JNCC Report
No. 702

Review of approaches for the assessment of marine Natural Capital in the context of UK marine environmental policy and management

Study team: Agata Makowska[a], Natalya Kharadi[a], Jake Kuyer[a], Rob Tinch[a], David English[a], Stephen Hull[b], Susanne Armstrong[b], Angus Middleton[c], Leon Baruah[c], Nicola Beaumont[d], Lauren Molloy[e], Vicky Morgan[e], Eugenia Merayo[e], Adrian Judd[f], Roger Proudfoot[g]

Reviewers: Ece Ozdemiroglu[a], Ian Dickie[a], Rachel Holtby[b]

February 2022

ISSN 0963 8091

JNCC's report series serves as a record of the work undertaken or commissioned by JNCC. The series also helps us to share, and promote the use of, our work and to develop future collaborations.

For further information on JNCC's report series please contact:
Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough PE1 1JY
https://jncc.gov.uk/
Communications@jncc.gov.uk

This report was produced for JNCC under an external contract, by eftec, ABPmer, and Viridian Logic as a part of the Defra Marine Natural Capital Ecosystem Assessment (mNCEA) Programme.

This report should be cited as:
Makowska, A., Kharadi, N., Kuyer, J., Tinch, R., English, D., Hull., S., Armstrong, S., Middleton, A., Baruah, L., Beaumont, N., Molloy, L., Morgan, V., Merayo, E., Judd, A. & Proudfoot, R. 2022. Review of approaches for the assessment of marine Natural Capital in the context of UK marine environmental policy and management. *JNCC Report* No.702, JNCC, Peterborough, ISSN 0963-8091.

[https://hub.jncc.gov.uk/assets/a0a9b99c-823c-4396-9445-325a99502876]

Author affiliation:
[a] eftec
[b] ABPmer
[c] Viridian Logic
[d] Plymouth Marine Laboratory
[e] Joint Nature Conservation Committee
[f] Centre for Environment, Fisheries and Aquaculture
[g] Environment Agency

Acknowledgments:
The project steering group members: Henk van Rein, Christina Ingle, Phil Kennedy, Sofiya Stoyanova, Will Le Quesne, Rachel Mulholland, Aisling Lannin, Clare Hedley, Tara Hooper, Mike Young, Sarah Young, Synasia Kalsey, Michael Nelson and Chris Jenkins.

Evidence Quality Assurance:
This report is compliant with JNCC's Evidence Quality Assurance Policy
https://jncc.gov.uk/about-jncc/corporate-information/evidence-quality-assurance/

Review processes were undertaken within the contracted project team and by the project steering group.

The views and recommendations presented in this report do not necessarily reflect the views and policies of JNCC.

Summary

This report was commissioned by the Joint Nature Conservation Committee (JNCC) to collate existing knowledge on how natural capital approaches have been applied to marine and coastal environments and gain insights from this experience for future management and policy work in the UK. This project is part of Defra's Marine Natural Capital Ecosystem Assessment (mNCEA) programme.

The report presents the key findings of the review of relevant studies, frameworks and tools (henceforth, jointly referred to as 'products'); the overall results of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and the findings of the Quick Scoping Review (QSR). The QSR focused on the priority gap identified by the SWOT analyses, namely, understanding the distribution of marine natural capital benefits and who accrues them.

Review and SWOT analyses of current marine natural capital approaches

The geographic scope of the review is the whole UK marine environment, including both intertidal and subtidal areas, estuaries, the coast, and offshore. Some evidence of international good practice has also been included to ensure recommendations on the best approach, and on future research, consider lessons from outside the UK. Tools for monetary valuation and economic accounting are outside the direct scope of this project. However, understanding the purpose and process of economic valuation is a crucial factor in the design of natural and social science research. This is because natural capital approaches (including accounting) are dependent on data and insights from multiple disciplines.

Thirty-five products were reviewed with regards to their methodologies and how they treat five features of marine natural capital:

- Extent of marine natural capital assets,
- Condition of marine natural capital assets,
- Delivery and status of ecosystem services,
- Climate change impacts, and
- Natural capital classifications and frameworks used.

Secondly, the relevance of each product to UK marine policy and management was analysed through the lens of its strengths, weaknesses, opportunities increasing their applicability, and threats (or risks) limiting their applicability. Some of the products were designed to deliver one part of the natural capital approach and inevitably have gaps on other parts. In the context of this review, these gaps were noted as weaknesses against those individual products. Importantly, the aim of the SWOT was not to criticise any methods used but to highlight any gaps in the existing evidence.

Each of the products' marine components was reviewed individually relative to the five features of the natural capital approach (i.e. looking at combinations of co-designed products was beyond the scope). Hence, the SWOT has not assessed how co-developed products cover each other's main weaknesses. A recommended further step in this analysis would be to assess the individual products in combination to identify how they work collectively and understand if they offer a package that points towards a preferred marine natural capital approach.

Individual product-level findings were aggregated to identify common themes across the evidence base. The overall SWOT results highlight several existing strengths and future

opportunities for development and the possibility of integrating the marine and coastal natural capital approach into decision making, as follows:

- With regards to the extent and condition of natural capital assets, products often use standardised methods, classifications, and data sets, making the assessments robust and scalable.
- Methods used to assess ecosystem services are mostly repeatable, and transferable with frameworks providing a route to further standardisation.
- The coverage of high-level ecosystem services is wide, with services linked to specific asset types at a granular level.
- There is a potential for the existing approaches to be developed further and move towards widely accepted standardised approaches which can be adapted to different contexts. Some approaches such as asset-service matrices have been highlighted as particularly useful.
- Another opportunity lies in undertaking innovative work to better understand how both species and habitats link to ecosystem service delivery across scales and contexts. Future efforts should be dedicated to assessing ecosystem services which have not been studied much to date (e.g. regulating services and cultural services other than tourism / recreation).
- There is also an opportunity to use understanding of approaches to measuring natural capital assets to develop better measurements of ecosystem services.

Addressing these and other development opportunities, including sufficient guidance, better quality data, and higher resolution assessments, can improve the robustness in ecosystem services methods. However, some of the solutions addressing these issues can be costly or methodologically challenging.

The SWOT results informed recommendations developed to outline good practice for a UK marine natural capital approach. The recommendations look across the natural capital approach and assessment cycle. This cycle starts with agreeing the purpose and scope, and engaging with relevant stakeholders including decision makers, those who provide supporting data and insights, those expected to benefit and those expected to be negatively affected as a result. Technical aspects such as the use of existing classifications, frameworks or data and valuation methodologies should also be considered when applying the marine natural capital approach.

Furthermore, 12 recommendations for future research to fill evidence gaps were developed, these focus on: the over-arching process, improvements to current practice, incorporating the future / temporal elements, and understanding the use and usefulness of evidence.

QSR of the distribution of benefits across different groups

The priority research gap as identified by the SWOT and selected in consultation with the steering group was the limited consideration of beneficiaries and the distribution of benefits to different beneficiary groups across the products. It was acknowledged that understanding who benefits from marine ecosystems services is essential for achieving buy-in to the marine natural capital approach as well as being key to making the approach coherent to stakeholders that want to implement it. Having robust evidence of the beneficiary groups could underpin decision-making in areas such as marine management, blue financing, and cost-benefit analyses.

The QSR explored the following priority research question: **What evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups?** A QSR protocol was developed to answer this question in

line with the Defra and Natural Environment Research Council (NERC) guidance (Collins *et al.* 2015).

The implementation of the QSR protocol identified 196 potentially relevant documents in total, with 75 documents deemed actually relevant to answer the priority research question. Of these relevant documents, 39 explicitly mention the distribution of benefits to beneficiaries. However, some studies may simply identify who the beneficiaries are, and some do this implicitly (e.g. through the monetary units used, such as £/visitor).

The QSR identified that detailed beneficiary assessments are rarely considered. The literature tends to use inconsistent classifications of beneficiaries, often defined for specific industries rather than different societal groups. The link between benefits and beneficiaries needs to be more comprehensive and include beneficiaries further removed from marine and coastal environments. This and other transferrable lessons can be learnt from the terrestrial literature, including formal tools for stakeholder mapping and trade-off analysis, which could support the identification of beneficiaries.

Beneficiary assessments require further guidance on distributional analysis and quantification and could benefit from quantification and monetisation of beneficiaries' individual benefits. The results of beneficiaries' assessments should be accompanied by explanation of how they can support decision making, particularly with the study of beneficiaries gaining more prominence through concepts such as 'just transition', linking climate change to social and environmental impacts. Consideration of equity across income groups and generations as justification for government intervention could be a key driver for adopting a natural capital approach. These collective findings from the existing evidence provide a solid foundation for future research but need to be developed further.

Contents

1 Introduction

This report for the Joint Nature Conservation Committee (JNCC) evaluates the existing evidence base on marine natural capital approaches in the UK as part of Defra's Marine Natural Capital Ecosystem Assessment (mNCEA) programme. The report presents the key findings of the review of relevant studies, frameworks and tools (henceforth, jointly referred to as 'products') and the overall results of a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analyses. The SWOT analyses fed into the development of a recommended marine natural capital approach and identified key gaps in the marine natural capital evidence base. One of these gaps, namely understanding the benefits and beneficiaries of marine natural capital, has been investigated through a Quick Scoping Review (QSR), the outputs of which are also presented here.

1.1 Project background

Marine policy and management increasingly reflect the importance of natural capital and the multiple ecosystem services it provides. Understanding and measuring stocks of natural capital assets and their benefits to society are essential for informing delivery of the ecosystem approach, as called for in the UK Marine Policy Statement (2011) and the UK Marine Strategy (2019).

The natural capital approach, as defined by the Natural Capital Coalition (now Capitals Coalition) (2019), has several important features including a distinction between the stocks of natural assets and associated flows of benefits to society; valuation of the benefits to make trade-offs explicit and prioritisation easier; and a forward-looking perspective to account for changes in quality and quantity of assets and risks such as climate change.

Defra's 'Enabling a Natural Capital Approach' (ENCA) guide (2020) has consolidated natural capital thinking and evidence. The Dasgupta Review (HM Treasury 2021) emphasises the importance of the natural capital approach for economic activity and human wellbeing, recognising biodiversity as an asset which we should stop degrading and actively restore. The application of the natural capital approach on land is being developed successfully but applying it to the marine environment remains challenging.

A range of approaches to putting marine natural capital and ecosystem services thinking into practice has been developed and trialled. There has also been some work to create standardised approaches (e.g. Hooper *et al.* 2019). There remains a need for greater convergence and standardisation of these approaches, and for their consistent use to support marine decision-making processes. Understanding the strengths and weaknesses of different approaches, including gaps and uncertainty in the evidence base and outputs of the applied approaches, is important for identifying recommendations for good practice and areas for further research. This report reflects the work that has started consolidating what we know.

1.2 Project objectives

This project aimed to explore how the natural capital approach can be applied to managing the UK marine environment. This involved a review of existing marine natural capital tools, methods, and studies applying them. The review started with a list of preselected 'products' which were identified by JNCC and the project team as potentially relevant to UK marine resource management and/or marine policy. However, it was expanded, in particular in the QSR phase, to include evidence from other contexts with relevance to the marine environment. The review reported what was found in the literature and the applicability of the

products to the marine environment. The review also identified evidence gaps and suggested areas for future research.

The application of natural capital and ecosystem services approaches is location and context specific. The key is to understand how (the extent and condition of) the stock of assets links to the flows of benefits and which management-related or other factors affect these linkages. A standardised UK marine natural capital framework cannot be entirely prescriptive as the linkages will vary depending on context. The challenge is to find effective and efficient ways of understanding the context and applying these approaches to different situations. In addition, any framework applied would have to be flexible to reflect the evolving understanding and evidence in this fast-developing area of work. Using a principles-based framework allows for flexibility, which enables the analysis to continue to support the maintenance and enhancement of marine and coastal environments. There could also be prescriptive elements where there are benefits to standardisation, and therefore, little risk of major changes in understanding, for example in recommended habitat classifications.

Given this context and challenge of finding the good practice in this complex area, the main objectives of the project were to:

- Collate information about existing marine natural capital products and provide a summary of the evidence base.
- Perform an in-depth SWOT analysis on each product and identify strengths, weaknesses, opportunities, and threats across the evidence base.
- Use the SWOT results to develop a recommended common approach and identify gaps that require further research.
- Carry out a QSR addressing a key gap identified through the SWOT analyses, namely, information on the benefits and their distribution across beneficiary groups, identified as the most immediately pressing evidence need.

1.3 Structure of the report

This report is structured in the following way:

- **Section 1: Introduction –** Describes the background to the project, the objectives, and the structure of the report.
- **Section 2: Review of current marine natural capital approaches –** Describes the SWOT analyses and presents the findings and recommendations.
- **Section 3: Quick scoping review (QSR) –** Summarises the QSR and presents the findings and remaining evidence gaps relating to the priority question.
- **Section 4: Conclusions –** Collates the recommendations from SWOT and QSR for future assessments of the UK marine natural capital.
- **Appendix 1: Abbreviations and acronyms**
- **Appendix 2: Glossary**
- **Appendix 3: Review catalogue and SWOT analyses workbook**
- **Appendix 4: Detailed SWOT criteria**
- **Appendix 5: Quick scoping review protocol**
- **Appendix 6: QSR evidence base**

2 Review of current marine natural capital approaches

This section summarises the scope, approach, and outcomes of the review and SWOT analyses of current marine natural capital approaches. In general terms, a natural capital approach is one that: distinguishes between stocks of natural assets and the flows of benefits they provide to society; focuses on how the changes in the stocks affect their capacity to deliver benefits; values the benefits (in any unit, including but not limited to, monetary) to show trade-offs and priorities; and incorporates future risks and opportunities. It also captures both living and non-living elements of nature (see Appendix 2 for glossary of terms).

2.1 Scope of analysis

The geographic scope of the review is the whole UK marine environment, including both intertidal and subtidal areas, estuaries, the coast, and offshore. The review focuses mainly on marine natural capital approaches applied in this area. Some evidence of international good practice has also been included, to ensure recommendations on the best approach and future research consider lessons from outside the UK.

The methodological scope includes methods for assessing the extent and condition of marine natural capital assets, as well as the delivery and status of ecosystem services. Tools and approaches such as asset and risk registers, natural capital asset indices, logic chains, asset-service matrices, and physical accounts are therefore all within scope.

Tools for monetary valuation and natural capital assessment are outside the direct scope of this project. However, many products in the scope of the review also use valuation evidence, combined with other elements of the natural capital approach (e.g. logic chains, physical accounts) and/or in supporting decision-making (e.g. natural capital accounting and policy appraisal). Understanding of economic valuation remains a factor in the assessment, since the ability to support subsequent valuation is an important attribute of physical data and analysis within natural capital approaches. This is in line with ongoing work to develop natural capital accounting standards both nationally and internationally.

2.2 Approach

This section outlines the approach to producing the reviews and SWOT analyses of the evidence base. First, a catalogue of marine natural capital products was created with reviews conducted to provide individual product summaries as well as evidence collated against review categories. Second, a SWOT structure was applied to produce an individual SWOT analysis for each product in terms of their appropriateness to be used for management and policy for the UK marine environment. The SWOT analyses also identified common themes across the evidence base. The SWOT outputs were then used to build a recommended approach for marine natural capital and recommendations for future research.

A total of 35 products were included, of which 21 were provided by JNCC and the project steering group, including work produced as part of Defra's mNCEA programme. A further 14 products were found by the project team. These consist of projects conducted by project team members that cover the application of the natural capital approach within the marine context. Note that additional searches were not undertaken to compile a list of products for review, and therefore the evidence does not represent the whole evidence base but rather a portion of it. Furthermore, there might be instances where some of the products reviewed were not the latest available editions.

The products are recorded in an Excel™ workbook (see Appendix 3). This review catalogue gives a unique reference number to each product and reports key information such as study date, author, and full reference. Review outputs and the SWOT analyses outputs are presented in additional worksheets. The Excel™ workbook structure allows the product list, reviews and subsequent SWOT analyses to be easily updated in the future.

2.2.1 Reviews

For consistency and efficiency, each product was reviewed by one team member. Where a team member is a (co)author of a product, two team members were assigned as reviewers to minimise bias. Each product was reviewed against each of the following five categories of information about marine natural capital:

- Extent of marine natural capital assets
- Condition of marine natural capital assets
- Delivery and status of ecosystem services
- Climate change impacts, and
- Natural capital classifications and frameworks used.

The relevant information under each category was extracted by the project team and summarised. Most information was specific to the category, for example listing the types of natural capital assets and the categories of ecosystem service considered. The geographic scope (e.g. UK, England, Wales, Scotland or other) was identified wherever possible, and a confidence rating was given to the evidence or data reviewed and given a low, medium and high rating where relevant. Some products were assessed against all five categories, but in many cases some of the categories were not relevant (for example, many products did not consider climate change impacts).

2.2.2 SWOT analyses

The SWOT analyses workbook (see Appendix 3) built on the content of the review catalogue. For each product additional summary information was compiled, including:

- Title and lead organisation(s)
- Timescale
- Cost
- Customer
- Funding source
- Contractors
- Technical focus and application (e.g. research project, local management, Marine Spatial Planning, UK Marine Strategy).
- Spatial focus
- Description of outputs
- Weblink to final (or interim) outputs

The SWOT analyses assessed each product in the context of its application of the natural capital approach and its application to UK marine environmental management needs and challenges. The following definitions were used:

- **Strengths:** Features of the product supporting its application to UK marine policy and management.
- **Weaknesses:** Features of the product that could be improved on (in the context of UK marine policy and management). Note that some of the products were designed to deliver one part of the natural capital approach and inevitably have gaps on other parts

– these were noted as weaknesses against those individual products. The aim of the SWOT was not to criticise any methods used but to highlight any gaps in the existing evidence.
- **Opportunities:** Wider context that could be exploited to increase the usefulness of the product for UK marine policy and management (e.g. economic, political, and technical).
- **Threats (Risks):** Factors that may prevent or limit the product's applicability to the UK marine policy and management.

Each product was put through four SWOT analyses with respect to their treatment of four features as show in **Table 1**. The table also shows the criteria considered in each category to decide on SWOT of each product, with detailed criteria presented in Appendix 4.

Table 1: Design of the SWOT analyses.

SWOT feature	SWOT criteria
Natural capital assets	• Asset coverage • Asset extent • Asset location and spatial configuration • Asset condition
Ecosystem services	• Ecosystem service coverage • Ecosystem service physical flow • Ecosystem service valuation • Ecosystem service delivery and status
Climate change and other impacts	• Coverage of climate change and other impacts • Trends and risks
Natural capital approach	• Consistency with natural capital approach

Each of the products' marine components was reviewed individually (i.e. looking at combinations of co-designed products was beyond the scope). Hence, the SWOT did not assess how co-developed products cover each other's main weaknesses.

The review matched the products to the relevant SWOT feature(s). Each reviewer was assigned a SWOT feature based on their expertise, in some instances there were more than one reviewer per feature. Reviewers used the findings of the reviews and referred to the product itself where necessary to complete the relevant SWOT analyses. The overall SWOT results for each feature reflect common themes or issues across relevant products, allowing for a holistic overview of the SWOT results. As part of the quality control, the SWOT analyses (both by product and overall) were reviewed by a member of the project team who was not involved in the initial reviews or SWOT to ensure consistency in application of the criteria and to ensure all commonalities have been captured.

The SWOT results for individual products are presented in the SWOT analyses workbook (Appendix 3), alongside the summarised SWOT results. The SWOT results were used by the project team to derive overall findings and recommendations. These include recommendations for a good practice approach to natural capital assessments for the UK marine environment. Good practice is defined in terms of:

1. Alignment to the natural capital approach (i.e. as defined by the Capitals Coalition 2019), and applicability to different marine management issues by different stakeholders; and

2. Suitability for use in practice including the trade-offs between the level of accuracy, depth and breadth of analysis, and resources and time required to conduct the assessment, and the appropriateness of different methods to inform different decision contexts.

In addition, gaps in the evidence base as well as key opportunities and threats informed the development of recommendations for future research. These recommendations, developed through discussions with the project team and JNCC, were used to derive a priority question for the QSR (see Section 3).

2.3 Review findings

The review process identified 35 products, from a variety of sources including government reports, tools, and databases, as well as frameworks and case studies published in academic and grey literature. Table 2 provides a summary of the number of products in each review category. Note that one product can feature in more than one category. 30 products are related to 'delivery and status of ecosystem services', including either qualitative, quantitative or monetary evidence on specific ecosystem services provided by marine and/or coastal assets. While 24 products consider the extent of marine natural capital, only 16 provide information on both the extent and condition. Only eight products reviewed covered climate change impacts, primarily qualitatively or acknowledging that climate change is a risk to marine and coastal assets. Note that as the review catalogue was not produced through an evidence search strategy, these product counts do not represent the current evidence base, but only the products included in this review.

