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Cumulative Effects Assessments to support marine plan development

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Executive Summary

This report presents an assessment of Cumulative Effects Assessment (CEA) methodologies and approaches as a means of supporting marine planning in the UK. The assessment or consideration of cumulative effects of human activities on the environment is a legal requirement driven by several policy instruments. However, the implementation of meaningful CEA (or Cumulative Impact Assessment) remains challenging due to a range of conceptual, scientific, and political uncertainties. The key to progress is to adopt a consistent, coherent, and acceptable approach to CEA.

To that end, this report presents the results of a study commissioned by JNCC to investigate the suitability of existing CEA methods relative to the requirement to adopt a standardised approach to CEA in support of marine plan development. The study comprised a literature review, interviews with practitioners and those requiring CEAs (including marine planners), and a critical assessment of CEA methodologies to determine the strengths and weaknesses relative to marine planning needs.

The study identified multiple possible CEA approaches, which resulted in the assessment of 15 different CEA methodologies. While some CEA methodologies have been applied to marine planning and management scenarios, the implementation of CEA in practical rather than academic situations are less commonplace. The most positive finding was identifying CEA methods that provide meaningful outputs where there is sufficiently robust data and information underpinning the assessment. Secondly, there are robust risk assessment approaches that can provide greater confidence in impact assessments where there are shortfalls in data. The study stops short of recommending a single, preferred CEA methodology, due to the need to better define the requirement driving each CEA to ensure the most appropriate method is applied.

The report concludes with a set of recommendations, which include:

- Define what CEA is needed for: define the context, the questions and the guiding principles, and what outputs are required to meet end user needs.
- Design and adopt an approach that supports the implementation of CEA as a process that can draw upon multiple CEA methodologies to address specific questions, while also providing consistency, coherence, and transparency.
- Enable a modular approach that can adapt to emerging technological advances.
- Agree the baseline to permit iterations and incremental improvements, and to enable a common baseline from which to bind together marine plans.
- Develop capacity among practitioners, institutions, and users to deliver consistent CEA across marine planning and delivery.

List of abbreviations

Abbreviation	Description
CE	Cumulative Effects
CEA	Cumulative Effects Assessment
CIA	Cumulative Impact Assessment
CIM	Cumulative Impact Map
DAPSIR	Driver-Activity-Pressure-State-Impact-Response framework
Defra	Department for Environment Food and Rural Affairs
DFO	Department of Fisheries and Oceans Canada
EIA	Environmental Impact Assessment
GES	Good Environmental Status
GIS	Geographical Information System
JNCC	Joint Nature Conservation Committee
MCAA	Marine and Coastal Access Act 2009
MMO	Marine Management Organisation
MSFD	Marine Strategy Framework Directive
NGO	Non-Governmental Organisation
NMP	Scotland's National Marine Plan
PMF	Priority Marine Feature
QAOP	Quantitative Analysis of Adverse Outcome Pathway
QSR	Quality Status Report
RMP	Scotland's Regional Marine Plans
SEA	Strategic Environmental Assessment
SwAM	Swedish Agency for Marine and Water Management
VC	Valued Component

Contents

1 Introduction

Across the UK, the uses of the marine environment have become more diverse and intensive, leading to higher demands on marine space and increasing pressures on marine habitats and wildlife. To ensure marine activities are planned and managed in a sustainable way that restores or maintains a healthy, clean, and diverse marine environment, the cumulative effects of multiple activities on the environment must be considered in decision making. Cumulative effects assessment (CEA) is a means of identifying the effects of multiple activities on the environment. Relative to many types of environmental assessment, CEA is a holistic approach that incorporates multiple activities, the pressures they create, and the impacts these pressures have on valued ecosystem components, such as marine habitats and species.

Although the academic discipline of CEA is relatively young, there is a growing and diverse range of models and approaches to conducting CEAs, each with varying benefits, challenges, and applications. In addition, definitions of what a CEA is vary and principles for application have not been agreed. The diversity of options available to marine planners has led to inconsistent CEAs and in some cases CEAs that are not fit-for-purpose. This has led to calls for a standardised CEA approach to be adopted across the UK to ensure that planning and management of the marine environment is supported by information that is consistent and coherent across sectors.

To support the adoption of a standardised CEA approach to support marine planning across the UK, the Joint Nature Conservation Committee (JNCC) commissioned Howell Marine Consulting (HMC) to work with a project Steering Group (including Marine Management Organisation, NatureScot, Scottish Government's Marine Directorate, Natural England, Natural Resources Wales, and Cefas) to conduct a literature review of recent CEA methods and to assess the suitability of short-listed methods as a tool to inform marine plan development. This report presents the findings of the literature review and the assessment of CEAs and includes recommendations for progressing the adoption of a consistent and coherent approach to assessing cumulative effects to support marine planning in UK waters.

2 Context

In busy waters, including those surrounding the UK, environmental and socio-economic outcomes are shaped by multiple causes, as opposed to one cause. Within that environment, marine policy, planning, and management bodies are working to ensure that biodiversity targets are not compromised and to reduce conflict between sectors and marine users. Coordinated planning and delivery will be greatly enhanced if informed by consistent, coherent, and accessible assessments of how single and multiple activities and events cause environmental change relative to a common baseline understanding. This in essence is what CEA should provide by systematically identifying and evaluating the significance of effects caused by multiple human activities and providing a reasoned judgement of the cumulative impact. The need for consistency stems from the likelihood that multiple CEAs will be required over time. The need for coherence stems from the possibility that the range of valued ecosystem components and the range of human activities may require bespoke approaches to address specific cumulative effects questions. And accessibility refers to the need for CEAs to speak to multiple stakeholders to increase impact and uptake.

The importance of cumulative effects as a driver of environmental change, coupled with the legislated obligations to assess and manage cumulative effects have led to high expectations of CEA. But despite decades of discussion about the importance of CEA, implementation of meaningful CEA remains partial at best. The assessments of cumulative impacts within recent offshore wind farm environmental impact assessments, for example, did not provide confidence that potential cumulative impacts were identified or evaluated (Willsteed *et al*. 2018b). There are multiple reasons why CEA implementation is challenging, including the realities of understanding how effects accumulate in complex adaptive systems combined with the lack of specificity about minimum requirements of CEA to meet policy needs.

In addition, there is no single accepted definition for CEA (or cumulative impact assessment, CIA). (In this report the term CEA is used to cover both CEA and CIA. Section 3, Definitions, provides greater context about terms used.) Definitions of CEA also vary; some researchers flag the lack of a universal definition as a problem (e.g. Cooper & Sheate, 2004) while other researchers note that the range of questions that require CEA precludes a single, appropriate definition being found for all scenarios (Judd *et al.* 2015; Willsteed *et al.* 2017). Further, simple definitions tend to reflect weak conceptions of cumulative effects and may mask the value set of the proponent (Duinker *et al.* 2012). However, the increasing pace of developments in coastal and marine systems in combination with climate change, and multiple international and national obligations to achieve sustainable development (noting that at the time of writing there are differences between the devolved nations, for example England has an integrated sustainability appraisal approach, while Scotland tends to keep SEA separate), provides continued impetus to overcome the shortcomings of CEAs completed for environmental impact assessments and strategic environmental assessments, and to bring systematic, regional CEA into marine planning and management. Sinclair (2017) conceptualised CEA as a series of lenses, covering three perspectives: technical; policy and legislative; and participatory. This study was intended to support UK marine planners and policy makers by providing insight into the first two perspectives, with the potential to influence the third.

3 Definitions

At the outset it is important to provide a set of definitions that guide the study and aid interpretation of the results. This includes defining the basic units of CEA, as definitions and interpretations of terms such as effect, impact, and cumulative effects vary across academia, across practice, and are variably referenced in UK legislation. Variations in understanding contribute to the variation in approaches, variation which is problematic for planners and regulators who need consistent CEAs that are robust and withstand scrutiny (Judd *et al.* 2015). The need to benefit from consistent practice and diverse approaches points towards frameworks and nested approaches to CEA (e.g. Tamis *et al.* 2021; Stelzenmüller *et al.* 2021). There is also an argument that in parallel with adopting a framework or nested approach to CEA, there is benefit in formalising the perspective and principles guiding CEAs for a common purpose to aid coherence across multiple CEAs (e.g. Tamis *et al.* 2015; Willsteed *et al.* 2018a).

For this study, the need is to define CEA in terms of marine plan development including the potential to support sustainability appraisals and SEA (again noting that at the time of writing there are differences between the devolved nations, for example England has an integrated sustainability appraisal approach, while Scotland tends to keep SEA separate).To define CEA requires a short detour into the nature of what is being assessed and to define key terms. For this study, effects are defined as changes to one or more valued components in a social-ecological system, that are the consequence of an action, stressor, or other cause (derived from Boehlert & Gill 2010). Valued components are entities or systems within social-ecological systems that we seek to conserve and/or restore, recover, or enhance. Impacts, which can be positive or negative, are defined as effects of sufficient intensity, duration, or severity that are predicted to cause significant measurable change in a valued component ('value' as defined by conservation legislation; from Boehlert & Gill 2010). The potential for positive impacts is relevant here, as there is potential that CEAs could provide robust information about Marine Net Gain outcomes associated with different planning scenarios, and to inform the need for and scale of strategic compensation measures under the Habitat Regulations. Significance is relative and can be subjective, particularly in the absence of thresholds, but is conceived here as being a measurement of the cost of impacts to valued components that can be weighed against the expected benefits of proceeding or continuing with an activity.

Cumulative effects are defined here as a predicted likely interaction of effects acting on a valued component over temporal and spatial scales set by the valued component. The definition highlights the need to be able to predict the likelihood and consequence of effects arising from multiple activities which cumulate, and the potential to measure and therefore validate predicted impacts. An additional consideration is the requirement for knowledge about the range of activities and other processes acting on valued components over scales relevant to that component ("the receptor's side matters" Segner *et al.* 2014). One additional consideration is the potential for effects to interact in additive, synergistic or irregular ways (Crain *et al.* 2008), however empirical or modelled studies about effect interactions, particularly at ecosystem scales are typically scarce, leading to recommendations to assume linear additive interactions in the absence of evidence to the contrary (Judd *et al.* 2015).

A Cumulative Effects Assessment (CEA) is defined here as a systematic assessment of the cumulative effects of multiple activities acting on a valued component, components, or ecosystem to derive an estimate of the impact of those activities to inform planning and management. This definition differs from academic definitions of CEA, as it includes an explicit purpose in providing information to planning and management. This study seeks to identify appropriate CEA approaches to support the development of marine plans, and so this definition is proposed to maintain focus on the outcome of the CEA as well as providing a framework from which to consider the strengths and weaknesses of different approaches.

Table 1. Definitions of terms commonly used in this document.

Term	Definition
Activity	A human activity taking place within the environment or area of interest (e.g. fishing, aquaculture, offshore wind development).
Pressure	A force acting upon the environment, as a consequence (directly or indirectly) of one or more activities that can negatively or positively affect components of the surrounding environment (e.g. noise, seafloor disturbance, or changes in nutrient flux).
Receptor	A component within the area of interest (usually an ecological component, such as a habitat or species) exposed to the pressure caused by an activity, both negatively and positively.
Valued Components	Entities or systems within social-ecological systems that we seek to con 2012serve and/or restore, recover, or enhance.
Cumulative effects	A predicted likely interaction of effects acting on a valued component over temporal and spatial scales set by the valued component.
Cumulative Effects Assessment	A systematic assessment of the cumulative effects of multiple activities acting on a valued component, components, or ecosystem to derive an estimate of the impact of those activities to inform planning and management.
Environmental Impact Assessment (EIA)	EIA is a process carried out to ensure that the likely significant environmental effects of certain projects are identified and assessed before a decision is taken on whether or how a proposal should be allowed to proceed.
Strategic Environmental Assessment (SEA)	SEA is a tool used at the policy, programme, plan-making stage to assess the likely effects of the PPP when judged against reasonable alternatives.

4 Cumulative effects literature

This section filters known CEA literature through a lens focused on CEA as a tool to support marine plan development and implementation. There is a wealth of literature on cumulative effects and to a lesser extent on CEA that can broadly be classified into two strands: research advancing CEA practice in response to legislative drivers, such as environmental protection law where legislation stipulates the consideration of cumulative effects in planning and development; and research driven by academia that responds to concerns about valued components, where CEAs provide evidence and insight into how cumulative effects are impacting valued components. There is a third strand to the literature base that focuses on how CEAs are used or respond to specific management questions. This is an emerging strand, but the few examples available provide useful insights for this project.

Literature and research that derive from seeking to understand how to meet the requirements set out in law can be traced back to the enactment of the National Environmental Policy Act of 1969 in the USA, which in turn was stimulated by popular and political concern over environmental degradation. Recognition that project-scale assessments were insufficient due to the scales over which valued components experience cumulative effects led to a burst of enquiry into CEA in the 1980s, which in terms of published literature appeared to stall before being driven forward again in the 21st Century by a proliferation of legislation requiring cumulative effects to be considered when making planning, development, and management decisions.

This research strand has reached consensus that project- or development-scale assessments are not effective relative to cumulative effects, and on the need for CEA to be applied at strategic or regional levels and scales. There is no consensus what to do with project-scale impact assessments; despite performing poorly as CEAs, Environmental Impact Assessments deliver high-resolution information that could contribute to overall understanding of the marine region (Willsteed *et al.* 2018a). Enabling coherence between assessment scales would be substantially enhanced by adopting an overarching framework with guiding principles that are scale independent.

The call from Judd *et al.* (2015) to increase CEA consistency and robustness to support marine planning and management is repeated in recent studies (e.g. Stelzenmüller *et al.* 2020; Tamis *et al.* 2021). Examples of contributing research in this regard include Tamis *et al.* (2015), Stelzenmüller *et al.* (2020) and Piet *et al.* (2021), who propose and test frameworks that can be replicated at different scales and for different valued components (VCs) and pressures. These frameworks apply risk-based approaches that simplify complexity, promote transparency regarding the treatment of uncertainty and can be iterated to make use of improved evidence. Importantly, such risk-based approaches permit progress and greater confidence in outputs when data are limited.

The literature base that stems from enquiry into the condition of valued components is diverse and expansive, with numerous published CEAs that address individual species (e.g. caribou, Johnson *et al.* 2015; harbour porpoises, Heinis *et al.* 2018), habitats (e.g. seagrass, Grech *et al.* 2011; fish habitat in estuaries, Teichert *et al.* 2016), and ecosystem functions and services (e.g. biodiversity: Andersen *et al.* 2015). The scale at which cumulative effects are assessed varies correspondingly from boundaries defined by the extent of pressures arising from a single development (e.g. within Environmental Impact Assessments), by species distribution (e.g. seabirds and bats, Leopold *et al.* 2014), to ecologically meaningful areas (e.g. watersheds, Squires & Dubé 2013; the Baltic, Korpinen *et al.* 2012) up to global marine areas (e.g. Halpern *et al.* 2008a, 2008b). and down to focused, fine-grained empirical studies of effects accumulating to impact protected populations (e.g. Stockbridge *et al.* 2021). Common threads within this research strand are found in the discussion sections, where there are calls for CEAs to be applied at strategic or regional scales, for additional data and novel approaches to analyse data, for progress defining thresholds and diverse values, and for better targeting of CEAs to address planning and management questions (reviewed in Willsteed *et al.* 2023). From the perspective of marine planning, a challenge with the knowledge generated by this research stream is the range and diversity of methods and outcomes, which present a challenge for planners in situations where coherence of outputs across ecosystem components is required (Judd *et al.* 2015).

