work.

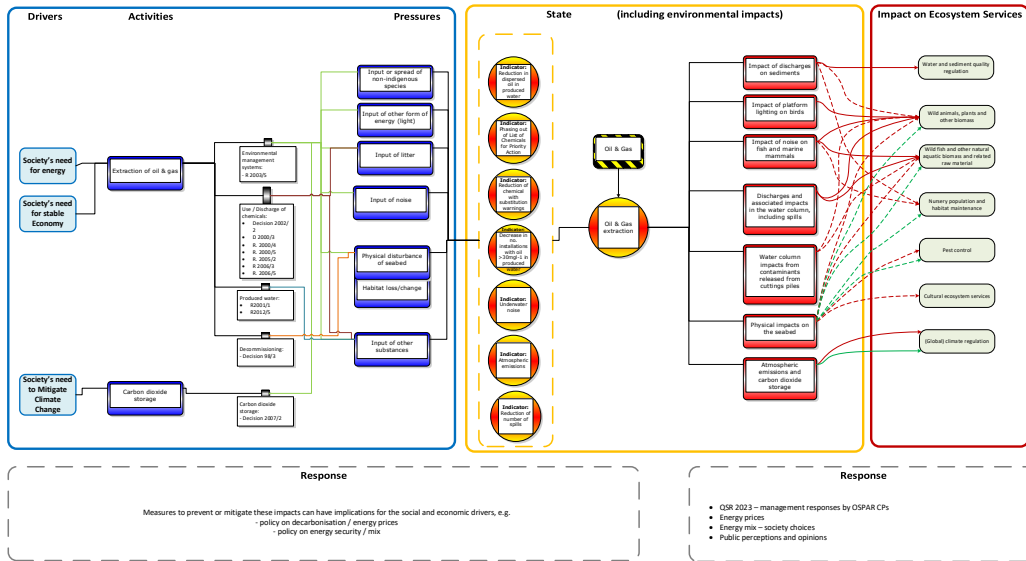
The DAPSIR are identified through reference to QSR 2023 support materials (draft indicator, thematic and other assessments); committee and expert group expert knowledge and scientific literature. A series of Bow Tie Analysis diagrams were generated (one for each thematic assessment) from either a human activity / pressure or a biodiversity perspective.

Human Activity / Pressure focused	Biodiversity focused
<ul style="list-style-type: none"> Offshore Renewable Energy – in the Human Activity Thematic Assessment Offshore Industry Radioactive Substances Underwater Noise <u>Marine Litter</u> Hazardous Substances Eutrophication Non-Indigenous Species Climate Change 	<ul style="list-style-type: none"> Pelagic Habitats Benthic Habitats Fish Marine Birds Marine Mammals