The majority (28 of 35) of products reviewed contain details on the classifications and frameworks used. This includes classification systems for assets and ecosystem services, as well as methods used to connect assets, ecosystem goods and services and benefits. The most commonly applied asset classification systems are (i) the European Nature Information System (EUNIS, European Environment Agency (2021a)) (used by 10 products) even though they use different levels of classification; and (ii) the UK eight broad habitats as adopted by the UK National Ecosystem Assessment (NEA) (UK NEA 2011) (used by a further seven products). The most commonly used ecosystem service classification system is the Common International Classification of Ecosystem Services (CICES, EEA (2021b)), applied by 13 products (using either version 4.3 or 5.1 depending on publication date). A further three products made use of the ecosystem service classification system developed by the UK NEA Follow-On project (UK NEA 2014).

For assessing links between marine and/or coastal assets, ecosystem service flows and the final goods and services provided, 10 products used logic chains and 24 used conceptual frameworks (including guidance but stopping short of providing logic chains).

Table 2: Number of products reviewed by review category.

Category	Number of products
Extent of marine natural capital assets	24
Condition of marine natural capital assets*	18
Delivery and status of ecosystem services	30
Climate change impacts	8
Classifications and frameworks	28
Total unique products	35

Table note: Products can appear in several categories. *:16 of these also include extent.

The geographic scope of the project is the UK. However, a few products included information from the European Union and UK Overseas Territories. A summary of the geographic scope is presented in Table 3.

Table 3: Number of products reviewed, by geographic scope and coverage of information about assets and services.

Geographic scope	Extent of marine natural capital assets	Condition of marine natural capital assets	Delivery and status of ecosystem services
England	11	6	12
Wales	7	2	6
Scotland	6	3	5
Northern Ireland	4	1	2
UK*	8	5	12
Other**	7	5	7

Table notes:
* 'UK' includes products providing information for the UK as a whole and those that disaggregate national data disaggregated to devolved nations.
**'Other' includes both specific locations within the UK (e.g. Isles of Scilly) and outside of the British Isles (e.g. Overseas Territories, European Union).

2.4 SWOT analyses results

2.4.1 Summary of findings

The SWOT results are presented for each SWOT features (see Table 1) in Table 4 to Table 7. These results are also presented in Appendix 3 (i.e. the SWOT analyses workbook) along with the product level SWOT results.

Natural capital assets (See Table 4)

A key strength of the products reviewed is the use of available data to measure natural capital asset extent and condition, including standardised national and EU datasets. These methods are often robust and scalable. However, the data is frequently of low resolution and/or modelled rather than directly measured. Where available, local data has been used to inform local assessments, However, this is not common potentially due to issues with collation, access and licensing of data. Generally, condition assessments are quite high level and based either on existing assessments or expert judgment. These assessments can therefore be hard to replicate and scale. For the most part, consistent asset classification and indicators are used (e.g. EUNIS). Abiotic (i.e. non-living) assets (e.g. marine aggregates) and other capital inputs or manufactured assets (e.g. area of installed offshore wind capacity, embankments, footpaths) tend to be omitted. The consideration of risks and trends in relation to natural capital assets is missing in many of the products, even though these are important considerations when informing management decisions.

There is potential for standardising approaches for assessing marine natural capital assets in the UK and internationally, such as the inclusion of abiotic assets and other capital inputs, which are used in some reviewed products. Further improvements could include developing approaches to assessing asset extent using standardised data sources and standardised methods for assessing condition of assets. Currently, information on asset condition is mostly lacking and measures of condition largely relate to ecosystem structure rather than

function. The existing datasets require improvements, regarding better spatial resolution or field-testing of model predictions. These improvements could be expensive so it would be prudent to consider the proportionality of expenditure on data collection, taking account of the multiple uses for improved data and the potentially significant benefits of improved marine management in the UK.

Ecosystem services (See Table 5)

The products use a range of data sources and methods to assess a wide selection of ecosystem services. The main ecosystem services assessed in most products include food provision, climate regulation, tourism/recreation and hazard regulation. There is a longer history of measuring these ecosystem services. Other ecosystem services such as those related to cultural services, other than tourism/recreation, are generally not assessed in most products reviewed, which is a shortcoming overall. Most current guidance on ecosystem service assessment is focussed primarily on terrestrial ecosystems. Methodologies for assessing ecosystem services tend to be data intensive, and applications to terrestrial ecosystems benefit from a longer and wider practice of data collection.

The ecosystem services considered primarily focus on those provided by habitats, rather than species (with the exception of food provision). It is important to note that, unlike terrestrial environment, many species in the marine environment are not simply linked to one habitat. For example, fish nursery may be linked to one habitat, but adult fish may live in a completely different habitat. Similarly, migratory species (e.g. sharks, turtles and birds) encounter numerous habitats in their life span. Existing habitat mapping is often weak or insufficient for the assessment of ecosystem service provision, for example, lacking information on habitat condition. There is a need to better understand how habitats support species. Furthermore, it is unclear how robust the ecosystem service assessments are, with confidence and/or uncertainty often discussed but not factored into the analysis.

Considering this, there is potential to standardise ecosystem service assessments across spatial areas to support the construction of a consistent evidence base that is transferrable, scalable and repeatable. The ecosystem service frameworks (e.g. CICES, UK NEA) are very similar and are used across a broad range of circumstances leading to similarities in ecosystem service assessments at different scales. The fact that the same frameworks can be applied repeatedly indicates that it is possible to build a comparable dataset of ecosystem services (e.g. de Groot *et al.* 2020). As mentioned in Section 2.3, CICES is currently the most commonly used ecosystem service classification system in most of the world (the US has developed a separate framework). However, CICES has been developed primarily for terrestrial ecosystems and there is potential to explore modifications to the system to make it clearer and better applicable to the marine environment, particularly with respect to the high connectivity of marine ecosystems across large scales. Improving the understanding of CICES amongst practitioners will also help ensure better consistency of applications.

Improving understanding of natural capital assets can inform knowledge of their provision of ecosystem services whilst further standardisation will make the level of understanding more balanced between the variety of practitioners working in the field of marine management. There is a need to clarify and quantify the links between the indicators of asset extent and condition and the resultant effects for ecosystem services and benefits. In many cases, existing knowledge of these links is not robust enough to inform policymaking, and it is common practice to apply the same knowledge (i.e. re-use existing asset-service matrices) across several contexts. Without a common evidence base moving forward, there is a risk of continually reinventing the wheel on ecosystem service valuation. Processes should be established to ensure that lessons are learned, and new findings are appropriately disseminated.

Climate change and other impacts (See Table 6)

A strength of products, that factor in climate change impacts, is their use of risk registers with climate change featuring as a pressure (negative impact) on natural capital assets. Some products discuss common impacts of climate change on the marine and coastal environment, including ocean acidification, sea-level rise, and temperature increase. However, these impacts are generally only considered across broad asset groups (e.g. marine or coastal) with little to no evidence examining effects of climate change or other impacts on specific assets (e.g. seagrass). Climate change risks for marine assets and ecosystem services are not quantified and rarely assessed qualitatively.

Overall, there is little existing evidence to factor climate change into future assessments due to gaps in the evidence base limiting the scope of current assessments. Where products have generated risk registers, there is little information on how the risks can be linked to quantified assessments (such as valuation), making existing analyses difficult to replicate. This is an area for future research. One important opportunity is to combine existing evidence on climate change predictions with climate change impact evidence or modelling and stakeholder engagement. This would help develop a more complete picture of impacts on natural capital assets and ecosystem services and opportunities for adaptation.

Natural Capital Approach (See Table 7)

The recommended natural capital approach should be aligned with the natural capital approach as defined by Capitals Coalition (2019) (see Section 1.1), for example focusing both on the stocks of natural capital assets and flows of benefits (not only the latter) and incorporate changes over time. However, the natural capital approaches applied in the products do not generally account for future changes in natural capital assets, ecosystem service provision and ultimately the benefits they provide. It is also common for the products to focus on the use of one type of data (e.g. environmental) rather than a combination of social, economic, and environmental data within the analysis. There is also minimal stakeholder involvement, which can be partly explained by such involvement not being emphasised in the guidance products reviewed.

As with the other SWOT features, there is scope for addressing these gaps in the natural capital approach. This is supported by the development of standards (e.g. UN *et al.* 2021 and BS 8632:2021 (British Standard Institute's standard on Natural Capital Accounting for Organizations). These standards can help organisations integrate natural capital considerations in a systematic manner and provide guidance on good practice in relation to the methods and approaches applied. If followed, approaches taken in different assessments will become more aligned, facilitating the monitoring and comparison of changes in natural capital assets and ecosystem services. Ultimately, improved comparability across the assessments could support decision-making.

The products reviewed highlight the uncertainty in how the natural capital approach has supported decision-making in practice. While a lack of strong evidence of such practical experience is a risk or threat (in the SWOT context), further testing of the approach for practical application remains an opportunity. The opportunity lies in engaging with decision-makers to assess what evidence is currently used to support marine policies and management and what gaps can be filled by applying a natural capital approach.

Table 4: Overall SWOT results for Natural Capital Assets.

SWOT	Key findings
Strengths	• With regards to the extent of natural capital assets, products often use national or EU data, including standardised data sets (e.g. EMODnet habitat map/EUSeaMap), with addition of local data when available. • Indicators provided and/or suggested for asset condition allow to use the currently available data. • Methods for measuring asset extent and condition are, on the whole, robust and scalable. • Guidance documents tend to support widely used methods/asset classification and indicator frameworks.
Weaknesses	• Habitat data used are often modelled or low resolution. • Data are not always of sufficient quality to inform local assessment. • Condition assessments are often lacking, or very high level (often drawing on existing assessments undertaken using expert judgement or relatively limited data). • Assessments are often high level and frequently do not include supporting Natural Capital Accounts or similar approaches that make comparability of findings easier. • Guidance documents often do not provide detailed methods for determining asset extent and assessing condition. • Assessments often omit abiotic assets and other capital inputs.
Opportunities	• Further research could fill gaps in methods for quantifying extent and condition of natural capital assets. • There is a good range of approaches to inform future developments and move towards widely accepted standardised approaches (be it national or international) that can be adapted to different contexts. • Frameworks and associated guidance can be developed to consider abiotic assets and other capital inputs.
Threats	• Better evidence on habitat extents and condition could be difficult to obtain due to high cost of collection / acquisition. • Lack of risk and trend information in many products makes them less attractive for management related decision making. • Theoretical frameworks often lack clarity and depth in the classification of non-habitat assets (e.g. species) or for abiotic assets. • There is a lack of standardised framework for abiotic assets and unclear whether or how frameworks should include other capital inputs.

Table 5: Overall SWOT results for Ecosystem Services.

SWOT	Key findings
Strengths	• Methodologies mostly scalable, repeatable and transferable. • Frameworks developed could provide a route to standardisation. • Good coverage of a wide selection of ecosystem service at a high level. • Often high degree of granularity as linked to the specific asset types. • Clear proposal of CICES as appropriate ecosystem service framework in most recent products. • Ecosystem services play a core role in many framework developments, rather than as an add on. • Asset-service matrix approach used, developed, and to some degree validated, for some ecosystem services. • Wide range of data sources and methods for commonly assessed ecosystem services: food, climate regulation, tourism/recreation and hazard regulation. • In some examples data and indicators are used to quantify benefits at all stages of the valuation process, so they do not rely on habitat/species data alone (i.e. changes in ecosystem services and associated welfare effects can be measured). • Indicators generally drawn from a broad body of previous work, and include ecosystem service provision, economic value and a range of wellbeing attributes.
Weaknesses	• Literature focuses on ecosystem services that have already been assessed and valued repeatedly such as food, climate regulation, tourism/recreation and hazard regulation. • Lack of specific guidance/examples for individual marine ecosystem services. • Gaps in valuation evidence (especially regulatory services, services provided by subtidal assets). • Methodologies are often data intensive, which can work well for a data-rich area, such as the North Devon Marine Pioneer, but may be more problematic in data-poor areas, reducing potential for transferability. • Often lack of standardisation of ecosystem service assessment methods. • Often lack of robustness in methods. • Emphasis often on asset assessment with reduced consideration of ecosystem service provision and over-reliance on previously developed generalised matrices. • Lack of clarity concerning how to measure/define some services when using the CICES classification. • Less robust economic valuations because monetary values often transferred between studies without appropriate consideration of value transfer processes. • Minimal stakeholder involvement. • Confidence assessment often quite minimal, uncertainty is often discussed but not actively included in the analysis.

SWOT	Key findings
	• Trends over time and human impacts (e.g. climate change, aggregate extraction, fishing, pollution) are often not included, with many assessments providing a snapshot of the current state. • Often little detail of current level of ecosystem service provision and only qualitative assessment of human impacts on ecosystem service. • Many overall approaches mostly driven by natural scientists. • Mostly focus on ecosystem service provided by habitats, rather than species. • Habitat classification/mapping often weak/insufficient for assessment of services.
Opportunities	• Some highly valuable, detailed, transferable, scalable and repeatable frameworks are available for application, with potential to standardise ecosystem service assessment across areas, and thus build up a consistent evidence base. • Some methodologies which were designed with research users and set within a policy context provide a good opportunity for impact assessment. • Ensure that the most up to date data are used. • Potential to learn from approaches to asset assessment and apply to ecosystem services to build up a better body of evidence about ecosystem service provision. • Explore modifications to CICES for marine/coastal systems, in particular recognising the high degree of connectivity across large scales, and the role of marine ecosystems in supporting service provision in other marine and terrestrial ecosystems. • Improve habitat classifications (e.g. use appropriate EUNIS levels) and better link asset/quality indicators to services and values. • Values matrix can be developed to compare all qualitative, quantitative, and economic values with guidance on when, where and how it can be used. • Further research and meta-analysis studies could fill valuation gaps. • Use stakeholder mapping and engagement to enhance buy-in and improve understanding of ecosystem service and associated benefits.
Threats	• Very high cost of assessing some services at fine scales. • Piecemeal and siloed approach across sectors. • Link between asset and ecosystem service may not be robust or site specific enough for policy confidence. • Focus generally on same ecosystem services: food provision, climate regulation, hazard regulation and recreation/tourism. This leaves many of the "trickier" but equally important and valuable ecosystem services out of consideration. • Lack of quantification may lead to issues for incorporation in policy/management.

SWOT	Key findings
	• High risk that data and resources will not be available to populate indicators/frameworks. • There are numerous gaps in the lists of indicators, potentially leaving resulting gaps in any ecosystem service assessment. • Re-use of existing asset-service matrices (e.g. Potts 2020) which are very dependent on expert knowledge, without understanding the potential variability and high levels of uncertainty, poses risks to decision making. • Risk of repeatedly reinventing the wheel, minimal learning mechanisms in place. • Poor economic valuation (and application of valuation) leading to poor decisions. • Poor innovation regarding linking ecosystem services to assets. • Site specificity of values means using standardised quantifications that do not take account of local context could lead to mistaken assessments – emphasising the need for good guidance on using a potential values matrix. • Mixture of qualitative, quantitative, and economic values within and between products can make comparison difficult • Tools are frequently not kept up to date. • Lack of stakeholder involvement in the design and application of the products could hinder their understanding of natural capital and ecosystem services and thus, acceptability of outputs.

Table 6: Overall SWOT results on Climate Change and Other Impacts.

SWOT	Key findings
Strengths	• Common impacts considered include ocean acidification, sea-level rise and temperature increase. • Generally, climate change is included, and negative impacts on assets is acknowledged. • Climate change as a pressure is factored in risk registers where possible.
Weaknesses	• Overall, climate change risks are identified but not quantified, and rarely qualitatively assessed (e.g. what ocean acidification means for fish populations). • Gaps in existing evidence limit the scope of the assessments. • Assessments are technically challenging and complex; modelling approaches may be expensive to apply. • Impacts on assets are generally considered across broad groups of assets (e.g. marine or coastal ecosystems) rather than specific assets (e.g. seagrass). • Little to no mention of impacts on ecosystem service provision.
Opportunities	• Areas of further research have been identified (e.g. future effects of climate change, difference between male and female species responses to climate change). • Assessments use a mixture of existing evidence, which is scalable and transferrable, and based on repeatable methods. • In some instances, stakeholder engagement has been used to identify risks facilitating the incorporation of local knowledge.
Threats	• Overall, if the existing issue of insufficient data persists in the future, factoring climate change into natural capital accounts will remain a significant challenge. • Lack of better guidance on how to link risk register information to quantified assessments (e.g. ecosystem service valuation) can prevent the successful inclusion of climate change impacts. • Scalability and transferability are dependent on data availability.

Table 7: Overall SWOT results on Natural Capital Approach.

SWOT	Key findings
Strengths	• Assessments make use of well-defined and replicable classification systems for both natural capital assets and ecosystem services. • Natural capital assets and the flow of (some) services and benefits they provide are often clearly identified. • Assessments often consider both biotic and abiotic natural capital assets. • Assessments acknowledge both the stocks of natural capital assets and flows of benefits.
Weaknesses	• Links between different frameworks used are often static. They do not generally account for future changes in natural capital assets and their benefits. • The potential impacts of management measures and interventions on asset condition are often not identified. • Many products lack robust social, economic, and environmental data. There is a tendency to focus on one type of data. • Often minimal stakeholder involvement or the need for stakeholder involvement is not emphasised in guidance documents.
Opportunities	• Develop targeted workstreams to address the gaps in the future. • Opportunity to improve asset mapping and condition assessments. • Application of a standardised approach can make the outcomes more comparable. • With new standards emerging in the natural capital area (e.g. UN *et al.* 2021) the natural capital approach might be more easily standardised. • Future research can be targeted towards filling in the gap regarding future profiling. • From a policy standpoint, it would be useful to understand which products have actually been used to support marine policies.
Threats	• Risk that additional effort to prepare meaningful natural capital accounts may be disproportionate to the benefits (i.e. extra effort may not demonstrably change understanding of problem or provide confidence in a preferred solution). • Risk that focusing on exchange values for natural capital accounting could displace research on welfare values needed for appraisal, and/or lead to confusion between the different value concepts leading to less robust analyses and poorer decisions. • Lack of future profiling (if not incorporated) might affect the robustness of methodologies and data used. • Lack of clear standards for quantifying economic values/transfers applied as part of the natural capital approach might mislead policy and management decisions). • Application of products in real decision-making contexts largely unknown. There is uncertainty over how products have been used in supporting marine policy.

2.4.2 Recommendations for UK marine natural capital assessments

The recommendations for a 'good practice' or common approach for UK marine natural assessments have been formulated based on the SWOT analyses. The recommendations identify current good practice (relating to strengths identified in the SWOT analyses) as well as suggested improvements (relating to delivering the opportunities and addressing the weaknesses and threats). As stated in Section 2.2.2, 'good practice' has been defined in terms of:

- Alignment to the Capitals Coalitions (2019) natural capital approach and its applicability to supporting marine management; and
- Expert judgment from the project team on the practicability of applying different methods within marine and coastal environments.

Where possible, links to existing guidance, standards and frameworks have been made. As indicated in the overall SWOT results, there are emerging standards within the natural capital area (e.g. UN *et al.* (2021) and BS 8632) which may make it easier to define and apply a 'common approach' to the marine environment. This would make the application of a good practice natural capital approach and its outcomes more comparable. Divergences from the good practice may not be possible to avoid but should be acknowledged and caveated in project outcomes and subsequent decision making. The implementation of good practice would also align with the Natural Capital Committee's (2019a) recommendation to employ marine natural capital assessments and accounting "to achieve updated understanding and evidence of assets, services and benefits from the sea, coastal waters and estuaries" (p.15) to facilitate monitoring of enhancements in the marine environment that are related to the 25 Year Environment Plan (Defra 2021).

The recommendations for future UK marine natural capital assessments are outlined below under the four main headings: purpose, scoping and engagement, classifications and frameworks, and data and methods.

Identify purpose

- State the purpose of applying a natural capital approach for assessing the marine environment
- Consider how the natural capital approach will be taken into account alongside other approaches and within stakeholder engagement
- Consider the scale of decisions that the natural capital approach is intended to support

The SWOT analyses show that why or how the existing evidence supports decision making is unclear. Explicit statement and agreement of the purpose is key to understanding whether the evidence is sufficient and that the means (of analysis) meets the end (of decision support). This is also stated in BS 8632 which highlights the need to identify the purpose of a natural capital account and makes a distinction between the scope of analysis and type of evidence needed for supporting different types of decisions (e.g. strategic understanding and prioritisation vs setting targets). This also helps identify the stakeholders that should be involved in the analysis and decisions (e.g. beneficiaries, data providers, etc.).