The third research strand, research that links CEA methods with decision-making needs is less well developed. Academically driven CEAs often call for CEA outputs to be used in decision-making, but there is rarely consideration of, for example:

- how CEA would fit into the way decisions are currently made,
- how CEA could fit into a more progressive decision-making system, particularly where assessment scales are comparable between strategic and project-level assessments,
- how trade-offs are considered and conflicts are resolved, and
- what institutional learning is needed to bring CEA into the design and delivery of policy and planning.

There are notable exceptions, with frameworks explicitly designed for marine planning needs (e.g. Hammar *et al.* 2020; Stelzenmüller *et al.* 2020; Piet *et al.* 2021), and focused CEAs that were designed to support regulators responding to legislative demands (e.g. Murray *et al.* 2019; Lieske *et al.* 2020). Recent research is also progressing the potential to implement CEA at strategic scales. Tamis *et al.* (2021) provide an approach to project-level assessments that can be integrated into strategic planning and that specifically estimate cumulative impacts, addressing project-level CEA shortcomings while aiming for consistency between assessment scales. Sutherland *et al.* (2016) systematically selected indicators for strategic CEA, which offers a transferable approach to forecasting present and future indicator condition. CEA approaches have also been applied to inform the prioritisation of management measures. For example, Tulloch *et al.* (2022) identified that addressing priority threats to keystone VCs reduces risks across the wider ecosystem. An observation is that while there are calls to increase consistency, there are multiple frameworks available and multiple approaches that tackle distinct requirements. Additional analysis would be needed to determine what the differences between frameworks imply for planners and regulators.

A fourth and final research stream to touch on is the substantial body of research that underpins CEAs. Like all management tools, the effectiveness of CEAs correlates to the availability, quality, and resolution of data available to inform the assessment. More specifically, CEAs require information about how VCs are affected by and impacted by stressors and the interaction between stressors. For example, how do changes in temperature and contaminant concentrations impact the energetics and growth of individuals, and hence of populations? How are seabirds impacted by multiple turbine installations and changing prey availability? Important resources currently available that provide information on the pressures and sensitivities of key features in UK waters are MarLIN's MareESA tool and FeAST in Scotland, and the cause-effect pathways and linkages developed under ODEMM. As is explored further in the multi-criteria analysis section, the availability of data is fundamental to the effectiveness of a CEA and is a key constraint for the scale at which CEA can be applied.

Information that is relevant to understanding CEA can cross scales, from organism to population, from local to regional. Relevant information can also span disciplines. Condensing VC specific research relevant to assessments of change, in general it can be observed that CEAs require:

- Spatial and temporal knowledge about the VC and of associated pressures driving change in that VC, including understanding of sensitivity, vulnerability resilience, and recovery of VCs to individual pressures.
- A baseline that, as far as data and knowledge permits, defines what the status of a VC is, what the trend in that status is, and trends in associated pressures.
- Knowledge about how the effects of those pressures accumulate relative to the VC.

Beyond these knowledge requirements, and to bring assessment findings into context of ecological and regional outcomes, CEAs also require knowledge about the role of the VC relative to the social-ecological system. Ecological network modelling using software such as ECOSIM has been used for this purpose in CEAs, for example investigating the effects of offshore wind developments on marine ecosystems in the English Channel (Rauox *et al.* 2018).

The range of relevant information points to the potential need for interdisciplinary CEAs, which may need to draw on multiple sources of data and expertise. Recognising this, and the importance of nested scales and of boundary-spanning information needs, questions arise about the capacity and infrastructure required by marine planners, regulators, academics, and practitioners to enable efficiency in information collation and sharing, knowledge about how to use different types of evidence, what capacity is needed to deliver and review CEAs.

The most recent review of CEAs is from Willsteed *et al.* (2023) that collated 118 academic papers and articles deemed relevant to inquire into the state of knowledge regarding CEA in marine and coastal environments. The paper included an analysis of 78 screened papers and articles and found that:

1. Calls to be explicit about a CEAs intention and objectives remain valid, with about half the research reviewed not defining the purpose of the CEA and the underlying interpretation of cumulative effects.
2. About 75% of CEAs applied quantitative methods that led to cumulative impact maps (loosely referred to as “CIM”, cumulative impact maps that are generally rooted in the Halpern *et al.* (2008b) CIM method). The range of methodologies applied is diverse, even within the CIM field, as different CEAs applied different levels of analysis to mapped outcomes, ranging from a simple presentation of overlapping pressures and sensitive valued components, to the additional application of statistical correlations and general linear modelling to inquire into relationships and trends.
3. Data requirements tend to be high. Murray *et al.* (2019), reporting on a formal CEA on a data-rich highly protected species, provides an indication of the range of data that was included to deliver a scientifically robust and planning-delivery directed CEA. Almost all CEAs state that more data are required to increase confidence in CEA outputs and expert opinion is commonly used. Recognising the need to progress CEA, risk-based frameworks have been emerging in recent years that provide a robust approach when significant knowledge gaps exist. Risk assessment approaches also speak a language that is often understood by industry stakeholders (Murray, pers. com), although specific terminology between ecological risk assessment approaches and EIA/SEA can differ pointing to the need to clarify language across stakeholders and assessment approaches.
4. Most CEAs responded to the recognised need for regional or strategic scale CEAs, focusing on ecosystems or valued components that are used as proxies for ecosystem status. Across the 78 CEAs, assessments focused on investigating the consequences of cumulative effects on: ecosystems; on multiple valued components;

or individual valued components. Within these broad categories, the range of components and pressures assessed is diverse.

5. Temporal analysis that is fundamental to measuring environmental change remains uncommon in CEA. About 75% of CEAs present a snapshot of time. CEAs that include explicit temporal analysis remain less common and involve greater analytical complexity. Recent CEAs more frequently note the need to increase static CEA value through updates, though this is dependent on underlying datasets being maintained. One option is to design CEAs around ongoing monitoring programmes or to explicitly build CEA into planning cycles and state of the seas assessments as required by national/devolved nation marine legislation.

6. In terms of methods and outputs, GIS algorithms applied to activity and valued component spatial datasets remain the most common, resulting in simple pressure maps or complex spatial analyses estimating the cumulative contribution of stressors on valued components. Examples of driver-activity-pressure-state-impact-response frameworks or derivatives (DAPSIR) are less numerous, while the least common CEA approaches are those that measure demographic change. The inclusion of formal risk assessment approaches is increasing over time in response to the need to enable rigorous CEAs that communicate uncertainty and trade-offs, and that can support ecosystem-based management by addressing the likelihood that accepted risks to ecosystem state changes will be exceeded.

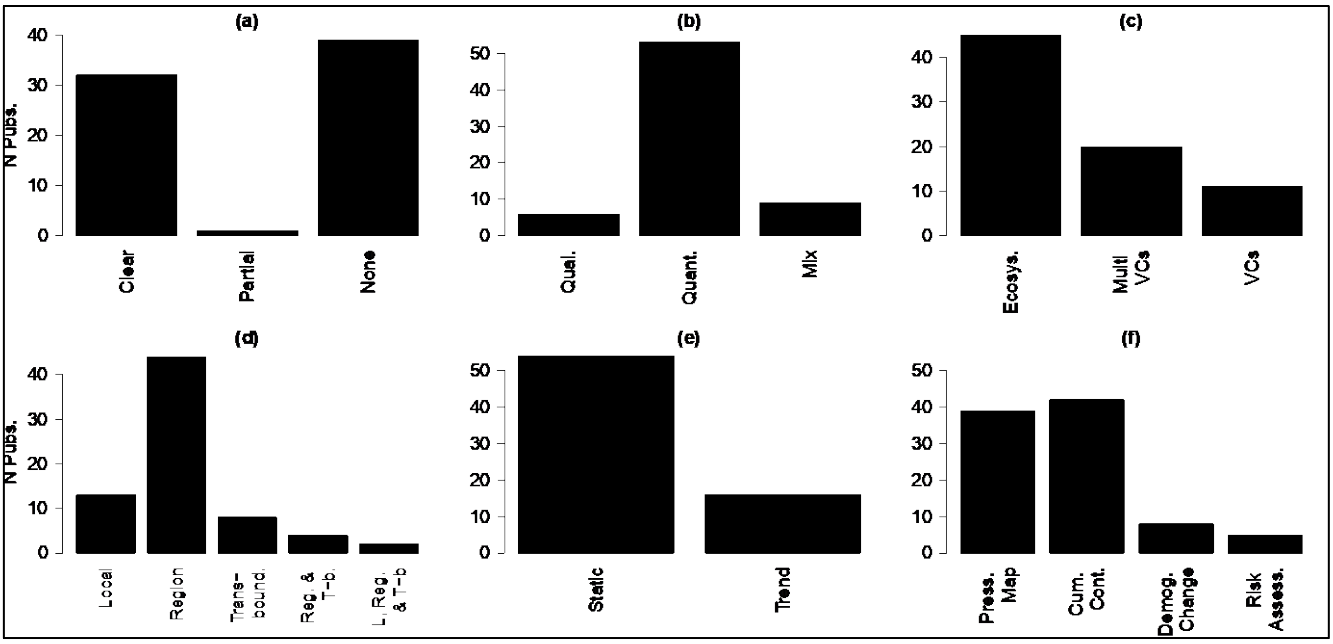

Figure 1. Counts of CEAs identified by Willsteed *et al.* (2023) against different criteria: a) with a clear definition of cumulative effects/impacts or no definition; b) applying qualitative, quantitative or mixed approaches; c) assessing cumulative effects on ecosystems, multiple VCs, or individual VCs; d) investigating effects over local, regional, transboundary, or a combination of spatial scales; e) presenting a snap-shot of cumulative effects (static) or where temporal trends are incorporated; f) with outputs coded as pressure maps, where the cumulative contribution of stressors were estimated, where demographic change was estimated, or where the risk of cumulative impacts were assessed. © Wilsteed *et al*. 2023.

The main observation relative to this study is the range of potential approaches and the range of questions to which CEA can be applied. Across the 78 CEAs reviewed, there is wide variance between the valued components at the centre of the assessments, the stressors and pressures included, and variable that is used to define ‘impact’. The data file accompanying this report (Annex 1) provides a list and detailed reviewed CEAs.

Advances in technology, specifically computing capacity, are undoubtably important to CEA. CEAs from the 1990s (e.g. Macdonald 2000) were substantially less computing heavy than the GIS cumulative impact maps produced in the 2000s (Halpern 2008b), which are in turn substantially less computing heavy than recent applications of the DPSIR-CEA model (Lin *et al.* 2023) or quantitative analysis of adverse outcome pathways approaches (QAOPs, e.g. Guo *et al.* 2023). With the emergence of machine learning and artificial intelligence, there is a strong argument that CEA capabilities will be very different in five years’ time, for example if an AI could transform and compare small-scale and large-scale datasets to build a multi-scale baseline for CEA. The relevance to this study and to CEA implementing agencies, is to consider the implications of adopting one CEA methodology or approach, how future-proof is the technology, or can specific CEA methodologies be deployed within an overarching, technology agnostic framework?

The final point in this section is to flag the importance of specificity and uncertainty to CEA. CEA is not a monolithic concept and can be applied as a tool to inform decision making in different ways. In addition, as highlighted by the definition of cumulative effects in the preceding section, effects interact in complex ways and over broad scales. The definition hints at an underlying challenge for CEA: how to provide robust and valued information about environmental change when there is i) substantial uncertainty about how effects accumulate in complex adaptive systems and ii) an expectation for clear direction and guidance for planning and management of licensed activities? An important starting point to address this challenge, and applies to this study also, is to specify what a CEA is for, who it is for, what it includes and excludes, and what the output means and to whom. This process helps frame cumulative effects questions that can guide identification of an appropriate CEA approach and brings into consideration proportionality and a means of weighing up value for money of more- or less complex approaches.

5 Interviews with experts

Experts, regulators, and practitioners experienced with CEAs, either through research or in their application, were consulted through a series of semi-structured meetings to gain further insight into: the application of CEAs in the marine environment, the different expectations in terms of use and outputs, the different methods of CEA being developed and used; the limitations of the different CEA methods, and the need for CEA in marine planning.

Among the 11 experts interviewed, there was consensus that for CEA to be applied effectively, it is essential to define the context within which it will be applied, identify the question that needs to be answered, and clarify what the expected outputs are. This is necessary to guide determination of which method is most appropriate for a given situation, the scale at which cumulative effects are assessed, and the information (e.g. data, evidence, and knowledge) that is required to inform the CEA. It is important to recognise that there is a difference between CEA approaches applied for an impact assessment and those used to inform planning and decision-making processes. Planning for example may require a CEA that tests the implications of different plan scenarios and can inform policies and plans to address trade-off decisions at a strategic level rather than identifying the cumulative impacts of one specific activity. Planners also expressed interest in integrating better CEAs into impact assessments including EIAs and SEAs, where consistency and effectiveness of current approaches are a concern.

Independent of which method of CEA is used, experts agreed that for those using the outputs of the assessment (e.g. marine planners or developers) need to understand how the outputs have been calculated and what the outputs mean for decision making. Further, a visual output (i.e. mapped spatial information) would be advantageous for communicating the findings of the CEA, particularly when presenting the findings to stakeholders, with the caveat that it is critical to also communicate the uncertainties and assumptions associated with mapped outputs.

In each of the interviews carried out, there was recognition that there is not one single method of CEA that can meet all needs, as many CEA methods have been developed to address specific questions and/or function at certain scales, resulting in each CEA method being context specific. Therefore, identifying the most appropriate CEA method to address the question being asked is essential. Interviewees expressed interest in knowing if it would be possible to identify and agree a suite of CEA methods that could be applied to different scenarios.

In many cases, CEA methods are technical, and it was commonly expressed that there is a need for experts to conduct the CEA to increase rigour, the correct proxies for ‘impact’ have been used, and the results have been interpreted and communicated correctly. Several options for building CEA expertise in marine planning emerged from discussions, including: the use of consultants, collaboration with academic institutions, internal training within marine planning teams, and the development of institutional capacity that can be drawn upon when a CEA is required. Independent of the approach used for conducting CEAs, interviewees pointed to the importance of consistency of language across CEA approaches and of likely benefits of establishing a centralised database to inform CEAs, which can be strengthened through the addition of data and CEA iterations.

Data availability was flagged as a challenge by all experts, who agreed that a baseline for CEAs is required, potentially covering a range of different scales, from which multiple assessments can be informed and can be validated against.

A key benefit of an aligned and integrated approach to CEAs across scales is moving away from siloed thinking and putting environmental requirements at the forefront of decision making. Some experts mentioned that there is a momentum to move away from feature-based assessments to ecosystem-focused ones, and that CEA is an approach that can enable ecosystem-based management through the provision of risk assessments of state changes due to different scenarios.

