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Developing a method for broadscale and feature-level sensitivity assessments: the MarESA aggregation

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Summary

Sensitivity assessments following the Marine Evidence-based Sensitivity Assessment (MarESA) methodology (Tyler-Walters *et al.* 2018) have been undertaken for a range of biotopes at Levels 4 to 6 of the Marine Habitat Classification for Britain and Ireland (JNCC 2015) and the EUNIS classification (Davies *et al.* 2004)[1]. These assessments, which are available on the Marine Life Information Network (MarLIN) website[2], are updated by the Marine Biological Association of the United Kingdom (MBA) using best available evidence and peer review.

Although MarESA provides sensitivity information at a detailed biotope level, for certain applications, an understanding of sensitivity is also required at a broadscale habitat (Level 3 of the habitat classifications) and Marine Protected Area (MPA) feature-level. Sensitivity assessments for broadscale habitats and MPA features are needed for a range of applications, including in the provision of Advice on Operations for MPA Conservation Advice, advice on marine industry casework, in offshore survey planning and in the development of marine biodiversity indicators.

Natural England developed a novel method to utilise the up-to-date MarESA assessments within their Designated Sites system to present MPA feature-level information for their Advice on Operations for English inshore MPAs. The following report sets out JNCC's MarESA aggregation project, which builds upon Natural England's work to improve the understanding of broadscale habitat and MPA feature sensitivity for the UK offshore waters. The project has produced an automated method to aggregate MarESA biotope sensitivity assessments from Levels 5 and 6 of habitat classifications, up to Levels 2 and 3, in order to provide broadscale sensitivity assessments. This aggregation has been undertaken on a biogeographical basis to reduce uncertainty in the resulting broadscale sensitivity assessments. The work utilises the MarESA sensitivity assessments as well as the outputs from a previous project, which assigned biotopes to each of the UK's Offshore Regional Seas (Tillin *et al.* 2020). The outputs from the MarESA aggregation will be used for a range of purposes, as listed above. In addition, the project also provides a starting point to develop a more specific feature-level aggregation, which will enable more complex feature-level sensitivity assessments to be produced.

Three spreadsheet outputs are provided alongside this report. These contain the aggregated sensitivity, resistance and resilience outputs for broadscale habitats. A list of which bioregion each offshore MPA occurs in is provided within these spreadsheets in the tab entitled 'MPAs&RegionalSeas'. A Readme tab is also included with instructions on how to use the spreadsheet.

[1] https://eunis.eea.europa.eu/habitats-code-browser.jsp
[2] https://www.marlin.ac.uk

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1 Introduction

Sensitivity assessments following the Marine Evidence-based Sensitivity Assessment (MarESA) methodology (Tyler-Walters *et al.* 2018) have been undertaken for a range of biotopes at Levels 4 to 6 of the Marine Habitat Classification for Britain and Ireland (JNCC 2015) and the EUNIS classification (Davies *et al.* 2004)[3]. Sensitivity has been assessed against a list of pressures, based upon those defined by the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C; OSPAR 2014). The sensitivity assessments, which are available on the Marine Life Information Network (MarLIN) website[4], are updated by the Marine Biological Association of the United Kingdom (MBA) using best available evidence and peer review.

Although MarESA provides sensitivity information at a detailed biotope level, for certain applications, an understanding of sensitivity is also required at a broadscale habitat (Level 3 of the habitat classifications) or MPA feature-level. JNCC has identified the need for up-to-date broadscale habitat and MPA feature-level sensitivity assessments for a range of applications:

- To further improve updated Advice on Operations for Marine Protected Area (MPA) Conservation Advice[5], including for broad-scale habitats, such as Annex I habitats.
- To allow inclusion of Annex I habitat sensitivity assessments and updates to Priority Marine Feature assessments in the Scottish Feature Activity Sensitivity Tool (FeAST)[6], for Scottish inshore and offshore MPAs conservation advice.
- To develop habitat sensitivity maps for vulnerability assessments, such as the Marine Strategy Framework Directive (MSFD) common indicator 'BH3: Extent of Physical Damage to Predominant and Special Habitats'[7].
- To improve understanding of the effects of pressures on MPA features to implement appropriate monitoring methods for offshore MPAs.

One of the challenges in using the MarESA assessments for broadscale or MPA feature-level assessments is the resolution of the assessments. Habitats can be composed of a range of biological communities (biotopes) and these communities often exhibit differing sensitivities to the same pressure. As such, broadscale habitat and/or MPA feature sensitivity assessments will often result in a range score (e.g. Low to High), with an associated low confidence score, as was the case for the MB0102 project (Tillin *et al.* 2010). The application of a range score can be difficult to use in practice and a precautionary approach is therefore frequently taken, with the most conservative score from the assessment being used. A further problem is that each habitat may be composed of different biotopes depending on where it is located, meaning the overall sensitivity may vary depending on geography.

Natural England developed a novel method to improve on the display of sensitivity information in their Designated Sites system[8], for Advice on Operations for English inshore MPAs. Their method utilises the up-to-date MarESA assessments to present feature-level sensitivity assessments for English inshore MPAs. To reduce the uncertainty within these sensitivity assessments, Natural England commissioned a piece of work to determine which biotopes occurred within each of the English inshore regional seas. Using the outputs of this

[3] EUNIS classification hierarchy available online at: https://eunis.eea.europa.eu/habitats-code-browser.jsp
[4] https://www.marlin.ac.uk
[5] http://jncc.defra.gov.uk/default.aspx?page=6849
[6] https://www.marine.scotland.gov.uk/feast/
[7] https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/habitats/extent-physical-damage-predominant-and-special-habitats/
[8] https://designatedsites.naturalengland.org.uk/

work, the MPA feature sensitivity information is presented on a biogeographical basis, whereby the sensitivity assessments are tailored to the specific biotopes that do, or could, occur within each MPA, based on the regional sea they occur in. The Designated Sites system displays a 'Sensitive' or 'Not sensitive' score for each pressure-feature combination for each MPA, for the marine activity selected by the user. The system then allows the user to view the range of sensitivity scores via MarLIN, for the biotopes associated with the protected feature.