Scope and engage with stakeholders

- Undertake stakeholder mapping to identify key stakeholders for engagement.
- Engage with local stakeholders to develop better understanding of natural capital assets, but also impacts and dependencies of economic activities of concern. This should also include identification of options and solutions, where necessary (e.g. if undertaking scenario analysis).

- Undertake scoping exercises to determine the assessment boundary, baseline year and timescales.
- Acknowledging that it will not be possible to assess all assets, services and benefits in each application, produce a materiality assessment to define the scope (see below).
- Identify beneficiaries of ecosystem services, including how benefits are distributed across different groups in society (e.g. socio-economic, ethnic) as well as inter-generational differences.
- Investigate distributional impacts of management options.
- Clearly state which of the material assets, services, benefits and beneficiaries are included and which are not, justify the reasons for exclusions and identify their implications for the results.

Overall, stakeholder engagement should continue throughout the natural capital assessment process, as recommended in the Natural Capital Evidence Handbook (Natural England 2021). Stakeholder engagement should not be limited to identifying potential beneficiaries but should also consider stakeholders who need to understand impacts and dependencies and, also those that can provide data. Therefore, regulatory stakeholders as well as local users should all be included in the assessment cycle.

Defining the marine and/or coastal assessment boundary can be inherently difficult, as there is often an issue with 'leaky' boundaries, especially in marine contexts where everything is connected over very large scales, and where links to/from terrestrial processes can be important. In scoping the assessments, existing standards and guidance can be useful. For example, the BS 8632 distinguishes between Scope 1 and Scope 2 accounting boundaries: Scope 1 includes assets and impacts under direct ownership or management of an organisation, and Scope 2 includes others' assets on which the organisation depends and impacts throughout the value chain of the organisation that can be attributed to it. These scope definitions can help determine the assessment boundary and can potentially factor in the link between terrestrial and marine environments.

Materiality assessment, as defined in Appendix 2, aims to identify what is potentially material in relation to a decision. Materiality here is not the same as importance but rather something is material when its exclusion would have a significant impact on the decision made. A materiality assessment shows which ecosystem services (and benefits) are likely to be provided by the natural capital assets within the scope. Furthermore, it highlights which asset-service relationships are included in the account and which are not. This can be determined in multiple ways, including an asset-service matrix (e.g. eftec & ABPmer, forthcoming). It should also reflect the evidence used to inform the assessment (e.g. expert judgment, review of relevant documents).

In relation to temporal scope, an initial starting point should be referring to The Green Book (HM Treasury 2020), which suggests economic appraisals should consider a 60-year appraisal period. However, both shorter and longer timescales can be used (e.g. if undertaking an assessment in relation to a specific policy).

Apply classifications and frameworks

- Use well-defined and replicable classification systems for both natural capital assets and ecosystem services.
- Include both the stocks of natural capital assets and flows of benefits in the analysis.
- Include both biotic and abiotic natural capital assets and ecosystem services. This does mean going beyond some classification systems that explicitly exclude abiotic assets and services.

- Clearly identify links between natural capital assets and ecosystem service provision – this should also factor in asset condition into ecosystem service provision where possible.
- Account for changes in natural capital assets and their benefits, including management impacts on extent/condition and changes to provision due to external pressures such as climate change.

The SWOT and review findings support the use of EUNIS as a common habitat classification system for natural capital assets. For ecosystem services, CICES and the UK NEA follow-on classifications are the most commonly used. EUNIS and CICES are also recommended by the recent Cefas report for Defra on classification systems to be used across the mNCEA programme (Mullholland *et al.* 2021) and the Natural Capital Committee (2019a). Some classification systems exclude abiotic assets and services, but their inclusion will be helpful especially when choices involved different uses of the marine environment (e.g. offshore wind and aggregates). In practice, the frameworks may need to be modified for application to the marine environment. Nevertheless, consistent application does support the creation of a consistent and comparable evidence base.

The use of logic chains to identify links between natural capital asset and ecosystem service provision has been documented in the UK marine evidence base (e.g. Lusardi *et al.* 2018). Ideally, research should identify logic chains leading through from asset extent and condition, as well as location and spatial configuration, to ecosystem service and value to beneficiaries. This is important even where the links can only be identified qualitatively. A qualitative chain identifies where influence can be exerted and where impacts might be felt and acts as a framework for identifying evidence gaps and prioritising data collection and modelling.

Accounting for trends over time is an important factor in the natural capital approach. Currently, the evidence base provides a snapshot of the state of natural capital assets and ecosystem service provision. It would be useful to develop more analysis that considers not only changes in natural capital assets but also ecosystem service delivery over time, both historically and into the future. This includes human activities (e.g. aggregate extraction, fishing, pollution) and climate change impacts, which could inform the development of management and adaptation schemes for the marine environment.

Utilise data and methods

- Integrate GIS data and consider spatial resolution when putting together natural capital asset extent, condition, location and spatial configuration and taking account of where assets, benefits and beneficiaries are, noting that all can be in different locations.
- Use a range of data types (e.g. combination of social, economic, and environmental data) that are robust or at least assess the quality of data.
- Incorporate qualitative and/or quantitative methods to assess natural capital assets and ecosystem services (including monetary approaches where relevant and possible).
- Make use of different values (e.g. exchange and/or welfare values) and valuation frameworks.
- Clearly explain gaps, caveats, and uncertainties in all stages of the accounting process together with implications for the results.
- Use sensitivity analysis or scenarios to consider the relevance of uncertainties.

The approaches to assessing natural capital assets and ecosystem services are complementary. In particular, it is recommended to use a mixture of qualitative and quantitative methods. Different stakeholders will have different interests and ways of understanding the assets and services, so different types of values and valuation

frameworks should be considered to ensure that outputs are developed and communicated in the most meaningful way for all participants.

In the application of the natural capital approach, clarity on the scope, data, evidence and interpretation of the results for decision making is key. This is a part of the materiality assessment (i.e. what is being looked at, what has been included, what has not and why). Therefore, gaps, caveats and uncertainties should be appropriately reflected throughout the natural capital assessment process (i.e. not just in relation to valuation). BS 8632 lists requirements for documentation to help comparability of natural capital accounts. Similar guidance and requirements could be used for other approaches too.

Note that guidance on monetary valuation, appraisal and value transfer is available from many sources. For the UK, The Green Book (HM Treasury 2020) and associated supplementary guidance is the primary source for public sector uses. Other relevant guidance includes the SEEA EA (UN 2021) for ecosystem accounting. The ONS marine natural capital account (2021a) is aligned with SEEA EA guidance. There is existing valuation evidence within a host of valuation databases (e.g. Environmental Valuation Reference Inventory (EVRI) and Ecosystem Service Valuation Database (ESVD)) which can be used following the UK Government's value transfer guidelines (Defra 2010). The databases and value transfer guidelines provide an assessment structure that standardises the data types and/or units use. This enables compatibility and comparability across natural capital assessments. The development of these databases also ensures that information can be easily shared and made available to both practitioners and decision-makers.

2.4.3 Recommendations for future research

In light of the gaps identified through the SWOT analyses and on the expert opinions of the project team, a list of 12 recommendations for future research has been developed. They have been grouped into four themes:

A. Big picture/over-arching process
B. Improvements to current practice
C. Incorporating the future/temporal elements
D. Understanding the use and usefulness of evidence

A. Big picture/over-arching process

1. **Standardisation should be applied flexibly to strike a balance between general guidance on high-level assessments and the complex modelling required by more refined or high resolution (spatial) assessments.** The effort to standardise should be in line with the level of detail and effort of analysis. For example, it could be efficient to use a high-level standardised guidance and evidence if a simple introductory or outline assessment is produced. On the other hand, an assessment supporting a bigger decision would require bespoke application of principles to the location and context specific data. Better guidance for what level of standardisation and bespoke application is appropriate in different contexts should be developed.

2. **Guidance and data used should be updated frequently to keep up the pace with the rapidly evolving area of environmental science and economics**. Many products are missing up-to-date information and rely on older datasets and reports. Conducting more meta-analysis studies, providing better signposting to existing data and establishing a dedicated and regularly updated marine valuation hub for easy access to evidence are all possible solutions. As well as evidence, analytical

frameworks should also be reviewed regularly to ensure that the approaches they propose remain applicable over time.

B. Improvements to current practice

3. **Aim to better understand and develop the links between different types of data** E.g. biophysical modelling and economic valuation and ensure each is applied with a degree of rigour within natural capital approach and interpreted together to generate robust and comprehensive overall findings.

4. **Strengthen the evidence on how a change in habitat condition affects the provision of related ecosystem services.** Linking natural capital asset condition (especially from anthropogenic stressors) to ecosystem service flows is often missing from the current evidence base. There is scope to undertake research to understand this relationship for certain assets. Some of the key gaps regularly encountered are the extent to which trawling (abrasion) pressure affects condition of soft sediment habitats and how this affects key services relating to food production and carbon sequestration. Another example is how the condition of saltmarsh affects erosion protection and flood protection functions. Other areas worth exploring might be how condition affects non-use values.

5. **Establish a clearer and more robust scientific link between assets and provision of ecosystem services**. Recognising that some of the relationships can be very complex, there is a need to better assess the full cycle from the impact of habitat condition on ecosystem services provision, its effects on benefits and ultimately, impacts of human activity on habitat condition.

6. **Future research should focus on filling in identified gaps and aim to quantify the more challenging services.** Some ecosystem services such as those related to cultural services (other than tourism/recreation) and regulating services (climate regulation and waste assimilation, storm/flood regulation), are not assessed in most products reviewed, which is a shortcoming overall.

7. **Improve the quality of economic valuation evidence (and its application) to support decision making**. There is a need for more bespoke primary valuation studies which could provide values specifically applicable to the marine context (and that can be used as robust transfer values) and help develop more methods which will inform valuation of ecosystem services. Valuation might benefit from (1) further standardisation of values used to allow comparisons between projects (2) use of interdisciplinary approaches allowing more involvement from social scientists alongside natural scientists.

8. **Include explicit consideration of the beneficiaries of ecosystem services and facilitate stakeholder participation and engagement.** This will help clarify distributional effects as well as aggregate impact for policy and project appraisal (i.e. in line with HM Treasury (2020) Green Book guidance).

C. Incorporate the future/temporal elements

9. **Improved quantification of known changes in natural capital assets and flows of ecosystem services is required to reduce uncertainty.** For example, carbon values are relatively well defined in the UK (e.g. BEIS 2021), however, it is difficult to produce estimates for the underlying physical flow/service data (e.g. how much carbon is removed and for how long). Similarly, projected changes in natural capital assets condition and extent are not captured in natural capital asset registers and

accounts overall. Research is needed to review existing methods for quantifying changes in natural capital assets and ecosystem service physical flows and to provide guidance on the use of different methods and their strengths and/or weaknesses.

10. **Greater efforts are needed on profiling benefit provision into the future to understand the total asset value of different ecosystems (not just annual revenue from selected flows of benefits)**. The issue here is taking account of possible changes in asset extent and condition, and also changes in demands and values, rather than making the implicit assumption that current flows are both sustainable and constant. This will allow for better understanding of the implications of different policy and management regimes and should consider scenarios incorporating future uncertainty, such as posed by climate change.

D. Understanding the use and usefulness of evidence

11. **Identify which products (as the term is used in this report) have been used in supporting marine policy and management decisions.** The overall SWOT results highlight that it is unknown how the reviewed products, and similar evidence more broadly, have been used to support decision-making. Understanding what kind of decisions have been supported and how (both the process and the outcome), and where the evidence is not used, why not, will help define good practice and prioritise data needs.

These 11 recommendations form the basis for the identification of the priority research question, discussed in 3.1.1.

During the final report synthesis process, a further recommendation was identified:

12. **Understand how products could be used in combination to provide an approach that meets all five review criteria**. In particular, products that have been co-developed

3 Quick scoping review (QSR)

This section summarises the quick scoping review (QSR) for **'What evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups?'** which was selected as the priority question based on the SWOT analyses.

3.1 Approach

This section describes the approach to selecting the priority question for the QSR, defining the QSR protocol and its implementation. The QSR undertaken as part of this work follows the Defra and Natural Environment Research Council (NERC) guidance (Collins *et al.* 2015) which defines a QSR as "an informed conclusion on the volume and characteristics of an evidence base and a synthesis of what that evidence indicates in relation to a question" (p. xi).

Defining the scope of the QSR was based on the SWOT analyses, specifically the 11 recommendations for future research set out in Section 2.4.3. The priority question for the QSR was agreed with the project steering group, as described in Section 3.1.1.

The following steps were taken for collecting and collating available literature to establish a QSR evidence base:

1. Develop a review protocol
2. Search for evidence and produce a database
3. Extract relevant evidence

The QSR protocol and its implementations are discussed further in Section 3.1.2. The resulting evidence is then synthesised to identify common themes and trends, as well as gaps to answer the priority question.

3.1.1 Selection of priority question for the QSR

A workshop with the project team and the steering group took place in September 2021, after the completion of the SWOT analyses and the identification of areas for future research in order to identify the priority question for QSR.

The attendees were divided into groups to discuss the 11 recommendations, with the aim of identifying their priority research area and an accompanying question. There are a few key areas that were consistently identified as particularly noteworthy by the steering group:

- Recommendation 1: Standardisation should be applied flexibly to strike a balance between general guidance on high-level assessments and the complex modelling required by more refined or high resolution (spatial) assessments.
- Recommendation 9: Improved quantification of known changes in natural capital assets and flows of ecosystem services is required to reduce uncertainty and improve robustness.
- Recommendation 11: Identify which products (as the term is used in this report) have been used in supporting marine policy and management decisions.

The discussions focused on the less technical aspects of a marine natural approach, particularly on how the natural capital approach can be made more accessible to relevant stakeholders and decision-makers, which linked back to Recommendation 8. Unless the natural capital approach is understood by non-practitioners, further refinement of technical

aspects will have limited impact in real decision processes. Nevertheless, it was concluded that conducting a QSR related to Recommendation 11 was beyond the scope of this project. This is due to there being limited evidence on how products have influenced marine management and policy making, thus limiting the scope for developing useful case studies and/or identifying useful approaches for decision-makers.

Recommendations 1 and 9 were also discussed across the groups, which led to the development of two potential priority research questions:

1. What evidence exists to understand the impacts and dependencies between ecosystem services and the benefits they deliver to the different beneficiary groups?
2. What does best practise look like for evidence for asset-service matrices, including linking flows of services to condition of assets?

The first question on beneficiaries was chosen to be the priority research question for the QSR. This question was seen as relevant to Recommendation 8 but also to Recommendation 11, as evidence on the distribution of benefits across different groups could be a key step in engaging decision makers with the natural capital approach and could underpin a range of decision-making processes in areas such as marine management, blue financing, and cost-benefit analysesThe second question was not taken forward given the greater risk of the QSR duplicating effort that went into the existing body of evidence.

The chosen priority question was further refined to ensure that the question can feasibly be answered by the project team within the project timeframe. Thus, the final priority question is: **'What evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups?**'

3.1.2 QSR protocol and its implementation

To address the priority research question defined in Section 3.1.1 through the QSR, a review protocol was developed in line with the Defra and NERC guidance on rapid evidence assessments (Collins *et al.* 2015). The QSR protocol, in addition to establishing the background, scope, and objective of the QSR, details the two-stage screening process by which literature in the QSR evidence base is collated and analysed. This ensured that relevant literature was collected and collated consistently across multiple reviewers, and that the approach used was transparent and replicable. The full QSR protocol can be found in Appendix 5.

The implementation of the review protocol ultimately fed into the development of the 'QSR evidence base' which includes relevant literature which reports sufficient information that can be used to answer the priority research question. This includes the identification of common themes and trends across the literature.

The first phase screening, entailed the implementation of the evidence search strategy as defined in the QSR protocol. In this stage, all possible combinations of pre-defined keywords and phrases (see Appendix 5) were entered into identified databases and search engines. When a combination of keywords was entered, the first page of results from a database was logged into the QSR evidence base. The following high-level summary information was recorded for each document:

- Author(s)
- Category/Type of study (e.g. natural capital account, literature review)
- Source type (e.g. database, government reports, journal articles)
- Corporate author/Commissioning body

- Date of publication
- Document title
- Weblink
- Document availability (e.g. full document or abstract only)
- Keywords/Phrases Used
- Search Engine/Database Used (e.g. Google Scholar, specified database)

A limit of 200 unique documents was selected due to the resource-constraints of the reviewers. Search engines (e.g. Google and Google Scholar) were first searched, followed by the ESVD, NORA and EVRI, until the document threshold was met. The 200-document threshold includes the 35 products reviewed as part of the SWOT analyses described in Section 2.

The second phase screening entailed a more in-depth review of those documents collected during the first stage, to determine which are relevant to answering the priority research question. The information that reviewers extracted, where possible, included:

- **Relevant:** Indicated with a “yes” or “no” based on inclusion and exclusion criteria in Appendix 5.
- **Distribution of benefits considered:** Indicated as a “yes” or “no” to reflect whether a study explicitly considers beneficiaries.
- **Beneficiaries identified:** Names of the groups identified as beneficiaries.
- **Beneficiaries’ methodology:** Describes how ecosystem services are linked to the beneficiaries and how the distribution of beneficiaries is considered.
- **Type of evidence:** Describes the methods used in a specific document.
- **Confidence rating:** Where possible, provides a confidence rating to the methodologies and measurements used by the document author.
- **Asset location**: Lists the spatial location of the assets considered in the document.
- **Asset type:** Specifies the types of habitats and/or species considered.
- **Broad ecosystem service type:** Provides the categories of ecosystem services these assets produce (cultural, regulating, and provisioning services).
- **Ecosystem services/benefits considered:** Lists which ecosystem services are considered within each of the broad ecosystem service types.

To ensure the 200 documents collected were relevant, some restrictions were placed on publication timing and document types. These restrictions are defined in the ‘Evidence Search Strategy’ in Appendix 5. Within these restrictions, any evidence which was deemed to be relevant to answering the priority research question could be included in this analysis. Only those documents which identified beneficiaries (i.e. deemed relevant) and explicitly considered the distribution of beneficiaries were used in developing an answer to the priority research question.

Valuation databases reviewed as part of the SWOT analyses were included in the QSR evidence base. For literature collected from the ESVD (de Groot et al. 2020), a pre-downloaded segment of the database (which had results filtered by whether they included the word ‘marine’) was used. Relevant documents were searched for using only the key search terms for beneficiary type in the QSR protocol (see Appendix 5: Quick scoping review protocol). This database was shared with JNCC. The EVRI database was also searched, however only one additional study was identified as relevant, with others already having been included in the QSR evidence base.

Of the 200 documents collected (including 35 from the SWOT), eight were removed due to duplication. An additional four documents were identified as relevant by the expert reviewers. Therefore, a total of 196 documents were included in the QSR evidence base.

3.2 QSR results

This section presents the evidence base and key findings related to the priority research question: **'What evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups?**'

3.2.1 State of the evidence base

Implementation of the QSR protocol, along with additional studies identified by the project team, resulted in 196 documents being included in the QSR evidence base. The evidence base is stored in an Excel™ workbook (see Appendix 6) that has been shared with the JNCC team. The majority of this evidence base was constructed through Google Scholar searches (approximately 46%) and as such, most are journal articles (60%) and government reports (21%). The reviewers were able to access most documents in full, with just under 30% accessible as abstract only. The QSR protocol defined the search time period as between 2017 to 2021. Documents published before this period and included in the QSR were either SWOT products or recommended by the reviewers for consideration.

Table 8 provides an overview of the number of documents that were deemed relevant, and the number that explicitly considered the distribution of benefits. After the first phase screening, a total of 75 out of 196 documents (39%) were deemed relevant to answer the priority research question. Of these relevant documents, 39 (20% of total and 52% of relevant documents) explicitly mention the distribution of beneficiaries. However, some studies may simply identify who the beneficiaries are, and some do this implicitly (e.g. through monetary units).

Table 8: Number of relevant documents identified in the QSR.

	Relevant	If relevant, considers distribution of benefits
Yes	75	39
No	121	36
Total	196	75

3.2.2 Key findings

Definitions of beneficiaries

There is a lack of clear and widely used definition of 'beneficiary'. The literature reviewed gives the impression that the word 'beneficiary' has been interpreted differently by different researchers. The variety of (explicit or implicit) definitions of beneficiary used in the literature could make comparison of evidence difficult. In particular, it seems that the difference between a stakeholder and a beneficiary is not always clear. Future work would benefit from beginning with clear definitions. Across the evidence reviewed, stakeholders seem to be local to the ecosystem service(s) and/or natural capital asset(s) with direct physical links, for example those whose decisions affect the marine environment or those who work in the marine environment. Beneficiaries are likely to include these but also those who may be further removed from the marine environment, for example, consumers of seafood or beneficiaries of carbon sequestration.

