

UK National Ecosystem Assessment Follow-on Work Package 4 – Coastal/marine ecosystem services: Principles and Practice

Summary

4.S.1 Introduction: coastal zones and ecosystem services.

The UK's coastal zone can be typically defined as a long narrow feature consisting of mainland, islands and adjacent seas, denoting the zone of transition between land and the marine domain. From a management perspective coasts are affected by environmental changes across a range of temporal and spatial scales including the continuum from river catchment to coastal ocean (IGBP LOICZ, Crossland *et al.*, 2005). Because coastal processes and ecosystem changes range over several spatial and temporal scales, they can only be better understood and adaptively managed (i.e. a more flexible approach informed by a 'learning by doing' philosophy) on the basis of an interdisciplinary 'knowledge' and 'methods/tools' capacity. **The ecosystem services framework** (UK NEA, 2011), building on the earlier and largely natural science-based **Ecosystem Approach**, and related tools provide a good pluralistic foundation for the deployment of adaptive management principles in the UK coastal policy practice.

Coastal zones in the UK include some of our most diverse habitats (salt marshes and seaweed beds, beaches and sand dunes, estuaries and lagoons), supporting hundreds of coastal specialist plants and animals. These habitats and the encompassing ecosystems provide a range of ecosystem services of significant benefit (value) to the economy and society. A number of these services can and have been valued in monetary terms although significant gaps remain. But coasts are in a constant state of flux, as environmental change drivers and pressures, both land and marine based, serve to alter the composition and volume (species and habitats) of the coastal service provision. While we lack trend data for many species, indicative information on species loss is a cause for concern. Of the 682 coastal species in the UK (with trend data available), 60% have declined and 29% have declined substantially (RSPB, 2013). Some 13% of coastal flowering plant species are regarded as facing possible extinction in the UK (*ibid.*). Large areas of coastal habitat have been lost or damaged in recent decades due to coastal urban/industrial and tourism development, coastal protection such as cliff stabilisation and sea defence works and changes in agricultural practices. This is part of a global change process resulting in significant loss of natural capital assets, e.g. 50% of fresh and salt water marshes have been lost or destroyed over the last three decades (MEA, 2005). There is a strong precautionary case for action to be taken despite the uncertainties that exist, and that flexibility will be a key feature of an **adaptive management approach** in coastal areas.

The goal of WP4 is to both take forward and tailor the NEA ecosystem services framework in the context of coastal zones and related ecosystem services. An overarching adaptive management strategy is recommended which contains a set of objectives focused on a decision support system (DSS) to improve management practice. The DSS toolbox encompasses problem scoping methods, e.g. the drivers, pressures, state changes, welfare impacts and policy responses framework (DPSWR); environmental change scenario analysis; ecosystem services change indicators; formal modelling; ecosystem services benefits valuation (in monetary and non-monetary terms) and appraisal/trade-off analysis formats (the 'balance sheet' approach).

4.S.2 Adaptive management

4.S.2.1 The conceptual framework: Principles.

Adaptive management principles aim to set the context for a more sustainable use of UK coasts, while at the same time at least maintaining the current supply of a set of ecosystem services. The underlying goal is not so much to conserve biodiversity at all cost, but **rather to manage the rate of change** in ecosystems (structure, species composition, habitats and processes) as the economy and society, together with the environment, co-evolve over time. A comprehensive and integrated systems-based approach to management is therefore required. The **Ecosystem Approach** initiated a trend in this management/policy direction but was more or less limited to natural science analysis. The **ecosystem services framework** advocated in the UK NEA (2011) supplemented the systems-based science with social science and humanities thinking. The combined conceptual framework explicitly links ecosystem structure, processes and functioning to outcomes in the form of services (e.g. sea defence, recreation, and many others) which contribute to goods and benefits associated with human wellbeing/welfare. To put the principles of the ecosystem services framework within adaptive management into practice, a DSS toolbox is developed (see **Figure 4.S.1**).