JNCC wishes to build upon the approach taken by Natural England to improve the understanding of broadscale habitat and MPA feature sensitivity for the UK offshore waters. This project, entitled the MarESA aggregation, will produce an automated method to integrate biogeographical data and make best use of the existing biotope sensitivity information available in MarESA. The resulting broadscale habitat assessments will provide resistance, resilience and sensitivity scores for a range of marine pressures. The assessments will be tailored to the UK offshore regional seas and sub-regions, allowing more precise scores to be given, in turn reducing uncertainty. The automated method will allow outputs to be updated regularly when new input data becomes available. JNCC is planning to use these broadscale habitat sensitivity assessments for the range of applications listed above. Furthermore, this project provides a starting point to develop a more specific feature-level aggregation which will enable more complex feature-level sensitivity assessments to be produced.

1.1 Aim

The aim of this project was to enable the best-available evidence on biotope sensitivity from MarESA to be applied to a broadscale habitat level for UK offshore waters, on a per pressure basis, taking biogeographic variation into consideration.

A future aim for the project is to further develop the method to be applied to other MPA features such as FOCI, Priority Marine Features and Annex I habitats.

2 Methods

An automated method was developed to aggregate MarESA sensitivity scores from Levels 5 and 6, up to Levels 2, 3 and 4 of the EUNIS habitat classification, on a biogeographical basis for offshore waters. Although the aggregation was undertaken using the EUNIS habitat classification biotope codes, the habitats can be easily correlated to those within the Marine Habitat Classification for Britain and Ireland, as the habitat names and classification levels are the same. The method can also be used for the MarESA resistance or resilience scores instead of the sensitivity scores if required. For simplicity however, the method is described here using the sensitivity scores only.

The method aggregates sensitivity scores for biotopes that occur in the offshore on a per pressure basis, from Level 5 (L5) or Level 6 (L6), up to Level 4 (L4), then to Level 3 (L3), and then to Level 2 (L2). The aggregation follows a set of rules as detailed in Section 2.2 below. Each aggregation has been completed on a biogeographical basis to reduce the number of biotopes being aggregated. This uses knowledge of which biotopes occur in each UK offshore biogeographic region, based on the outputs of Tillin *et al.* (2020). A confidence scoring process for the aggregated outputs has also been developed and is detailed in Section 2.3. Definitions for the key terminology used is given in Annex 1.

The aggregation and confidence scoring method has been automated using the Python 3.6 software, and the steps that the script follows are outlined in Appendix 1.

2.1 Input datasets

Two main data sources were used for the MarESA aggregation: the MarESA database extract and the bioregions extract. The MarESA database extract contains sensitivity assessments for the majority of UK biotopes from the Marine Habitat Classification for Britain and Ireland and the EUNIS classification, whilst the bioregions extract details which biotopes occur, or may occur, within each UK offshore regional sea.

2.1.1 MarESA database extract

The MarESA method was developed by the MBA as part of the MarLIN project[9]. The method follows an evidence-based approach, involving a detailed literature review and a peer-review process. Sensitivity assessments have been undertaken for biotopes at Levels 5 and 6 of the Marine Habitat classification for Britain and Ireland (JNCC 2015) and the EUNIS classification (Davies *et al.* 2004), as well as for some Level 4 biotope complexes. Sensitivity is assessed against the defined intensities (known as 'benchmarks') of a range of pressures[6] based on the OSPAR pressures list[2] (OSPAR 2014). The resistance and resilience of each biotope to each of the pressures, are categorically scored based on the evidence, and then combined to give an overall sensitivity score (see Table 1).

Table 1. Table showing the combination of resistance and resilience scores to categorise sensitivity (taken from Tyler-Walters *et al.* 2018).

	Resistance			
Resilience	**None**	**Low**	**Medium**	**High**
Very low	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Not sensitive

Where assessments are not possible, scores of 'No evidence', or 'Not assessed' are assigned (definitions of these can be found in Annex 1). Further detail on the MarESA method, including definitions of the scoring scales for resistance and resilience, can be found in the MarESA methods report (Tyler-Walters *et al.* 2018).

Under the MarLIN project[4], sensitivity assessments for remaining biotopes are being undertaken and existing assessments will be updated following peer-review and user feedback. An updated MarESA database extract is delivered every 6-months, and this is also publicly available on the MarLIN website[10]. The automated nature of the MarESA aggregation allows updates to be made when new versions of the input datasets become available.

2.1.2 Bioregions extract

In March 2017, JNCC contracted the MBA to undertake a project entitled 'Assigning the EUNIS classifications to UK's Offshore Regional Seas' (Tillin *et al.* 2020). This work (hereafter referred to as the 'bioregions project') followed the approach taken by Natural England in their equivalent UK regional seas project for the English territorial seas (Hiscock 2016), however a slightly different method was followed.

[9] The MarLIN project (https://www.marlin.ac.uk/) is funded through a Memorandum of Agreement between JNCC, Defra, Natural England, Natural Resources Wales, Department of Agriculture, Environment and Rural Affairs, Marine Scotland, Scottish Natural Heritage.
[10] The MarESA data extract can be downloaded from: https://www.marlin.ac.uk/data-extract

In summary, the bioregions project sub-divided the Charting Progress 2 (CP2) regional seas (known as 'regions') from the offshore environment into sub-regions, based upon their environmental characteristics. A map and list of these CP2 regions and sub-regions (hereafter referred to collectively as 'bioregions') is provided in Figure 1 and Table 2. For more information on the methods used, see Tillin *et al.* (2020).