ENCA guidance (Defra 2020) provides a useful definition: "Beneficiaries may be households (as consumers, visitors or passive recipients), businesses (for example, where there are cost savings) or government or taxpayers (local or national)". The guidance also identifies key considerations for a natural capital approach, including the need to identify who and how

many may be affected. This should be done as part of evaluating welfare impacts prior to any valuation approaches being applied. It is interesting to note here that (according to the ENCA guidance) the focus should not just be on what to do, but also on why that can be useful (e.g. for new sources of investment and funding or making marine policy decisions).

Studies that consider beneficiaries tend to be focused on one, or a small number of benefits and/or beneficiaries, such as reviewing cultural services in one specific location. Beneficiary divisions are either very local (e.g. male vs female fishers in a village) or very broad (e.g. wider society, or 'local, regional, national and international beneficiaries').

Economic sectors are sometimes considered as beneficiaries, rather than individual groups like businesses, workers, households. The most common beneficiary sectors covered in the studies reviewed are fisheries (i.e. landings and fishers, rather than consumers) and tourism/recreation (i.e. visits and/or visitors). Some mapping work could easily link these sectors to wider beneficiary groups.

The discussion tends to be in terms of types of use / benefit, so it is not focused on the net effects for individuals, but rather on the ways particular groups explicitly benefit. Many people, especially residents/workers, will fall into several boxes (e.g. homeowner, dog walker, swimmer, employee in resource-dependent industry, non-use values) and in some cases how they are impacted by a change in the marine environment and its management could be conflicting. In other words, when something changes, they might win via one category and lose via another (e.g. as consumers their water bills may go up, but as swimmers they may benefit from cleaner bathing waters).

The reports on environmental/ecosystem accounting (ONS 2021a, 2021b) do not, at present, have much detail on specific beneficiaries. This is discussed as something they want to achieve in the future (partly with the intention of improving understanding of distribution). Therefore, it will be useful to report on the usefulness of having beneficiary information to ONS who is currently consulting on their future natural capital accounting roadmap.

Links between natural capital assets or ecosystem services and beneficiaries

There is some mapping of individual natural capital assets and ecosystem services onto individual groups of beneficiaries in the QSR literature. Following from the above finding that most studies focus on one or small number of benefits, mapping of beneficiaries also tends to be limited. For example, fisheries benefit not only the fishers but also the fish processors, consumers, and tourists who like looking at fishing boats. There are rare exceptions. For example, Langle-Flores and Quijas (2020) have made use of a Sankey Diagram which could potentially address this issue of multiple linkages. Despite their diagram mapping out only indirect beneficiaries of ecosystem services (i.e. users of ES valuation data rather than those who accrue benefits), it can provide a useful example of how multiple natural capital assets (and ecosystem services) can be mapped onto multiple beneficiaries. Further improvements in the approach should be considered, such as using arrow widths proportional to the total flows of value provided or presenting the value of other inputs (e.g. labour or physical capital) to understand and compare the scale of ES impact across beneficiaries. There are some trade-off analyses between ecosystem services, but these offer limited analysis of trade-offs between beneficiaries. In some cases, humans are also included as a pressure rather than a beneficiary group.

Methodology for assessing beneficiaries

There is minimal use of a standardised structure or methodology for defining beneficiaries. ENCA (Defra 2020) provides some valuable guidance, as do Frederiksen *et al.* (2021), Small

et al. (2017) and Harris *et al*. (2019a), but these have not been widely applied yet. Where beneficiaries are assessed, disparate methodologies are applied, with participatory approaches often being used for local beneficiaries and valuation being used for regional/national assessments. The methodological approach seems to be very much in its infancy, with much of the relevant evidence having been published recently.

Furthermore, ENCA (Defra 2020) observes that values for many ecosystem services (specifically, regulating and cultural services) will vary by location. This is due to the identification of beneficiary populations and their proximity to the benefits, as well as spatial variation in the extent, condition and spatial configuration of assets providing the flow of ecosystem services. However, while many studies mention stakeholder and/or beneficiary groups, the local variation in the distribution of benefits is not covered in any great detail, or not routinely across the literature. Drakou *et al.* (2017) review several case studies and report that local case studies focused on coastal issues using participatory approaches, economic valuation tools and multi-criteria assessments, while larger scale studies also considered the open ocean and were more likely to use geospatial mapping and environmental modelling tools.

Approaches used to identify beneficiaries

One way to identify beneficiaries would be to unpick the economic valuation evidence. If there is sufficient information provided on the link between values and beneficiaries, some studies could be re-analysed to quantify the benefits to different groups. For example, in the ESVD (de Groot *et al.* 2020) each valuation includes:

- The beneficiary unit for which the value observation is reported (e.g. visitor, person, household, or total number of beneficiaries).
- The number of beneficiaries that benefit from the ecosystem service (e.g. number of visitors, population, or number of households) over which a value estimate is extrapolated to obtain a total value of the service. Note this is not the same as the sample size or number of beneficiaries surveyed.
- Text description of the type of beneficiary of the service (e.g. visitors, residents, non-users, tourists, etc.).

Identifying beneficiaries based on valuation units provides a starting point; however, this evidence does need to be built-on. Note that this does take a human-centric view of value (even if non-use values and values of non-users are acknowledged) and subsequently the definition of a beneficiary. Furthermore, recent studies mention the need to consider cultural services and ‘non-material’ benefits, and therefore advocate valuation approaches other than monetary. Where this is the case, there is also a greater focus on social concern, making the consideration of beneficiaries and the distribution of benefits more inherent. There appears to be a modest signal from across the evidence that this is an evolving process, becoming more aware of human influences on services and less focused on habitats alone.

Several studies within the QSR evidence base have identified and mapped stakeholders through participatory mapping. This approach used in Burdon *et al.* (2019), Burdon and Potts (2020), Friedrich *et al.* (2020) and Blythe *et al*. (2020) is particularly interesting as a way forward, to supplement the economic valuation previously discussed. Suffolk Pioneer (Burdon & Potts 2020) is an example of a good approach to systematically identifying beneficiaries or associating specific benefits provided by ecosystem service to beneficiaries. Burdon and Potts (2020) made use of logic chains and participatory mapping to map benefits to beneficiaries. However, it is not clear how the logic chains were established and further insight on this would be interesting to understand the transferability of the methods used.

Ultimately, the approach used to identify beneficiaries will depend on the policy goal achieved. The approach taken by Burdon and Potts (2020) works well at a local scale (e.g. Deben Estuary), but may be less suitable at the national scale. Therefore, participatory mapping should be considered alongside more traditional stakeholder analysis, distributional analysis, and Green Book appraisal methods (HM Treasury 2020). A range of methods may be necessary to identify and assess beneficiaries for some benefits (e.g. food for human consumption), where the range of beneficiaries can be large and complicated.

Distributional analysis

It is unclear if the lack of beneficiary-related studies is specific to marine and coastal environments. On the one hand, the link between marine natural capital and ecosystem service and beneficiaries has long been documented as harder to conceptualize than for terrestrial environments as there is a physical separation between people and the sea (see Drakou 2017). For example, for terrestrial environments, the Online Recreation Valuation (ORVal) tool (Day & Smith 2018) has the potential to identify beneficiaries related to coastal paths (i.e. visitors), as does Quijas *et al*. (2019), and Clark *et al*. (2017), whilst for freshwater see Everard *et al*. (2019). On the other hand, the study of beneficiaries is becoming more important across all ecosystems, as the societal discourse starts to include topics like ‘just transition’ for climate change that starts to link equity, social justice, and environmental impacts. Traditionally, economic appraisal would recommend options that could achieve “Pareto efficiency”, i.e. deliver total benefits greater than total costs, without regard to who benefits and who loses. This was the basis of cost benefit analysis. This is also changing with more demand for knowing who benefits and who loses, and also whether and how the losers should be compensated.

At the valuation stage, ENCA (Defra 2020) notes the need to consider socio-economic differences between beneficiary or affected groups, by asking:

1. Whose values are measured?
2. Are those affected by a change the local, regional or the whole national population?
3. Are there socio-economic differences between beneficiary or affected groups?

With regards to the last point, the distribution of income is an important factor to consider when assessing the value of benefits. Defra (2020) explains that “it is important to understand to whom the estimated benefits accrue following the Green Book guidance”. Distributional impacts are cited as a possible justification for intervention, and there is the option of using income weighting and/or considering how values depend on populations (see Annex 3 of Green Book). Going forward, and with the intention of bringing environmental and social policies closer together, it would be prudent to make such considerations part of the norm rather than optional extras. ENCA guidelines (Defra 2020) also leave scope for considering broader ranges of values or diverse perspectives and make specific reference to Annex 2 of the Green Book (HM Treasury 2020), the UK NEA ‘Balance Sheet approach’ (Turner *et al.* 2014), and the UK NEA Follow-on phase work "Shared, Plural and Cultural Values" handbook (Kenter *et al.* 2014).

Some socio-economic impact assessment studies (e.g. Marine Scotland 2019) have sought to quantify costs and benefits of interventions using Green Book methodologies, which help to clarify potential trade-offs. But due to limited available evidence to quantify benefits, identification of beneficiaries was also incomplete.

Stakeholder mapping can help ensure that a more comprehensive list of impacts is considered, which could be important for the overall distributional implications. Burdon *et al*. (2019), for example, record that at the local scale, there is a lack of understanding on how benefits are identified, where they are provided and to whom. For example, the benefits of

conservation are often not well understood and hence their comprehensive integration into decision-making and public discourse is rare. As such, they tend to be overlooked in trade-offs between development decisions and supporting the wellbeing of local populations. Moreover, Burdon *et al*. (2019) highlight that small-scale, low impact, activities (e.g. related to tourism) are generally not captured within local assessments, and also not present within the national marine evidence. Stakeholder mapping can facilitate the identification of these missing links and ensure that they are included in the decision-making process.

There are studies that follow through logic chains or similar approaches to linking ecosystem processes/state through services to benefits, without talking about distribution. In some cases, this next step is discussed but not carried out. Part of the issue may be that assessment of distributional impacts/winners/losers is recognised as requiring a more stakeholder-led approach, rather than the topic of more 'remote' assessments, for example, ABPmer (2019), which evaluated options for beneficial use of dredge sediment to restore Solent marshes, saw a next step as to "engage with, and actively involve, the local community, and carry out a non-use local community valuation study" (p.90).

There is also an issue that more science-focused assessments can be looking at the potential to deliver ecosystem services, rather than actual ecosystem service delivery. They do not consider the human demand factors that convert potential to actual service/benefit (e.g. Tillin *et al.* 2020). In fact, De La Cruz (2021) argues that studies in general "have focused on specification of the ecological generation of ecosystem service to the detriment of understanding how they actually contribute to well-being" (p.18). Clark *et al.* (2017), for example, stop short of any valuation and present their primarily qualitative analysis in terms of the impacts identified. However, they demonstrate that it can be feasible, albeit complex and data-intensive, to construct multiple specific logic chains linking stressors through ecosystems to final services and specific beneficiaries (this is not in a coastal marine context, but the general approach would transfer).

3.2.3 Outstanding gaps

Quantitative information on the impacts of policy interventions is often lacking, which makes assessment of benefits and beneficiaries challenging. In line with the natural capital approach, the identification of benefit and beneficiaries need to go hand-in-hand and definition of beneficiaries should build on methods for, at least, identifying and, ideally, quantifying benefits. 'Wider society' is often identified as a beneficiary from increased levels of regulating and cultural services, where the identification of beneficiaries is intended to help clarify who might contribute to the costs of an intervention. It is also necessary to identify those organisations (e.g. public and third sector) which represent wider society. On the other hand, beneficiaries of provisioning services are generally linked to specific sectors and ultimate consumers (e.g. 'food provision' to fishing industries or 'minerals' to mining).

Beneficiaries that are further removed from marine and coastal environments are not reflected in the QSR evidence base. This is related to the general lack of coverage of the links between (the change in) marine and coastal natural capital assets and (the change in) ecosystem services. This is a key distinction between marine and terrestrial assessments, where marine beneficiary groups without direct use are rarely included. This in part could be assessed using distance decay analysis as part of valuation approaches.

The studies in the QSR evidence base did not split users of the marine environment into different generations. This is an existing gap to be addressed, as this will often be a key aspect of investments, especially with significant environmental impacts, and where heavy up-front costs lead to much longer-term gains (e.g. habitat creation / planting) or the reverse (e.g. nuclear energy). ENCA guidelines (Defra 2020) mention the consideration of equity

concerns across income groups and generations as justification for government intervention as a key aspect of the natural capital approach.

3.2.4 Recommendations from the QSR

A sensible next step would be to review the marine beneficiary and stakeholder literature and identify where bridges can be built with the current ecosystem service and natural capital approach evidence. For example, Solomonsz *et al.* (2021) make a start at this in relation to the Southern Ocean which may be a transferrable approach and framework.

The above also highlights the need to look at international studies, which may have methodologies that can be transferrable to the UK context.

The current marine and coastal evidence could also be re-analysed to determine beneficiary groups more explicitly (e.g. re-assessing the ESVD database where monetary units are associated with a beneficiary). In doing so, the most common beneficiary groups (e.g. households) would be readily identified, paving the way for appropriate distributional analysis to be used (e.g. breaking down households by socio-economic status).

There may be transferrable lessons from the terrestrial literature, including formal tools for stakeholder mapping and trade-off analysis, which could be added to the natural capital approach to support the identification of beneficiaries. Relevant areas would include the payments for ecosystem services (PES) literature and further review of regulatory impact assessment studies (similar to Marine Scotland 2019). For example, the Online Recreation Valuation (ORVal) tool (Day & Smith 2018) has the potential to identify beneficiaries related to coastal paths (i.e. visitors), as do Quijas *et al*. (2019), and Clark *et al.* (2017). It could be interesting to compare terrestrial and freshwater evidence and see if lessons could be learned (e.g. Everard *et al*. 2019) acknowledging that there will be inherent differences between the different ecosystems.

The terrestrial evidence may also provide useful insights on how to undertake participatory mapping as well as lessons learnt that could inform its development within the marine and coastal context. For example, Raum (2018), which looks at forest ecosystem services, identifies additional evidence that could be reviewed in order to make better use of stakeholder mapping approaches within the marine context (see also Duggan *et al*. 2013; Maguire *et al*. 2012).

4 Conclusions

In line with the objectives set out at the start, the project:

- Collated information about existing marine natural capital tools, methods, project (referred to as 'the products') and performed SWOT analyses (Section 2).
- Recommended a good practice natural capital approach for the UK marine environment policy and management, based on the results of the SWOT (Section 2.4.2).
- Based on the SWOT, performed a QSR focusing on how the relevant literature identifies and assesses benefits, defines beneficiaries, and investigates the distribution of benefits across beneficiaries (Section 3).

This section summarises the conclusions drawn from both the SWOT analyses and QSR – with more detail already presented in Sections 2 and 3.

4.1 Current marine natural capital approaches and evidence

The evidence reviewed highlights the strengths of the marine natural capital approach and opportunities for further development and integration with decision-making processes.

It is clear that, relative to terrestrial environments, the application of the natural capital approach to marine and coastal faces many challenges. Overall, the natural capital approach has been applied fairly widely, but how it is, can or should be used by decision-makers is unknown. The standards and guidelines such as ENCA (Defra 2020), SEEA EA (UN 2021) and the BS 8632 are relevant for applying the natural capital approach to the marine environment. Such standardisation of principles and good practice is also intended to increase the trust in the approach and its uptake by policy and decision makers.

The overall SWOT results informed the development of recommendations for UK marine natural capital assessments, by identifying common approaches but also future improvements that could be incorporated. The recommendations looked across the natural capital approach and assessment cycle, starting with agreeing purpose and scope and engaging with relevant stakeholders. Stakeholders could include those whose decisions will be influenced by the application of the natural capital approach (regulators, policy makers, sector representatives), beneficiaries from the marine environment and policy and management decisions, as well as those who may be negatively impacted by such decisions. Recommendations have also been made on technical aspects, such as the use of existing natural capital asset and ecosystem service classifications, frameworks or data and valuation methodologies.

The asset-service matrices have also been highlighted as useful. Innovative work can and should be undertaken to better understand how both species and habitats link to ecosystem service delivery across scales and contexts. This is also linked to better understanding and reflecting the importance of a variety of marine and coastal habitats across the life span of many species (e.g. juvenile vs adult fish). With regards to ecosystem services, there should be more work on services that have not been studied much to date (e.g. regulatory services, and cultural services other than tourism / recreation).

Identifying the gaps in the current evidence base contributed to the formulation of 12 recommendations for future research. These cover the following four areas: big picture/over-arching process, improvements to current practice, incorporating the future and understanding the use and usefulness of evidence.

4.2 Distribution of benefits across different groups

The priority question chosen for the Quick Scoping Review was: **what evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups?** This was chosen as the existing evidence base was shown to have a very limited discussion of beneficiaries and the distribution of benefits to different beneficiary groups. It was acknowledged that understanding who benefits from marine ecosystems services is essential for achieving buy-in to the marine natural capital approach as well as being key to making the approach coherent to stakeholders that want to implement it. Having robust evidence of the beneficiary groups could underpin decision-making in areas such as marine management, blue financing, and cost-benefit analyses.

The overall findings of the study are:

- Despite there being many studies linking natural capital to ecosystem services (and benefits), only a few of them include a detailed assessment of beneficiaries.
- Unlike in terrestrial assessments, beneficiaries without direct use or further removed from marine and coastal environments are rarely included. The coverage of links between marine and coastal natural capital assets and ecosystem services is often insufficient. This and other transferrable lessons can be learnt from the terrestrial literature, including formal tools for stakeholder mapping and trade-off analysis, which could support the identification of beneficiaries.
- Assessments of beneficiaries should explain how they can support decision making (e.g. for new sources of investment and funding or making marine policy decisions). Study of beneficiaries is only now becoming more important, as the societal discourse starts to include topics like ‘just transition’ for climate change that starts to link equity, social justice, and environmental impacts.
- Consideration of equity across income groups and generations as justification for government intervention could be a key driver for adopting a natural capital approach as it explicitly identifies benefits (but will need beneficiaries to be added).

Furthermore, the QSR shows that the literature tends to break down beneficiaries across specific uses or economic sectors (e.g. fisheries), rather than different societal groups (e.g. consumers). Most studies limit the coverage of beneficiaries to either singular, or small number of groups (e.g. male vs female fishers) and often high-level categories (e.g. the ‘wider society’). Even if individual beneficiary groups are identified, there is a tendency to limit the analysis to one-to-one relationships, effectively omitting more complex, multiple linkages (e.g. fisheries do not only benefit fishers, but also fish processors and consumers). The evidence is still fairly conceptual and, in the UK examples so far, beneficiaries that are further removed from the marine and coastal environments do not seem to be included in the analyses.

There is plenty of evidence on marine stakeholders and beneficiaries (e.g. Raum 2018), but it has not generally crossed paths with the natural capital approach nor linked to ecosystem services. Several of the studies discuss or make use of stakeholder identification and/or mapping, which is a useful form of analysis to aid understanding of distribution, but also supports effective management, even though a full stakeholder mapping exercise could be a major undertaking. Stakeholder mapping is highlighted as a useful method to enable a more comprehensive list of impacts to be considered, which could be important for overall distributional implications.

There has been a lot of work on stakeholders, how they benefit from the marine environment and relationships of power and influence between them, but these do not necessarily deal with quantifying and valuing benefit flows. The guidance on beneficiary assessments found

in ENCA (Defra 2020) or the Green Book (HM Treasury 2020) has, for the most part, not yet been applied in the marine natural capital or ecosystem service context. Future studies should show quantitative and, where relevant, monetary assessment of benefits accruing to individual beneficiary groups. Further guidance on identifying such groups and on adding distributional analysis to the assessment approaches is needed.

Whilst individual studies may include limited analysis of beneficiaries, collectively they provide a solid foundation for future research. Many of these studies recognise the potential opportunity in considering which stakeholders accrue benefits and how those benefits are distributed among them. Hence, it is recommended that this area of research is further developed, in particular, considering both those groups that benefit and those that lose from a given policy or management change.

References

Within this report

These are the references referred to in this report in addition to the products included in the SWOT analysis and the QSR evidence log.

Capitals Coalition (formerly Natural Capital Coalition). 2019. What is a Natural Capital Approach? Available from: https://naturalcapitalcoalition.org/wp-content/uploads/2019/06/NCC-WhatIs-NaturalCapitalApproach-FINAL.pdf

Collins, A.M., Coughlin, D., Miller, J. & Kirk, S. 2015. The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/560521/Production_of_quick_scoping_reviews_and_rapid_evidence_assessments.pdf

Defra. 2010. Valuing environmental impacts: guidelines for the use of value transfer. Report by eftec for Defra. Available from: https://www.gov.uk/government/publications/valuing-environmental-impacts-guidelines-for-the-use-of-value-transfer

Defra. 2018. 25 Year Environment Plan. Available from: https://www.gov.uk/government/publications/25-year-environment-plan

Duggan, D.E., Farnsworth, K.D. & Kraak, S.B. 2013. Identifying functional stakeholder clusters to maximise communication for the ecosystem approach to fisheries management. Marine Policy, 42, 56-67.