Overall, it was recognised by all experts interviewed that CEA is essential for marine planning and to meeting multiple policy objectives, by explicitly informing decision making relative to sustainable development goals. It was also emphasised that CEA are complex and highly context specific, suggesting that one single method will not be appropriate for all scenarios. Further, for CEA to be effectively and appropriately applied, it is essential that there is a shared understanding of what CEAs are, what the limitations of the data used are, and what their outputs mean. Whichever method is used, it is fundamental that the outputs and associated assumptions are clear, easily understood by the end user, and easy to communicate to a range of stakeholders.

6 Legal and policy context

6.1 Legal obligations

This section sets out the legal and policy context into which a CEA approach would be introduced to aid the specification of the CEA. There is an increasing recognition in legislation of the importance of considering multiple environmental impacts in combination and their cumulative effects (Judd *et al.* 2015). The following sections lay out instruments relevant to this study starting at international and regional levels, then at UK level, then at the level of the Devolved Administrations relative to marine planning.

6.1.1 International and regional (EU) law

The 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') provides a legal framework to regulate economic activities while safeguarding marine ecosystems and resources. Annex V Article 2 summarises the obligations of Parties to the Convention in relation to environmental protection:

> "ARTICLE 2.
>
> In fulfilling their obligation under the Convention to take, individually and jointly, the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected, as well as their obligation under the Convention on Biological Diversity of 5 June 1992 to develop strategies, plans or programmes for the conservation and sustainable use of biological diversity,
>
> Contracting Parties shall:
>
> a. take the necessary measures to protect and conserve the ecosystems and the biological diversity of the maritime area, and to restore, where practicable, marine areas which have been adversely affected; and
>
> b. cooperate in adopting programmes and measures for those purposes for the control of the human activities identified by the application of the criteria in Appendix 3."

OSPAR are guided by the ecosystem approach, defined as *"*… the comprehensive integrated management of human activities based on the best available scientific knowledge of the ecosystem and its dynamics, to identify and take action on drivers, activities and pressures that adversely affect the health of marine ecosystems. The ecosystem approach thereby achieves the sustainable use of ecosystem goods and services and the maintenance of ecosystem integrity. The ecosystem approach takes into consideration cumulative effects …" (OSPAR 2021)*.* OSPAR considers CEA's to be an enabling process for an ecosystem-based approach in decision-making through a Drivers-Activities-Pressures-State-Impact-Response framework and has therefore integrated it into the suite of Thematic Assessments in the OSPAR's Quality Status Report 2023 (Figure 2).

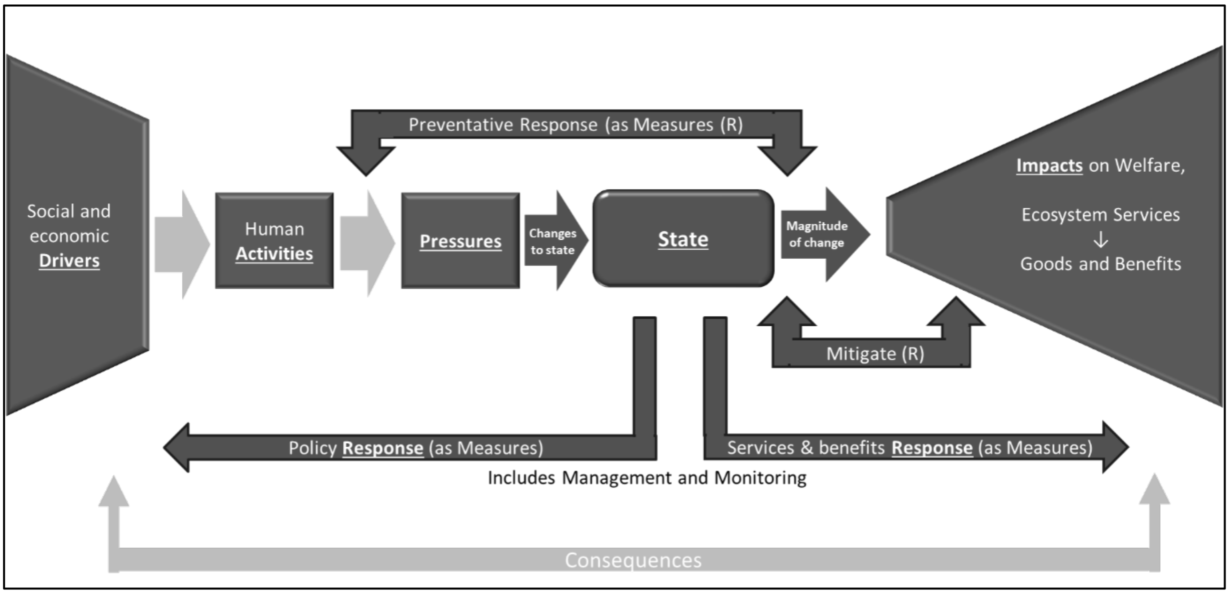

Figure 2. OSPAR process for CEAs (taken directly from OSPAR Agreement 2023-01 (adapted from Judd & Lonsdale 2021)).

Another Convention of 1992 – the Convention on Biological Diversity, incorporates an ecosystem-based approach and requires Parties under Art. 7 to:

> "(c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques;"

And through Article 14 on Impact Assessments to:

> "(a)Introduce appropriate procedures requiring environmental impact assessment of its proposed projects that are likely to have significant adverse effects on biological diversity with a view to avoiding or minimizing such effects and, where appropriate, allow for public participation in such procedures;"

With the adoption of a new global framework under the CBD – the Kunming Montreal Global Biodiversity Framework, cumulative effects are included in Target 7 relating to the impacts form pollution.

In relation to assessing environmental impacts resulting from human activities, EU Directives initiating and incorporating requirements to assess cumulative effects on the environment include the following:

- 1992: 92/43/EEC (Habitats Directive)
- 2000: 2000/60/EC (Water Framework Directive)
- 2001: 2001/42/EC (SEA Directive)
- 2008: 2008/56/EC (Marine Strategy Framework Directive)
- 2009: 2009/147/EC (Birds Directive)
- 2014: 2014/52/EU (EIA Directive)

The most important aspect of these legally binding instruments is that an assessment of impacts or effects is required prior to a project or planned activity in order to make an informed decision on, for example, approving such activity/plan/project, mitigating or avoiding impacts, or reducing risks. Furthermore, the Marine Strategy Framework Directive (MSFD) required the UK to conduct an initial assessment of the state of the marine environment, which, in line with Article 8, should take cumulative effects into account:

> “Article 8. Assessment 1.
>
> In respect of each marine region or subregion, Member States shall make an initial assessment of their marine waters, taking account of existing data where available and comprising the following:
>
> (b) an analysis of the predominant pressures and impacts, including human activity, on the environmental status of those waters which:
>
> […]
>
> (ii) covers the main cumulative and synergetic effects”

These have been transposed into national legislation and retained following EU exit through the European Withdrawal Act 2018, as described in the next section.

6.1.2 National laws driving CEA requirement

The national legislative framework enabling the application of CEAs is based on the requirements for environmental assessments for plans and projects under several relevant instruments, and the development of marine plans. The following sections provide a brief overview of these laws, their focus/purpose and relevance to consider cumulative effects.

1. The requirement for Sustainability Appraisals for development plans and planning, through the Environmental Assessment of Plans and Programmes Regulations 2004 (amended 2020) and the Marine and Coastal Access Act 2009, ensure that a strategic environmental assessment (SEA) is carried out, considering not only environmental factors and impacts but social and economic issues alongside in the decision-making process. These regulations implement Directive 2001/42/EC.

The Marine Works (Environmental Impact Assessment) Regulations 2007 regulate environmental requirements for planned projects that need regulatory approval. The Marine Works EIA Regs require an EIA for projects that are likely to have a significant impact on the environment and oblige regulatory authorities to consider such potential of significant effects in the decision-making process. Whether an EIA should be conducted, is subject to a screening process. Schedule 3 of the Marine Works EIA regs specifies the requirements for an environmental statement that the developers must provide for any given project. It stipulates that such statement should entail cumulative effects (2c) but does not explicitly demand how these should be included.

However, there are some projects with are exempt from an EIA, which are not likely to have significant effects (the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020).

2. The requirement for an appropriate assessment for projects and plans having the potential to cause significant effects on a European Site through the **Habitats Regs 2017** (as amended 2019 following EU exit - the Conservation of Habitats and Species Regulations 2017 and The Conservation of Offshore Marine Habitats and Species

Regulations 2017). These effects must take into consideration the cumulative impacts in combination with other plans or projects. In cases where the plan is subject to an appropriate assessment then it will normally also require a Strategic Environmental Assessment.

Devolved governments have set up their own legislative instruments, which reflect those requirements. For example, in Scotland the main relevant instrument through which the requirement for strategic environmental assessment was brought into practice is the Environmental Assessment (Scotland) Act 2005.

6.2 Policy development

Policies are enabling actions plans or guidelines that, as a minimum, fulfil legal obligations and provide more detail on processes and requirements. They are also simpler to update and therefore more adaptable to evolving needs. There are several marine policies that support and drive the need to consider the cumulative effect of activities, plans, and projects:

UK Marine Strategy: Based on the EU's MSFD, as transposed through the Marine Strategy Regulations 2010, obliged the UK to conduct an initial assessment of the state of the UK's marine environment by 2012, as mentioned above, and submit updated reports on the progress of achieving Good Environmental Status (GES) every six years for eleven descriptors. (These are: Descriptor 1: Marine biodiversity; Descriptor 2: Non-indigenous species; Descriptor 3: Commercial fish and shellfish; Descriptor 4: Food webs; Descriptor 5: Eutrophication; Descriptor 6: Seabed integrity; Descriptor 7: Hydrographical conditions; Descriptor 8: Contaminants; Descriptor 9: Contaminants in seafood; Descriptor 10: Marine litter; Descriptor 11: Energy, including underwater noise; including the impacts of climate change.) For many descriptors the cumulative effects of human pressures are dominated by one or a small number of pressures. To manage those and achieve GES, the establishment of a monitoring programme, as updated in 2021 (part 2), and programme of measures (updated 2023, part 3), is required.

2011 UK Marine Policy Statement: The main policy guiding marine plan development and highlights that planning and decision-making should identify management for potential impacts of human activities, including cumulative effects.

> "The marine plan authority will need to consider the potential cumulative impact of activities and, using best available techniques, whether for example:
>
> - The cumulative impact of activities, either by themselves over time or in conjunction with others, outweigh the benefits;
> - A series of low impact activities would have a significant cumulative impact which outweighs the benefit;
> - An activity may preclude the use of the same area/resource for another potentially beneficial activity.
>
> These considerations will be picked up in the Marine Plan making process particularly through the Sustainability Appraisal for each Marine Plan created under the Marine and Coastal Access Act 2009. The Sustainability Appraisal will consider the potential social, economic, and environmental benefits and adverse effects of the proposals set out in a draft Marine Plan. It will incorporate a Strategic Environmental Assessment (SEA). An Appropriate Assessment may also be required for a Marine Plan and an impact assessment will also need to be undertaken."

This policy goes further by stating that within the planning process cumulative effects can inform limits and specific targets for a plan area (Section 2.3.1.6):

> "Marine Plans should provide for continued, as well as new, uses and developments in appropriate locations. They should identify how the potential impacts of activities will be managed, including cumulative effects. Close working across plan boundaries will enable the marine plan authority to take account of the cumulative effects of activities at plan boundaries. The consideration of cumulative effects alongside other evidence may enable limits or targets for the area to be determined in the Marine Plan, if it is appropriate to do so."

Scotland Blue Economy Vision (2022) set outs Scotland's ambitions for develop marine industries and emphasizes that:

> **"**There will be difficult choices in delivering the aspirations contained within this vision. Science and evidence must underpin decision-making about what activities are prioritised where and when. This will involve consideration of co-dependencies, synergies or trade-offs between different interests and any cumulative impacts."

National Policy Statements for Energy Infrastructure (NPS), revised in January 2024, are a material consideration for the MMO when making decisions in accordance with the Marine Policy Statement and any applicable marine plans. Within the NPS, it states that for offshore wind and multi-purpose interconnector projects:

> "…development consent applications should include details of how connected infrastructure will be consented, how cumulative impacts will be assessed and whether any necessary consents, permits and licences have been obtained."

Further, with regards to weighing proposed developments adverse impacts against its benefits, the Secretary of State should take into account:

> "…its potential adverse impacts, including on the environment, and including any long-term and cumulative adverse impacts, as well as any measures to avoid, reduce, mitigate or compensate for any adverse impacts, following the mitigation hierarchy."

6.2.1 Marine plans and planning

The laws mentioned in Section 6.1 guide the processes and principles of marine development and planning. Marine developments (plans and projects), as described above are integrated and guided by strategic planning strategies in form of marine plans. Marine plans across the UK are being implemented under the following legislation:

- England & Wales: Marine and Coastal Access Act 2009 (MCAA)
- Scotland: Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009
- Northern Ireland: Marine Act (Northern Ireland) 2013

In Scotland, the development of regional and sectoral marine plans form part of the planning framework as set out in the National Marine Plan. The Marine (Scotland) Act stipulates that in the process of preparing regional and national plans, an assessment must be carried out to determine the condition of the plan area, including significant pressures and impacts from human activities.

Part 3 of the 2009 MCAA regulates the process of marine planning for England and the Scottish offshore region, as outlined in Figure 3. Under the MCAA the marine plan authority has a duty to maintain oversight over 'relevant matter', which include, inter alia:

> "(a) the physical, environmental, social, cultural and economic characteristics of the authority's region and of the living resources which the region supports;
>
> […]
>
> (d) any other considerations which may be expected to affect those matters."
>
> (3) The matters also include—
>
> > (a) any changes which could reasonably be expected to occur in relation to any such matter;
> >
> > (b) the effect that any such changes may have in relation to the sustainable development of the region, its natural resources, or the living resources dependent on the region."

Further, Schedule 6, Part 10 of the MCAA states that "a marine plan authority preparing a marine plan must carry out an appraisal of the sustainability of its proposals for inclusion in the plan." As indicated under the SEA Regs, these plans are subject to reviews and sustainability appraisals, which can lead to amendments of a marine plan.