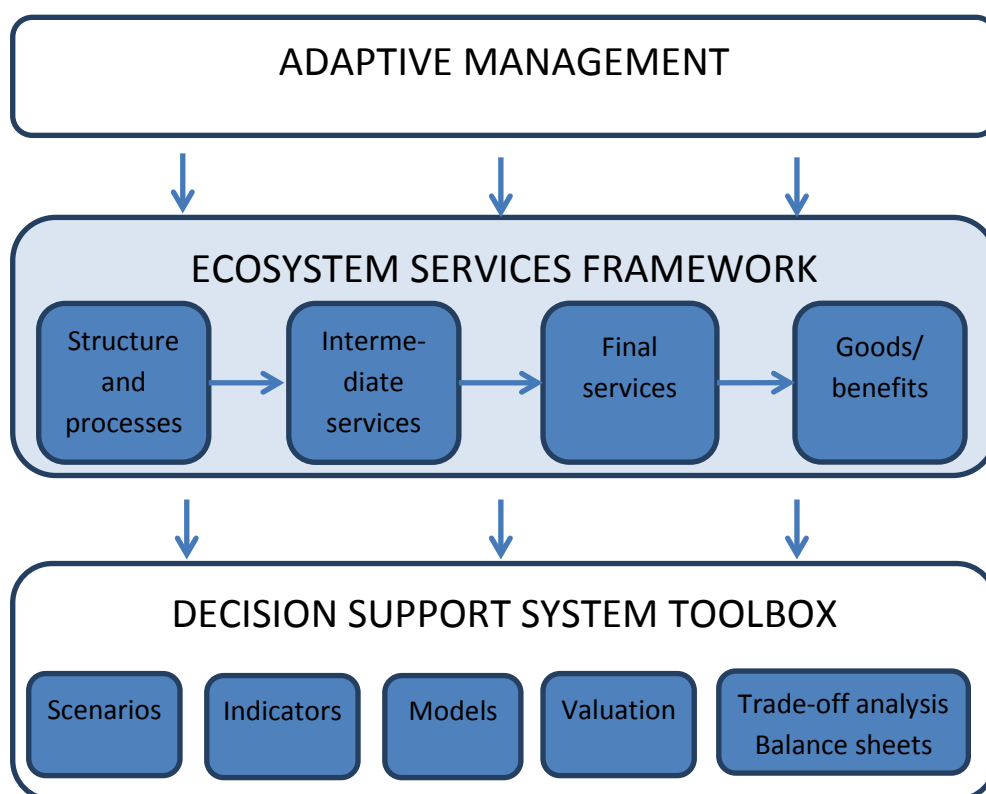


Figure 4.S.1. Conceptual framework.

Ecosystems are complex systems that through their processes and functions provide flows of interdependent ecosystem services that deliver goods and benefits for society. An ecosystem services framework designed for the UK coastal/ marine environment must be consistent with this perspective. Modified from the UK NEA (2011), this framework captures the importance of distinguishing between components and processes, intermediate and final ecosystem services, and goods and benefits (see **Figure 4.S.2**). Complementary capital (i.e. physical, human, social) is typically required to secure goods and benefits for human wellbeing.