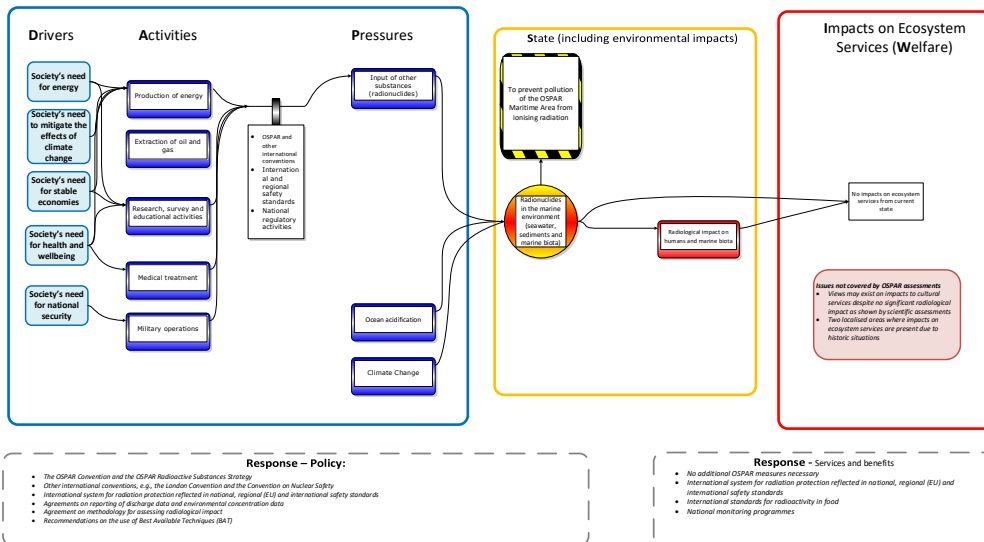
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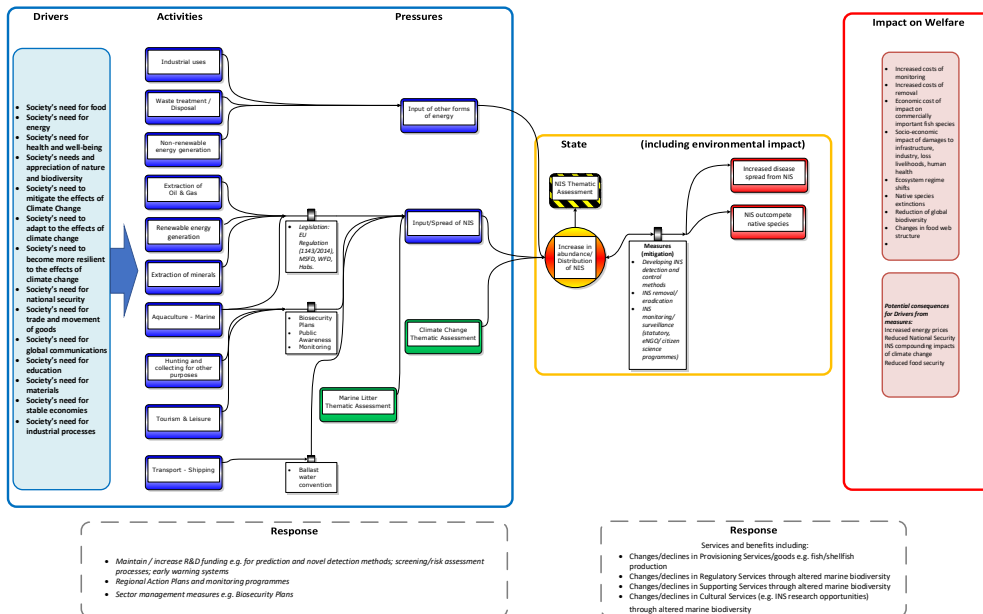
Offshore Industry Thematic Assessment



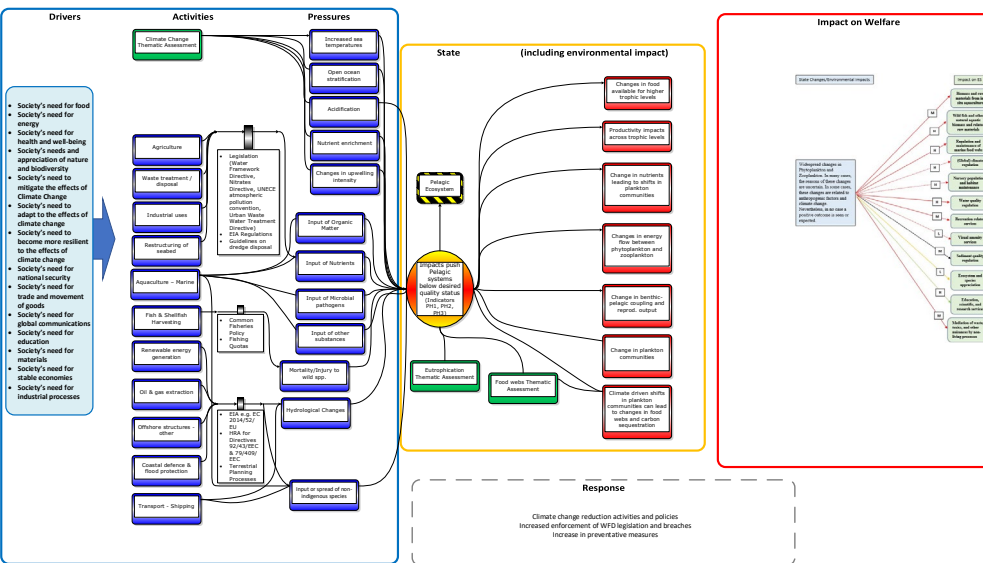
Radioactive Substances Thematic Assessment