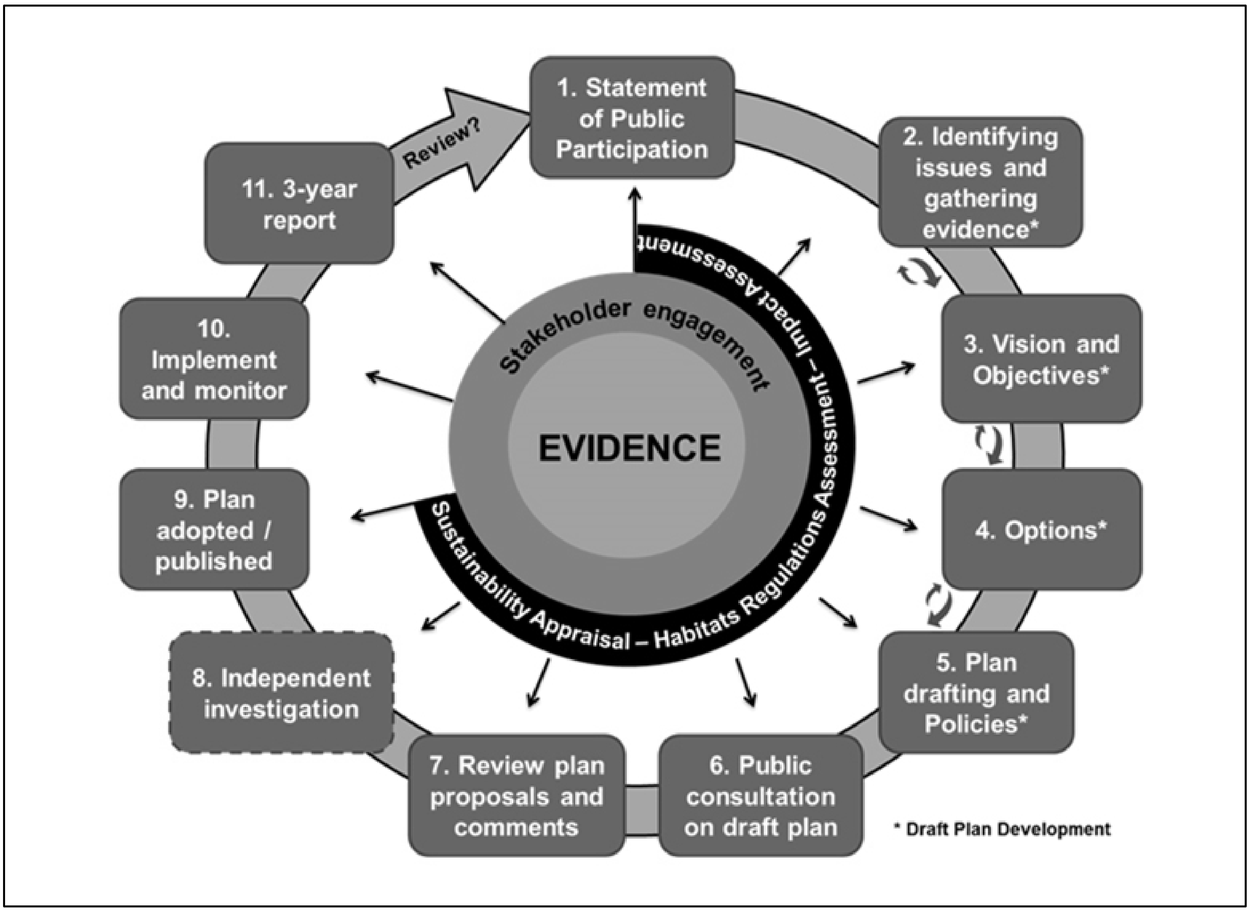

Figure 3. Schematic diagram of the marine planning process in England (image from [MMO](MMO)).

6.2.2 Status of marine plans

The current status of marine plans across the UK is described in the following and there are several opportunities where CEA could inform the development or review of such plans.

6.2.2.1 England

The responsibility of developing, monitoring, and reporting on marine plans is a delegated function of the MMO. The English marine planning authority is the Secretary of State for the Environment, Food and Rural Affairs.

Eleven marine plan areas were developed covering all English waters, following a Defra-led public consultation. The MMO subsequently developed the following six marine plans covering all 11 areas:

- East Inshore and Offshore Marine Plans – 2 April 2014 (currently being replaced)
- South Inshore and South Offshore Marine Plan (the South Marine Plans) – 17 July 2018
- North East Inshore and North East Offshore Marine Plans – 23 June 2021
- North West Inshore and North West Offshore Marine Plans – 23 June 2021
- South West Inshore and South West Offshore Marine Plans – 23 June 2021
- South East Inshore Marine Plan – 23 June 2021

With the legal requirement, under the MCAA, all plans are subject to a review every three years. Cumulative effects are considered in the plans, an example in the North-West Marine Plan states:

> "Proposals which may have adverse cumulative effects with other existing, authorised, or reasonably foreseeable proposals must demonstrate that they will, in order of preference:
>
> a) avoid
>
> b) minimise
>
> c) mitigate
>
> - adverse cumulative and/or in-combination effects so they are no longer significant."

6.2.2.2 Scotland

Marine Scotland (now known as Scottish Government's Marine Directorate) published a National Marine Plan (NMP) in 2015, which covers all of Scotland's inshore and offshore waters. An updated version of the NMP, set to replace the current version, is currently under development. Within the 'General Policies' of the first NMP, cumulative effects are considered and "should be addressed in decision making and plan implementation." Guidance on how this should be carried out is also provided:

> "Planning authorities and decision makers will consider the potential cumulative impact of activities and, using best available techniques, whether:
>
> - the cumulative impact of activities, either by themselves over time or in conjunction with others, outweigh the benefits;

- a series of low impact activities would have a significant cumulative impact which outweigh the benefit;
- an activity may preclude the use of the same area/resource for another potentially beneficial activity."

Scotland's NMP sets the marine planning framework and proposed 11 marine regions that extend out to 12 nautical miles from the coast, covering Scotland's inshore waters. There is potential for a Regional Marine Plan (RMP) to be developed for each of the regions, each in alignment with the policies of the NMP. Currently the Shetland, Clyde and Orkney regions are the most advanced in developing RMPs.

6.2.2.3 Wales

Wales developed a marine plan in 2019 with the objectives to:

> "Support the sustainable development of the Welsh marine area by contributing across Wales' well-being goals, supporting the Sustainable Management of Natural Resources (SMNR) through decision making and by taking account of the cumulative effects of all uses of the marine environment." (Objective 1)

A specific policy aim for cumulative effects within the plan states:

> "Proposals should demonstrate that they have assessed potential cumulative effects and should, in order of preference:
>
> a. avoid adverse effects; and/or
>
> b. minimise effects where they cannot be avoided; and/or
>
> c. mitigate effects where they cannot be minimised.
>
> If significant adverse effects cannot be avoided, minimised, or mitigated, proposals must present a clear and convincing case for proceeding. Proposals that contribute to positive cumulative effects are encouraged".

6.2.2.4 Northern Ireland

Northern Ireland is in the process on developing its marine plan, which will be made of two plans (inshore/offshore) covered in one document. The draft marine plan covers cumulative impacts as follows:

> "Public authorities must consider the cumulative impact of proposals on other marine activities, uses and/or the marine area. Where a proposal has a likely significant adverse cumulative impact, a public authority will require the proposer to demonstrate:
>
> a) that the likely significant adverse cumulative impact is avoided; or
>
> b) where the likely significant adverse cumulative impact is unavoidable, it is minimised and where appropriate mitigated; or
>
> c) where the likely significant adverse cumulative impact cannot be avoided or minimised, it is mitigated."

6.3 Legal and policy summary

Across the UK, the consideration of cumulative effects in decision-making is a legal obligation at both regional and national scales and can inform an ecosystem-based approach to managing human activities in the marine environment. In addition to informing and extending EIA, CEAs have the potential to improve and inform other legal obligations, such as marine plan reviews and development, and comprehensive status assessments of the overall environment, as required under the UKMS. While the law and respective policies clearly indicate the need for the consideration of cumulative effects on the environment, they do not define the approach to be taken, as this is context specific.

The following sections will discuss the applicability of different CEA methods.

7 Cumulative effects assessment in wider practice

Section 6 provides a brief introduction to CEA as applied to specific needs, including EIA, SEA, integrated planning, and to address cumulative impact questions targeted at specific valued components.

7.1 Environmental Impact Assessment

CEAs completed as subcomponents of EIAs have long been recognised as being inadequate for the task (Burris & Canter 1997; Canter & Ross 2010; Cooper & Canter 1997; Foley *et al.* 2017). Shortcomings relative to assessing cumulative effects stem from the narrow spatial boundaries applied by EIAs, by the lack of consideration of the range of pressures acting on receptors, shifting baselines and the difficulty assessing how significant project-level impacts are for valued components that are affected by multiple human activities (Duinker & Greig 2006; Squires & Dubé 2013; Therivel & Ross 2007). In brief, EIAs and the CEA methodologies used in EIAs are not suitable for cumulative effects assessment without being guided by an overarching approach and regional perspective (Willsteed *et al.* 2018a; Hague *et al.* 2022).

The information collected by project proponents to deliver EIAs is valuable and EIAs probably result in some of the most detailed surveying and monitoring data within the footprint of licence applications. For example, the British Marine Aggregates Producers Association regional assessment approach to determine cumulative effects of the aggregate extraction industry demonstrates the potential of organising and collating information across licence holders, and the consequent benefits to CEA. There is a substantial amount of high-resolution survey and monitoring data collected for EIAs, which, if made publicly available, has the potential to create a valuable resource of high-resolution data on the environment that could inform CEAs. However, issues over the commercial sensitivities of data sharing make this challenging. Further, weaving such data into a regionally coherent picture can be difficult. This challenge was recognised by Willsteed *et al.* (2018a), who recommended repurposing EIAs to deliver CEAs that feed an ongoing strategic CEA, where the former provides baseline data into the latter. This approach would enable a regional process that supports regional planning and management (Willsteed *et al.* 2018b).

7.2 Strategic Environmental Assessment

There have long been calls for cross-border regional or strategic approaches to CEA to overcome the shortcomings of project-led CEA. The rationale for strategic approaches to proceed project-level assessments is intuitive and well founded, in essence enabling the assessment of cumulative effects at broader regional scales and at the strategic level where there is more theoretical potential to manage cumulative effects (Lobos & Partidario 2014; Tetlow & Hanusch 2012). The reality tends to be less progressed, however.

In many instances project-level assessments have preceded strategic assessment (as with early offshore wind developments in the UK; Glasson *et al.* 2012) and SEAs have not reduced the reliance on project-level CEAs. Decision-making processes in SEA are often less robust than EIA processes (Gunn & Noble 2011). SEAs also suffer from the same conceptual challenges as EIA, such as what stressors and receptors should be included, what time and spatial scales for assessment are appropriate, how to consider exogenic pressures. SEAs also operate with the same knowledge gaps and so are limited by the same scientific uncertainties as EIAs, such as how receptors respond to multiple stressors.

It is also relevant that SEA emerged from EIA approaches and tend to apply standard EIA methods to impact assessment (Lobos & Partidario 2014). Many examples of SEA tend to apply an "EIA-plus" approach (Therivel & Ross 2007). focussing on the effects of a proposed policy, programme, or plans on receptors (ecological or social), rather than providing the more complete picture required that assesses how a receptor is being impacted by multiple activities (see Figure 4).

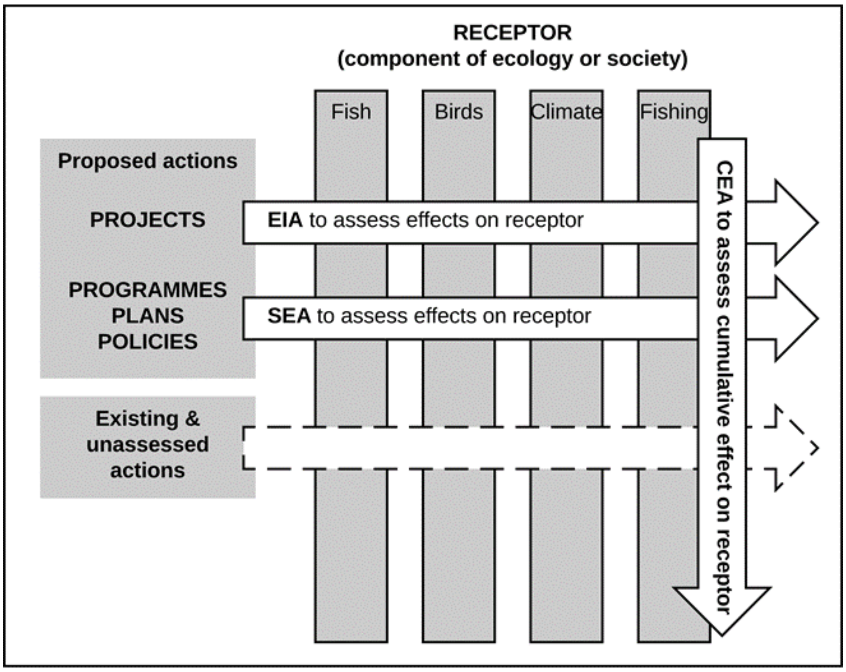

Figure 4. Relationship between EIA and SEA, and the theoretical role of cumulative effects assessment in cutting across the various assessment levels to provide a comprehensive understanding of how a receptor is impacted by the many actions effecting change. The dashed arrow indicates actions that are not subject to assessment, but which contribute to incremental change in receptor condition. Example of ecological and/or societal receptors are shown. Adapted from Therivel & Ross (2007).

By focusing on policies, plans, or programmes, rather than specific activity proposals, SEAs should permit better assessment of cumulative effects beyond individual projects, but as noted, progress has been slow. Canada provides an international example of progressing cumulative effects assessment within SEA, with guidance available to support practitioners and those requiring CEA within SEA (Scientific Criteria Documents / Regional Strategic Environmental Assessment in Canada [Principles and Guidance] / Practitioner's Guide to Federal Impact Assessments. The findings from Gunn and Noble (2009), who interviewed SEA-CEA practitioners and administrators, likely remain valid; SEA-CEA is most effective when supported by a regional vision about the future state of the environment and development, and when supported by targets, thresholds, and indicators. SEA-CEA or regional CEA would also be improved if connections with project-level CEA were strengthened. To this end, generic frameworks to coordinate tiered environment assessments have been proposed (e.g. CUMULEO), as well as conceptual frameworks to support coherence between local and regional assessments.

7.3 Integrated planning

One of the key regulatory challenges for managing cumulative effects is the varying spatial and temporal scales at which they occur and how they often differ from the activities that cause the original pressures. For example, a cumulative effect recognised by stakeholders may not be the result of pressures caused by local activities, but by activities in other areas, or past activities, whose impacts manifest at different scales. To develop management strategies that address cumulative effects, it is essential that the activities that cause disturbances, which contribute to the cumulative effect, are recognised and managed. Often, these activities take place outside the management area and an integrated planning approach is required.

Through the development of policy-driven, integrated plans that involve collaboration across jurisdictions, stakeholders, and landscapes, many of the challenges associated with cumulative effects can be addressed. Integrated plans have the potential to provide the "overarching framework for multi-jurisdictional engagement, the inclusion of community and stakeholder interests, the setting of ecological objectives informed by multi-sectoral interests, the compilation of information from different knowledge systems, and ecosystem-based and adaptive management" (Cormier *et al.* 2022).

Integrated plans are the "ideal platform for incorporating CE because comprehensive assessments of CE often require understanding of not only ecological impacts, but the human activities, policies, and legislative infrastructure that led to CE affecting the condition of natural resources" (Cormier *et al.* 2022).

Examples of integrated planning approaches include:

- Integrated Marine Management approach on UK Overseas Territories: Ascension Island and St Helena. In Ascension, cross-sectoral planning and management of marine conservation and sustainable use of resources to maximise socio-cultural and economic impacts. In St Helena, a new licensing framework for marine developments developed within an existing sustainable use MPA. (Hardman *et al.* 2022)
- Norwegian integrated management plans: integrated and comprehensive policy on the marine environment based on an ecosystem approach.
- The Great Barrier Reef 2050 Plan: Australian and Queensland Government's overarching framework for protecting and managing the Great Barrier Reef to 2050.
- Canadian watershed management: review of the cumulative effects considerations for integrated planning for freshwater and marine environments (Cormier *et al.* 2022).
- Beaufort Sea Partnership, Canada: Integrated Oceans Management Plan is a collaborative approach by Aboriginal, Territorial, and Federal government departments, management bodies, northern coastal community residents, industries, NGOs, academia, and other interested parties who collaborate in the decision-making processes that influence the future of the Beaufort Sea region.