European Environment Agency. 2021a. *EUNIS Habitat Classification*. [online]. Available from: https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1

European Environment Agency. 2021b. *Common International Classification of Ecosystem Services (CICES) - Version 5.1*. [online]. Available from: https://cices.eu/resources/

HM Treasury. 2020. The Green Book: appraisal and evaluation in central government. [online]. Available from: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

Kenter, J.O., Reed, M.S., Everard, M., Irvine, K.N., O'Brien, E., Molloy, C., Bryce, R., Brady, E., Christie, M., Church, A., Collins, T., Cooper, N., Davies, A., Edwards, D., Evely, A., Fazey, I., Goto, R., Hockley, N., Jobstvogt, N., Orchard-Webb, J., Ravenscroft, N., Ryan, M. & Watson, V. 2014. Shared, plural and cultural values: A handbook for decision-makers. UK National Ecosystem Assessment follow-on phase. Cambridge, UNEP-WCMC. [online]. Available from: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

Maguire, B., Potts, J. & Fletcher, S. 2012. The role of stakeholders in the marine planning process—Stakeholder analysis within the Solent, United Kingdom. Marine Policy, 36(1), 246-257.

Mullholland, R., Le Quesne, W. & Mynott, F. 2021. Rapid review of marine natural capital asset classes and logic chains to identify priority information gaps. Cefas Project Report for Defra.

Turner, K., Schaafsma, M., Elliott, M., Burdon, D., Atkins, J., Jickells, T., Tett, P., Mee, L., van Leeuwen, S., Barnard, S., Luisetti, T., Paltriguera, L., Palmieri, G. & Andrews, J. 2014. UK National Ecosystem Assessment Follow-on. Work Package Report 4: Coastal and

marine ecosystem services: principles and practice. UNEP-WCMC, LWEC, UK. Available from: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

UK National Ecosystem Assessment Follow-on. 2014. The UK National Ecosystem Assessment Follow-on: Synthesis of the Key Findings. UNEP-WCMC, LWEC, UK. [online]. Available from: http://randd.defra.gov.uk/Document.aspx?Document=12099_01.UKNEAFOSynthesis.pdf

United Nations *et al*. 2021. System of Environmental-Economic Accounting— Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting

Reviews and SWOT analyses

ABPmer. 2020. Beneficial Use of Dredge Sediment in the Solent (BUDS) Phase 2, Feasibility Review for Sediment Recharge Project(s) on the West Solent Saltmarshes, ABPmer Report No. R.3155. A report produced by ABPmer for Solent Forum, February 2020. [online]. Available from: http://solentforum.org/services/Current_Projects/buds/BUDS2Report_ABPmer.pdf

ARIES. 2021. ARIES for SEEA explorer - a tool for rapid natural capital accounting. [online]. Available from: https://aries.integratedmodelling.org/aries-for-seea-explorer/

Armstrong, S., Hull, S., Pearson, Z., Wilson, R. & Kay, S. 2020. Estimating the Carbon Sink Potential of the Welsh Marine Environment. NRW, Cardiff, 74p. [online]. Available from: https://cdn.naturalresources.wales/media/692035/nrw-evidence-report-428_blue-carbon_v11-002.pdf

Ashley, M., Rees, S., Mullier, T., Reed, B., Cartwright, A., Holmes, L. & Sheehan, E. 2020. Isles of Scilly Natural Capital Asset and Risk Register to Inform Management of Isles of Scilly Fisheries Resources. A report by research staff of the Marine Institute at the University of Plymouth. [online]. Available from: https://secure.toolkitfiles.co.uk/clients/19937/sitedata/pdfs/SCILL-E-Report-2020.pdf

Ashley, M., Rees, S.E. & Cameron, A. 2018. North Devon Marine Pioneer Part 1: State of the art report of the links between ecosystem and ecosystem services in the North Devon Marine Pioneer. A report to WWF-UK by research staff the Marine Institute at Plymouth University

British Standard Institute. (2021). BS 8632: Natural Capital Accounting for Organizations - Specification. [online]. Available from: https://shop.bsigroup.com/ProductDetail?pid=000000000030401243&_ga=2.268293066.557840663.1629196930-941568371.1629196927

Culhane, F., Frid, C., Royo Gelabert, E. & Robinson, L., 2019. EU Policy-Based Assessment of the Capacity of Marine Ecosystems to Supply Ecosystem Services. ETC/ICM Technical Report 2/2019: European Topic Centre on Inland, Coastal and Marine Waters, 263 pp. [online]. Available from: https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-report-2-2019-eu-policy-based-assessment-of-the-capacity-of-marine-ecosystems-to-supply-ecosystem-services

Day, B.H. & Smith, G. 2018. Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0, Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter. [online]. Available from: https://www.leep.exeter.ac.uk/orval/

de Groot, R., Brander, L. & Solomonides, S. 2020. Ecosystem Services Valuation Database (ESVD) Version December 2020. [online]. Available from: https://www.es-partnership.org/esvd/

Defra. 2020. Enabling a Natural Capital Approach: Guidance, v1.1 January 2020. [online]. Available from: https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance

eftec & ABPmer. 2021. A Natural Capital Account for the Industrial Sandeel Fishery. For Natural England. unpublished.

eftec, SQW, CEH & ABPmer. 2019. The ecosystem contribution to tourism and outdoor leisure. Report to Defra, September 2019. [online]. Available from: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20245"

eftec. 2015. Environmental Value Look-Up (EVL) tool. [online]. Available from: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=19514#Description

ENCORE. 2021. Exploring Natural Capital Opportunities, Risks, and Exposure, UN Environment Programme (UNEP). [online]. Available from: https://encore.naturalcapital.finance/en/

Erhard, M., Teller, A., Maes, J., Meiner, A., Berry, P., Smith, A., Eales, R., Papadopoulou, L., Bastrup-Birk, A., Ivits, E., Royo Gelabert, E., Dige, G., Petersen, J.-E., Reker, R., Cugny-Seguin, m., Kristensen, P., Uhel, R., Estreguil, C., Fritz, M., Murphy, P., Banfield, N., Ostermann, O., Abdul Malak, D., Marín, A., Schröder, C., Conde, S., Garcia-Feced, C., Evans, D., Delbaere, B., Naumann, S., Davis, M., Gerdes, H., Graf, A., Boon, A., Stoker, B., Mizgajski, A., Santos Martin, F., Jol, A., Lükewille, A., Werner, B., Romao, C., Desaulty, D., Wugt Larsen, F., Louwagie, G., Zal, N., Gawronska, S. & Christiansen, T. 2016. Mapping and assessment of ecosystems and their services. mapping and assessing the condition of Europe's ecosystems: Progress and challenges. Luxembourg: Publications office of the European Union. [online]. Available from: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/3rdMAESReport_Condition.pdf

European Commission. 2021. The EU Blue Economy Report. 2021. Publications Office of the European Union. Luxembourg. [online]. Available from: https://ec.europa.eu/oceans-and-fisheries/system/files/2021-05/the-eu-blue-economy-report-2021_en.pdf

EVRI. n.d. Environmental valuation reference inventory. [online]. Available from: https://www.evri.ca/en

Hooper, T. & Austen, M. 2020. Application of the natural capital approach to Sustainability Appraisal. Final Report. October 2020. Report prepared as part of the South West Partnership for the Environment and Economic Prosperity (SWEEP) and the Marine Pioneer programme.

Hooper, T., Ashley, M., Börger, T., Langmead, O., Marcone, O., Rees, S., Rendon, O., Beaumont, N., Attrill, M. & Austen, M. 2019. Application of the natural capital approach to the marine environment to aid decision-making. Phase 1 Final Report. Report prepared for the Department for Environment Food and Rural Affairs (project code ME5115). [online]. Available from:

https://www.researchgate.net/publication/332780893_Application_of_the_natural_capital_approach_to_the_marine_environment_to_aid_decision-making_PHASE_1_FINAL_REPORT

InVEST. n.d. Integrated Valuation of Ecosystem Services and Tradeoffs. [online]. Available from: https://naturalcapitalproject.stanford.edu/software/invest

La Bianca, G., Tillin, H., Hodgson, B., Erni-Cassola, G., Howell, K. & Rees, R. 2018. Ascension Island - Natural Capital Assessment. Prepared for South Atlantic Environmental Research Institute (SAERI) - Ness Smith. [online]. Available from: https://data.jncc.gov.uk/data/353f5200-775a-4f90-9ada-df9a14071e68/ot-nca-sup-sat-03-asi-asinca-oct2018.pdf

Lovett, A., Turner, K., Sünnenberg, G., Ferrini, S., Stephanou, E. & Greaves, S. 2018. A natural capital asset check and risk register for the Anglian Water combined services area. Report to Anglian Water Services Ltd. [online]. Available from: https://www.anglianwater.co.uk/environment/our-biodiversity-work/natural-capital/

Lusardi, J., Rice, P., Waters, R.D. & Craven, J. 2018. Natural capital indicators: for defining and measuring change in natural capital. Natural England Research Report. [online]. Available from: http://publications.naturalengland.org.uk/publication/6742480364240896

Maes, J., Teller, A., Erhard, M., Grizzetti, B., Barredo, J.I., Paracchini, M.L., Condé, S., Somma, F., Orgiazzi, A., Jones, A., Zulian, A., Vallecilo, S., Petersen, J.E., Marquardt, D., Kovacevic, V., Abdul Malak, D., Marin, A.I., Czúcz, B., Mauri, A., Loffler, P., Bastrup-Birk, A., Biala, K., Christiansen, T. & Werner, B. (2018) Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg. [online]. Available from: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/5th%20MAES%20report.pdf

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M.L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P.H., Condé, S., Schägner, J.P., San Miguel, J., Estreguil, C., Ostermann, O., Barredo, J.I., Pereira, H.M., Stott, A., Laporte, V., Meiner, A., Olah, B., Royo Gelabert, E., Spyropoulou, R., Petersen, J.E., Maguire, C., Zal, N., Achilleos, E., Rubin, A., Ledoux, L., Brown, C., Raes, C., Jacobs, S., Vandewalle, M., Connor, D. & Bidoglio, G. 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. [online]. Available from: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Marine Ecosystems Research Programme (MERP). (n.d.). Marine Ecosystems Research Programme - Natural Capital. [online]. Available from: https://www.marine-ecosystems.org.uk/getmedia/7acf319e-084a-4eaa-87d7-807df4581aa8/MERP_Natural_Capital_Leaflet_HR.pdf

Office for National Statistics. 2021. Marine accounts, natural capital, UK: 2021. [online]. Available from: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/marineaccountsnaturalcapitaluk/2021

Office for National Statistics. 2021. Tourism and outdoor leisure accounts, natural capital, UK: 2021. [online]. Available from:

https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/tourismandoutdoorleisureaccountsnaturalcapitaluk/2021

Rees, S.E., Ashley, M. & Cameron, A. 2019. North Devon Marine Pioneer Report 2: A Natural Capital Asset and Risk Register A SWEEP/WWF-UK report by research staff the Marine Institute at Plymouth University. [online]. Available from: https://www.researchgate.net/publication/332225506_North_Devon_Marine_Pioneer_2_A_Natural_Capital_Asset_and_Risk_Register

Rice, P., Lusardi, J., Lord, A. & Sunderland, T. (2021). Natural Capital Evidence Handbook: to support place-based planning and decision-making. Natural England Research Report, Number 092. [online]. Available from: http://publications.naturalengland.org.uk/publication/4658498148499456

Thornton, A., Luisetti, T., Grilli, G., Donovan, D., Phillips, R. & Hawker, J. 2019. Initial natural capital accounts for the UK marine and coastal environment. Final Report. Report prepared for the Department for Environment Food and Rural Affairs. [online]. Available from: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=20240

Tillin, H.M., Langmead, O., Hodgson, B., Luff, A, Rees, S., Hooper, T. & Frost, M. 2019. Feasibility study for a Marine Natural Capital Asset Index for Scotland. Scottish Natural Heritage Research Report No. 1071. [online]. Available from: https://www.nature.scot/sites/default/files/2019-02/Publication%202019%20-%20SNH%20Research%20Report%201071%20-%20Feasibility%20study%20for%20a%20Marine%20Natural%20Capital%20Asset%20Index%20for%20Scotland.pdf

Van Rein, H., Molloy, L., Lourenço, G., Day, J., Hooper, T., Hartley, M., Chambers, A., Parker, R., Benson, L., Hedley, C., Young, M. & Morgan, V. 2021. Natural Capital Approaches for Improving Marine Planning: A proof of concept 'quick-win' project for the Marine Natural Capital and Ecosystem Assessment Programme. JNCC.

Watson, S., Preston, J., Beaumont, N. & Watson, G. 2020. Assessing the natural capital value of water quality and climate regulation in temperate marine systems using a EUNIS biotope classification approach. Science of The Total Environment, 74. [online]. Available from: https://doi.org/10.1016/j.scitotenv.2020.140688

Wigley, S., Paling, N., Rice, P., Lord, A. & Lusardi, J. 2020. National Natural Capital Atlas, Natural England Commissioned Report Number 285. [online]. Available from: http://publications.naturalengland.org.uk/publication/4578000601612288

QSR and priority question

ABPmer. 2020. Beneficial Use of Dredge Sediment in the Solent (BUDS) Phase 2 Feasibility Review for Sediment Recharge Project(s) on the West Solent Saltmarshes. Available from: http://solentforum.org/services/Current_Projects/buds/BUDS2Report_ABPmer.pdf

ABPmer & eftec. 2019. Socio-Economic Impact Assessment of proposed Marine Protected Areas. Available from: https://consult.gov.scot/marine-scotland/four-new-marine-protected-areas/supporting_documents/MPA Sustainability Appraisal Project Final with covers SEIA Report 06 June 2019.pdf

Acharya, R.P., Maraseni, T. & Cockfield, G. 2019. Global trend of forest ecosystem services valuation – An analysis of publications. Ecosystem Services, 39, 100979. https://doi.org/10.1016/j.ecoser.2019.100979

Ainsworth, G.B., Kenter, J.O., O'Connor, S., Daunt, F. & Young, J.C. 2019. A fulfilled human life: Eliciting sense of place and cultural identity in two UK marine environments through the Community Voice Method. Ecosystem Services, 39, 100992. https://doi.org/10.1016/j.ecoser.2019.100992

Andrews, B., Ferrini, S. & Bateman, I. 2017. Good parks – bad parks: the influence of perceptions of location on WTP and preference motives for urban parks. Journal of Environmental Economics and Policy, 6, 204–224. https://doi.org/10.1080/21606544.2016.1268543

Angradi, T.R., Williams, K.C., Hoffman, J.C. & Bolgrien, D.W. 2019. Goals, beneficiaries, and indicators of waterfront revitalization in Great Lakes Areas of Concern and coastal communities. Journal of Great Lakes Research, 45, 851–863. https://doi.org/10.1016/j.jglr.2019.07.001

Armstrong, S., Hull, S., Pearson, Z., Kay, S. & Wilson, R. 2020. Estimating the Carbon Sink Potential of the Welsh Marine Environment. Available from: https://cdn.naturalresources.wales/media/692035/nrw-evidence-report-428_blue-carbon_v11-002.pdf

Arthur, R. & Martin, S. 2013. Studies for carrying out the Common Fisheries Policy: Lot 3 Socio-economic dimensions in EU fisheries. Available from: https://www.researchgate.net/publication/332142377_Studies_for_carrying_out_the_Common_Fisheries_Policy_Lot_3_Socioeconomic_dimensions_in_EU_fisheries_MARE201107

Ascui, F. & Cojoianu, T.F. 2019. Implementing natural capital credit risk assessment in agricultural lending. Business Strategy and the Environment, 28, 1234–1249. https://doi.org/10.1002/bse.2313

Ashley, M., Rees, S., Reed, T., Bethany, M., Cartwright, A., Holmes, L. & Sheehan, E. 2020. Isles of Scilly Natural Capital Asset and Risk Register to Inform Management of Isles of Scilly Fisheries Resources. Available from: https://secure.toolkitfiles.co.uk/clients/19937/sitedata/pdfs/SCILL-E-Report-2020.pdf

Asmus, M.L., Nicolodi, J., Anello, L.S. & Gianuca, K. 2019. The risk to lose ecosystem services due to climate change: A South American case. Ecological Engineering, 130, 233–241. https://doi.org/10.1016/j.ecoleng.2017.12.030

Austen, M., Hattam, C., Hooper, T., Papathanasopoulou, E., Wyles, K., Kelvin, B. & Lockett, J. 2017. Ecosystem Services Valuation for Coastal Managers. Available from: https://www.pml.ac.uk/System_pages/PML_ES_services_guide_en

Bagstad, K.J., Villa, F., Batker, D., Harrison-Cox, J., Voigt, B. & Johnson, G.W. 2014. From theoretical to actual ecosystem services: mapping beneficiaries and spatial flows in ecosystem service assessments. Ecology and Society, 19, art64. https://doi.org/10.5751/ES-06523-190264

Barton, D.N., Kelemen, E., Dick, J., Martin-Lopez, B., Gómez-Baggethun, E., Jacobs, S., Hendriks, C.M.A., Termansen, M., García- Llorente, M., Primmer, E., Dunford, R., Harrison, P.A., Turkelboom, F., Saarikoski, H., van Dijk, J., Rusch, G.M., Palomo, I., Yli-Pelkonen, V.J., Carvalho, L., Baró, F., Langemeyer, J., van der Wal, J.T., Mederly, P., Priess, J.A.,

Luque, S., Berry, P., Santos, R., Odee, D., Pastur, G.M., García Blanco, G., Saarela, S.-R., Silaghi, D., Pataki, G., Masi, F., Vădineanu, A., Mukhopadhyay, R. & Lapola, D.M. 2018. (Dis) integrated valuation – Assessing the information gaps in ecosystem service appraisals for governance support. Ecosystem Services, 29, 529–541. https://doi.org/10.1016/j.ecoser.2017.10.021

Bateman, I.J. & Mace, G.M. 2020. The natural capital framework for sustainably efficient and equitable decision making. Nature Sustainability, 3, 776–783. https://doi.org/10.1038/s41893-020-0552-3

Bellanger, M., Speir, C., Blanchard, F., Brooks, K., Butler, J.R.A., Crosson, S., Fonner, R., Gourguet, S., Holland, D.S., Kuikka, S., Le Gallic, B., Lent, R., Libecap, G.D., Lipton, D.W., Nayak, P.K., Reid, D., Scemama, P., Stephenson, R., Thébaud, O. & Young, J.C. 2020. Addressing Marine and Coastal Governance Conflicts at the Interface of Multiple Sectors and Jurisdictions. Frontiers in Marine Science, 7. https://doi.org/10.3389/fmars.2020.544440

Blythe, J., Armitage, D., Alonso, G., Campbell, D., Esteves Dias, A.C., Epstein, G., Marschke, M. & Nayak, P. 2020. Frontiers in coastal well-being and ecosystem services research: A systematic review. Ocean & Coastal Management, 185, 105028. https://doi.org/10.1016/j.ocecoaman.2019.105028

Boeri, M., Stojanovic, T.A., Wright, L.J., Burton, N.H.K., Hockley, N. & Bradbury, R.B. 2020. Public preferences for multiple dimensions of bird biodiversity at the coast: insights for the cultural ecosystem services framework. Estuarine, Coastal and Shelf Science, 235, 106571. https://doi.org/10.1016/j.ecss.2019.106571

Bonsu, N.O., McMahon, B.J., Meijer, S., Young, J.C., Keane, A. & Dhubháin, Á.N. 2019. Conservation conflict: Managing forestry versus hen harrier species under Europe's Birds Directive. Journal of Environmental Management, 252, 109676. https://doi.org/10.1016/j.jenvman.2019.109676

Brain, M.., Nahuelhual, L., Gelcich, S. & Bozzeda, F. 2020. Marine conservation may not deliver ecosystem services and benefits to all: Insights from Chilean Patagonia. Ecosystem Services, 45, 101170. https://doi.org/10.1016/j.ecoser.2020.101170

Brandon, C., Brandon, K., Fairbrass, A. & Neugarten, R. 2021. Integrating Natural Capital into National Accounts: Three Decades of Promise and Challenge. Review of Environmental Economics and Policy, 15, 134–153. https://doi.org/10.1086/713075

Bright, G., Connors, E. & Grice, J. 2019. Measuring natural capital: towards accounts for the UK and a basis for improved decision-making. Oxford Review of Economic Policy, 35, 88–108. https://doi.org/10.1093/oxrep/gry022