Non Indigenous Species Thematic Assessment



Pelagic Habitats



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exercise of the activity-pressure-state (APS) components of DAPSIR has been undertaken **as an indicative assessment of cumulative effects** to identify those activities and pressures of greatest potential concern (and meriting priority action). Weightings have been generated by applying the [Pressure Assessment | ODEMM](#) methodology. Linkages between [Drivers] – Activities – Pressures – State Changes – Impacts (on Ecosystem Services) – Responses (Management Measures) were established and agreed with experts in the Bow Tie Analysis for each thematic assessment. The ODEMM pressure assessment methodology was applied to the Bow Tie Analysis linkages for Activity-Pressure-State Changes, in order to assess and rank the threat associated with any particular Activity-Pressure combination on any State Changes for each ecological component (namely the five focus biodiversity thematic assessments). A different methodology was applied to weight the State-Impact connections (see the Impact chapter of the thematic assessment <insert hyperlink>). The analyses were informed by the detail and evidence set out in the DAPS chapters of this thematic assessment. It has only been possible to apply the ODEMM methodology at the NEA scale for this QSR, however as many of the human activities, pressures and ecosystem components vary widely across the OSPAR maritime area the outputs presented here are indicative of the broadscale situation so has limitation and future more refined analyses is recommended for future assessments. These weighted connections in the Bow Tie Analyses for APS and SI are compiled in Sankey diagrams (Figure 3). The Response chapter of this thematic assessment describes the relevant management measures however it also highlights the difficulty in quantifying the effectiveness of these measures. If such quantification had been undertaken these measures could be incorporated into the Bow Tie Analyses / Sankey diagrams to assess their effectiveness in managing state changes. As this has not been possible the responses have been excluded from the Sankey diagrams in this QSR, but this is something to be further developed for future assessments. In addition, improving linkages between impacts on ecosystem services, societal drivers and human activities are required to better inform future assessments. Whilst described in the Drivers chapter of this QSR <insert hyperlink>, these have not been incorporated into the Sankey diagrams.

There are three main outputs derived from the ODEMM weightings approach (Figure 2):

- **Exposure module** (comprising spatial and temporal overlap) – indicative cumulative pressure assessment - scores are assigned for 1) spatial extent, and 2) frequency of occurrence for each of the identified linkage chains (human activity–pressure–state component) and multiplied together to achieve the aggregated exposure score. Scores are informed by the QSR supporting materials (e.g., indicator, thematic and other assessments, and feeder reports). Outputs in this thematic assessment are descriptive only.
- **Impact potential module** (comprising exposure and likely impact) - scores are assigned for 1) spatial extent, 2) frequency of occurrence, and 3) degree of impact for each of the identified linkage chains (human activity–pressure–state component) and multiplied together to achieve the aggregated impact potential score. Scores are informed by the QSR supporting materials (e.g., indicator, thematic and other assessments, and feeder reports). Outputs in this thematic assessment are descriptive and a Sankey diagram – the thickness of the connecting lines in the Sankey diagram represents the relative contribution of the human activity – pressure combination on state change as an indication of cumulative effects, The thicker the line the greater the potential threat.
- **Risk module** (comprising exposure, likely impact and pressure persistence) – indicative cumulative effects assessment - scores are assigned for 1) spatial extent, 2) frequency of occurrence, 3) degree of impact, 4) persistence, and 5) resilience for each of the identified

linkage chains (human activity–pressure–state component) and multiplied together to achieve the aggregated risk score. Scores are informed by the QSR supporting materials (e.g., indicator, thematic and other assessments, and feeder reports). Given the low confidence in the outputs the risk module has not been included in this thematic assessment but a short description is provided.