7.4 Specific valued component

The fundamental design of CEAs enables the person conducting the assessment to focus on an activity, a pressure, or a valued component (i.e. receptor), depending on the question being addressed. While CEAs are often applied to proposed activities, recognising the pressure(s) they produce and the subsequent impact, many start with a valued component, for example a species or habitat, and work in the opposite direction by identifying pressures on that component and the activities that cause those pressures.

A component-focused CEA can take various forms. For example, in Scotland, the Centre for Ecology and Hydrology have begun a new project, ECOWINGS (Ecosystem Change, Offshore Wind, Net Gain and Seabirds), that will provide evidence about the predicted cumulative impacts all planned offshore wind developments will have on key seabird species, such as kittiwakes, guillemots, razorbills and puffins. In this case the valued components are seabirds, and the cumulative effect of interest stems from multiple examples of a single activity type (i.e. offshore wind farms).

Other component focused CEAs can target specific pressures. For example, in 2020, JNCC along with Natural England and DAERA produced ‘Guidance for assessing the significance of noise disturbance against conservation objectives of harbour porpoise SACs’. In this example, the specified valued component is the harbour porpoise, but the guidance focuses specifically on a single pressure (i.e. noise) within SACs from multiple marine activities, such as offshore wind development, the use of acoustic deterrents, and seismic surveys. Through this approach, a noise disturbance threshold can be established that all marine activities must operate within, minimising the impact on harbour porpoise and maintaining the integrity of the SAC.

Other examples of component-focused CEAs take a more comprehensive approach by identifying all the pressures on a particular species, and the activities associated with those pressures, to inform management. For example, in Canada, Clarke Murray *et al.* (2021) focused on the resident killer whale populations in the Northeast Pacific and used a Pathways of Effect conceptual model to assess the influence of several different anthropogenic threats and build future scenarios of different management and mitigation measures. This study highlighted the importance of considering the collective impact of multiple threats to imperilled species and the necessity of modelling different management approaches.

8 Cumulative effects assessments of marine areas

8.1 International

8.1.1 Sweden

The Symphony tool, developed by the Swedish Agency for Marine and Water Management (SwAM), is used to calculate how pressures from human activities in the ocean affects nature values in each location in the Swedish sea. It is a method to quantitatively weigh ecosystems and environmental pressures, which enables the cumulative environmental impact from different marine spatial planning options to be compared. The results are visualised in heat maps, enabling areas of high and low environmental impact to be easily identified.

There are five key steps to the Symphony method:

1. Develop a distribution map of ecosystem components (e.g. cod, fish spawning areas, mussel reefs).
2. Map the spatial intensity of environmental pressures from human activities.
3. Develop a sensitivity matrix describing how sensitive each ecosystem component is to each pressure.
4. Calculate the cumulative impact for every area of the sea by summing up all of the impacts of all environmental pressures on all ecosystem components.
5. Interpret the results using heat maps, which can be used in planning and stakeholder engagement showing different planning alternatives and find solutions with minimal environmental impact.

Symphony has been used in several international collaborations, including NorthSEE, Baltic LINes, and ClimeMarine. Symphony is also included in ongoing international collaboration with countries in the Western Indian Ocean through SwAM's Program for Development Cooperation (SwAM Ocean 2019–2022).

8.1.2 Baltic Sea Region

In recognition of the poor status of the Baltic Sea and the transboundary nature of human activities, pressures, and species distribution, cumulative impact assessments (CIA) of the Baltic Sea region within HELCOM (Baltic Marine Environment Protection Commission) have been carried out, producing the Baltic Sea Impact Index (BSII).

To facilitate a regionally coherent assessment of cumulative impacts, a BSII Cumulative Impact Assessment Toolbox (BSII CAT) was developed, which includes tools for calculating the BSII and the Baltic Sea Pressure Index. Further, it supports the identification of areas with high ecological value or high potential provision of ecosystem services.

The BSII methodology is currently used in environmental assessments of HELCOM, with the aim to develop on the connections between marine spatial planning and environmental management.

8.1.3 South Korea

Building on the CIA techniques used for marine spatial planning in Europe and North America, Choi *et al.* (2021) performed the first CIA in Korea, which involved an assessment of the cumulative impact of human activities on the marine ecosystem in Gyeonggi Bay. Information on the marine ecosystems and influencing activities was collected to inform an activity-pressure-ecosystem relationship approach.

The study provides an overview for quantifying the cumulative impact of marine activities within a spatial context, highlighting the importance of data collection and processing prior to performing a CIA, the need to consider the current conditions of the study area to improve the accuracy and reliability of CIA, and the need for improvements to analysis and mapping techniques.

8.1.4 Yellow Sea Large Marine Ecosystem

In their 2023 paper, Ma *et al.* investigated the application of CEA to the Yellow Sea Large Marine Ecosystem (YSLME), located between China and the Korean peninsula, recognising the need for transboundary cooperation between multiple countries with different marine spatial planning processes.

The approach adopted by Ma *et al.* built on the risk-based CEA framework, focusing on risk identification and spatially explicit risk analysis, with the aim of understanding the most influential cause-effect pathways and risk distribution pattern. Through this approach, Ma *et al.* were able to identify seven human activities and three pressures that were the main causes of environmental problems, identify the six most vulnerable ecosystem components to cumulative effects, and determine that cumulative effects were concentrated nearshore, although some could also be observed in the transboundary area.

8.1.5 Adriatic Sea

The Adriatic Ionian maritime spatial planning (ADRIPLAN) project aimed to deliver a commonly agreed approach to cross-border marine spatial planning in the Adriatic-Ionian region, focusing on the Northern Adriatic Sea and the Southern Adriatic/Northern Ionian Sea. For the project, a cumulative impact tool was developed and used as the main methodological tool in ADRIPLAN to evaluate the potential impact of marine activities on the environment by quantifying the pressures generated by the uses on the environmental components.

The tool was developed for the Adriatic-Ionian sub-basin but can be applied to any research area around the globe and was intended to be a useful instrument for supporting the construction of future marine spatial plans under an ecosystem-based approach.

The tool enables identifying the main environmental pressures emerging from each maritime activity and localising them in marine space. The main output of the tool is a spatial representation of cumulative impacts.

8.2 UK

8.2.1 Shetland Marine Region

As part of the development of the Shetland Island’s Marine Spatial Plan (now recognised as the Shetland Regional Marine Plan), a model for mapping cumulative effects of marine activities within the plan area was developed. (Kelly *et al.* 2014) The model adopted an ecosystem-based risk approach that used spatial data of marine activity (e.g. fishing, aquaculture, and shipping) and the pressures they create (using likelihood of impact, frequency, timescale to recovery, and confidence in data) to determine an impact score for each sector. The results were sense checked via workshops with sector experts to ensure the identified pressures were realistic and meaningful. Following the workshops, all activity was then analysed using the ArcGIS 'Weighted Sum' tool to create pressure maps based on combined cumulative scores. The impact scores were subsequently grouped into 'Low', 'Medium', 'High', and 'Very High' using the standard classification method 'Natural Breaks (Jenks)' in ArcGIS, where classes are based on natural groupings within the data. It is important to note that, by using this method, the impact scores calculated are relative to pressure groupings within the data, rather than informed by the level of environmental impact.

This approach focuses on marine sector activities and the pressures they create to provide a spatial overview of cumulative impacts within Shetland's marine region. The model outputs can be used to identify areas subject to high cumulative pressures, which can subsequently trigger the need for future management measures, such as investigation into the types of marine habitats and species within these areas and their sensitivity to the pressures affecting that area.

9 Assessing the suitability of CEA approaches

This section provides detail of the process applied to identify CEA approaches that were considered for inclusion in a multicriteria analysis, the analysis of shortlisted approaches, and a rationalisation of approaches into broad CEA categories.

9.1 Methodology

The methodology process, shown in Figure 5, below, started with a wide search for CEA methodologies and approaches. Interviews and Steering Group input informed identification of the need for CEA and a broad scope to guide the shortlisting process. Shortlisted CEAs were assessed against criteria which then informed the evaluation of CEA approaches relative to marine planning. The methodology steps are described in more detail in the following sections.

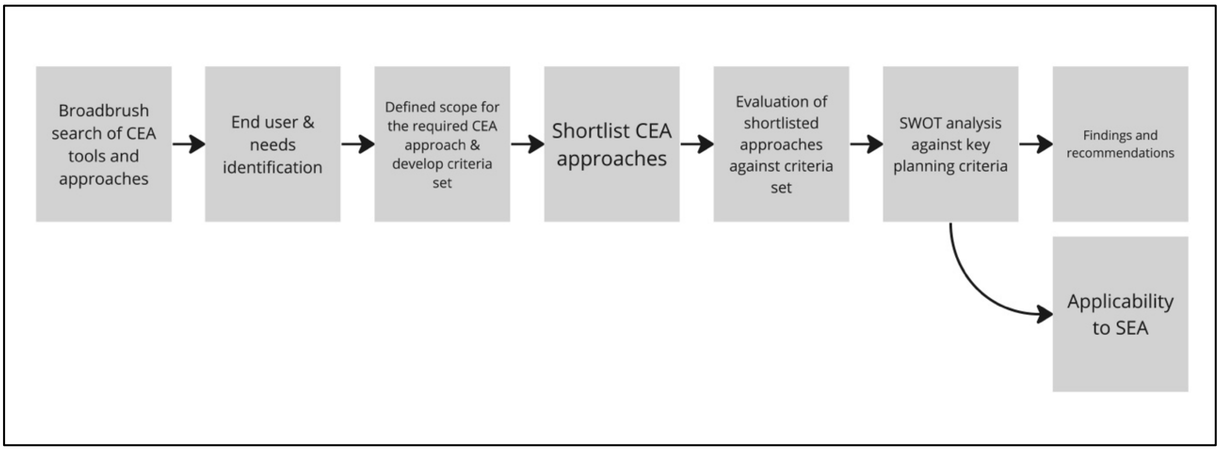

Figure 5. Flow chart demonstrating methodology applied to study.

9.2 Longlist of CEA tools and approaches

The starting point was the long list of CEA approaches and tools listed in Willsteed *et al.* 2023, supplemented by documentation provided by JNCC and project partners at the outset of the study, and by CEA approaches and models flagged by interviewees and the SG (Table 2).

Table 2. Longlist of CEA approaches derived from 2022 review of CEA approaches and tools (Willsteed *et al.* 2023) and supplemented by searches conducted for this study and leads provided by the project Steering Group.

Longlist of CEA approaches	Shortlisted (Y/N)
DAPSIR approaches (ODEMM, Aquacross, SCAIRM)	Y – distinctive category for assessment
'CIM' – Cumulative Impact Mapping, derived from the Halpern *et al*. method.	Y – distinctive category for assessment
Collision modelling	N – specialist approach
CUMULEO	Y – applied CEA
ECOSIM	N – supporting tool, not CEA
Field survey	N – supporting tool, not CEA

Longlist of CEA approaches	Shortlisted (Y/N)
General Linear Modelling, General Additive Modelling, statistical correlation	N – specialist approach, supporting tool, not CEA
Life cycle model, GIS with demographic simulation	N – specialist approach
Marxan	Y – distinctive category for assessment
MaxEnt, species suitability distribution modelling	N – supporting tool, not CEA
Other GIS modelling approach	N – specialist approach
Principal Component Analysis, PERMANOVA, PERMDISP	N – specialist approach, supporting tool, not CEA
'RBF' – Risk-based frameworks, Monte Carlo, Bayesian Belief Networks	N – supporting tool, not CEA, incorporated in included approaches
Structural equation models, regression trees, forest models	N – specialist approach, supporting tool, not CEA
MSPACE	Y – applied CEA
Human Footprint Index	Y – applied CEA
Marine CEA (Lonsdale *et al.* 2020)	Y – applied CEA

The 2023 review by Willsteed *et al.* identified more than 100 applications of CEA (included in Annex 1), which were aggregated into the longlist of approaches (Table 2). Several of these approaches were not CEAs, as per the CEA definition provided in Section 3, but were contributing tools that provided insight into cumulative effects. These approaches were excluded from further analysis. Some approaches were applicable to very specific situations, such as collision modelling or calculations of energetic impacts of disturbance and were excluded from further analysis based on being highly specialised.

Noting the importance of specialist CEAs to answer specific questions, a specific CEA category has been suggested in Section 9.5. Searches conducted for the study also highlighted that within some categories of CEA, notably DAPSIR and Cumulative Impact Mapping, there are applied examples that have notable differences in approach, and which warranted further analysis. For example, the Shetland CEA and Symphony are both grounded in "the Halpern approach", but have evolved and been applied in different ways, hence both were shortlisted.

The shortlisting process led to the identification of 18 potential approaches, of which three (HOLAS, HELCOM, HARMONY) are linked approaches, resulting in a final shortlist of 15 CEA approaches. The next stage was a more detailed assessment against a set of criteria that were intended to capture detail about individual approaches to search for strengths and weaknesses relative to marine planning needs.

9.3 CEA assessment criteria

The criteria for assessing different methods of CEA were developed jointly between the HMC team and the project Steering Group (Table 3). The criteria were not weighted at this point, to permit flexibility when deciding the appropriateness of a specific CEA approach depending on the user need.

Table 3. CEA assessment criteria.

Evidence review criteria	Explanation
Model	Name of CEA model/approach.
Source	Where can the CEA be found?
Contact	Is there a listed contact associated with the CEA?
Summary	A brief narrative of what the CEA is designed to do, why and where it has been applied, and any other relevant background.
Associated organisation	Is the CEA associated with a specific organisation?
Evidence of application	Has the CEA been applied?
Methodology available?	Is there documentation that details the underlying methodology?
Methodology type	What is the type of methodology applied? For example, spatial analysis, general linear model, expert opinion, statistical correlation, MARXAN, DPSIR.
What is included in the CEA?	What does the process of undertaking the CEA include? For example, pressure-sensitivity matrices, summed impact maps, expert review.
Can exogenous factors be included (e.g. climate change, land-based activity)?	Does the CEA permit the inclusion of drivers of change that are exogenous to the area of study?
What is measured?	What does the CEA measure, what form of change is measured?
What is the output?	What is the final output of the CEA? For example, a heat map, a correlation analysis, a trend analysis.
Can outputs be validated?	Are the outputs amenable to being validated using empirical data? For example, is the output a spatial output with predicted impacts that can be tested through surveying?
Resolution of outputs (scale and applicability)	How coarse or fine are the outputs of the CEA, what resolution of output is delivered by the approach?
What geographical scale is the approach applied to?	What is the geographical scale that the CEA has been applied to? For example, local, regional, marine plan, global.