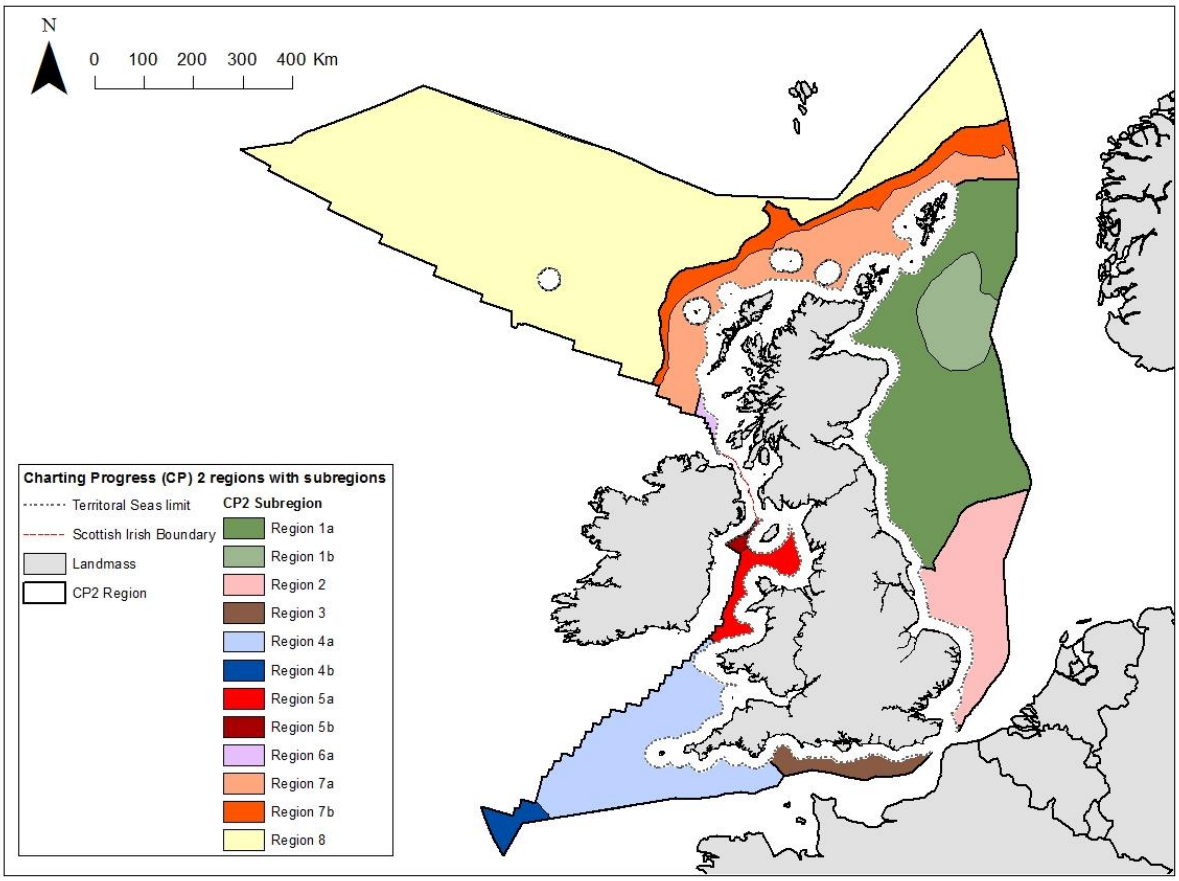

Figure 1. CP2 regions, and the subregions in the offshore, as proposed by the Tillin *et al.* (2020) project entitled 'Assigning the EUNIS classifications to UK's Offshore Regional Seas'. Please note that although Region 7a and Region 8 are shown on the map, these were outside the scope of the project.

Table 2. List of the CP2 regions and their sub-regions in the offshore, identified based upon their environmental characteristics in the project 'Assigning the EUNIS classifications to UK's Offshore Regional Seas'.

CP2 Regions	Sub-regions
Region 1 (Northern North Sea)	Sub-region 1a
	Sub-region 1b
Region 2 (Southern North Sea)	-
Region 3 (Eastern Channel)	-
Region 4 (Western Channel & Celtic Sea)	Sub-region 4a
	Sub-region 4b
Region 5 (Irish Sea)	Sub-region 5a
	Sub-region 5b
Region 6 (Minches and Western Scotland)	Sub-region 6a
Region 7 (Scottish Continental Shelf)	Sub-region 7a
	Sub-region 7b (deep sea)
Region 8 (deep sea)	-

The project assigned a list of relevant EUNIS biotopes to each bioregion based on a series of rules (see Annex 2). These rules considered the presence or absence of survey data, modelled data, environmental information, species records and literature. Expert judgement

was also accounted for. Depending upon which rules were met, biotopes were assigned as either 'Yes', 'Possible', 'Unlikely' or 'No' to show whether they were present in each bioregion. Where biotopes were not relevant (e.g. those occurring in ice, the water column, or inshore-only), they were marked accordingly. Region 8 was not included because it is specific to the deep sea which was outside the remit of the project.

Following peer review comments from the bioregions project methods report, and for the purposes of the MarESA aggregation, it was subsequently decided that two rules would be changed due to the level of uncertainty associated with expert judgement and use of EUSeaMap. Therefore, the following rules were changed so that biotopes were assigned as 'Possible' rather than 'Yes' for presence, if either of these rules were met (the resulting, amended rules are set out in full in Annex 2):

1. there were no Marine Recorder data points, but EU SeaMap predicted the biotope to be present;
2. expert judgement/experience indicated that the biotope was present in that region.