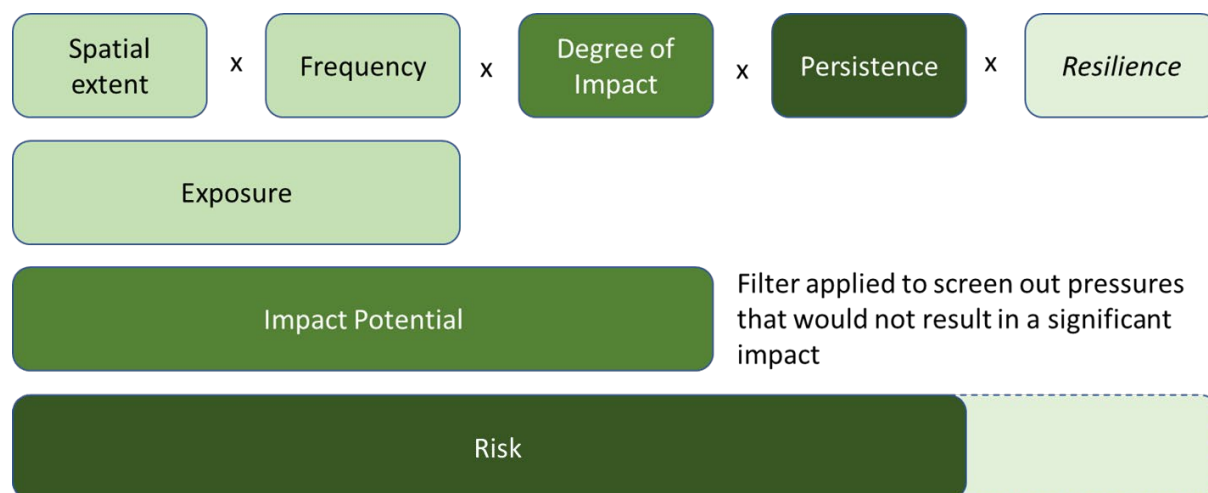


Figure 2. ODEMM pressure assessment adapted for the OSPAR QSR 2023. *Resilience (italicised) has been excluded.*

A modular approach has been undertaken with each of these three outputs being a module.

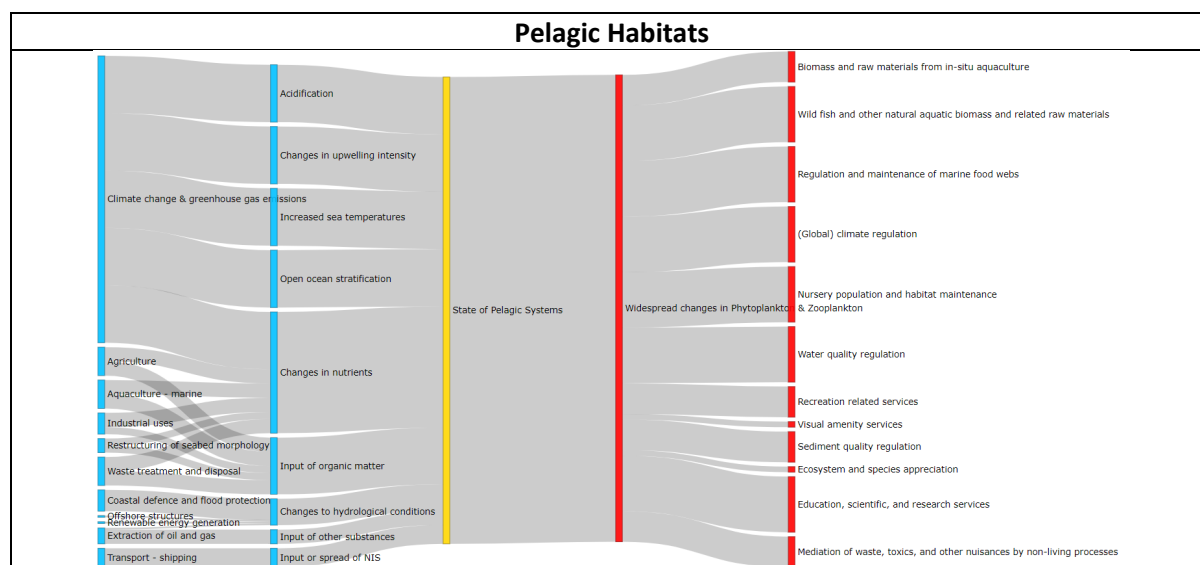
Following the categories defined in Knights et al., 2015 after Robinson et al., 2013, the ODEMM methodology was applied and the components assessed and weighted as follows:

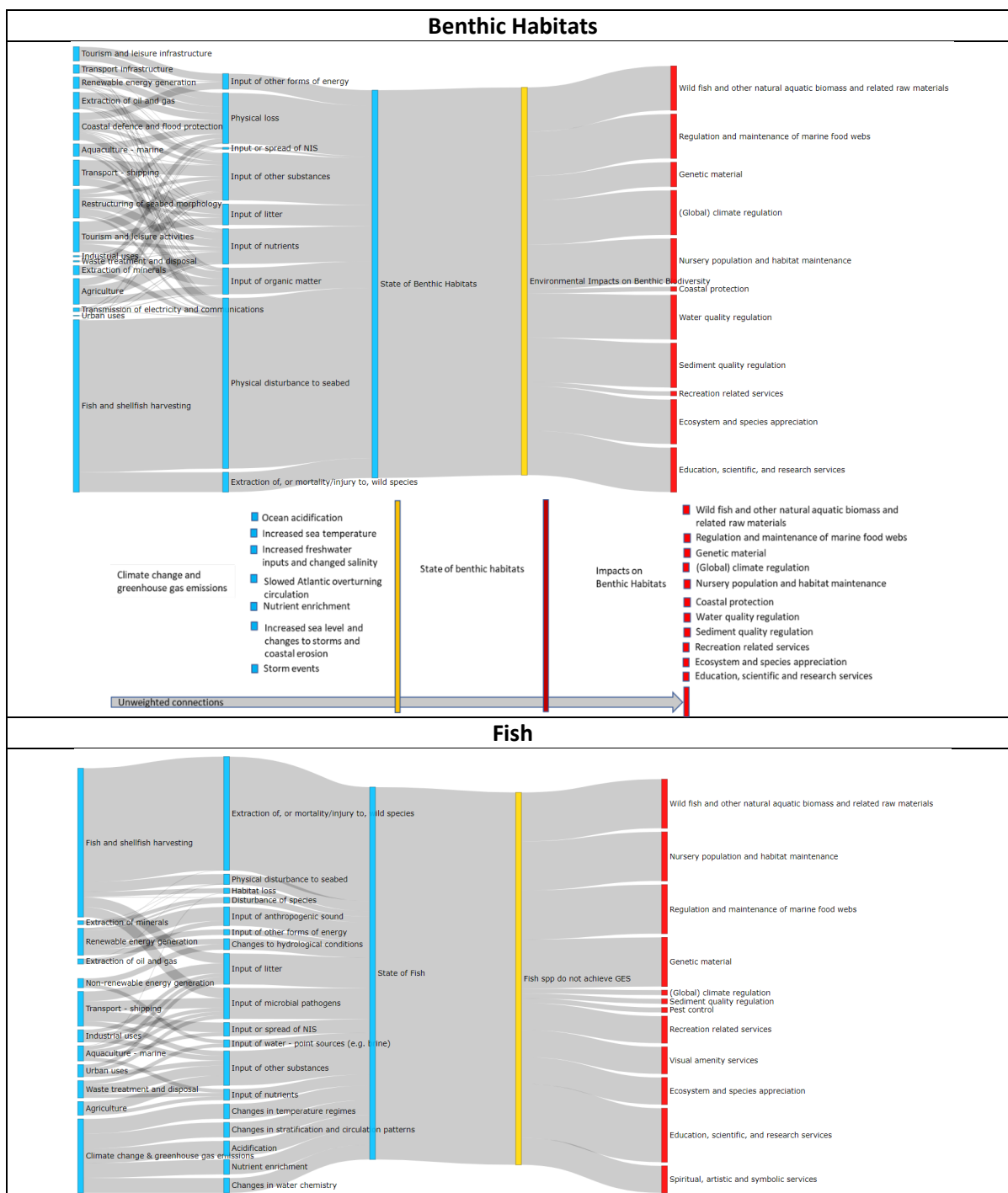
- **Spatial Extent** describes how much pressure from human activities there is in the NEA in terms of overlap between a pressures type and ecological component:
 - Widespread: where a sector overlaps with an ecological component by 50% or more (max is 100%) – Scored 1.0.
 - Local: where a sector overlaps with an ecological component by >5% but <50% – Scored 0.37.
 - Site: where a sector overlaps with an ecological component by >0% but <5% – Scored 0.03.
 - No overlap: where activity=pressure overlaps with an ecological component <0% -Scored 0.
- **Frequency** describes how much pressure from human activities there is in the NEA in terms of how often a pressure type and ecological characteristic interaction occurs, measured in months per year:
 - Persistent: where a pressure is introduced throughout the year, i.e., 12 months – Scored 1.0.
 - Common: where a pressure is introduced up to 8 months of the year – Scored 0.67.
 - Occasional: where a pressure is introduced up to 4 months of the year – Scored 0.33.
 - Rare: where a pressure is introduced up to 1 month of the year – Scored 0.08.
- **Impact potential:**
 - Acute: severe effects after a single interaction, which kills a large proportion of individuals and causes an immediate change in the characteristic feature – Scored 1.0.