Evidence review criteria	Explanation
How are temporal considerations treated?	Are temporal datasets included, does the CEA enable insights into change over time?
What is the underlying policy driver? (Purpose)	Is there a clear policy driver behind the CEA? For example, MSP, biodiversity conservation.
What is the jurisdictional application?	Is the CEA associated with a specific jurisdictional region?
What types of data are included?	Does the CEA use ecological, pressure, social, … data?
What are the data requirements?	What are the specific datasets required (e.g. habitat maps)?
What are the data formats?	What data formats does the CEA rely on? For example, GIS appropriate datasets, time series.
What is the processing requirement?	What are the computational needs to undertake the CEA, are specific software packages identified? For example, ArcGIS, QGIS, R.
How is uncertainty treated?	Is there explicit recognition of and discussion of the treatment of uncertainty, underlying assumptions, how assumptions feed into confidence assessments of the outcomes?
Flexibility	Can the CEA incorporate multiple or different receptors, stressors, drivers?
Portability	Can the CEA be applied to different situations? For example, if applied to offshore wind scenario analysis, could it be applied to MNG?
Adaptability	Can the CEA be modified to reflect novel evidence or legislative drivers, to bold on or remove model components and variables.
Evidence of effectiveness	Is there evidence of how effective the CEA is? For example, has it been validated, has it been used to inform decision-making, has it led to a change in outcome?
Usability	How useable is CEA from a user perspective? Is the approach and software open access, are there specialist processing requirements, are the outputs easily read and understood, are assumptions and implications easy to communicate?
Communication	How usable is the output from a communication perspective?

9.4 Assessing the CEAs against the criteria set

For each CEA approach, supporting documentation was reviewed and supporting information or judgements were recorded in an Excel spreadsheet (see Annex 1). The master data is recorded in the worksheet “Criteria_assessment_MASTER”.

The master data provided the basis for a rapid assessment of the relative strengths and weaknesses of the CEA approaches (Table 4) using a simple qualitative scoring scale that was applied to criteria amenable to being scored from “strong” (dark grey) to “weak” (white).

Table 4. Qualitative scoring scale used to assess relative strengths and weaknesses of CEA approaches (1 = strongest, 4 = weakest).

KEY	Associated organisation	Evidence of application	Methodology available?	Exogenous factors	Can outputs be validated?	Geographical scale/s	Temporal feature	Flexibility	Portability	Adaptability	Evidence of effectiveness	Usability	Communication
1	Organisation with formal role in marine management	Multiple applications or application to formal reporting scenario	Yes, with easily accessible full supporting information	Clear feature of CEA	Clear potential for validation studies	Evidence of application at multiple scales	Explicit inclusion of time	Good, straight-forward to include different components	Good, straight-forward to apply to different scenarios	Good, straight-forward to modify or adapt to new information	Clear evidence of application in decision making	Simple methodology with no specialist knowledge required	Intuitive output recognisable to non-technical
2	Research organisation with identified link to organisation with formal role in marine management	Real-world case study	Yes, with evidence of full supporting information	Included in scope but not observed	Assumed potential for validation	Clear potential to be applied at multiple scales	Implicit consideration of time	Fair, possible to incorporate different components with modifications	Fair, possible to apply to different scenarios with modifications, or theoretical portability	Fair, possible to adapt to new information with modifications, or theoretical adaptability	Evidence of applicability to decision making	Limited specialist knowledge required, and/or open-source software	Output can be understood with basic learning
3	Research institution, academics, private firm or NGO	Theoretical case study	Partial methodology identified	Potential to be included	Potential challenges for validation	Applied to one scale	Potential to be included	Limited flexibility, narrow scope, or theoretical	Limited portability, narrow scope	Limited adaptability, narrow scope	Potential applicability to decision making	Specialised knowledge and software required	Output requires technical knowledge to understand
4	Not identified	Not identified	Not identified	Not included	Not identified	No spatial component	No temporal component	Low, or Not identified	Low, or Not identified	Low, or Not identified	Not identified	Highly specialised knowledge required, and specialised software, and/or heavy computational requirements	Output difficult to understand

Applying this key to the CEAs provided a quick visual reference from which to compare the shortlisted approaches (Table 5). The scale and the scoring were validated with the SG. The scale could be adapted and there is the potential for applying weighting for evaluate specific CEA approaches relative to specific CEA needs.

Table 5. Summary of relative strengths and weaknesses of shortlisted CEA approaches against criteria amenable to scoring, where dark grey (1) = strong, and light grey (4) = weak (see Table 4). Black cells are those where no supporting information was available or identified over the course of the study.

	Associated organisation	Evidence of application	Method-ology available?	Exogenous factors	Can outputs be validated?	Geographical scale/s	Temporal feature	Flexibility	Portability	Adaptability	Evidence of effectiveness	Usability	Communication
SYMPHONY	1	1	1	1	1	2	4	1	1	1	1	2	1
BalticCAT	2	2	4	2	4	2	3	-	-	-	-	-	-
HELCOM BSI II	1	1	1	1	1	2	3	1	1	1	1	2	1
PROTECT BALTIC	1	4	1	4	1	2	4	-	-	-	-	-	-
ADRIPLAN	2	2	1	4	1	2	4	1	1	1	2	2	1
CUMULEO	2	2	1	4	3	1	4	1	1	1	3	3	2
ODEMM/ AQUACROSS	3	1	1	4	3	2	4	1	1	1	2	3	2
SIMCelt	3	2	1	3	1	2	3	1	1	1	3	3	1
SCARIM	3	2	1	4	3	2	4	1	1	1	3	3	2
OSPAR CEA	1	1	1	4	3	2	4	1	1	1	2	3	2
Shetland	3	2	1	4	1	2	4	1	1	1	2	2	1
MSPACE	3	4	4	1	4	2	2	3	2	-	-	-	-
MARXAN	3	1	1	1	2	1	1	1	1	1	1	3	2
HFI	3	2	1	4	1	1	4	3	3	3	3	2	1
Lonsdale *et al* (2020)	3	3	1	4	2	1	4	1	2	1	3	3	2

9.5 Observations

- Overall, each approach has strengths and weaknesses, the scoring of which will vary depending on user needs. A clearly defined CEA question is needed to guide analysis of which approach is most appropriate for a specific need.
- There are examples of CEAs that have been applied in formal marine management processes, although the evidence of effectiveness (evidence that CEAs have informed and being included in decision making) was less common.
- Except for two approaches that are in development (BaltickCAT and MSPACE), methodologies and supporting information is available. Transparency of the methodologies is broadly good.
- Exogenous factors such as climate change were included in a minority of CEAs that specifically included climate change in the scope.
- The potential to validate CEA outputs is variable, with an assumption made that regional approaches are more difficult to validate due to the scales and potential for variability over large spaces. Local-scale CEAs or CEAs linked to existing monitoring and indicators are more amenable to validation.
- There are examples of CEAs that have been applied at different scales that could support consistency across different assessment scales.
- The inclusion of temporal data (trends) in CEAs remains a general weakness, pointing to the need for consistent iterations over time and to the potential value in exploring how to incorporate past data/knowledge that can provide indications of trends.
- Multiple CEA approaches can be applied to different scenarios, are flexible and can include or exclude different components and variables and can be adapted to account for new legislative drivers or evidence.
- The usability of CEA approach points to the need for specialists to support the implementation of approaches. Most of the CEAs make use of open-source software, with QGIS and MARXAN supported by extensive knowledge banks and training materials.
- Maps are the most intuitive outputs to understand for non-technical people, although this should be considered in parallel with the treatment of uncertainties and assumptions. Cause-effect pathways require more explanation for non-technical people but are easy to interpret once understood. For all approaches, there is an onus on the practitioners to be explicit about the treatment of uncertainties and assumptions, and the implications for interpretation of outputs.

9.6 Discussion

Some form of rationalisation of CEA methodologies and approaches is necessary; based on search parameters used in Willsteed *et al.* (2023), 118 examples of CEA were published between 2015 and 2022 (the CEA longlist is included in the accompanying data annex (Annex 1)). Approaches identified in those CEAs and those additionally reviewed for this study can be broadly aggregated into 4 categories: Cumulative Impact Mapping, DAPSIR, risk assessment, and specialist. There are overlaps between categories, hybrids, and the lines between categories are not absolute, but there are objective differences between the four that can be summarised as follows.

9.6.1 Cumulative Impact Mapping

Overlaying maps of receptors and activities, derives from a global CEA by Halpern and colleagues that mapped the overlap between multiple human activities and selected receptors (Halpern *et al.* 2008b). The approach has been replicated numerous times at scales from local to regional to global, has evolved to address a variety of scenarios and with more refined algorithms defining how "impact" is measured. At the heart of these GIS-based CEAs is the interaction between spatially-linked data layers and an algorithm that – defined by the programmer – calculates how activity layers additively impact sensitive receptor layers. Examples reviewed assume additive impacts, rather than synergistic, antagonistic relationships between stressors acting on receptors. Evidence about non-additive effects is scarce and the additive assumption is legitimate in the absence of evidence (Judd *et al.* 2015).

Expert advice often underpins sensitivity settings. Data resolution (e.g. geospatial precision, spatial distribution, and amount of data points) is critical, defining what granularity is possible. For example, a fishing activity data layer with a 10 km-by-10 km grid scale will assume uniform fishing activity within each 100 km^2 area. A habitat data layer will assume that a sensitive receptor is equally distributed within each grid. Resolution can (and should) be challenged if map outputs are being used in decision making, particularly where decisions may be being made about sectoral activities that impact the environment at finer scales than the resolution permitted by the available data.

Outputs are maps, which are effective communication tools and can rapidly support understanding of why CEA is necessary to deliver on policy commitments. The strength of sensitivity-activity mapping, CIMs, is showing where cumulative effects are (thought to be). There is the potential for faster generation of outputs assuming spatial datasets are available, due to the less complete treatment of cause-effect pathways observed in some examples relative to DAPSIR approaches. There are more complete examples where there is a more comprehensive treatment of baseline data, of sensitivity matrices, and that permits the comparison of expected environmental effects of different marine plan alternatives (notably Symphony – see Hammar *et al.* 2020).

9.6.2 DAPSIR

DAPSIR approaches are CEAs underpinned by the Driver-Activity-Pressure-State-Impact-Response framework that has been widely used in environmental management to describe causal relationships between society and the environment (Atkins *et al.* 2011). The strength of DAPSIR approaches is showing the relationship between activities and receptors, how cumulative effects are occurring, and the relative contribution of activities to pressures on receptors, permitting assessment of the implications of those effects on society and the environment.

Broadly speaking, DAPSIR approaches applied to the marine environment have emerged in response to the need to implement ecosystem approach management. As with the preceding category, the DAPSIR framework has evolved over time and has been adapted relative to UK and EU policy and legislative drivers (e.g. Elliott *et al.* 2017). The most recent evolution identified is SCARIM (Spatially Cumulative Impact Assessment of Impact Risk for Management) and examination of the evolution of the approach points to the work involved in developing CEAs that account for the many linkages present in marine ecosystems.

Examples of DAPSIR approaches have been applied to ecosystem services and could equally be linked to GES, or natural capital, and are currently used for OSPAR QSR reporting (OAP - All Thematic Assessments / OSPAR CEMP Guideline: Cumulative effects assessment for the QSR 2023 (Bow Tie Analysis)). Expert advice is important in defining the relationships between causes and effects, and weighting of impact pathways. Interviews with practitioners interviewed who are close to marine management pointed to some having greater confidence in DAPSIR methods compared with sensitivity-activity mapping methods relative to informing marine planning through a more rigorous treatment of relationships between model components. DAPSIR based approaches are well advanced through OSPAR, ICES, and through regional programmes, such as HOLAS.

9.6.3 Risk assessment

The risk assessment category CEAs apply robust risk assessment methodologies to inform risk management. Given the almost certain presence of data gaps and uncertainties about cause-effect pathways, formalised risk assessment provides a rigorous and defensible means of defining the likelihood that undesirable state changes will occur and the potential effectiveness of management measures to address the risk. Risk assessment and risk management can draw on a well-established and evolving knowledge base, drawing on evidence and research from across many scenarios, such as health care, industrial strategy, environmental management, operational delivery.

There are advantages to using the terminology associated with risk approaches; practitioners and marine planners interviewed noted that industrial interests understand risk language, supporting cross-sectoral communications. Many CEAs include environmental risk assessment concepts to identify the risk of impacts to receptors and consequent impacts on society and the environment. The current challenge is that there is variation in how risk assessment approaches are being included in CEAs, reflecting the variation in CEA drivers, objectives, and assessment endpoints (Stelzenmüller *et al.* 2020). This highlights the importance of framing and establishing clear definitions of risk approaches and criteria to support consistency across CEAs being used for the same purpose (e.g. marine planning).

9.6.4 Specialist CEA

Specialist category CEAs are those that are highly focused on specific situations, and that tend to involve more complex computational approaches that integrate, for example, bioenergetic consequences of disturbance on individuals and populations. The range of specialist CEAs is broad, but in UK terms CEAs for seabirds addressing the risk of cumulative impacts of offshore wind development on those populations are perhaps best known. Data richness is a feature of these CEAs complemented by extensive datasets. Examples reviewed typically focus on modelling the population consequences of multiple developments from one sector, and are evolving to include ecosystem considerations as well, such as competition with commercial fishing for prey.

As noted above, there are hybrid approaches, notably the inclusion of environmental risk assessment into CEAs. If a framework approach to CEA is adopted that permits the application of different methodologies to address specific questions, the inclusion of a requirement to apply a standardised risk assessment approach would be advisable. A second potential hybrid to flag is from Sweden where CIM and DAPSIR approaches have been completed for Swedish waters (CIM in Hammar *et al.* 2020, DAPSIR in Bryhn *et al.* 2020). While the two approaches have not been integrated yet, interviews pointed to interest and perceived value in hybridising the two approaches to enable mapped outputs with more robust cause-effect underpinnings that are amenable to testing expected management intervention effectiveness and that carry the power of communication associated with maps.

9.6.5 CEA method summary

Each of the categories brings strengths and weaknesses that are emphasised by the specific questions driving the CEA and by the availability of supporting data or knowledge to support application. Recognising that there are multiple questions that can be asked of CEA and that there are multiple policy drivers that require cumulative effects to be considered, assessed, or managed, there is merit in seeking to provide a policy framework for assessing cumulative effects for marine planning and management, which can incorporate different methods to predict cumulative effects or impacts. Such a framework would respond to the need specified in the context section of this report for consistent, coherent, and accessible assessments of how single and multiple activities and events cause environmental change relative to a common baseline understanding. An example process and framework are included in Appendix 1.

10 Gaps between theory, practice, and need

The development of CEA in academia is advancing at a pace that exceeds its application in real-world decision making, often at the expense of usability and understanding by those informing and making decisions. Further, the development of complex modelling approaches, using sophisticated and advanced techniques (e.g. Bayesian models), present challenges for practitioners (e.g. marine planners) required to translate, communicate, and explain how the results were calculated to a range of stakeholders with varying levels of understanding of CEAs. While complex models should, in theory, provide more robust assessments, using the outputs of complex models needs to be balanced with the challenges of communicating the methodologies and results to stakeholders and the trust that those stakeholders will have in the outputs. There is also a blunt reality that CEA is seeking to understand change within complex adaptive systems; there will always be uncertainty and complex models need to be careful that the implications of uncertainty are clearly communicated without stifling strategic decisions. Striking a balance between the advancement of CEA methodologies and end-user comprehension and ability to communicate the approach and results, will be a key challenge going forward.