Furthermore, since the bioregions project was undertaken, updates to the Marine Recorder dataset and EUSeaMap have been released, in addition to JNCC survey reports. It was also agreed that it would be more appropriate to use UKSeaMap instead of EUSeaMap, as it contains higher resolution data for UK marine habitats. In light of this, JNCC developed a script in Python 3.6 to review these new datasets and assess these against the amended rules (as set out in Annex 2). These new data outputs were combined with the original project outputs to create the 'bioregions extract' for use in the MarESA aggregation.

2.2 Aggregation steps and associated rules

The MarESA aggregation process comprises a number of steps, with associated rules, as set out in Table 3. Further rationale for the rules is provided in the additional information column. The aggregation process can be run on either resistance, resilience or sensitivity scores, however for simplicity the method is described using sensitivity scores.

Table 3. Table setting out the steps for the MarESA aggregation method. A number of rules are included in this process, and the rationale for those is given in the Additional information column.

Aggregation steps		Sub-steps			Additional information
1.	Preparation of input datasets	**a.**	The input datasets are prepared using the following rules:		
			i)	Only biotopes listed as 'Yes' and 'Possible' for each bioregion (from the bioregions extract) are included in the aggregation.	See Annex 2 for the rules associated with the 'yes' and 'possible' definitions.
			ii)	'Inshore only' biotopes are excluded.	
			iii)	The term 'Unknown' is assigned to biotopes without sensitivity assessments.	See Appendix 2 for details of the process for assigning 'unknown' biotopes.
		b.	The bioregions extract and MarESA database extract input datasets are joined together based on EUNIS code.		
		c.	The combined dataset is cleaned and reformatted using the following rules:		
			i)	Sensitivity scores of 'Not Sensitive', 'Low', 'Medium' and 'High' are listed as 'assessed' scores.	

			ii)	Where there is no interaction between the pressure and biotope, this is scored in MarESA as 'Not relevant'. For the purposes of the aggregation, this is listed as an 'assessed' score .	Unassessed scores are only those where an assessment could be made in the future if evidence became available. This is therefore not the case for 'Not Relevant' assessments and these could be interpreted as a high confidence assessment in their own right.
			iii)	Scores which are not related to the sensitivity, i.e. 'Not assessed', 'No evidence' and 'Unknown', are listed as 'unassessed' scores, to show that assessments have not been possible or are not yet complete.	
2.	Aggregation, per pressure, of biotopes	**a.**	'Assessed' and 'unassessed' scores are aggregated separately.		Since 'unassessed' scores are not related to the sensitivity, it was not considered logical to aggregate these with the 'assessed' scores. This also ensures that the confidence can be calculated more easily (based on unassessed scores; see Section 2.3) and that the final sensitivity scores can be taken directly from the assessed column.
		b.	All assessed and unassessed L6 scores (i.e. the 'child' biotopes) are aggregated to the L5 (i.e. 'parent' biotope). Where a L5 sensitivity assessment is already available, an aggregation has **still** been created and that score is used moving forward.		Sensitivity assessments are based upon the species specified in the biotope descriptions, which can vary between the L5 and L6 biotopes, with L6 having additional species. The presence of additional species can result in different sensitivity scores between levels. As L6 is considered the most detailed level of assessment, these scores are taken forward in the aggregation to replace existing L5 scores, to ensure this detail is not lost.
		c.	For L5 biotopes which have **no** child biotopes at L6, the L5 assessment is used where available.		
		d.	All resultant L5 scores (both aggregated from L6 and those existing L5 scores) are aggregated to L4. Where a L4 assessment is already complete, an aggregation **has still** been created and that score is used moving forward*.		L4 sensitivity literature review assessments are based on the L4 biotope complex descriptions, but these descriptions don't take into account all the characterising species in the child L5 and L6 biotopes. Therefore, the L4 assessments may not be representative of the full range of potential biotopes existing as part of the L4 biotope complex. *The exception to this rule is the A5.71 L4 sensitivity assessment, which is used instead of aggregating the L5 and L6 biotopes. Only one of the eight child biotopes has a sensitivity assessment, so in the absence of more detailed sensitivity information, the A5.71 assessment provides a more precautionary overarching score.
		e.	For L4 biotope complexes which have **no** child biotopes at L5 or		In this circumstance, the L4 score provides the best available information.

			L6, the L4 assessment is used where available.	
		f.	All aggregated and non-aggregated L4 scores are aggregated to L3	MarESA does not contain any L3 assessments
		g.	All aggregated L3 scores are aggregated to L2	MarESA does not contain any L2 assessments
3.	Output aggregated sensitivity assessments	**a.**	Biotopes that don't occur in UK waters, but appear in the aggregation due to their child biotopes being present (i.e. A2.611 and B3), are manually changed to 'Not applicable' at the end of the aggregation process.	This avoids an aggregated score being shown for non-UK biotopes.
		b.	The final aggregated scores are recorded in the *FinalSensitivity* column of the output (Excel csv format). All final scores are detailed (i.e. a range such as High-Low is not produced, instead the combination of scores such as 'High, Medium, Low' is shown).	This decision was made so that the aggregated scores are transparent and don't over- or under-represent certain scores. For example, a range 'Low-High' may be made up of six low, four medium and one high, but the range removes this important detail.
		c.	'Assessed' and 'unassessed' scores are provided in the output in separate columns. The number of assessed and unassessed scores that have been aggregated up are listed in the spreadsheet output under *AssessedCount* and *UnassessedCount* respectively. If no aggregated scores exist for the 'Unassessed Count', 'Not Applicable' is stated instead.	
		d.	Where 'assessed' scores exist for a biotope, these are listed in the *FinalSensitivity* column. In the absence of 'assessed' scores, 'unassessed' scores are listed instead.	This ensures that there is always a final sensitivity score stated. The assessed and unassessed scores are not shown together so that the focus is always on the scores relating to High, Medium or Low sensitivity, or Not sensitive. Adding the unassessed scores to this would detract from this as it can appear confusing when other scores exist.
		e.	'Not relevant' is included in the *AssessedCount* column, but is excluded from the *FinalSensitivity* column, unless it is the only 'assessed' score.	This ensures the focus is on scores relating to High, Medium or Low sensitivity, or Not sensitive. Adding 'Not relevant' would detract from this as it can appear confusing when other scores exist.
		f.	A confidence score for the aggregation is included in the output (see Section 2.3 below).	