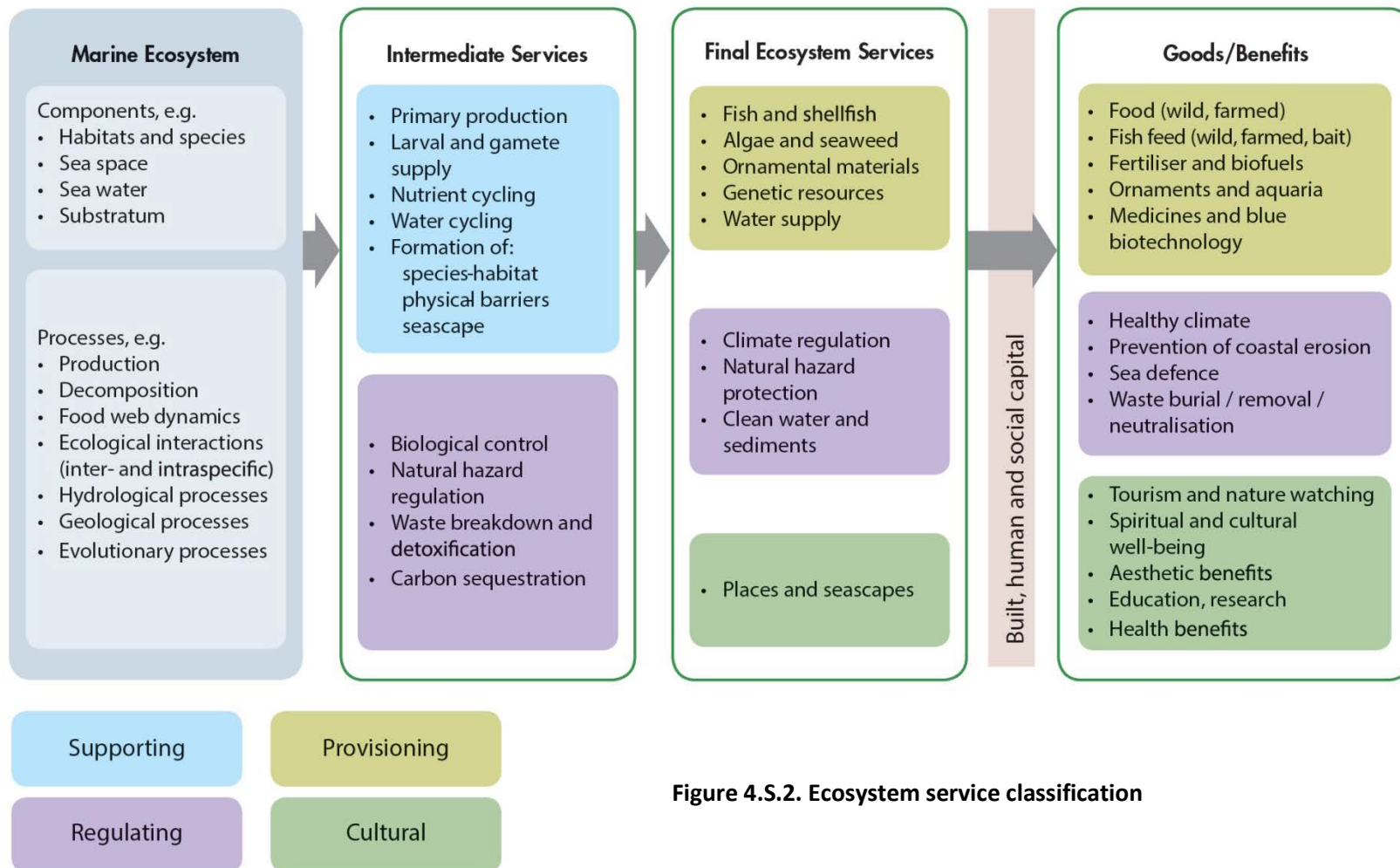


Figure 4.S.2. Ecosystem service classification

The welfare gains/losses can then be evaluated in either monetary or non-monetary terms from an individual perspective. But coastal areas may also represent socio-cultural entities with specific historical conditions and symbolic significance. The values expressed for such cultural services can manifest themselves through collective social networks such as groups, communities and even nations. They may therefore not be best identified through an individualistic lens, but through group deliberation and ‘shared values’ elicitation. So the socio-economic appraisal of different policy/management options also needs an extended format which goes beyond standard cost-benefit analysis, which we have labelled as the ‘balance sheet’ approach (see Section 4.S.7).

4.S.2.2 Decision Support System (DSS): Practice.

Adaptive coastal management requires a flexible DSS in order to enable actual changes in policy/management practice and ‘learning by doing’ follow up. The DSS allows for the assessment of the economic marginal value and social significance of the **flow** of ecosystem services over time; and with further manipulation (including discounting) the **stock** of wealth position (natural capital contribution) at any given point in time. The format in which the information is displayed to policy-makers is also important and has to be adjusted according to the ‘complexity’ of the decision making context (see balance sheet approach, Section 4.S.7).

The DSS needs to be composed of a number of sequential (depending on the exact policy/issues context) but overlapping components:

- A scoping exercise using DPSWR to establish baseline conditions and trends, together with a focused attempt to identify ‘key’ policy contexts/issues;
- A futures assessment through the use of scenario analysis;
- The selection and development of appropriate functionally related indicators of ecosystem state (the stock position) and changes in services (the flow position) supply over time;
- The deployment of ‘tools’ (including models) to enable a scientific, economic and social appraisal of policy options, including distributional concerns;
- Appropriate formatting of the appraisal data and assumptions; and
- Setting up adequate monitoring and review procedures.

We look at the main components of the DSS below.

4.S.2.3 Scoping ecosystem services stock and flow positions

While it is true that coastal and marine issues and contexts can be complex and that a range or combination of variables influence individuals and groups, under any given governance regime, partial decomposition of problems is possible and useful (Ostrom, 2007). So scoping devices can and should be deployed to focus on ‘significant’ problem contexts in order to enable progress towards management options and choices. The so-called Drivers, Pressures, State changes, Impacts and policy Responses (DPSIR) framework in modified DPSWR form (with W emphasising human Welfare impacts) can adequately serve to scope the key policy issues and set out the main conditioning parameters in a policy/management context that is of concern - see **Figure 4.S.3** (Turner *et al.*, 1998; Cooper, 2013). The impacts stage can be specifically calibrated in terms of ecosystem services and interactions/feedbacks (Kelble *et al.*, 2013).