In addition to capturing the environmental impacts of marine planning decisions, there is also growing interest in social and economic impacts, as highlighted in, for example, Defra's 25 Year Environment Plan and the Scottish Government's Blue Economy Vision. A natural capital approach that incorporates the ecosystem service flows that come from natural assets could prove to be a valuable addition to the CEA approach and enable social and economic impacts to be considered. In combining both approaches, a CEA approach could be used to inform different planning scenarios and identify impacts on VCs (i.e. natural capital assets), which could then inform the natural capital approach, where the resulting impacts on ecosystem services could be assessed. The natural capital approach and the ecosystem approach share many similarities (in the core data and approach) and by combining the two approaches, collaborative and integrated analyses by natural scientists, social scientists and economists could be facilitated (Judd & Lonsdale 2021).

Building on the natural capital approach, a 'five capitals' approach that considers the interactions between natural, social, human, manufactured, and financial assets would enable a more comprehensive investigation into the environmental, social, and economic impacts of different planning scenarios. The applicability of the five capitals approach to marine planning has previously been explored for the East Marine Plan in England (Collin *et al.* 2023), highlighting the potential for assessing different trade-off scenarios in decision making (e.g. different levels of offshore wind development within the plan area) and their implications for each of the five capitals, as well as other marine sectors.

11 Integrating CEAs into SEAs

As with CEAs for marine planning, there is potential for existing CEA methodologies to be adopted to support SEA. Again, the necessary question is what is required of CEA relative to SEA. The Swedish SYMPHONY approach, for example, applies a CIM and has been used successfully as a tool for communication, to strengthen SEA participation, and that provides a common understanding from which to debate the costs and benefits of future scenario. CEAs will, though, shine a spotlight on how we deal with the information from those CEAs, as captured in the following quote:

“Based on lessons from practice and interviews with practitioners and administrators, we observe that assessing cumulative effects in a regional SEA context is most effective when there is a shared regional vision about the future state of environment and development; the development of regional environmental targets, thresholds and indicators takes precedent over cumulative impact prediction; strategies can be translated into operational terms and mandates; the assessment is sensitive to key decision windows; and CEA is recognised to be more than simply the “adding up” of environmental effects” (Gunn & Noble 2009).

In their 2011 paper, Gunn and Noble further explored the conceptual and methodological challenges to integrating SEA and cumulative effects assessment, identifying, through interviews with experts, several challenges, including: the level of understanding and agreement on the nature and definition of a ‘cumulative’ environmental effect; aggregating cumulative effects beyond the scale of an individual project; the role of aggregation in CEA and management; and, notably, the relationship between SEA that attempts to capture CEA for a region and regional environmental planning initiatives.

Gunn and Noble emphasise that, while SEA and regional planning share many fundamental features, including a focus on the future, strategic decision making, and relationships between various components of society and environment, they are arguably different in what they are intended to accomplish, albeit complementary. For example, as an impact assessments process, SEA includes scoping, identification and comparison of alternatives, and evaluation based on technically and publicly agreed criteria, whereas regional environmental planning is the process through which goals and objectives are set.

Cooper and Sheate (2012) found that most experts interviewed in their study were in favour of integrating CEA into SEA of plans. They suggest that the consideration of cumulative effects in the UK planning process could be improved by integrating CEA into strategic planning levels, allowing for these effects to be considered early in the planning cycle and enabling CEA at a plan level to facilitate CEA at a project level. Further, it is theorised that CEA fits into SEA because it uses a baseline approach for assessing the effect on the valued environmental resource. A proposed framework for integrating CEA into the SEA, and plan making processes is provided (Figure 6).

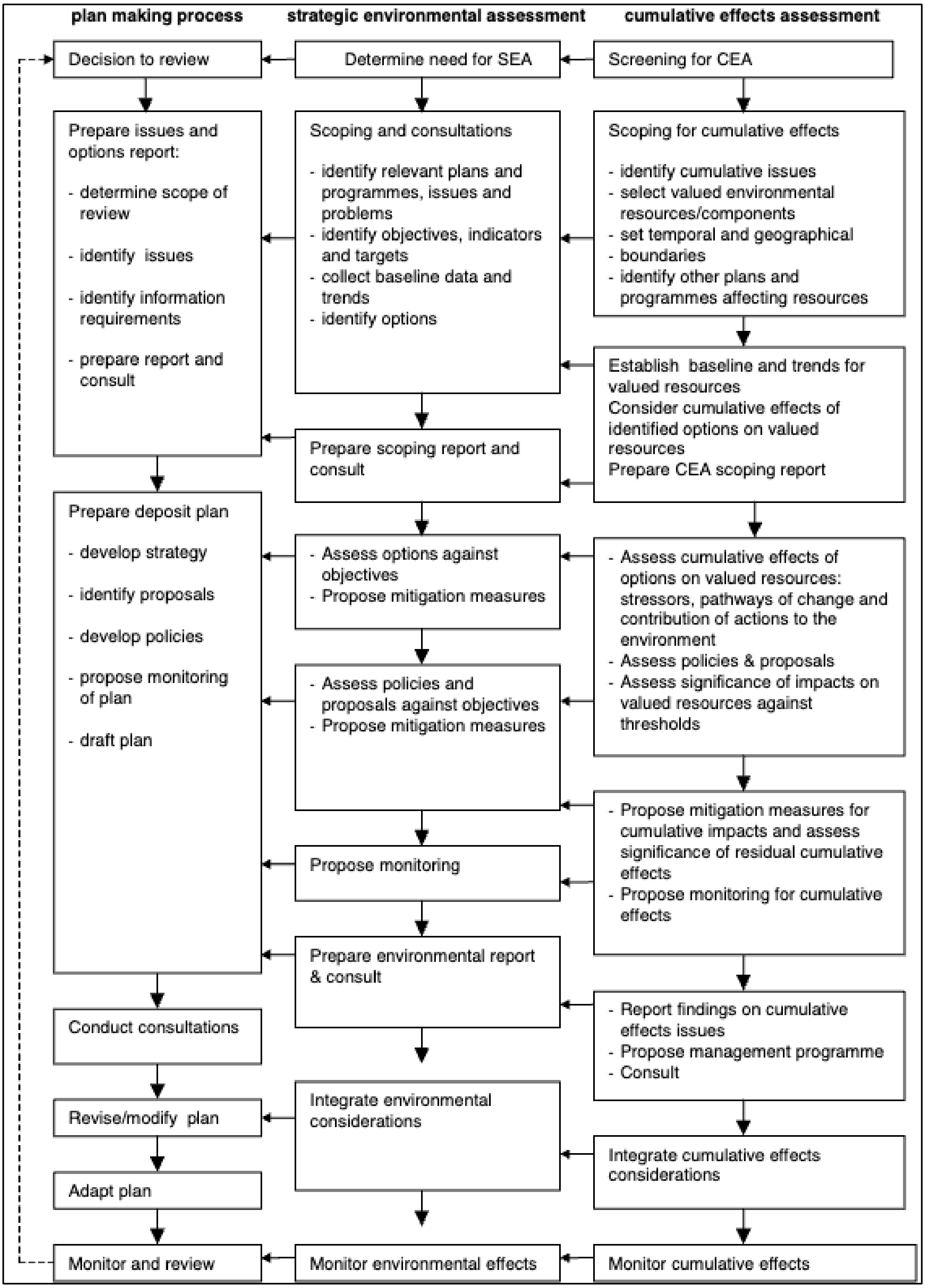

Figure 6. Framework for integrating CEA, SEA, and the plan making process (from Cooper & Sheate 2012).

In 2020, the consultancy Levett-Therivel also investigated the potential for integrating CEA into SEA with their report 'Good Practice Guidance on Cumulative Effects Assessment in Strategic Environmental Assessment', developed for the Environmental Protection Agency, Ireland. In the report, they identify five principles that underpin the CEA process in SEA:

1. CEA should be integrated in the SEA and not be a separate process.
2. CEA should focus on receptors – consider the characteristics of each receptor, its current condition, and how it is likely to change both with and without implementation of the plan.
3. Cumulative impacts require cumulative mitigation – cumulative impacts are caused by many actions and can only be addressed through many actions.
4. The level of baseline data, assessment, and proposed mitigation in CEA should be proportionate and relevant (fit for purpose).
5. CEA should acknowledge and cope with uncertainties – data is often lacking on receptors' capacity to accommodate change, and on likely impact of other actions.

Like Cooper and Sheate (2012), the Levett-Therivel focus on the different stages of SEA and provide a breakdown of which CEA tasks should take place at each SEA stage (Table 6).

Table 6. CEA tasks at each SEA stage: key tasks are numbered (Levitt-Therivel 2020).

SEA Stage	CEA Task
Screening	Consider likely significant cumulative effects during screening
Scoping and consultation	Task 1. Identify receptors. 'Scope in' plan impacts that, alone, might be insignificant but cumulatively would be significant (for instance, climate change). This may require consultation beyond usual stakeholders.
Plan description	-
Objectives, indicators, and targets	Task 2. Identify limits/thresholds/standards. These will be used during impact assessment (task 4) to determine the significance of the cumulative impacts.
Existing and likely future environment	Task 3. Describe the 'current state of the environment and likely evolution thereof without implementation of the plan' (SEA Directive Annex Ib), including changes due to other plans, programmes, projects, and general trends. This will then be considered cumulatively with the plan's impacts at task 4.
Alternatives	-
Impact assessment: likely significant effects of the plan	Task 4. Assess the impacts of the plan plus those of other actions (from task 3). Compare these against the limits/thresholds (from task 2) to determine significance.
Mitigation measures	Task 5. Mitigate significant cumulative impacts. This is likely to require additional discussion with other stakeholders.
Environmental report	Describe cumulative impacts, uncertainties inherent in the assessment of cumulative impacts, and how the uncertainties have been managed
Monitoring	Task 6. Monitor for significant cumulative impacts. In the future, review monitoring findings to inform identification of key cumulative effects issues at next cycle of plan making and SEA/CEA.

Some studies focused on methodological approaches to integrating CEA into SEA. For example, Bragagnolo *et al.* (2012) focussed on addressing cumulative effects in SEAs of spatial planning. They investigated the application of CEA at the different stages of an SEA and identified three critical aspects for ensuring good practices:

- the selection of valued environmental components;
- the adoption of future-oriented approaches; and
- the use of spatially explicit information.

However, Declerck *et al.* (2022) presented a new strategic framework for cumulative impact assessments (CIA) that uses a holistic and pragmatic ecosystem approach based on spatio-temporal Bayesian network to identify pressure pathways, keystone components, ecosystem connectivity and resilience, and population-level changes. They suggest that the framework will support more transparent and multi-disciplinary collaborations and provide a multi-dimensional decision-making toolkit for more efficient SEAs.

Academic literature that specifically investigates the application and/or integration of CEAs into SEAs is limited and most of those studies have focused on SEAs in terrestrial planning. For example, (Bidstrup *et al.* 2016) used the Danish mining sector as a case study to explore how plan boundaries influence the analytical boundaries applied for assessing cumulative effects in SEA. It was found that cumulative effects are to some extent assessed and managed throughout the planning process, however with a focus on lowering the cumulative stress of mining, rather than the cumulative stress on and capacity of the receiving environment.

Bonnell and Storey (2000) focused on how SEAs can facilitate a planning approach for addressing the cumulative effects of a development. In their paper, a small hydro development in Newfoundland, Canada is used as a case study to demonstrate the potential benefits of SEA in the assessment and management of cumulative effects, further illustrating how SEA could be used to address potential cumulative effects at various stages in the planning process.

12 Recommendations

- **Define what CEA is needed for: define the context, the questions, guiding principles, and determine what output best meets end user needs.**

  At a minimum, it is necessary to clarify the driver and context for CEAs, definitions to be applied, and guiding principles that can enable consistency between CEAs. Noting that ecosystem-based management needs to be meaningfully implemented, “a sound understanding of cause-effect pathways describing the link from human pressures causing potential state changes of ecosystem components, processes, or functions should form the backbone for management frameworks” (Stelzenmüller *et al.* 2020). For management, DAPSIR approaches appear more robust. For marine planning, where there is a communication and participation element, CIM approaches may be sufficient and there are versions (e.g. Symphony) with explicit scenario testing add-ons. A future workshop focused on addressing these core questions may be beneficial for advancing the use of CEA in marine plan development.

- **Design and adopt a CEA approach rather than a methodology.**

  Given current constraints, CEA will likely be more effective if implemented within an overarching process such as marine planning. Given the range of potential CEA questions and the need for multiple CEAs over time, there is an argument to enact a framework approach, which implies a process (Figure 7). Such a framework would permit the use of specific CEA methodologies to address specific CEA questions.

  A toolbox of established CEA approaches that can be drawn from to address a range of questions would be beneficial. Accompanying the toolbox should be guidance on which approach is most appropriate to use, what the expected outputs from the approach are, and how these outputs can be used. The toolbox should seek to make use of existing tools that are relevant to CEA, for example, NatureScot’s FEAST tool to investigate valued component sensitivity to activities.

  Following this study, further investigation is required to define and develop the CEA process (building on the example provided in Appendix 1). This should include identifying which CEA methods should be included in the toolbox (noting the continued emergence and evolution of CEA methods and approaches, such as MYTILUS and GES4SEAS) and how those methods identified in Table 2 as ‘supporting tools’ can inform the CEA process.

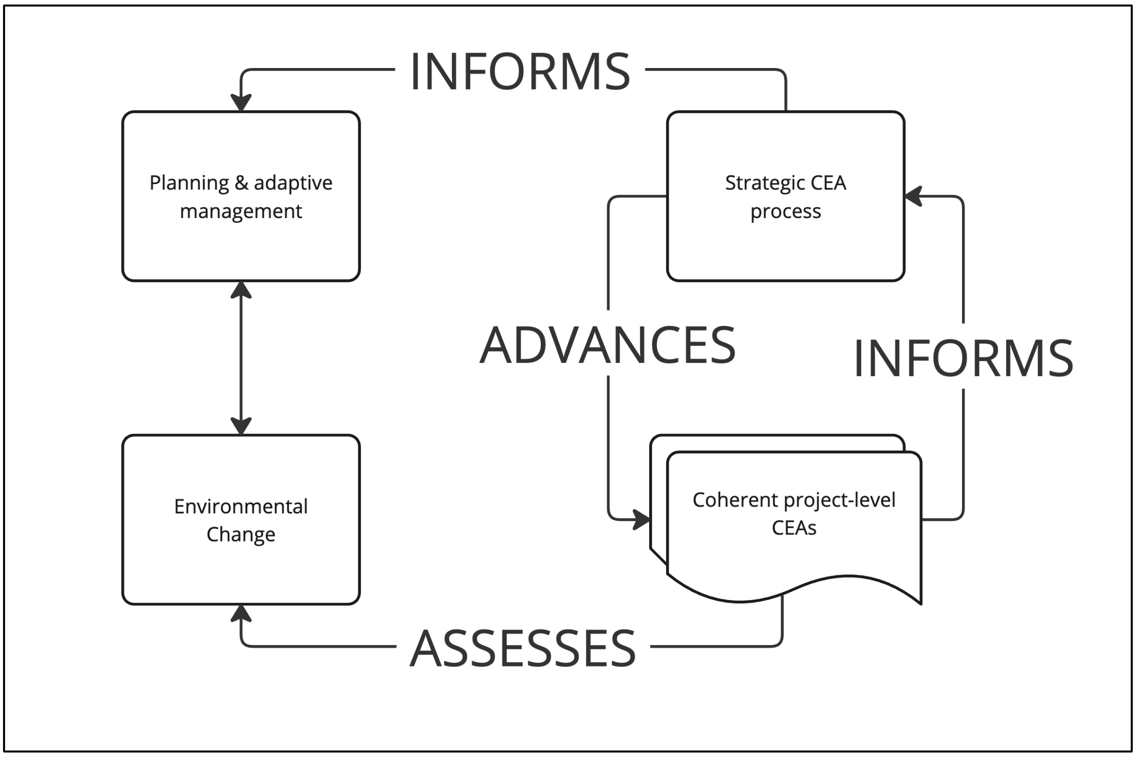

Figure 7. High-level concept for CEA process spanning assessment scales and informed and strengthened through feedback from higher resolution localised CEAs.