Broszeit, S., Beaumont, N.J., Hooper, T.L., Somerfield, P.J. & Austen, M.C. 2019. Developing conceptual models that link multiple ecosystem services to ecological research to aid management and policy, the UK marine example. Marine Pollution Bulletin, 141, 236–243. https://doi.org/10.1016/j.marpolbul.2019.02.051

BSI. 2021. Natural Capital Accounting for Organizations. Specification. Available from: https://shop.bsigroup.com/products/natural-capital-accounting-for-organizations-specification?pid=000000000304012438_ga=2.268293066.557840663.1629196930-941568371.1629196927

Buck, J.J.H., Bainbridge, S.J., Burger, E.F., Kraberg, A.C., Casari, M., Casey, K.S., Darroch, L., Rio, J. Del, Metfies, K., Delory, E., Fischer, P.F., Gardner, T., Heffernan, R., Jirka, S.,

Kokkinaki, A., Loebl, M., Buttigieg, P.L., Pearlman, J.S. & Schewe, I. 2019. Ocean Data Product Integration Through Innovation-The Next Level of Data Interoperability. Frontiers in Marine Science, 6. https://doi.org/10.3389/fmars.2019.00032

Bullock, C., Joyce, D. & Collier, M. 2018. An exploration of the relationships between cultural ecosystem services, socio-cultural values and well-being. Ecosystem Services, 31, 142–152. https://doi.org/10.1016/j.ecoser.2018.02.020

Bullock, J.M. & Ding, H. 2018. A Guide to Selecting Ecosystem Service Models for Decision-Making. Available from: https://www.ceh.ac.uk/sites/default/files/ESPA Guide to Ecosystem Services Modeling final web.pdf

Buonocore, E., Appolloni, L., Russo, G.F. & Franzese, P.P. 2020. Assessing natural capital value in marine ecosystems through an environmental accounting model: A case study in Southern Italy. Ecological Modelling, 419, 108958. https://doi.org/10.1016/j.ecolmodel.2020.108958

Buonocore, E., Grande, U., Franzese, P.P. & Russo, G.F. 2021. Trends and Evolution in the Concept of Marine Ecosystem Services: An Overview. Water, 13, 2060. https://doi.org/10.3390/w13152060

Buonocore, E., Picone, F., Donnarumma, L., Russo, G.F. & Franzese, P.P. 2019. Modelling matter and energy flows in marine ecosystems using emerging and eco-exergy methods to account for natural capital value. Ecological Modelling, 392, 137–146. https://doi.org/10.1016/j.ecolmodel.2018.11.018

Burdon, D. & Potts, T. 2020. Participatory Mapping of Natural Capital and Benefits: Method Guidance Document. Hull. Available from: https://static1.squarespace.com/static/5e85a98d5277001874963880/t/5f6b1ff025a5ff10d1ebf565/1600856073017/Participatory+Mapping+Guidance+Document+Final+200520.pdf

Burdon, D., Potts, T., McKinley, E., Lew, S., Shilland, R., Gormley, K., Thomson, S. & Forster, R. 2019. Expanding the role of participatory mapping to assess ecosystem service provision in local coastal environments. Ecosystem Services, 39, 101009. https://doi.org/10.1016/j.ecoser.2019.101009

Burke, T., Whyatt, J.D., Rowland, C., Blackburn, G.A. & Abbatt, J. 2020. The influence of land cover data on farm-scale valuations of natural capital. Ecosystem Services, 42, 101065. https://doi.org/10.1016/j.ecoser.2020.101065

Capitals Coalition 2020. Using Natural Capital Approaches to Manage Shared Dependencies. Available from: https://capitalscoalition.org/wp-content/uploads/2021/01/IFC_CC_Using-Natural-Capital-Approaches-to-Manage-Shared-Dependencies-2020.pdf

Carvalho, L., Mackay, E.B., Cardoso, A.C., Baattrup-Pedersen, A., Birk, S., Blackstock, K.L., Borics, G., Borja, A., Feld, C.K., Ferreira, M.T., Globevnik, L., Grizzetti, B., Hendry, S., Hering, D., Kelly, M., Langaas, S., Meissner, K., Panagopoulos, Y., Penning, E., Rouillard, J., Sabater, S., Schmedtje, U., Spears, B.M., Venohr, M., van de Bund, W. & Solheim, A.L. 2019. Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. Science of The Total Environment, 658, 1228–1238. https://doi.org/10.1016/j.scitotenv.2018.12.255

Cebrián-Piqueras, M.A., Karrasch, L. & Kleyer, M. 2017. Coupling stakeholder assessments of ecosystem services with biophysical ecosystem properties reveals importance of social contexts. Ecosystem Services, 23, 108–115. https://doi.org/10.1016/j.ecoser.2016.11.009

Centre for Climate Change Economics and Policy. 2020. Distributional issues in natural capital accounting: An application to land ownership and ecosystem services in Scotland (No. 382). Available from: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2020/11/working-paper-354-Atkinson-Ovando.pdf

Church, A., Coles, T. & Fish, R. 2017. Tourism in sub-global assessments of ecosystem services. Journal of Sustainable Tourism, 25, 1529–1546. https://doi.org/10.1080/09669582.2017.1291649

CIEEM England Policy Group. 2019. Natural Capital and Biodiversity: A Briefing Note for Ecologists and Environmental Managers. Available from: https://cieem.net/wp-content/uploads/2019/07/CIEEM-Natural-Capital-Briefing-for-EEMs-July2019-.pdf

Claret, C., Metzger, M.J., Kettunen, M. & ten Brink, P. 2018. Understanding the integration of ecosystem services and natural capital in Scottish policy. Environmental Science & Policy, 88, 32–38. https://doi.org/10.1016/j.envsci.2018.05.019

Clark, C.M., Bell, M.D., Boyd, J.W., Compton, J.E., Davidson, E.A., Davis, C., Fenn, M.E., Geiser, L., Jones, L. & Blett, T.F. 2017. Nitrogen-induced terrestrial eutrophication: cascading effects and impacts on ecosystem services. Ecosphere, 8. https://doi.org/10.1002/ecs2.1877

Collins, C.M.T., Cook-Monie, I. & Raum, S. 2019. What do people know? Ecosystem services, public perception and sustainable management of urban park trees in London, U.K. Urban Forestry & Urban Greening, 43, 126362. https://doi.org/10.1016/j.ufug.2019.06.005

Cosgrove, P. 2020. Suffolk Marine Pioneer: Lessons & recommendations for applying the natural capital approach in England. Melton. Available from: https://www.suffolkcoastandheaths.org/wp-content/uploads/2021/01/2020-Suffolk-Marine-Pioneer-Applying-Natural-Capital-Approach-Gudiance.pdf

Costanza, R. 2020. Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. Ecosystem Services, 43, 101096. https://doi.org/10.1016/j.ecoser.2020.101096

Costanza, R., Atkins, P.W.B., Hernandez-Blanco, M. & Kubiszewski, I. 2021. Common asset trusts to effectively steward natural capital and ecosystem services at multiple scales. Journal of Environmental Management, 280, 111801. https://doi.org/10.1016/j.jenvman.2020.111801

Culhane, F., Frid, C., Gelabert, E.R. & Robinson, L. 2019. EU Policy-Based Assessment of the Capacity of Marine Ecosystems to Supply Ecosystem Services. Available from: https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-report-2-2019-eu-policy-based-assessment-of-the-capacity-of-marine-ecosystems-to-supply-ecosystem-services

Culhane, F.E., Frid, C.L.J., Royo Gelabert, E., White, L. & Robinson, L.A. 2018. Linking marine ecosystems with the services they supply: what are the relevant service providing units? Ecological Applications, 28, 1740–1751. https://doi.org/10.1002/eap.1779

Cziesielski, M.J., Duarte, C.M., Aalismail, N., Al-Hafedh, Y., Anton, A., Baalkhuyur, F., Baker, A.C., Balke, T., Baums, I.B., Berumen, M., Chalastani, V.I., Cornwell, B., Daffonchio,

D., Diele, K., Farooq, E., Gattuso, J.-P., He, S., Lovelock, C.E., Mcleod, E., Macreadie, P.I., Marba, N., Martin, C., Muniz-Barreto, M., Kadinijappali, K.P., Prihartato, P., Rabaoui, L., Saderne, V., Schmidt-Roach, S., Suggett, D.J., Sweet, M., Statton, J., Teicher, S., Trevathan-Tackett, S.M., Joydas, T. V., Yahya, R. & Aranda, M. 2021. Investing in Blue Natural Capital to Secure a Future for the Red Sea Ecosystems. Frontiers in Marine Science, 7. https://doi.org/10.3389/fmars.2020.603722

Davidson, N.C., van Dam, A.A., Finlayson, C.M. & McInnes, R.J. 2019. Worth of wetlands: revised global monetary values of coastal and inland wetland ecosystem services. Marine and Freshwater Research, 70, 1189. https://doi.org/10.1071/MF18391

Davies, H. & Dutton, A. 2021. Tourism and outdoor leisure accounts, natural capital, UK: 2021.

Defra. 2020. Enabling a Natural Capital Approach guidance. Available from: https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance

Dickie, I. & Neupauer, S. 2019. Natural capital accounts: nations and organizations. Journal of Environmental Economics and Policy, 8, 379–393. https://doi.org/10.1080/21606544.2019.1639219

Doggett, M., Baldock, L. & Goudge, H. 2019. A review of the distribution and ecological importance of seabed communities in the deep waters surrounding Scotland. Available from: https://data.jncc.gov.uk/data/4722c3b6-767c-4dd3-b5b4-b7a1281f4fcf/JNCC-Report-625-FINAL-WEB.pdf

Dolan, R., Bullock, J.M., Jones, J.P.G., Athanasiadis, I.N., Martinez-Lopez, J. & Willcock, S. 2021. The Flows of Nature to People, and of People to Nature: Applying Movement Concepts to Ecosystem Services. Land, 10, 576. https://doi.org/10.3390/land10060576

Drakou, E.G. Kermagoret, C., Liquete, C., Ruiz-Frau, A., Burkhard, K., Lillebø, A.I., van Oudenhoven, A.P.E., Ballé-Béganton, J., Rodrigues, J.G., Nieminen, E., Oinonen, S., Ziemba, A., Gissi, E., Depellegrin, D., Veidemane, K., Ruskule, A., Delangue, J., Böhnke-Henrichs, A., Boon, A., Wenning, R., Martino, S., Hasler, B., Termansen, M., Rockel, M., Hummel, H., El Serafy, G. & Peev, P. 2017a. Marine and coastal ecosystem services on the science–policy–practice nexus: challenges and opportunities from 11 European case studies. International Journal of Biodiversity Science, Ecosystem Services & Management, 13, 51–67. https://doi.org/10.1080/21513732.2017.1417330

Drakou, E.G. Pendleton, L., Effron, M., Ingram, J.C. & Teneva, L. 2017b. When ecosystems and their services are not co-located: oceans and coasts. ICES Journal of Marine Science, 74, 1531–1539. https://doi.org/10.1093/icesjms/fsx026

Drius, M., Jones, L., Marzialetti, F., de Francesco, M.C., Stanisci, A. & Carranza, M.L. 2019. Not just a sandy beach. The multi-service value of Mediterranean coastal dunes. Science of The Total Environment, 668, 1139–1155. https://doi.org/10.1016/j.scitotenv.2019.02.364

Dunford, R., Harrison, P., Smith, A., Dick, J., Barton, D.N., Martin-Lopez, B., Kelemen, E., Jacobs, S., Saarikoski, H., Turkelboom, F., Verheyden, W., Hauck, J., Antunes, P., Aszalós, R., Badea, O., Baró, F., Berry, P., Carvalho, L., Conte, G., Czúcz, B., Garcia Blanco, G., Howard, D., Giuca, R., Gomez-Baggethun, E., Grizzetti, B., Izakovicova, Z., Kopperoinen, L., Langemeyer, J., Luque, S., Lapola, D.M., Martinez-Pastur, G., Mukhopadhyay, R., Roy, S.B., Niemelä, J., Norton, L., Ochieng, J., Odee, D., Palomo, I., Pinho, P., Priess, J., Rusch, G., Saarela, S.-R., Santos, R., van der Wal, J.T., Vadineanu, A., Vári, Á., Woods, H. & Yli-

Pelkonen, V. 2018. Integrating methods for ecosystem service assessment: Experiences from real world situations. Ecosystem Services, 29, 499–514. https://doi.org/10.1016/j.ecoser.2017.10.014

Dvarskas, A. 2018. Mapping ecosystem services supply chains for coastal Long Island communities: Implications for resilience planning. Ecosystem Services, 30, 14–26. https://doi.org/10.1016/j.ecoser.2018.01.008

Ecosystem Services Partnership. 2020. Ecosystem Services Valuation Database (ESVD) [WWW Document]. Available from: https://www.es-partnership.org/esvd/esvd-download/esvd-version-december-2020/

Eftec. 2021. Natural Capital Accounting Practices in the UK. Available from: https://www.eftec.co.uk/sites/default/files/pdf/NCA Practices in the UK Briefing Note - eftec in partnership with COWI.pdf

eftec & JNCC. 2019. Natural Capital Accounting for the UK Overseas Territories: a Guide. Available from: https://data.jncc.gov.uk/data/ee730d0b-5884-4620-b9c6-df1cd49e60f1/UKOTNaturalCapitalGuidance.pdf

England, J.R., O'Grady, A.P., Fleming, A., Marais, Z. & Mendham, D. 2020. Trees on farms to support natural capital: An evidence-based review for grazed dairy systems. Science of The Total Environment, 704, 135345. https://doi.org/10.1016/j.scitotenv.2019.135345

Espa. 2018. How can ecosystem services support equitable and sustainable fisheries? Available from: https://www.espa.ac.uk/files/espa/ESPA Fisheries Policy Brief WEB FINAL_0.pdf

European Commission. 2013. Mapping and Assessment of Ecosystems and their Services An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020.

European Environment Agency. 2016. Mapping and Assessment of Ecosystems and their Services. Available from: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/3rdMAESReport_Condition.pdf

Evans, A.J., Firth, L.B., Hawkins, S.J., Hall, A.E., Ironside, J.E., Thompson, R.C. & Moore, P.J. 2019. From ocean sprawl to blue-green infrastructure – A UK perspective on an issue of global significance. Environmental Science & Policy, 91, 60–69. https://doi.org/10.1016/j.envsci.2018.09.008

Evans, A.J., Garrod, B., Firth, L.B., Hawkins, S.J., Morris-Webb, E.S., Goudge, H. & Moore, P.J. 2017. Stakeholder priorities for multi-functional coastal defence developments and steps to effective implementation. Marine Policy, 75, 143–155. https://doi.org/10.1016/j.marpol.2016.10.006

Fairbrass, A., Mace, G., Ekins, P. & Milligan, B. 2020. The natural capital indicator framework (NCIF) for improved national natural capital reporting. Ecosystem Services, 46, 101198. https://doi.org/10.1016/j.ecoser.2020.101198

Fenichel, E.P. & Hashida, Y. 2019. Choices and the value of natural capital. Oxford Review of Economic Policy, 35, 120–137. https://doi.org/10.1093/oxrep/gry021

Fletcher, R., Dressler, W.H., Anderson, Z.R. & Büscher, B. 2019. Natural capital must be defended: green growth as neoliberal biopolitics. The Journal of Peasant Studies, 46, 1068–1095. https://doi.org/10.1080/03066150.2018.1428953

Fox, N., Graham, L.J., Eigenbrod, F., Bullock, J.M. & Parks, K.E. 2021. Reddit: A novel data source for cultural ecosystem service studies. Ecosystem Services, 50, 101331. https://doi.org/10.1016/j.ecoser.2021.101331

Frajka-Williams, E., Beaulieu, C. & Duchez, A. 2017. Emerging negative Atlantic Multidecadal Oscillation index in spite of warm subtropics. Scientific Reports, 7, 11224. https://doi.org/10.1038/s41598-017-11046-x

Franzese, P.P., Buonocore, E., Donnarumma, L. & Russo, G.F. 2017. Natural capital accounting in marine protected areas: The case of the Islands of Ventotene and S. Stefano (Central Italy). Ecological Modelling, 360, 290–299. https://doi.org/10.1016/j.ecolmodel.2017.07.015

Frederiksen, P., Morf, A., von Thenen, M., Armoskaite, A., Luhtala, H., Schiele, K.S., Strake, S. & Hansen, H.S. 2021. Proposing an ecosystem services-based framework to assess sustainability impacts of maritime spatial plans (MSP-SA). Ocean & Coastal Management, 208, 105577. https://doi.org/10.1016/j.ocecoaman.2021.105577

Friedrich, L.A., Glegg, G., Fletcher, S., Dodds, W., Philippe, M. & Bailly, D. 2020. Using ecosystem service assessments to support participatory marine spatial planning. Ocean & Coastal Management, 188. https://doi.org/10.1016/j.ocecoaman.2020.105121

García-Llorente, M., Harrison, P.A., Berry, P., Palomo, I., Gómez-Baggethun, E., Iniesta-Arandia, I., Montes, C., García del Amo, D. & Martín-López, B. 2018. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodiversity and Conservation, 27, 1575–1597. https://doi.org/10.1007/s10531-016-1152-4

Garcia Rodrigues, J., Conides, A., Rivero Rodriguez, S., Raicevich, S., Pita, P., Kleisner, K., Pita, C., Lopes, P., Alonso Roldán, V., Ramos, S., Klaoudatos, D., Outeiro, L., Armstrong, C., Teneva, L., Stefanski, S., Böhnke-Henrichs, A., Kruse, M., Lillebø, A., Bennett, E., Belgrano, A., Murillas, A., Sousa Pinto, I., Burkhard, B. & Villasante, S. 2017. Marine and Coastal Cultural Ecosystem Services: knowledge gaps and research priorities. One Ecosystem, 2, e12290. https://doi.org/10.3897/oneeco.2.e12290

Garrett, A. 2019. Ecosystem services and the UK seafood industry. Available from: https://www.seafish.org/document/?id=bbc461fd-3710-4e1f-9e76-575508f91042

Gilby, B.L., Weinstein, M.P., Baker, R., Cebrian, J., Alford, S.B., Chelsky, A., Colombano, D., Connolly, R.M., Currin, C.A., Feller, I.C., Frank, A., Goeke, J.A., Goodridge Gaines, L.A., Hardcastle, F.E., Henderson, C.J., Martin, C.W., McDonald, A.E., Morrison, B.H., Olds, A.D., Rehage, J.S., Waltham, N.J. & Ziegler, S.L. 2021. Human Actions Alter Tidal Marsh Seascapes and the Provision of Ecosystem Services. Estuaries and Coasts, 44, 1628–1636. https://doi.org/10.1007/s12237-020-00830-0

Graham, L.J. & Eigenbrod, F. 2019. Scale dependency in drivers of outdoor recreation in England. People and Nature, 1, 406–416. https://doi.org/10.1002/pan3.10042

Gray, M. 2018. The confused position of the geosciences within the “natural capital” and “ecosystem services” approaches. Ecosystem Services, 34, 106–112. https://doi.org/10.1016/j.ecoser.2018.10.010

Green, J.M.H., Cranston, G.R., Sutherland, W.J., Tranter, H.R., Bell, S.J., Benton, T.G., Blixt, E., Bowe, C., Broadley, S., Brown, A., Brown, C., Burns, N., Butler, D., Collins, H., Crowley, H., DeKoszmovszky, J., Firbank, L.G., Fulford, B., Gardner, T.A., Hails, R.S., Halvorson, S., Jack, M., Kerrison, B., Koh, L.S.C., Lang, S.C., McKenzie, E.J., Monsivais, P., O'Riordan, T., Osborn, J., Oswald, S., Price Thomas, E., Raffaelli, D., Reyers, B., Srai, J.S., Strassburg, B.B.N., Webster, D., Welters, R., Whiteman, G., Wilsdon, J. & Vira, B. 2017. Research priorities for managing the impacts and dependencies of business upon food, energy, water and the environment. Sustainability Science, 12, 319–331. https://doi.org/10.1007/s11625-016-0402-4

Grilli, G., Ferrini, S., Luisetti, T. & Kerry Turner, R. 2021. The role of choice experiments in natural capital accounting approaches: fast track versus simulated exchange value in the Deben Estuary saltmarshes. Journal of Environmental Planning and Management, 1–20. https://doi.org/10.1080/09640568.2021.1957794

Harrison, P., Sier, A., Acreman, M., Bealey, B., Fry, M., Jones, L., Maskell, L., May, L., Norton, L., Read, D., Reis, S., Trembath, P. & Watkins, J. 207AD. Natural capital metrics. Phase 1 final report: central components. Available from: http://nora.nerc.ac.uk/id/eprint/519669/