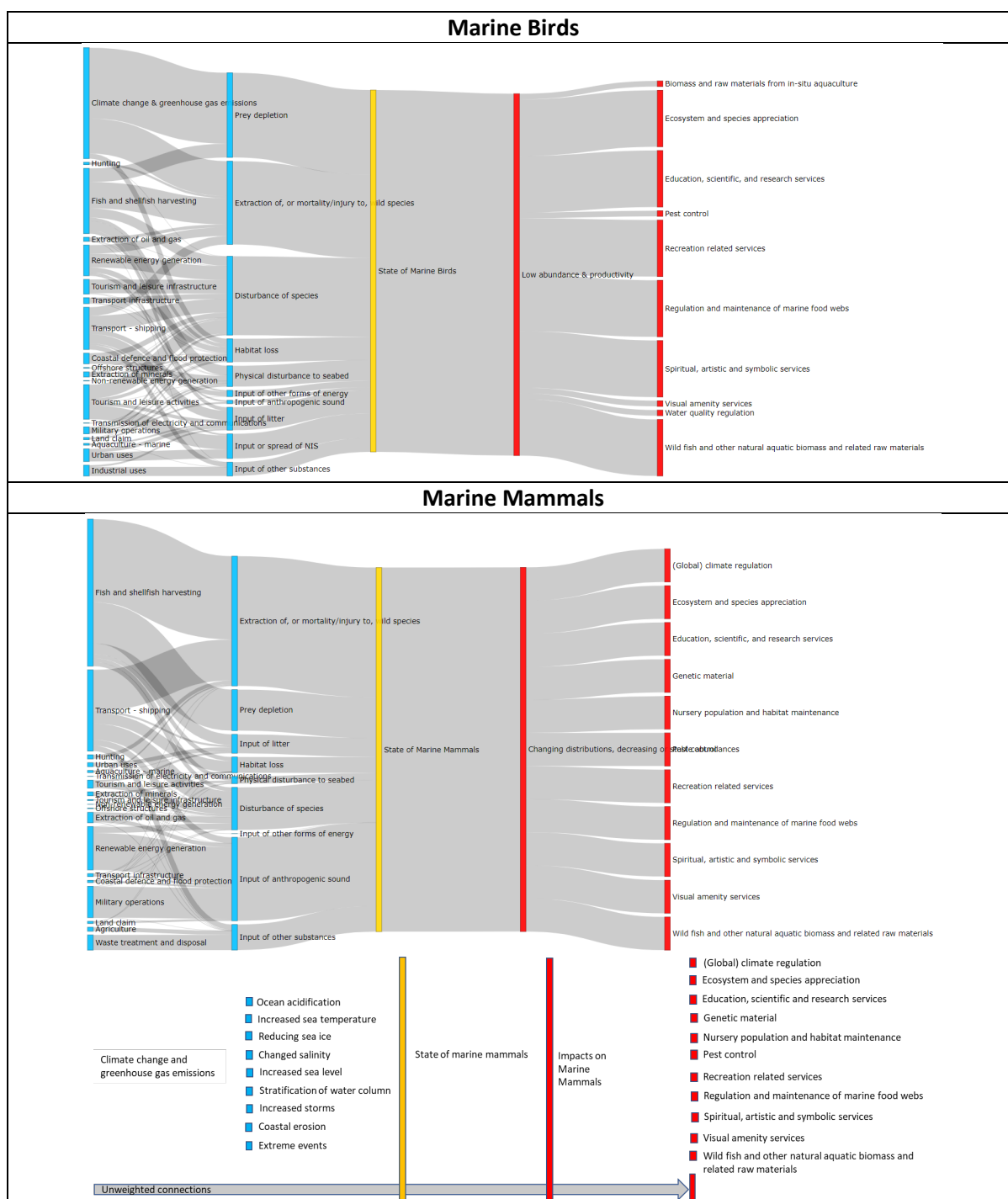
- Chronic: severe effects occurring at a frequency that could have detrimental consequences, if often enough and/ or at high enough levels – Scored 0.13.
- Low: Severe effect not expected - interaction never causes high levels of mortality, loss of habitat, or change in the typical species or functioning irrespective of the frequency and extent of the event(s) – Scored 0.01.
- **Persistence** is the period over which the pressure continues to cause impact following cessation of the activity introducing that pressure:
 - Continuous: the pressure continues to impact the ecosystem for at least 100 years – Scored 1.0.
 - High: the pressure continues to impact the ecosystem for between 10 and 100 years – Scored 0.55.
 - Moderate: the pressure continues to impact the ecosystem for between 2 and 10 years – Scored 0.06.
 - Low: the pressure continues to impact the ecosystem for between 0 and 2 years – Scored 0.01.