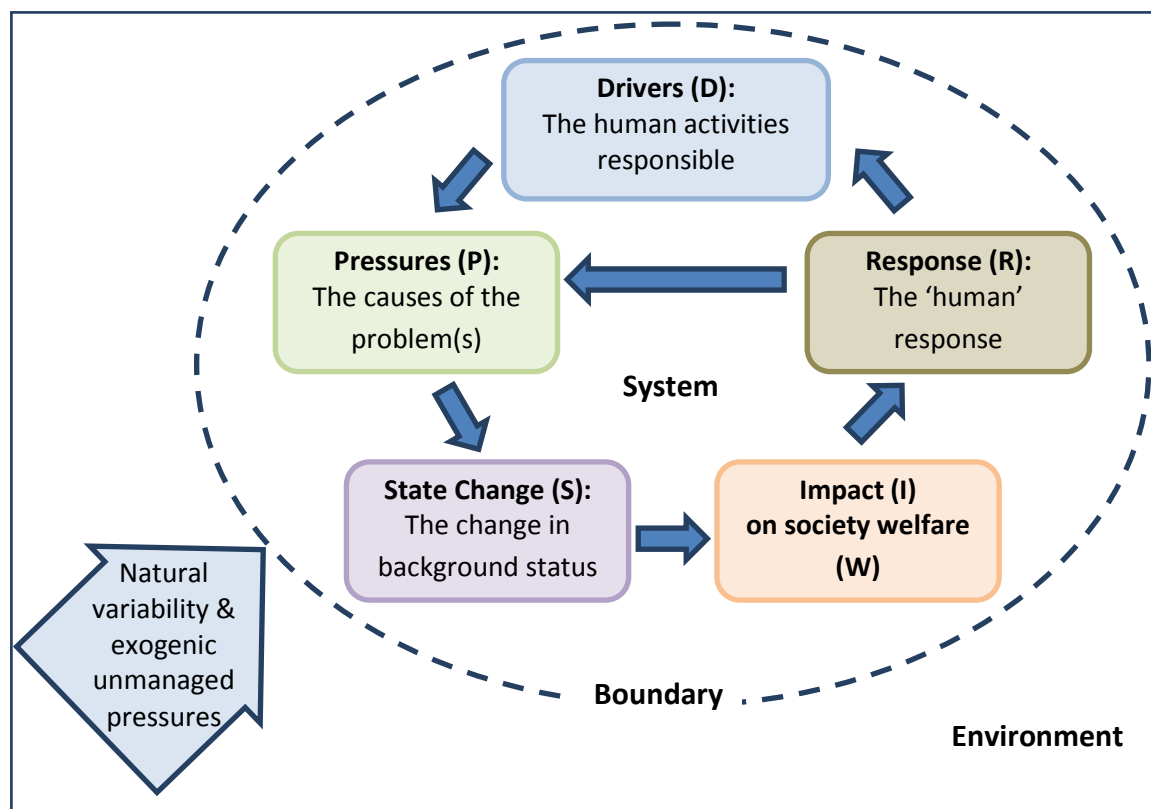


Figure 4.S.3. The DPSI(W)R framework can be explicitly focused on ecosystem services through the S and I(W) stages.

Recent applications of the DPSWR framework have also moved away from just expert-driven evidence focused modes of use towards the use of the framework as a heuristic device to facilitate engagement, communication and understanding between different stakeholders. The application of scenario analysis to the DPSWR framework can be a useful way to further incorporate the DPSWR into the DSS for management decision-making.

4.S.3 Scenario analysis for coastal/marine contexts.

As shown by forecasts of climate, simulations with numerical models can be used to predict change within a defined envelope of uncertainty. The consequences of global changes for ecosystem services are, however, not fixed. They depend in part on the societies and economies linked to those services, for example on the extent to which, and the means by which, society manages the human activities that impact on these services. In principle, the socio-economic effects might be explored using models of social-ecological systems driven by projections of global change. However, although relevant ecosystem models are in the course of development, their coupling to socio-economic models is no more than embryonic. Additionally, there are many feedbacks of unknown intensity. For example, societal response to the effects of climate change might be to reduce emissions of greenhouse gases, or to become more adaptive in, for example, adjusting to sea-level rise. An alternative to numerical modelling is to bring together a group of experts in what is called a 'Delphi process'. Such a process aims to explore expert views and assemble them into consistent 'best guesses' of alternative futures.