Haslett, J.R., Garcia-Llorente, M., Harrison, P.A., Li, S. & Berry, P.M. 2018. Offshore renewable energy and nature conservation: the case of marine tidal turbines in Northern Ireland. Biodiversity and Conservation, 27, 1619–1638. https://doi.org/10.1007/s10531-016-1268-6

Hill, S.L., Hinke, J., Bertrand, S., Fritz, L., Furness, R.W., Ianelli, J.N., Murphy, M., Oliveros-Ramos, R., Pichegru, L., Sharp, R., Stillman, R.A., Wright, P.J. & Ratcliffe, N. 2020. Reference points for predators will progress ecosystem-based management of fisheries. Fish and Fisheries, 21, 368–378. https://doi.org/10.1111/faf.12434

Hooper, T., Ashley, M., Börger, T., Langmead, O., Marcone, O., Rees, S., Rendon, O., Beaumont, N., Attrill, M. & Austen, M. 2019. Application of the natural capital approach to the marine environment to aid decision-making. Available from: https://www.researchgate.net/profile/Tobias_Boerger/publication/332780893_Application_of_the_natural_capital_approach_to_the_marine_environment_to_aid_decision-making_PHASE_1_FINAL_REPORT/links/5cc95d4da6fdcc1d49bc6552/Application-of-the-natural-capital-a

Hooper, T. & Austen, M. 2020. Application of the natural capital approach to Sustainability Appraisal. Final Report. Available from: https://www.northdevonbiosphere.org.uk/uploads/1/5/4/4/15448192/sustainability_appraisal_final_report.pdf

Islam, M.M. & Hossain, M.M. 2017. Community Dependency on the Ecosystem Services from the Sundarbans Mangrove Wetland in Bangladesh, in: Wetland Science. Springer India, New Delhi, pp. 301–316. https://doi.org/10.1007/978-81-322-3715-0_16

Ivarsson, M., Magnussen, K., Heiskanen, A.-S., Navrud, S. & Viitasalo, M. 2017. Ecosystem services in MSP: ECOSYSTEM SERVICES APPROACH AS A COMMON NORDIC UNDERSTANDING FOR MSP. Available from: https://norden.diva-portal.org/smash/get/diva2:1138007/FULLTEXT01.pdf

JNCC & CEFAS. 2021. Marine accounts, natural capital, UK: 2021. Available from: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/marineaccountsnaturalcapitaluk/2021

Jones, L., Vieno, M., Morton, D., Hall, J., Carnell, E., Nemitz, E., Beck, R., Reis, S., Pritchard, N., Hayes, F., Mills, G., Cryle, P., Dickie, I., Koshy, A. & Holland, M. 2019. Developing estimates for the valuation of air pollution removal in ecosystem accounts. Final report for Office of National Statistics. Available from: http://nora.nerc.ac.uk/id/eprint/524081/

Kuhfuss, L., Rivington, M., Roberts, M. & James Hutton Institute 2018. The 'Payment for Ecosystem Services' approach - relevance to climate change. Available from: https://www.climatexchange.org.uk/media/3271/payment-for-ecosystem-services.pdf

Küpper, F.C. & Kamenos, N.A. 2018. The future of marine biodiversity and marine ecosystem functioning in UK coastal and territorial waters (including UK Overseas Territories) – with an emphasis on marine macrophyte communities. Botanica Marina, 61, 521–535. https://doi.org/10.1515/bot-2018-0076

Küpper, F.C. & Kamenos, N.A. 2017. Future of the Sea: Marine Biodiversity. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/663897/Future_of_the_Sea_-_Marine_Biodiversity_Final.pdf

Langle-Flores, A. & Quijas, S. 2020. A systematic review of ecosystem services of Islas Marietas National Park, Mexico, an insular marine protected area. Ecosystem Services, 46, 101214. https://doi.org/10.1016/j.ecoser.2020.101214

Leach, K., Grigg, A., O'Connor, B., Brown, C., Vause, J., Gheyssens, J., Weatherdon, L., Halle, M., Burgess, N.D., Fletcher, R., Bekker, S., King, S. & Jones, M. 2019. A common framework of natural capital assets for use in public and private sector decision making. Ecosystem Services, 36, 100899. https://doi.org/10.1016/j.ecoser.2019.100899

Lindegren, M., Holt, B.G., MacKenzie, B.R. & Rahbek, C. 2018. A global mismatch in the protection of multiple marine biodiversity components and ecosystem services. Scientific Reports, 8, 4099. https://doi.org/10.1038/s41598-018-22419-1

Lopes, R. & Videira, N. 2017. Modelling feedback processes underpinning management of ecosystem services: The role of participatory systems mapping. Ecosystem Services, 28, 28–42. https://doi.org/10.1016/j.ecoser.2017.09.012

Lovett, A., Turner, K., Sünnenberg, G., Ferrini, S., Stephanou, E. &, Greaves, S. 2018a. Feasibility study for a Marine Natural Capital Asset Index for Scotland. Available from: https://www.nature.scot/sites/default/files/2019-02/Publication 2019 - SNH Research Report 1071 - Feasibility study for a Marine Natural Capital Asset Index for Scotland.pdf

Lovett, A., Turner, K., Sünnenberg, G., Ferrini, S., Stephanou, E. & Greaves, S. 2018b. A Natural Capital Asset Check and Risk Register for the Anglian Water Combined Services Area. Available from: https://www.anglianwater.co.uk/environment/our-biodiversity-work/natural-capital/

Luisetti, T., Turner, R.K., Andrews, J.E., Jickells, T.D., Kröger, S., Diesing, M., Paltriguera, L., Johnson, M.T., Parker, E.R., Bakker, D.C.E. & Weston, K. 2019. Quantifying and valuing carbon flows and stores in coastal and shelf ecosystems in the UK. Ecosystem Services, 35, 67–76. https://doi.org/10.1016/j.ecoser.2018.10.013

Lusardi, J., Rice, P., Waters, R. & Craven, J. n.d. Natural Capital Indicators: for defining and measuring change in natural capital. Available from: http://publications.naturalengland.org.uk/publication/6742480364240896

MacDonald, M.A., de Ruyck, C., Field, R.H., Bedford, A. & Bradbury, R.B. 2020. Benefits of coastal managed realignment for society: Evidence from ecosystem service assessments in two UK regions. Estuarine, Coastal and Shelf Science, 244, 105609. https://doi.org/10.1016/j.ecss.2017.09.007

Maes, J., Teller, A., Erhard, M., Grizzetti, B., Barredo, J.I., Paracchini, M.L., Condé, S., Somma, F., Orgiazzi, A., Jones, A., Zulian, G., Vallecilo, S., Petersen, J.-E., Marquardt, D., Kovacevic, V., Malak, D.A., Marin, A.I., Czúcz, B., Mauri, A., Loffler, P., Bastrup-Birk, A., Biala, K., Christiansen, T. & Werner, B. 2018. Mapping and Assessment of Ecosystems and their Services. Luxemburg. Available from: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/5th MAES report.pdf

McKenna, T., Blaney, R., Brooker, R.W., Ewing, D.A., Pakeman, R.J., Watkinson, P. & O'Brien, D. 2019. Scotland's natural capital asset index: Tracking nature's contribution to national wellbeing. Ecological Indicators, 107, 105645. https://doi.org/10.1016/j.ecolind.2019.105645

McKinley, E., Ballinger, R.C. & Beaumont, N.J. 2018. Saltmarshes, ecosystem services, and an evolving policy landscape: A case study of Wales, UK. Marine Policy, 91, 1–10. https://doi.org/10.1016/j.marpol.2018.01.021

McKinley, E., Pagès, J.F., Wyles, K.J. & Beaumont, N. 2019. Ecosystem services: A bridge or barrier for UK marine stakeholders? Ecosystem Services, 37, 100922. https://doi.org/10.1016/j.ecoser.2019.100922

McNicholas, G. & Cotton, M. 2019. Stakeholder perceptions of marine plastic waste management in the United Kingdom. Ecological Economics, 163, 77–87. https://doi.org/10.1016/j.ecolecon.2019.04.022

McVittie, A., Hutchison, J., Marengo, I., Smith, N. 2019. South Atlantic Natural Capital Assessment; Modelling St Helena's Natural Capital. Available from: https://data.jncc.gov.uk/data/bcb4e6a3-02dc-44a6-88d1-f59be6c242a1/ot-nca-sup-sat-32-sth-apr2019.pdf

Mehring, M., Zajonz, U. & Hummel, D. 2017. Social-Ecological Dynamics of Ecosystem Services: Livelihoods and the Functional Relation between Ecosystem Service Supply and Demand—Evidence from Socotra Archipelago, Yemen and the Sahel Region, West Africa. Sustainability, 9, 1037. https://doi.org/10.3390/su9071037

Mullin, K. 2019. Natural capital and environmental justice: A socio-spatial analysis of ecosystem services in England. University of Leeds.

Mullin, K., Mitchell, G., Nawaz, N.R. & Waters, R.D. 2018. Natural capital and the poor in England: Towards an environmental justice analysis of ecosystem services in a high income country. Landscape and Urban Planning, 176, 10–21. https://doi.org/10.1016/j.landurbplan.2018.03.022

National Infrastructure Commission. 2021. NATURAL CAPITAL AND ENVIRONMENTAL NET GAIN. Available from: https://nic.org.uk/app/uploads/Updated-Natural-Capital-Paper-Web-Version-Feb-2021.pdf

Natural Capital Committee. 2019a. Net environmental gain: The Natural Capital Committee's response to Defra's commission. Available from:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/909268/ncc-advice-net-gain-response1.pdf

Natural Capital Committee. 2019b. Marine and the 25 Year Environment Plan. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/909093/ncc-advice-marine.pdf

Newton, A., Brito, A.C., Icely, J.D., Derolez, V., Clara, I., Angus, S., Schernewski, G., Inácio, M., Lillebø, A.I., Sousa, A.I., Béjaoui, B., Solidoro, C., Tosic, M., Cañedo-Argüelles, M., Yamamuro, M., Reizopoulou, S., Tseng, H.-C., Canu, D., Roselli, L., Maanan, M., Cristina, S., Ruiz-Fernández, A.C., Lima, R.F. de, Kjerfve, B., Rubio-Cisneros, N., Pérez-Ruzafa, A., Marcos, C., Pastres, R., Pranovi, F., Snoussi, M., Turpie, J., Tuchkovenko, Y., Dyack, B., Brookes, J., Povilanskas, R. & Khokhlov, V. 2018. Assessing, quantifying and valuing the ecosystem services of coastal lagoons. Journal for Nature Conservation, 44, 50–65. https://doi.org/10.1016/j.jnc.2018.02.009

Newton, A.C., Watson, S.C.L., Evans, P., Ridding, L., McCracken, M., Anger-Kraavi, A. & Bullock, J. n.d. Trends in Natural Capital, Ecosystem Services and Economic Development in Dorset. Available from: http://nora.nerc.ac.uk/id/eprint/525416/

O'Garra, T. 2017. Economic value of ecosystem services, minerals and oil in a melting Arctic: A preliminary assessment. Ecosystem Services, 24, 180–186. https://doi.org/10.1016/j.ecoser.2017.02.024

Office for National Statistics. 2017. Principles of Natural Capital Accounting. Available from: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting

Office for National Statistics. 2018. UK Natural Capital: interim review and revised 2020 roadmap. Available from: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/uknaturalcapitalinterimreviewandrevised2020roadmap

Office for National Statistics. 2017. UK natural capital: developing UK mountain, moorland and heathland ecosystem accounts. Available from: https://backup.ons.gov.uk/wp-content/uploads/sites/3/2017/07/UK-natural-capital-developing-UK-mountain-moorland-and-heathland-ecosystem-accounts-2.pdf

Outeiro, L., Ojea, E., Garcia Rodrigues, J., Himes-Cornell, A., Belgrano, A., Liu, Y., Cabecinha, E., Pita, C., Macho, G. & Villasante, S. 2017. The role of non-natural capital in the co-production of marine ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management, 13, 35–50. https://doi.org/10.1080/21513732.2017.1415973

Özdemiroğlu, E. 2019. Natural capital – a practitioner's overview of concepts and applications. Journal of Environmental Economics and Policy, 8, 343–352. https://doi.org/10.1080/21606544.2019.1639220

Palomo, I., Willemen, L., Drakou, E., Burkhard, B., Crossman, N., Bellamy, C., Burkhard, K., Campagne, C.S., Dangol, A., Franke, J., Kulczyk, S., Le Clec'h, S., Abdul Malak, D., Muñoz, L., Narusevicius, V., Ottoy, S., Roelens, J., Sing, L., Thomas, A., Van Meerbeek, K. & Verweij, P. 2018. Practical solutions for bottlenecks in ecosystem services mapping. One Ecosystem, 3, e20713. https://doi.org/10.3897/oneeco.3.e20713

Perkins, D.M., Durance, I., Edwards, F.K., Grey, J., Hildrew, A.G., Jackson, M., Jones, J.I., Lauridsen, R.B., Layer-Dobra, K., Thompson, M.S.A. & Woodward, G. 2018. Bending the rules: exploitation of allochthonous resources by a top-predator modifies size-abundance scaling in stream food webs. Ecology Letters, 21, 1771–1780. https://doi.org/10.1111/ele.13147

Picone, F., Buonocore, E., D'Agostaro, R., Donati, S., Chemello, R. & Franzese, P.P. 2017. Integrating natural capital assessment and marine spatial planning: A case study in the Mediterranean sea. Ecological Modelling, 361, 1–13. https://doi.org/10.1016/j.ecolmodel.2017.07.029

Pouso, S., Borja, Á. & Uyarra, M.C. 2020. An Interdisciplinary Approach for Valuing Changes After Ecological Restoration in Marine Cultural Ecosystem Services. Frontiers in Marine Science, 7. https://doi.org/10.3389/fmars.2020.00715

Quijas, S., Romero-Duque, L.P., Trilleras, J.M., Conti, G., Kolb, M., Brignone, E. & Dellafiore, C. 2019. Linking biodiversity, ecosystem services, and beneficiaries of tropical dry forests of Latin America: Review and new perspectives. Ecosystem Services, 36, 100909. https://doi.org/10.1016/j.ecoser.2019.100909

Raum, S. 2018. A framework for integrating systematic stakeholder analysis in ecosystem services research: Stakeholder mapping for forest ecosystem services in the UK. Ecosystem Services, 29, 170–184. https://doi.org/10.1016/j.ecoser.2018.01.001

Raum, S. 2017. The ecosystem approach, ecosystem services and established forestry policy approaches in the United Kingdom. Land Use Policy, 64, 282–291. https://doi.org/10.1016/j.landusepol.2017.01.030

Reed, M.S., Allen, K., Attlee, A., Dougill, A.J., Evans, K.L., Kenter, J.O., Hoy, J., McNab, D., Stead, S.M., Twyman, C., Scott, A.S., Smyth, M.A., Stringer, L.C. & Whittingham, M.J. 2017. A place-based approach to payments for ecosystem services. Global Environmental Change, 43, 92–106. https://doi.org/10.1016/j.gloenvcha.2016.12.009

Rees, S.E., Ashley, M. & Cameron, A. 2019. North Devon Marine Pioneer 2: A Natural Capital Asset and Risk Register. Available from: https://www.researchgate.net/publication/332225506_North_Devon_Marine_Pioneer_2_A_Natural_Capital_Asset_and_Risk_Register

Rees, S.E., Sheehan, E. V., Stewart, B.D., Clark, R., Appleby, T., Attrill, M.J., Jones, P.J.S., Johnson, D., Bradshaw, N., Pittman, S., Oates, J. & Solandt, J.-L. 2020. Emerging themes to support ambitious UK marine biodiversity conservation. Marine Policy, 117, 103864. https://doi.org/10.1016/j.marpol.2020.103864

Runko Luttenberger, L., Gudelj, I. & Hršak, V. 2018. Natural Capital Preservation in the Coastal Area. Pomorstvo, 31, 191–200. https://doi.org/10.31217/p.31.2.4

Ryfield, F., Cabana, D., Brannigan, J. & Crowe, T. 2019. Conceptualizing 'sense of place' in cultural ecosystem services: A framework for interdisciplinary research. Ecosystem Services, 36, 100907. https://doi.org/10.1016/j.ecoser.2019.100907

Saarikoski, H., Primmer, E., Saarela, S.-R., Antunes, P., Aszalós, R., Baró, F., Berry, P., Blanko, G.G., Goméz-Baggethun, E., Carvalho, L., Dick, J., Dunford, R., Hanzu, M., Harrison, P.A., Izakovicova, Z., Kertész, M., Kopperoinen, L., Köhler, B., Langemeyer, J., Lapola, D., Liquete, C., Luque, S., Mederly, P., Niemelä, J., Palomo, I., Pastur, G.M., Peri, P.L., Preda, E., Priess, J.A., Santos, R., Schleyer, C., Turkelboom, F., Vadineanu, A.,

Verheyden, W., Vikström, S. & Young, J. 2018. Institutional challenges in putting ecosystem service knowledge in practice. Ecosystem Services, 29, 579–598. https://doi.org/10.1016/j.ecoser.2017.07.019

Schröter, M., Stumpf, K.H., Loos, J., van Oudenhoven, A.P.E., Böhnke-Henrichs, A. & Abson, D.J. 2017. Refocusing ecosystem services towards sustainability. Ecosystem Services, 25, 35–43. https://doi.org/10.1016/j.ecoser.2017.03.019

Selig, E.R., Hole, D.G., Allison, E.H., Arkema, K.K., McKinnon, M.C., Chu, J., Sherbinin, A., Fisher, B., Glew, L., Holland, M.B., Ingram, J.C., Rao, N.S., Russell, R.B., Srebotnjak, T., Teh, L.C.L., Troëng, S., Turner, W.R. & Zvoleff, A. 2019. Mapping global human dependence on marine ecosystems. Conservation Letters, 12. https://doi.org/10.1111/conl.12617

Sing, L., Metzger, M.J., Paterson, J.S. & Ray, D. 2018. A review of the effects of forest management intensity on ecosystem services for northern European temperate forests with a focus on the UK. Forestry: An International Journal of Forest Research, 91, 151–164. https://doi.org/10.1093/forestry/cpx042

Smale, D.A., Wernberg, T., Oliver, E.C.J., Thomsen, M., Harvey, B.P., Straub, S.C., Burrows, M.T., Alexander, L. V., Benthuysen, J.A., Donat, M.G., Feng, M., Hobday, A.J., Holbrook, N.J., Perkins-Kirkpatrick, S.E., Scannell, H.A., Sen Gupta, A., Payne, B.L. & Moore, P.J. 2019. Marine heatwaves threaten global biodiversity and the provision of ecosystem services. Nature Climate Change, 9, 306–312. https://doi.org/10.1038/s41558-019-0412-1

Small, N., Munday, M. & Durance, I. 2017. The challenge of valuing ecosystem services that have no material benefits. Global Environmental Change, 44, 57–67. https://doi.org/10.1016/j.gloenvcha.2017.03.005

Smith, A.C., Harrison, P.A., Pérez Soba, M., Archaux, F., Blicharska, M., Egoh, B.N., Erős, T., Fabrega Domenech, N., György, Á.I., Haines-Young, R., Li, S., Lommelen, E., Meiresonne, L., Miguel Ayala, L., Mononen, L., Simpson, G., Stange, E., Turkelboom, F., Uiterwijk, M., Veerkamp, C.J. & Wyllie de Echeverria, V. 2017. How natural capital delivers ecosystem services: A typology derived from a systematic review. Ecosystem Services, 26, 111–126. https://doi.org/10.1016/j.ecoser.2017.06.006

Solé, L. & Ariza, E. 2019. A wider view of assessments of ecosystem services in coastal areas: the perspective of social-ecological complexity. Ecology and Society, 24, art24. https://doi.org/10.5751/ES-10883-240224

Solomonsz, J., Melbourne-Thomas, J., Constable, A., Trebilco, R., van Putten, I. & Goldsworthy, L. 2021. Stakeholder Engagement in Decision Making and Pathways of Influence for Southern Ocean Ecosystem Services. Frontiers in Marine Science, 8. https://doi.org/10.3389/fmars.2021.623733

Spake, R., Bellamy, C., Graham, L.J., Watts, K., Wilson, T., Norton, L.R., Wood, C.M., Schmucki, R., Bullock, J.M. & Eigenbrod, F. 2019. An analytical framework for spatially targeted management of natural capital. Nature Sustainability, 2, 90–97. https://doi.org/10.1038/s41893-019-0223-4

Stainthorp, R. 2020. NORTH DEVON MARINE NATURAL CAPITAL PLAN. Available from: https://www.northdevonbiosphere.org.uk/uploads/1/5/4/4/15448192/north_devon_marine_plan_final_version_approval__1_.pdf

Stebbings, E., Hooper, T., Austen, M.C., Papathanasopoulou, E. & Yan, X. 2021. Accounting for benefits from natural capital: Applying a novel composite indicator framework to the marine environment. Ecosystem Services, 50, 101308. https://doi.org/10.1016/j.ecoser.2021.101308