2.3 Confidence scoring

The MarESA method assesses confidence in the evidence for each sensitivity assessment using three categories:

- the quality of the evidence or information used;
- the degree to which evidence is applicable to the assessment; and
- the degree of concordance (agreement) between studies.

These three-part confidence categories are scored independently for resistance and resilience, and then combined following a matrix to give an overall three-part sensitivity confidence score. Confidence levels of High, Medium and Low are used. Further detail on this approach can be found within the MarESA methods report (Tyler-Walter *et al.* 2018).

Confidence scores associated with the evidence for each sensitivity assessment, as detailed above, are not included within the aggregation. Confidence scores are specific to each individual biotope assessment and cannot be easily aggregated to higher levels as they need to link to the specific assessments made, so aggregated scores would become meaningless. The sensitivity confidence scores can instead be found on the MarLIN website and in the MarESA database extract.

Confidence in the aggregation itself has been assessed based on a numerical tally and is provided in the aggregation outputs. This **is not based on the evidence base behind the sensitivity scores** but instead represents the level of confidence in each of the aggregations. This accounts for any uncertainty in the final aggregated sensitivity scores, which would result from the presence of biotopes with 'Unknown' sensitivity scores (i.e. those with no sensitivity assessment) or those with insufficient evidence to score sensitivity (i.e. No evidence or Not assessed scores). As stated above, these are termed 'Unassessed'. This means that an aggregation comprised of a high proportion of 'assessed' component biotopes would result in a higher aggregation confidence, regardless of the confidence scores associated with the sensitivity assessments of the component biotopes. For example, an aggregation with a majority of 'assessed' component biotopes that have low sensitivity assessment confidence scores could be assigned a high aggregation confidence, and vice versa.

The confidence in the aggregation is based on the number of biotopes in the aggregation that have been assessed, divided by the total number of biotopes in the aggregation:

Assessed count / (Assessed Count + Unassessed Count)

The resultant confidence value (between 0-1) is recorded under the column *AggregationConfidenceValue* in the aggregation output spreadsheet. These values are then assigned to a score category (*AggregationConfidenceScore* column) of either High, Medium or Low, based on equal breaks (see Table 4 below). Using equal breaks ensures that the quantiles will not change regardless of whether the number (spread) of data changes (which may happen if scores are updated)[11].

[11] Quantile values were also trialled, however these gave very high (>0.9) values for most of the breaks (and hence a higher confidence across the board) due to the inflation of the number of assessed to unassessed values. This approach therefore gave disproportionate scores, so equal breaks were chosen instead.

Table 4. Table showing the confidence score categories assigned to the aggregation, and the associated confidence value for each. Equal breaks between 0-1 are used.

Aggregation confidence score	Aggregation confidence value
Low	Less than or equal to 0.33
Medium	Greater than 0.33 and less than 0.66
High	Greater than or equal to 0.66

2.4 Outputs

The MarESA aggregation project has produced aggregated resistance, resilience and sensitivity scores for broadscale habitats in each of the UK offshore CP2 regions (and sub-regions) on a per pressure basis. The broadscale habitats consist of Levels 2, 3 and 4 of the EUNIS habitat classification which directly correlate to the broadscale habitats within the Marine Habitat Classification for Britain and Ireland. Confidence scores for each of the aggregated outputs are also provided alongside the final resistance, resilience or sensitivity scores. The resulting aggregated scores for resistance, resilience and sensitivity are available in separate Excel spreadsheets.

To assist with the subsequent application of the aggregation outputs, a list of which bioregion each offshore MPA occurs in is provided alongside in the tab entitled 'MPAs&RegionalSeas'. A Readme tab is also included with instructions on how to use the spreadsheet.

The automated aggregation will be run every six-months, when the latest MarESA extract is released, following peer review of existing assessments and/or new biotope assessments. This will ensure that the most up-to-date MarESA sensitivity assessments are used in the aggregation. The bioregions extract will also be updated every 6-months to account for any new biotope data identified in the latest Marine Recorder snapshots and survey reports.

2.5 Quality assurance

The MarESA sensitivity assessment input data undergoes a thorough quality control and peer-review process as part of the MarLIN project. The methods used for the bioregions contract, which produced the bioregions extract input dataset for the MarESA aggregation project, have been peer-reviewed by the Statutory Nature Conservation Bodies.

To quality check the output dataset, a manual aggregation of biotopes was undertaken for a single pressure, for EUNIS code A3 (from Level 6 to 2) for sub-region 7a, and for EUNIS code A4 for sub-region 1a. The results provided the same end scores as the automated aggregation, which confirmed the automated aggregation had worked correctly.

3 Aggregation worked example

The below worked example shows the aggregation process for the EUNIS habitat A4 (Circalittoral rock and other hard substrata) for Sub-region 6a (within the Minches and Western Scotland) and the pressure 'Removal of target species'.