The scores are combined to generate the exposure, impact potential and risk aggregated scores as described in Figure 2.

For the QSR 2023 only outputs from the Exposure and Impact Potential module were incorporated. The outputs for the impact potential module were presented in Sankey diagrams – these show the addition of weightings to the APS connections to identify those activity-pressure combinations exerting the highest collective contribution to state change and there meriting priority action.







Whilst work was initiated, outputs from the Risk module were not completed to a sufficient degree of confidence to be included in the QSR 2023.

Given the low confidence scoring the outputs from the risk analyses have not been included in this thematic assessment for the QSR 2023. However, whilst not incorporated into the assessment for the QSR 2023, it is beneficial to consider the agreed outputs of the persistence weightings.

Risk incorporates persistence and resilience to the 'impact potential' scores for each human activity – pressure combination:

- Persistence here relates to the length of time it would take for the pressure associated with a particular activity to disappear after cessation of any further activities causing the particular pressure (Robinson et al, 2013).
- Resilience of the ecological component is assessed based on its current status in the regional sea and categorised based on recovery times following cessation of the pressure (Robinson et al, 2013). Resilience is defined as the recovery time of the ecological characteristic to return to pre-impact conditions (Knights et al., 2015).

Collectively, the risk scores provide an indication of the spatial and temporal collective threat of these pressures from the specified human activities on pelagic habitats.

Whilst very important with regards to high mortalities and associated population threats, resilience was excluded from the assessment because it was decided there were too many variables to consider within the scope of this assessment that could not be addressed within the QSR 2023 timeframe. The thematic assessment covers a broad group of ecological receptors, each group contains many different species/habitats across the OSPAR regions. Resilience is likely to vary between species, groups and in different locations. It was felt that trying to determine an average value for pelagic habitats that accounted for all of these factors could create an unrealistic output at this point in time, but this will be a priority for action post-QSR 2023.

Agreement was reached on the persistence scores, however, including these in the analyses without the resilience scores generated outputs which were both difficult to explain and on which no consensus could be reached.

4. Discussion and recommendations for continuation of the analyses

The OSPAR North-East Atlantic Environment Strategy, Strategic Objective 7 focuses on the sustainable use of the marine environment, through the integrated management of current and emerging human activities, including addressing their cumulative impacts. Specifically, to further develop methods for the analysis of cumulative effects in the marine ecosystems of the North-East Atlantic, taking into account relevant spatial and temporal information on human activities, pressures, sensitive receptors and habitats, and use the results to inform the establishment of measures and actions to prevent, reduce or otherwise manage impacts (S7.01). The outputs presented here provide an important step towards more holistic analyses than was presented in the QSR 2010. However, whilst linkages between DAPSIR components have been established and agreed with experts in the Bow Tie Analysis for each thematic assessment, and the ODEMM pressure assessment methodology applied to the Bow Tie Analysis linkages for Activity-Pressure-State Changes to rank their relative threat in the Sankey diagrams, these outputs have limitations:

- It has only been possible to apply the ODEMM methodology at the NEA scale for this QSR, however as many of the human activities, pressures and ecosystem components vary widely across the OSPAR maritime area the outputs presented here are indicative of the broadscale situation so has limitations and more refined analyses is recommended for future assessments.
- Whilst the work has been progressed with the aim of transparency, circumstances have meant that engagement, whilst extensive, has mostly been via dialogue with expert groups, committees and working groups individually with limited opportunity for collective discussion

and working. One of the benefits of applying this approach should be transparency where everyone has the opportunity to contribute and follow each step to generate the outputs.

- This is very much a first step in a complicated area of marine assessment and ultimately management. The more integrated discussion and collaborations in this QSR (compared to previous assessments) and the connectivity provided by the DAPSIR framework in each thematic assessment has been an important introduction. However, it has taken time to be fully embedded which has delayed the detailed analyses of cumulative effects. This delay has restricted what can be delivered in the time remaining for inclusion in this QSR.
- It should be noted that the Sankey plots and associated narratives in this thematic assessment are an illustrative representation of a complex set of interactions between DAPSIR components at the coarse North-East Atlantic scale and should be considered and interpreted alongside the supporting full thematic assessment narrative. As such, the Sankey plots should be applied with caution and not considered or used as the sole basis for management decisions.