Stebbings, E., Papathanasopoulou, E., Hooper, T., Austen, M.C. & Yan, X. 2020. The marine economy of the United Kingdom. Marine Policy, 116, 103905. https://doi.org/10.1016/j.marpol.2020.103905

Sullivan, S. 2017. On 'Natural Capital', 'Fairy Tales' and Ideology. Development and Change, 48, 397–423. https://doi.org/10.1111/dech.12293

Thomas, H. & Bhola, N., WWF 2017. Assessing the integration of an ecosystem-based approach into UK and Ireland Marine Spatial Plans. Available from: https://www.wwf.org.uk/sites/default/files/2017-12/Final Report_WWF_Ecosystem-based approach in MSP %28002%29.pdf

Thornton, A., Luisetti, T., Grilli, G., Donovan, D., Hawker, R. & Johanna, P. 2019. Initial natural capital accounts for the UK marine and coastal environment. Available from: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=20240

Thornton, A, Luisetti, T., Grilli, G., Donovan, D., Phillips, R. & Hawker, J. 2019. Natural capital accounts for marine areas – UK experience. Available from: https://seea.un.org/sites/seea.un.org/files/uk_marine_accounts_paper_0.pdf

Tian, Y., Wu, H., Zhang, G., Wang, L., Zheng, D. & Li, S. 2020. Perceptions of ecosystem services, disservices and willingness-to-pay for urban green space conservation. Journal of Environmental Management, 260, 110140. https://doi.org/10.1016/j.jenvman.2020.110140

Tillin, H.M., Langmead, O., Hodgson, B., Luff, A., Rees, S., Hooper, T. & Frost, M. 2019. Feasibility study for a Marine Natural Capital Asset Index for Scotland. Available from: https://www.nature.scot/sites/default/files/2019-02/Publication 2019 - SNH Research Report 1071 - Feasibility study for a Marine Natural Capital Asset Index for Scotland.pdf

Tillin, H.M., Langmead, O., Pegg, S., Carr, S., Gibson- Hall, E., La Bianca, G., Luff, A., Keen, P.W., Wilding, C., Nicholson, J.C., Ivory, P. & van Rein, H. n.d. Development of JNCC Marine Ecosystem Services Optimisation models. Available from: https://data.jncc.gov.uk/data/73e5fe5a-e7d7-4205-8bbd-cce9277acadc/JNCC-Report-650-FINAL-WEB.pdf

Tinch, R., Bugter, R., Blicharska, M., Harrison, P., Haslett, J., Jokinen, P., Mathieu, L. & Primmer, E. 2018. Arguments for biodiversity conservation: factors influencing their observed effectiveness in European case studies. Biodiversity and Conservation, 27, 1763–1788. https://doi.org/10.1007/s10531-018-1549-3

Townsend, M., Davies, K., Hanley, N., Hewitt, J.E., Lundquist, C.J. & Lohrer, A.M. 2018. The Challenge of Implementing the Marine Ecosystem Service Concept. Frontiers in Marine Science, 5. https://doi.org/10.3389/fmars.2018.00359

UK Government. 2020. The government's response to the Natural Capital Committee's State of Natural Capital Report 2020. Available from: https://www.gov.uk/government/publications/natural-capital-committees-seventh-annual-report-government-response/the-governments-response-to-the-natural-capital-committees-state-of-natural-capital-report-2020

UK Government. 2017. How to do it: a natural capital workbook. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957503/ncc-natural-capital-workbook.pdf

UK National Ecosystem Assessment. 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. Cambridge. Available from: https://www.sustainabilityexchange.ac.uk/files/uk_nea_synthesis_report.pdf

Urquhart, J. & Acott, T. 2014. A Sense of Place in Cultural Ecosystem Services: The Case of Cornish Fishing Communities. Society & Natural Resources, 27, 3–19. https://doi.org/10.1080/08941920.2013.820811

Veidemane, K., Ruskule, A., Strake, S., Purina, I., Aigars, J., Sprukta, S., Ustups, D., Putnis, I. & Klepers, A. 2017. Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia. International Journal of Biodiversity Science, Ecosystem Services & Management, 13, 398–411. https://doi.org/10.1080/21513732.2017.1398185

Velasco, A.M., Pérez-Ruzafa, A., Martínez-Paz, J.M. & Marcos, C. 2018. Ecosystem services and main environmental risks in a coastal lagoon (Mar Menor, Murcia, SE Spain): The public perception. Journal for Nature Conservation, 43, 180–189. https://doi.org/10.1016/j.jnc.2017.11.002

Verutes, G.M., Arkema, K.K., Clarke-Samuels, C., Wood, S.A., Rosenthal, A., Rosado, S., Canto, M., Bood, N. & Ruckelshaus, M. 2017. Integrated planning that safeguards ecosystems and balances multiple objectives in coastal Belize. International Journal of Biodiversity Science, Ecosystem Services & Management, 13, 1–17. https://doi.org/10.1080/21513732.2017.1345979

Walz, A., Schmidt, K., Noebel, R., Bullock, C., Cojocaru, G., Collier, M.J., Lentsch, A. de V., Dyankov, A., Ingwall-King, L., Joyce, D., Lascurain, J., Lavorel, S., Marba, N., Metzger, M., Rosário, I., Ruiz-Frau, A., Santos-Reis, M. & Scholte, S. 2017. Integrating stakeholder perspectives into environmental planning through social valuation of ecosystem services: Guidance and Prototype Applications. Available from: https://oppla.eu/sites/default/files/uploads/synthesisscvaluationmarch2017.pdf

Watson, S. & Newton, A. 2018. Dependency of Businesses on Flows of Ecosystem Services: A Case Study from the County of Dorset, UK. Sustainability, 10, 1368. https://doi.org/10.3390/su10051368

Watson, S.C.L., Preston, J., Beaumont, N.J. & Watson, G.J. 2020. Assessing the natural capital value of water quality and climate regulation in temperate marine systems using a EUNIS biotope classification approach. Science of The Total Environment, 744, 140688. https://doi.org/10.1016/j.scitotenv.2020.140688

Wentworth, J. 2021. Rebuilding marine biodiversity. Available from: https://post.parliament.uk/rebuilding-marine-biodiversity/

Wigley, S., Paling, N., Rice, P., Lord, A. & Lusardi, J. 2020. National Natural Capital Atlas: Mapping Indicators (NECR285). Available from: http://publications.naturalengland.org.uk/publication/4578000601612288

Willcock, S., Martinez-Lopez, J., Dandy, N. & Bullock, J.M. 2021. High Spatial-Temporal Resolution Data across Large Scales Are Needed to Transform Our Understanding of Ecosystem Services. Land, 10, 759. https://doi.org/10.3390/land10070759

Willis, C., Papathanasopoulou, E., Russel, D. & Artioli, Y. 2018. Harmful algal blooms: the impacts on cultural ecosystem services and human well-being in a case study setting, Cornwall, UK. Marine Policy, 97, 232–238. https://doi.org/10.1016/j.marpol.2018.06.002

Woodhead, A.J., Hicks, C.C., Norström, A. V., Williams, G.J. & Graham, N.A.J. 2019. Coral reef ecosystem services in the Anthropocene. Functional Ecology, 1365-2435.13331. https://doi.org/10.1111/1365-2435.13331

Wüstemann, H., Bonn, A., Albert, C., Bertram, C., Biber-Freudenberger, L., Dehnhardt, A., Döring, R., Elsasser, P., Hartje, V., Mehl, D., Kantelhardt, J., Rehdanz, K., Schaller, L., Scholz, M., Thrän, D., Witing, F. & Hansjürgens, B. 2017. Synergies and trade-offs between nature conservation and climate policy: Insights from the “Natural Capital Germany – TEEB DE” study. Ecosystem Services, 24, 187–199. https://doi.org/10.1016/j.ecoser.2017.02.008

Zulian, G., Stange, E., Woods, H., Carvalho, L., Dick, J., Andrews, C., Baró, F., Vizcaino, P., Barton, D.N., Nowel, M., Rusch, G.M., Autunes, P., Fernandes, J., Ferraz, D., Ferreira dos Santos, R., Aszalós, R., Arany, I., Czúcz, B., Priess, J.A., Hoyer, C., Bürger-Patricio, G., Lapola, D., Mederly, P., Halabuk, A., Bezak, P., Kopperoinen, L. & Viinikka, A. 2018. Practical application of spatial ecosystem service models to aid decision support. Ecosystem Services, 29, 465–480. https://doi.org/10.1016/j.ecoser.2017.11.005

Appendix 1: Abbreviations and acronyms

Abbreviation/Acronym	Description
CICES	Common International Classification of Ecosystem Services
Defra	Department for Environment, Food & Rural Affairs
EEA	European Environment Agency
ESVD	Ecosystem Service Valuation Database
EVRI	Environmental Valuation Reference Inventory
EUNIS	European Natural Information System
JNCC	Joint Nature Conservation Committee
MPA	Marine Protected Area
MRMP	Marine Resource Management Plan
NERC	Natural Environment Research Council
NORA	NERC Open Research Archive
ORVal	Online Recreation Valuation tool
SWOT	Strengths-Weaknesses-Opportunities-Threats
NEA	National Ecosystem Assessment
QSR	Quick Scoping Review

Appendix 2: Glossary

Term	Definition	Source
Benefit	The goods and services that are ultimately used and enjoyed by people and society.	UN *et al.* (2021)
Ecosystem service(s)	Direct and indirect value(s) or benefit(s) people and society receive from ecosystems.	BS 8632
First phase screening	The first phase of screening of the evidence found by the evidence review, using only the title or headline of the evidence found.	Collins *et al.* (2015)
Natural capital	Stocks of the elements of nature that provide benefits to society, such as forests, fisheries, rivers, biodiversity, soils, minerals, the atmosphere and oceans, as well as natural processes and functions. Natural capital includes both the living and non-living aspects of ecosystems.	BS 8632
Natural capital approach	A natural capital approach integrates the concept of natural capital into decision-making. Thinking in 'capital' terms enables comparison of many changes and decisions at the same time. The natural capital approach uses information from, and provides input to, many existing environmental management and analytical approaches.	Capitals Coalition (2019)
Natural capital asset	Distinctive component or grouping of biotic and abiotic components and other elements which function together or interact within a spatial area, including ecosystems, ecological communities, species, soils, freshwater, land, atmosphere, minerals, sub-soil assets and oceans.	BS 8632
Natural capital extent	The quantity, volume, or amount of a natural capital asset.	BS 8632
Natural capital condition	Quality of natural capital assets measured in terms of their biotic and abiotic characteristics and their ability to maintain flows of benefits.	BS 8632
Materiality	Impact or dependency on natural capital is material if consideration of its value (irrespective of whether or not that value can be quantified or monetized), as part of the set of information used for decision making, has the potential to alter that decision.	BS 8632
Second phase screening	Screening phase that involves reading the abstract or first paragraph of the evidence that has passed the first screening phase in order to identify evidence that will be used further in the evidence extraction and synthesis stages of the evidence review.	Collins *et al.* (2015)
Quick scoping review	A type of evidence review that aims to provide an informed conclusion on the volume and characteristics of an evidence base and a synthesis of what that evidence indicates in relation to a question.	Collins *et al.* (2015)

Appendix 3: Review Catalogue and SWOT analyses workbook

This workbook has been created for JNCC by eftec, ABPmer, Viridian, PML.

eftec, in partnership with ABPmer, Viridian Logic, and PML, aimed to identify a uniform approach to applying the natural capital approach to managing the marine environment. The project reviewed existing marine natural capital tools, methods and projects to inform a Strength, Weakness, Opportunity, Threat (SWOT) analysis of existing natural capital approaches as well as provide recommendations for future research. In addition, a Quick Scoping Review (QSR) will address the key evidence gap identified in order to make the best possible contribution to strengthening the application of a marine natural capital approach in the UK. The findings of both the SWOT analysis and the QSR will be summarised in a summary report.

This workbook collates information about existing marine natural capital products and provide a summary of the evidence base through product reviews. It also presents an in-depth SWOT analysis of each product against four categories, identifying the strengths, weaknesses, opportunities, and threats across the evidence base. Note the purpose of the SWOT is not to review the methodologies applied, but rather how the evidence produced by the product can be used to support marine environmental management and decision-making. Some of the products were designed to deliver one part of the natural capital approach and inevitably have gaps on other parts. In the context of this review, these gaps were noted as weaknesses against those individual products. Each of the products' marine components was reviewed individually relative to the five features of the natural capital approach (i.e., looking at combinations of co-designed products was beyond the scope). Hence, the SWOT has not assessed how co-developed products cover each other's main weaknesses. A recommended further step in this analysis would be to assess the individual products in combination to identify how they work collectively and understand if they offer a package that points towards a preferred marine natural capital approach.

See: JNCC-Report-702-Appendix3-Review Catalogue & SWOT Analyses Workbook.xlsx

[https://hub.jncc.gov.uk/assets/a0a9b99c-823c-4396-9445-325a99502876]

Appendix 4: Detailed SWOT criteria

The following features of each product were identified as the most relevant and hence the focus of the SWOT analyses for an in-depth overview:

1. Natural capital assets
2. Ecosystem services
3. Climate change and other impacts
4. Natural capital approach

Each feature was reviewed against a set of SWOT criteria and detailed criteria. The former is presented in Section 2.2.2, whilst the latter are presented within this appendix.

Natural capital assets

Table 9: Detailed SWOT criteria for natural capital assets.

SWOT criteria	Detailed SWOT criteria
Asset coverage	• Coverage of assets in the product • Granularity of asset categories covered • Asset location information and the importance given to location in the product
Asset extent	• Extent measures used (e.g. kilometres) • Use of quantified measures, metrics, indicators and models • Data sources used and methods applied • Confidence in measure and scale of existing evidence • Scalability, repeatability and transferability
Asset condition	• Condition measure used • Use of quantified measures, metrics, indicators and models • Data sources used and methods applied • Confidence in measure and scale of existing evidence • Scalability, repeatability and transferability • Impact of human activities on asset condition

Ecosystem services

Table 10: Detailed SWOT criteria for ecosystem services.

SWOT criteria	Detailed criteria
Ecosystem service coverage	• Coverage of ecosystem services and benefits in the product • Granularity of ecosystem services and benefits categories covered • The importance given to ecosystem services and benefits in the product
Ecosystem service physical flow	• Benefits measures used • Type of assessments (i.e. qualitative and/or quantified physical flow) • Use of metric, indicators and/or models (e.g. whether they are used and why) • Data sources used and methods applied • Confidence in measure and scale of existing evidence • Scalability, repeatability, and transferability
Ecosystem service valuation	• Type of assessment (monetary value estimated) • Ability to link to economic valuation approaches • Scalability, repeatability, and transferability
Ecosystem service delivery and status	• Status of ecosystem services and benefits • Impacts of human activities on ecosystem services • Scalability, repeatability, and transferability

Climate change and other impacts

Table 11: Detailed criteria for climate change and other impacts.

SWOT criteria	Detailed criteria
Coverage of climate change and other impacts	• Coverage of climate change and/or other impacts in the product • Assets and/or ecosystem services affected • Methods of accounting for climate change and other impacts in the product • Thresholds, tipping points, sustainability or regulatory limits considered • Scale of existing evidence • Scalability and transferability
Trends and risks	• Trends and risks identified • Future profiling • Confidence levels used nad reported

Natural capital approach

Table 12: Detailed criteria for natural capital approach.

SWOT criteria	Detailed criteria
Consistency with natural capital approach	The degree to which the product: • Focuses on stocks of natural capital assets and flows of benefits • Uses both biotic and abiotic natural capital assets • Assesses future changes in stocks and flows • Considers dependencies between economic activities and natural capital and their impact on natural capital • Uses valuation of impacts and dependencies (i.e. qualitative, quantitative and/or monetary) • Uses specific classification systems or frameworks that are used in each product and their effectiveness, robustness, repeatability and scalability • Links between assets and services and asset condition to the provision of services • Is responsive to changes in status, or service delivery of indicators and model • Holds what scale of evidence at the required levels: at the marine protected area (MPA), marine resource management plan (MRMP) and UK scale • Includes impacts of management measures on asset condition and services • Links all the above features to support systems-based thinking for policy and management

Appendix 5: Quick scoping review protocol

To address the priority research question defined in Section 3.1.1 through QSR, the following review protocol was developed in line with the Defra and NERC guidance on rapid evidence assessments (Collins *et al.* 2015).

Background

Following from the SWOT analyses and the recommendations for future research, the QSR focuses on the priority of understanding how the literature covers the distribution of benefits across beneficiaries in order to strengthen the application of a marine natural capital approach in the UK. The review will inform JNCC about the size and features of the available evidence base relating to the priority question.

The QSR is conducted in line with Defra and NERC guidance outlined in '*The Production of Quick Scoping Reviews and Rapid Evidence Assessments'* (Collins *et al.* 2015). Performing a QSR will allow reviewers to consider a more focused body of evidence some of which may have been outside the scope of the initial evidence review and SWOT analyses.

Scope

Due to time and resource constraints, a maximum of 200 documents will be reviewed as part of the QSR. This is to ensure that reviewers have sufficient time to review all literature comprehensively and ensure the quality of the QSR results.

In order to ensure the 200 documents collected are relevant, some restrictions have been placed on publication timing and document types. These restrictions are defined in the 'Evidence Search Strategy' section below. Within these restrictions, any evidence which is deemed to be relevant to answering the priority research question (as defined below) can be included in this analysis.

Objectives

Priority question for review: **What evidence exists to understand the distribution of the benefits of marine and coastal ecosystem services to different beneficiary groups***?*

The QSR will give an overview of the evidence that is available regarding the priority question but will not necessarily give a full set of answers regarding how ecosystem services or benefits are distributed across beneficiaries. The QSR will also identify gaps in the existing evidence base.

Evidence search strategy

Evidence sources

The review will consider literature from a variety of sources including databases, government reports, journal articles, policy briefings, academic publications, technical reports and working papers.

Relevant literature will be systematically collected by entering the combinations of keywords and phrases into search engines and literature databases as shown in the table below. Each time one keyword or phrase will be chosen from each column (these will be combined using the logical operator OR) i.e. we will apply the logical operator AND down the rows in the second column.

Exact keyword combinations will not be searched for, rather the occurrence of each individual keyword shall be searched for within documents.

Table 13: Search terms used in the QSR.

Search term category	Key search terms
Habitat type	• Marine • Coastal
Ecosystem service / natural capital	• Ecosystem service(s) • Natural capital
Beneficiary type	• Users • Beneficiary • Beneficiaries • Stakeholders • Dependencies • Distribution
Location	• UK

Please note that these are the initial search criteria which might be refined at a later stage if required. Particularly, more specific searches with narrow criteria might be proposed if the search results leave blanks e.g. 'ecosystem services' might be replaced with references to specific services such as tourism or recreation, etc. Similarly, we might want to search for specific types of beneficiaries e.g. public/non-public etc.

Search engines and databases

- Google
- Google Scholar
- NERC Open Research Archive (NORA)
- EVRI database
- ESVD database

Within each database/search engine, evidence searches will only be performed for those documents published between 2017 – 2021 inclusive.

For each combination of search term entered into the search engines (with relevant filters), the results of the first page of search results shall be added to the literature log. All results will be added to the log regardless of their title or how relevant they initially appear to be. Only unique search results will be added to the log. If a single source appears in search results across multiple combinations of keywords, it shall only be logged once. In instances where the results of a keyword combination have all already been logged, then the search will still be restricted to the first page, and no additional literature will be added.

Methods

Relevant literature will be documented in an evidence log and reviewed through a two-stage screening process. The first stage of this screening process will collect high-level summary information about the document such as the author, year of publication, type of source, the keywords/phrases used to find it, and the database from which it was collected.

Once this first stage has been completed, all literature will be put through a more in-depth review during the second stage of the screening process. This stage will determine whether a piece of literature is relevant by collecting information answering any supporting questions such as: if any beneficiaries are identified, who they are, how they were identified and how they were related to ecosystem services, asset location(s), and the types of ecosystem services and benefits considered.

Inclusion and exclusion criteria

During the second stage of the screening process, literature will be identified as being relevant according to the following criteria:

Inclusion Criteria:

- Must identify marine or coastal ecosystem services
- Must identify actual or potential beneficiaries of ecosystem services
- Should identify distribution of beneficiaries (i.e. distribution of beneficiaries does not have to be identified for a study to be relevant, however, each relevant study must be assessed against this criterion)

Exclusion Criteria:

- File cannot be accessed (unless the relevant information can be found in the abstract or any other available part of the study).
- File is not published between the years 2017 and 2021.

Appendix 6: QSR evidence base

Excel document collating the body of evidence that was reviewed for the quick scoping review. This is available upon request.