As set out in Table 5, where Level 6 biotopes are present, the associated MarESA sensitivity scores are aggregated together to provide a score for the parent L5 biotope. In the absence of a Level 6 biotope, the Level 5 MarESA sensitivity score is used directly. The resulting L5 scores are subsequently aggregated together to give a score for the parent L4 biotope complex. This process is repeated again to provide an aggregated score for the parent L3 habitat, then the L2 habitat which is the end point of the aggregation. The sensitivity scores and the counts of each, are detailed in the table.

Table 5. Example aggregation process, showing how the Level 6 (L6) biotopes and their MarESA sensitivity scores are aggregated together to provide Level 5 (L5) scores. The L5 scores are then aggregated to provide Level 4 (L4) scores. The L4 scores are similarly aggregated to provide Level 3 (L3) scores, and the L3 are aggregated to give a Level 2 (L2) score. The sensitivity scores and the counts of each are given in the table.

L6 biotope	L6 score & count	L5 biotope	L5 score or aggregated score & count	L4 biotope complex	L4 aggregated score & count	L3 habitat	L3 aggregated score & count	L2 habitat	L2 aggregated score & count
NA		A4.121	High (1)	A4.12	High (1)	A4.1	High (2) Not relevant (1)	A4	High (4) Medium (3) Not relevant (10) No evidence (2)
NA		A4.132	Not relevant (1)	A4.13	High (1) Not relevant (1)				
NA		A4.133	High (1)						
A4.2111	High (1)	A4.211	High (2)	A4.21	High (2) Medium (1) Not relevant (7) No evidence (2)	A4.2	High (2) Medium (1) Not relevant (7) No evidence (2)		
A4.2112	High (1)								
A4.2121	Not relevant (1)	A4.212	Not relevant (1) No evidence (1)						
A4.2122	No evidence (1)								
NA		A4.213	Not relevant (1)						
A4.2141	Medium (1)	A4.214	Medium (1) Not relevant (5)						
A4.2142	Not relevant (1)								
A4.2143	Not relevant (1)								
A4.2144	Not relevant (1)								
A4.2145	Not relevant (1)								
A4.2146	Not relevant (1)								
NA		A4.215	No evidence (1)						
NA		A4.215	No evidence (1)						
A4.3111	Medium (1)	A4.311	Medium (1) Not relevant (1)	A4.31	Medium (2) Not relevant (2)	A4.3	Medium (2) Not relevant (2)		
A4.3112	Not relevant (1)								
NA		A4.312	Not Relevant (1)						
NA		A4.313	Medium (1)						

When the aggregation results are presented in the aggregation output (as described in Step 3 of Section 2.2), the sensitivity scores are split out and the level of confidence in the aggregation is presented for each habitat classification level. The output allows the appropriate 'Level' of interest to be selected. Table 6 shows how the results would be presented if the Level 3 output was chosen from the example above.

Table 6. The resulting aggregation output for Level 3 for the pressure 'Removal of target species' for Sub-region 6a. The term 'Not Applicable' is used where there are no scores; in this example it indicates that there are no unassessed scores for A4.1 and A4.3.

Level 3	L3 Final Sensitivity	L3 Assessed Count	L3 Unassessed Count	L3 Aggregation Confidence Value	L3 Aggregation Confidence Score
A4.1	High	H(2), NR(1)	Not Applicable	1	High
A4.2	High	H(2), M(1), NR(7)	NE(2)	0.6	Medium
A4.3	Medium	M(2), NR(2)	Not Applicable	1	High

In the example shown in Table 6, the confidence value for A4.2 is 0.6, which equates to a confidence score of Medium. This is based upon there being one biotope which has an unassessed score of 'No Evidence' (this is shown in Table 6 to be A4.215).

4 Conclusions

The MarESA aggregation method enables the best-available and most up-to-date evidence on biotope sensitivity, from MarESA, to be applied at the broadscale habitat level in the UK offshore waters. Specifically, the method produces sensitivity assessments on a per pressure basis at Levels 2, 3 and 4 of the EUNIS classification, or the Marine Habitat Classification for Britain and Ireland, by aggregating up sensitivity assessments from Levels 5 and 6. Through the integration of biogeographical data within the method, the outputs are tailored to the UK offshore regional seas and sub-regions, allowing more precise sensitivity scores to be given, in turn reducing uncertainty. Confidence in the aggregated scores is also encompassed within the outputs, indicating where sensitivity knowledge gaps exist. JNCC chose to automate the aggregation process through developing a Python script to ensure the long-term sustainability of the work. This will allow the aggregation process to be re-run when new data inputs become available, ensuring that the outputs are as up-to-date as possible.

The project outputs will be used to update JNCC's Advice on Operations for offshore MPA Conservation Advice. For this, sensitivity assessments are required for MPA features, such as MCZ Broadscale Habitats. The MarESA aggregation directly provides Level 3 habitat sensitivity assessments which equate to these MCZ broadscale habitats, for example Subtidal coarse sediment (A5.1). Other MPA features, such as Annex I habitats, correlate to a range of biotopes across different levels of the classification. Therefore, the MarESA aggregation provides a starting point to develop a more specific feature-level aggregation which will enable more complex feature-level sensitivity assessments to be produced. These feature-level sensitivity assessments are also required for the Scottish Feature Activity Sensitivity Tool (FeAST)[5], which is used in conservation advice for Scottish inshore and offshore MPAs. Planned updates for this tool include the addition of Annex I habitat sensitivity assessments and updates to Priority Marine Feature sensitivity assessments.