- **Enable a modular approach from simplicity to increasing complexity and integrate standardised risk analysis into the framework.**

  Recognising that technological advances may permit rapid advances in what can be processed, how existing data can be transformed to new purposes (such as SEA CEA), and the likelihood of rapid advances in computer processing, modularity of the approach is advisable to make use of CEA waypoints established (such as those completed for marine plan revisions and future marine plans). The increasing complexity will improve resolution over time supported by robust time-series from preceding CEAs (as achieved by the OSPAR QSR series, for example). To provide the rigour required to establish confidence in CEAs while substantial knowledge and data gaps exist, the approach or framework should specify a standardised risk-based approach including definitions and terminology to provide decision-makers with transparent assessments of the risk of state changes and the expected effectiveness of management interventions to mitigate predicted high risks.

- **Focus on agreeing the baseline and bind together marine plans and impact/sustainability assessments with a common foundation.**

  The role of iteration in improving CEA is clear, for example OSPAR, ICES, and Sweden, where experts and data have been contributing to regional CEA approaches, and applications of those approaches, over extended periods of time. CEAs that build upon preceding CEAs produce better results: depending on the question, there are suitable existing approaches to deliver CEA for marine planning (and potentially management).

  There is a question of how to integrate CEA into marine planning. A compelling argument proposes that progress can be made by establishing a baseline, tackling marine planning cumulative effects questions through a CEA toolbox approach, and repeating the process over time to generate indications of change relative to planning and policy objectives.

Suitable baselines may already exist through environment reports (albeit at varying scales) that are underpinned by data and datasets associated with existing marine data portals and webGIS platforms. Extensive environmental monitoring and data programmes exist, but unless already complete, an audit of data compatibility with specific methods may be warranted. For example, when reviewing ODEMM, CUMULEO, and HARMONY for OSPAR, Korpinen (2015) identified a disconnect between OSPAR indicators, available data, and the CEA approaches. A resolution was required before a recommendation to adopt one approach over another could be made, which led OSPAR to work on a framework approach that could benefit from thematic data availability while promoting consistency across themes.

- **Consider developing institutional capacity to deliver consistent CEA across marine planning and delivery.**

  Given the requirement for CEA across multiple policy, planning and delivery themes, there is an argument to develop institutional CEA capacity that can be shared across multiple agencies. A central team of CEA specialists could be a valuable resource for assessing whether a CEA is required, identifying which method should be applied, and conducting the assessment. A good example of this approach is the Canadian Department of Fisheries and Oceans, which contains centralised CEA capacity that responds to cross-sectoral CEA needs. The team consists of six CEA specialists available to conduct CEAs, when required, using a toolbox approach of four or five different methods ('risk-based framework' and 'cumulative impact mapping' are the two main approaches used). The team works closely with the academic community, bringing in subject experts to collaborate, workshop, and advise on data, methods, and outputs. The team then play a key role in communicating the CEA results with marine planning decision makers. Establishing a similar central resource would bring a consistent approach to applying CEAs across the UK, enable a 'learning-by-doing' approach, and support the development of a centralised database to inform CEAs.

- **Invest in CEA training to increase the capacity within marine planning teams to scrutinise, communicate, and incorporate CEA findings into the decision-making process.**

  The rapidly evolving and complex discipline of CEA can create challenges for marine planners looking to incorporate its use into decision making. By investing in building and maintaining internal capacity, through the provision of CEA training opportunities, marine planning teams will be better placed to identify when a CEA is required, determine which method is most appropriate, and apply the findings to marine plan development and decision making. Regular engagement with the academic community, as well as other national and international CEA experts, would ensure marine planning teams are aware of the latest advancements in CEA methodology and application.

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Appendix 1: Outline CEA framework and process map

To bring together the observations and discussion in sections 9.5 and 9.6, and building on the recommendations above, an example process map for CEA to aid marine planning is presented in this Appendix (Figure 8). The process map could be co-developed and adapted to support development of a framework or decision-tree to guide consistency, coherence, and accessibility, with the overarching objective of implementing a standardised CEA approach (as opposed to a standardised methodology) to support marine planning.

The overarching step is the establishment of the context within which marine planning CEA operates. Suggested components to provide the supporting structure for CEAs of different shapes and sizes include:

1. Defining a CEA policy statement relative to marine planning.
2. Ensuring CEA definitions and principles are clear.
3. Defining minimum requirements to meet policy needs.
4. Specifying the risk approach to be applied consistently across CEAs.
5. Identifying links between the CEA process and monitoring and management of cumulative effects.

Based on discussions with the steering group, it was identified that there are different minimum requirements for CEA depending on the driver and the information need. For example, requirements may be more tightly defined if inclusive of a need to consider cumulative effects under the habitat regulations (as part of plan-level HRA), or to respond to reporting requirements under OSPAR. Further study would be needed to determine what minimum requirements per need would be and whether it would be feasible to specify these under the framework, or if it would be pragmatic to specify minimum requirements at context defining stage of the process. The box below the “context” process seeks to convey that a common baseline will aid CEA as a process and promote consistency between CEAs, but that such a baseline implies significant time and effort thus is considered less essential than the preceding steps.

The process of specification is intended to lead to a clearly articulated and bounded CEA that includes objectives that respond to the policy or planning need, that clearly specifies the minimum requirement of the assessment, and that reflect a place-based approach considering multiple activities, and which is defined in space and time. An interim step in the process between specifying the CEA and the more detailed CEA scoping process is a rapid risk assessment that could guide decisions about the effort and resources warranted to respond to the need to consider or assess cumulative effects. This step is suggested as a means of guiding expectations around CEAs, which can easily become complex.

The process of scoping follows a series of steps that aid identification of what components to include in a CEA. Recognising that valued component trends, thresholds and targets may not exist, an additional rapid risk assessment step could aid identification of the risk and hence the prioritisation of research to provide that information.

The CEA box comprises preparation of the assessment and a toolbox of methodologies that could be applied depending on the CEA specification. The preparation steps include specification of the delivery modality, whether in-house to the planning body, or outsourced to external parties. Based on the CEA specification and the associated priorities and/or availability of evidence, different methodologies within the toolbox could be justifiably selected.

Outputs would vary depending on the CEA specification and the methodology applied. A suggestion is that a CEA framework specifies a requirement for the CEA to produce an impact statement that provides an estimate of the impact of activities on specified valued components to inform planning and management.

Additional considerations that are relevant to CEA are included, perhaps most importantly participation, and identifying where participation and stakeholder input should feature in the process.

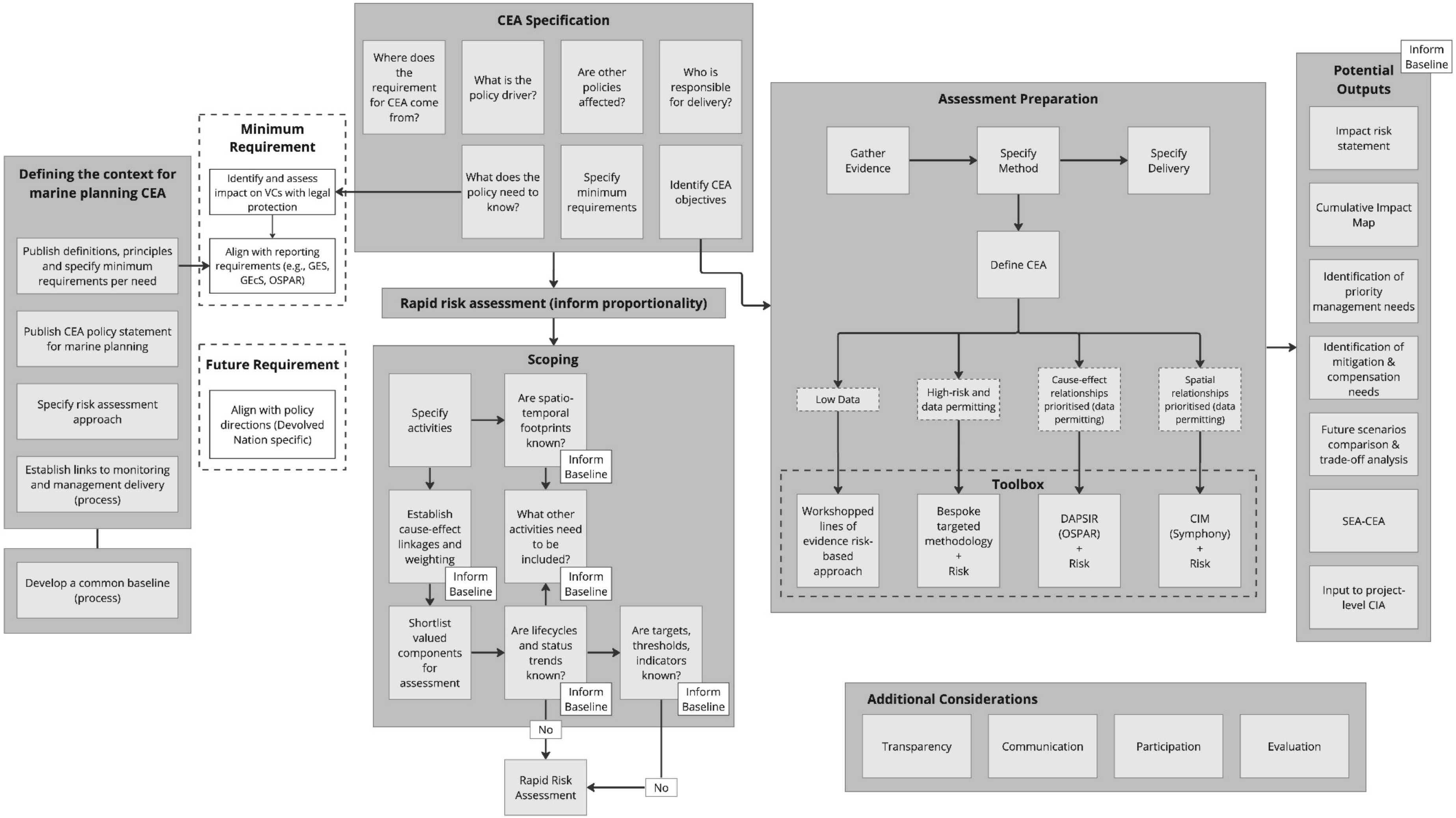

Figure 8. Example process map for CEA to aid marine planning.

Appendix 2: Establishing institutional CEA capacity

The following stems from background research and an interview with the Canadian Department of Fisheries and Ocean (DFO), as an example of a CEA planning and delivery team set up within one institution that provides support to government teams requiring CEA to meet legislated obligations.

1. Establish CEA team in chosen institution (or establish a cross-administration/institution team) with a central role in marine planning and management, with a clear role, mandate, processes, and financing. In the DFO case this started with the initial recruitment of a thematic expert who over four years has developed a five-person team that has been operational for four years. The advantage of this approach is that the team develops CEA capacity and institutional capacity over time increasing value and, if supported by effective processes, efficiency. This efficiency and value extends to benefit a wide range of teams and departments with CEA needs. The centralisation of resource also provides a focal point for knowledge and the potential for the CEA team to play a leading role in linking CEA to monitoring and management. The CEA team remain independent of the decision making process and act as a hub providing consistently robust, defensible, and informative CEAs capable of responding to varied CEA requirements.
2. In parallel, develop the CEA framework that will apply to all CEAs, bringing consistency and coherence to CEA practice across different needs. This is an additional step to the current DFO model. The interview with the representative of the DFO CEA team discussed the benefits of a framework. It was agreed that a balance between standardisation and flexibility is key to CEA as a process to support marine planning and management, hence there are clear benefits in establishing a framework. It was also agreed that CEA, as a process, would ideally also be supported by a coordinated database to support CEA and integrated assessments, that brings together data and knowledge of activities, valued component, cause-effect relationships, environmental targets and thresholds.
3. The CEA team respond to policy and management requests where that institution has a key planning and/or regulatory role, and where the requests relate to the need for CEA to fulfil a legal requirement to consider CE (or words to that effect). The CEA teamwork with the institution, department or team submitting the CE request and co-transform the request into a CE question and scope the CEA.
4. Working within the framework, the CEA team lead the preparation of the CEA, either developing the specification for outsourcing or identifying which of the CEA methodologies in the toolbox to apply. In the DFO example, the CEA team identify an appropriate methodology, identify delivery partners, if necessary, identify sources of evidence, conduct initial analyses if required, convene an expert working group to sift, review, and weigh evidence to derive a succinct impact statement that constitutes formal scientific advice in response to the policy or management request. This is the end of the CEA team's remit. The challenge of how to use the CEA and the impact statement lies with the originating institution/department/team. The CEA team remain independent of the decision-making process but have a recognised role in contributing evidence to that process.

Cost-recovery was not discussed with the DFO representative. However, as CEA is a relatively common requirement, as the service takes hold and is accompanied by good communication about the use and benefits of CEAs as communication and knowledge tools, cost recovery could be supported through a levy placed on institutions/departments submitting CEA requests, for example.

Appendix 3: Marine planning questions relative to CEA

Shown below, Table 7 includes questions that were provided by the project steering group to give examples of questions asked of marine planners, and where cumulative effects have a bearing on the outcome. The second column identifies whether the questions relate to the need to establish suitable baselines that could support CEA, or whether the questions are amendable to CEA and, if so, which approach would be appropriate.

Table 7: Questions provided by the project steering group.

Questions asked of marine planners	Is this a baseline question or a CEA question?
What would the policy implications of scenarios x, y, or z be?	CEA – CIM & DAPSIR
What is the magnitude & distribution of pressures (legacy & current) to which habitats/species x/y/z are sensitive?	Baseline
What strategic action is needed to recover habitat X?	CEA – DAPSIR
Are habitats/species x/y/z below, close to, at or beyond their ecological threshold for pressures they are sensitive to?	Baseline
What is the environmental carrying capacity for pressures/activities x/y/z?	Baseline
Would pressure/activity scenario x/y/z exceed environmental capacity / any ecological thresholds?	CEA – DAPSIR
What are the main conflicts of different plan scenarios (zones/non-spatial), What trade-offs would ease these conflicts?	CEA – CIM
How might future development impact habitat/species x/y/z (e.g. an increase in offshore wind capacity, increases in aquaculture or changes to fishing practices?).	CEA – CIM & DAPSIR
What will different management measures do to reduce the magnitude and distribution of pressures on specific habitats/species (e.g. highly sensitive PMFs?).	CEA – CIM & DAPSIR
What are the trends (time-series) of cumulative pressures/effects? (at different levels in the ecosystem, e.g. ecosystem function, functional group, valued component). including positive effects? (e.g. are we successfully stopping biodiversity loss and reversing trends?)	Baseline