As such there is further work required for consideration in future assessments, e.g.,

- Regional analyses - the Arctic Waters; Greater North Sea; Celtic Seas; Bay of Biscay and Iberian Coast; Wider Atlantic scale (undertaking such assessments at the North-East Atlantic scale obscures regional variations and further assessments should be undertaken by region, this would inform and guide indicator and thematic development and therefore improve the evidence so cumulative effects can be appropriately managed.
- Built-in collaboration and engagement across OSPAR Expert Groups and Committees from the outset.
- Better identification and quantification of impacts on ecosystem components and ecosystem services.
- Better understanding of additive, multiplicative, synergistic or antagonistic interactions.
- Refinements of the persistence and resilience analyses.
- Incorporating management responses and to 'test' effectiveness of measures.
- Considering how to use DAPSIR / ODEMM weightings to support OSPAR management.
- Spatial analyses – mapping human activities, pressures, ecosystem components and impacts.
- Improved collaboration and engagement across OSPAR Contracting Parties.
- Improved collaboration and engagement with external bodies, e.g., ICES, HELCOM.
- Improved integration between human activity, pressure, biodiversity assessments and economic / social analyses (Ecosystem Approach - DAPSIR).
- DAPSIR – Natural Capital Accounting continued alignment.

5. References

- Cooper, L.M. (2003). “Draft Guidance on Cumulative Effects Assessment of Plans”, Environmental Policy and Management Group (EPMG) Occasional Paper 03/ LMC/CEA, 2003. Imperial College, London, England
- Cormier, R., Elliott, M., Rice, J., (2019). Putting on a Bow-tie to sort out who does what and why in the complex arena of marine policy and management. *Science of the Total Environment*, 648: 293-305. <https://doi.org/10.1016/j.scitotenv.2018.08.168>.
- Cormier, R., Elliott, M., and Kannen, A. (2018). IEC/ISO Bow-tie analysis of marine legislation: A case study of the Marine Strategy Framework Directive. ICES Cooperative Research Report No. 342. 70 pp. <https://doi.org/10.17895/ices.pub.4504>
[http://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20\(CRR\)/CRR342/CRR342.pdf](http://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20(CRR)/CRR342/CRR342.pdf)
- Elliott, M., Burdon, D., Atkins, J.P., Borja, A., Cormier, R., de Jonge, V.N. and Turner, R.K. (2017). “And DPSIR begat DAPSI(W)R(M)!” - A unifying framework for marine environmental management. *Marine Pollution Bulletin*, Volume 118, Issues 1–2
- Judd, A., Backhaus, T. and Goodsir, F. (2015). An effective set of principles for practical implementation of marine cumulative effects assessment. *Environmental Science & Policy*, Volume 54
- Judd, A. and Lonsdale, J-A. (2021). Applying systems thinking: The Ecosystem Approach and Natural Capital Approach – Convergent or divergent concepts in marine management? *Marine Policy* 129 (2021) 104517
- Knights, A. M., Piet, G. J., Jongbloed, R. H., Tamis, J. E., White, L., Akoglu, E., Boicenco, L., *et al.* 2015. An exposure-effect approach for evaluating ecosystem-wide risks from human activities. *ICES Journal of Marine Science*, 72: 1105–1115.
<http://academic.oup.com/icesjms/article/72/3/1105/703182/An-exposureeffect-approach-for-evaluating> (Accessed 15 July 2019).
- OSPAR (1992). Convention for the Protection of the Marine Environment of the North-East Atlantic
- OSPAR (2000) Quality Status Report
- OSPAR (2010) Quality Status Report
- OSPAR (2017) Intermediate Assessment
- OSPAR (2021) Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2030 (Agreement 2021-01)
- Patrício J, Elliott M, Mazik K, Papadopoulou K-N and Smith CJ (2016) DPSIR—Two Decades of Trying to Develop a Unifying Framework for Marine Environmental Management? *Front. Mar. Sci.* 3:177
- Robinson, L.A., White, L.J., Culhane, F.E. and Knights, A.M. 2013. ODEMM Pressure Assessment Userguide V.2. ODEMM Guidance Document Series No.4. EC FP7 project (244273) ‘Options for Delivering Ecosystem-based Marine Management’. University of Liverpool. ISBN: 978-0-906370-86-5: 14 pp.