JNCC's Advice on Operations outputs, available through the MPA Site Information Centres[4], provide information on the sensitivity of protected features to pressures caused by marine activities. This data is used in the preparation of Habitat Regulation Assessments (HRAs) for proposed developments that may impact a European Designated Site. For proposed developments, including those away from MPAs, Environmental Impact Assessments (EIAs) also require habitat sensitivity information. Biotope level information is often not available for the proposed development sites, so broadscale habitat sensitivity assessments are required instead. The MarESA aggregation presents habitat sensitivity assessments at these broadscale levels, be it at Level 2, 3 or 4 of habitat classifications, allowing sensitivity

information to be included within EIAs. It is therefore anticipated that the MarESA aggregation outputs will be of use to marine consultancies and developers when preparing HRAs and EIAs.

Another direct application of the MarESA aggregation outputs is in the development of habitat sensitivity maps for vulnerability assessments, such as the Marine Strategy Framework Directive (MSFD) common indicator 'BH3: Extent of Physical Damage to Predominant and Special Habitats'[12]. Habitat maps are commonly presented at Levels 3 and 4 of the habitat classifications, so the MarESA aggregation broadscale sensitivity assessments will enable the sensitivity of these habitats to be mapped. Where the aggregated score comes out as a range (e.g. medium, low), the user can either select the most sensitive (i.e. most precautionary) score, or the modal score, using the information on assessed count provided in the aggregation output.

The main gaps in the MarESA aggregation at present are the deep-sea biotopes from the Marine Habitat Classification for Britain and Ireland. These have been excluded from the aggregation as there are only a very limited number of deep-sea sensitivity assessments in MarESA at present, and the deep-sea regions and sub-regions were not included in the bioregions contract outputs. It is also important to note that the aggregation method currently runs using the EUNIS classification, which has a different, less detailed deep-sea section. As new deep-sea sensitivity assessments are added to MarESA, it is anticipated that the aggregation will be expanded to include the deep-sea regions, sub-regions and their biotopes.

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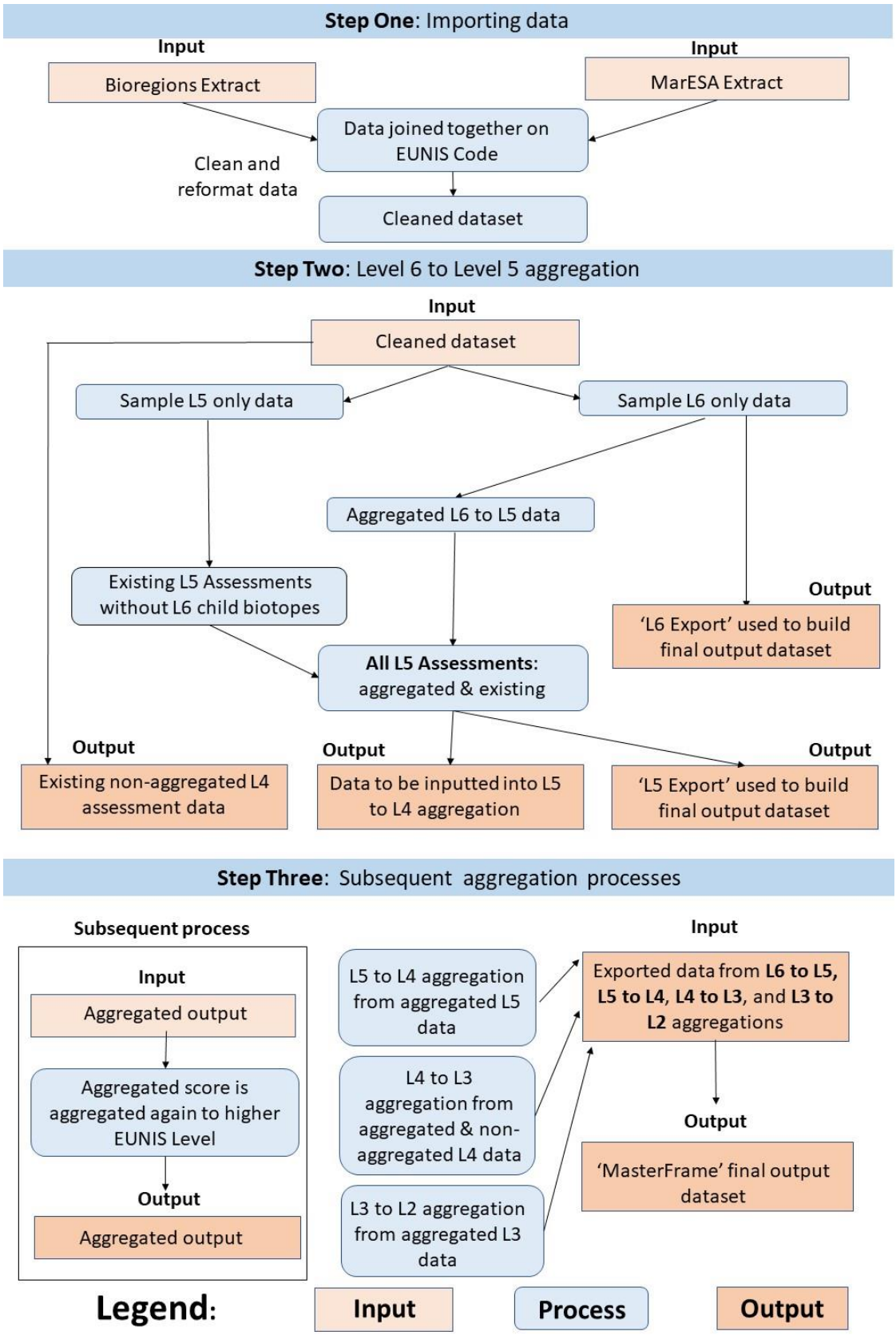
[12] https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/habitats/extent-physical-damage-predominant-and-special-habitats/

Appendix 1: Flow diagram of the MarESA aggregation process followed in the Python script



Appendix 2: Process for the identification of 'unknown' sensitivity scores and knowledge gaps

For the MarESA aggregation process, the term 'Unknown' is assigned to biotopes without sensitivity assessments. To prepare the MarESA database extract for the aggregation process, the following steps are taken to identify the biotopes without sensitivity assessment and assign these as 'Unknown':

1. Using the JNCC Marine Habitats Correlation Spreadsheet[13], all L4, L5 and L6 biotopes which do not have existing MarESA assessments are identified.
2. A template data frame with the string 'Unknown' assigned to all sensitivity assessment columns is cross-joined with all identified L4, L5 and L6 data. This creates a new data frame with the same schema as the MarESA database extract, comprising unknown records for biotopes without sensitivity assessments.
3. The cross-joined data frame is appended into the existing MarESA database extract, creating a new iteration for use within the aggregation process, which accounts for unknown values and knowledge gaps.

The resulting amended MarESA database extract is then used as the input to the aggregation process.

[13] https://hub.jncc.gov.uk/assets/62a16757-e0d1-4a29-a98e-948745804aec

Annex 1: Glossary of key terms

Key term	Definition
Habitat	A 'habitat' represents the physical and environmental conditions that support a particular biological community. Levels 2 and 3 of the Marine Habitat Classification for Britain and Ireland and the EUNIS classification can be described as 'habitats', as these give detail of sediment type, energy level and environmental zone.
Biotope	The physical 'habitat' with its biological 'community'; a term which refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. Levels 5 and 6 of the Marine Habitat Classification for Britain and Ireland and the EUNIS classification can be described as 'biotopes', as these provide information on the species characterising a physical habitat.
Biotope complex	Level 4 of the Marine Habitat Classification for Britain and Ireland and the EUNIS classification can be described as 'biotopes complexes', as these represent communities made up of multiple species-level biotopes from L5 and L6.
Parent biotope	A biotope under which sits one or more lower level biotope(s) (or 'child' biotope(s)). For example, A5.6 is the parent biotope to A5.61, A5.62, A5.63 and A5.64 (the 'child' biotopes).
Child biotope	A biotope above which sits a higher-level biotope (or 'parent' biotope). For example, A5.61, A5.62, A5.63 and A5.64 are child biotopes of A5.6 (the 'parent' biotope).
Not assessed	Term used in the MarESA method - recorded either where the available evidence is extremely limited, poorly understood, completely absent or where there are issues with the pressure benchmark (e.g. for Litter). As a result, the pressure/feature combination cannot be assessed. To date this has only been applied to the pressure 'Litter'.
No evidence	Term used in the MarESA method – recorded where: - There is not enough evidence to assess the sensitivity of the specific feature/pressure combination; or - There is no suitable proxy information regarding the habitat (biotope) or species on which to base decisions; and - Expert judgement alone does not allow an assessment to be made with any confidence. An assessment of 'No evidence' does not mean that there is no information available for a feature but that the evidence does not support an assessment. As a result, the pressure/feature combination cannot be assessed. For example, some species have a limited distribution (e.g. a few or only one location) so that even basic physical, chemical, or biological tolerances cannot be inferred.
Not relevant	Term used in the MarESA method - recorded where the evidence suggests that there is no direct interaction between the pressure and the habitat (biotope) or species. 'Not relevant' is also used to denote interactions that are unlikely to occur at present or in future and to denote interactions that are literally 'not relevant', for example, deep mud habitats are not exposed to changes in emersion.
Unknown	Term used to indicate where a sensitivity assessment has not been undertaken.
Unassessed	Term used to indicate scores which are not related to sensitivity, i.e. where a biotope either has not had a sensitivity assessment undertaken (an Unknown), or where an assessment has not been possible (in the case of Not assessed and No evidence).
Assessed	Term used to indicate scores where a biotope has had a sensitivity assessment undertaken, and either where a sensitivity score of High, Medium, Low or Not sensitive was assigned, or where a biotope was Not relevant. (Not relevant is included as it could be interpreted as a high confidence assessment in its own right).
Not applicable	Recorded where no aggregation scores exist. For example, if no aggregated scores exist for the 'Unassessed Count', 'Not Applicable' is stated instead.

Annex 2: Rules for determining biotope categories (as amended from the bioregions contract, Tillin *et al.* 2020)

A biotope was assessed as present (i.e. 'yes') in a region or subregion when any of the following criteria were met:

- there were >1 Marine Recorder data points;
- the biotope was recorded by survey reports or other literature; or
- a Level 5 biotope or Level 6 sub-biotope was present (child biotope) then the higher Level 4 biotope complex (parent biotope) was considered present by default (note, other biotopes/sub-biotopes in the complex were not recorded as present by default on this basis).

A biotope was assessed as possibly present (i.e. 'possible') when any of the following criteria were met:

- there was a single Marine Recorder data point but no further information;
- habitats within the region were considered likely to be suitable for a biotope to occur and characterising species were recorded within the region;
- another very similar biotope within the biotope complex was present; or
- the Level 4 biotope complex (parent biotope) was assessed as present based on data and there were no factors to rule out the presence of the Level 5 or 6 biotope/sub-biotope (child biotopes);
- there were no Marine Recorder data points, but EU SeaMap predicted the biotope to be present; or
- expert judgement/experience indicated that the biotope was present in that region.

A biotope was assessed as 'unlikely' where there was no evidence to support presence and confidence in presence was low, but its presence could not be entirely discounted.

A biotope was assessed as not present (i.e. 'no') when either:

- the habitat was known to be unsuitable for a biotope to occur, based on the JNCC (2015) description, for example very shallow biotopes would not be present in regions that are very deep;
- when the region or subregion was outside the species distribution range (based on literature or NBN records); or
- when the region was outside the recorded biotope distribution based on the JNCC (2015) description (this was interpreted cautiously as some biotopes may be under recorded).