We convened an expert workshop in May 2013 and presented it with five scenarios (**Figure 4.S.4**). The scenarios, which drew on earlier work for the 2011 UK NEA report and the European ELME

project, might be thought of as alternative futures for UK society. Alternatively, they might be seen as descriptions of different societal organisation in relation to (i) the importance of market forces (versus other methods of resource allocation) and (ii) the dominant level of environmental government (from local through national to supranational). The first view implies that the scenarios are like railway tracks and that society could, if it wished, operate points so as to switch to a new future. The second view merely asks 'what if ...', and provides a focus for discussions about management methods that might be used to maintain ecosystem services under the 'Baseline' (also called 'Go with the Flow' or 'Business as Usual') scenario that assumes continuation of present socio-economic trends and successful implementation of current policies.

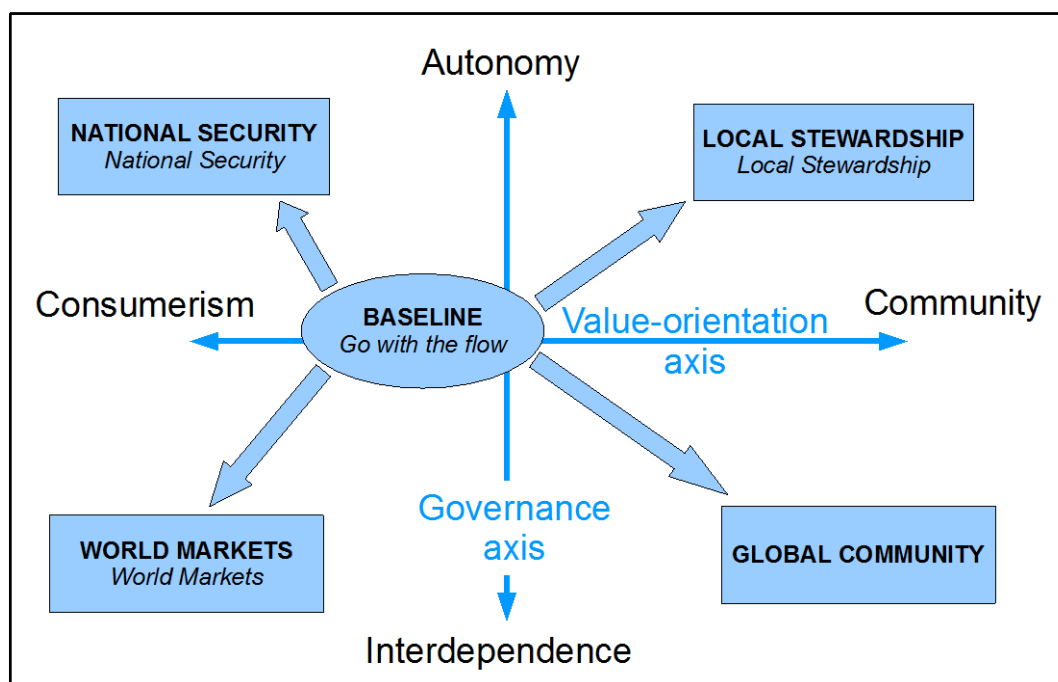


Figure 4.S.4. The five scenarios discussed during the expert workshop, arranged according to what they assume in terms of (i) individuality versus collectivity, and (ii) the main level of governance. Titles in italics are those of the scenarios in the UK NEA 2011 report.

The experts were asked to assess how marine ecosystem services would alter by 2060 under projected macroeconomic conditions and climate change in the Baseline scenario, and how the services would respond to shocks such as a half-year of shading by volcanic dust, the pollution consequent on an overtopping of the Thames barrier, or another financial crisis such as that of 2008. Although there was a range of opinions, the overall view was mildly optimistic. It was that UK marine ecosystems would prove resilient to such temporary shocks, and that there would be some improvement in services as a consequence of present trends in environmental policy.

The four alternative scenarios were called 'National Security' (market society with small state but strong commitment to national culture and interests), 'Global Markets' (with emphasis on free markets, growth and consumer choice), 'Local Stewardship' (communitarian, pro-environment, maximum subsidiarity in government) and 'Global Community' (world emphasis on equity and sustainability). Together with 'Baseline', the first three of these correspond to four of the six scenarios proposed in the first NEA report. Opinion (summarised in **Figure 4.S.5**) was that marine ecosystem services would worsen (compared to Baseline) under climate change and 'National Security' or 'Global Markets', and would improve (above Baseline) under 'Local Stewardship' or

'Global Community'. In all cases there would be differences between physically and socially defined regions of Britain (i.e. between the S-E of England, the rest of England & Wales, and Scotland).

Final Ecosystem Service	Scenario	Baseline (1)			Baseline (2)			National Security			World Markets			Global Community			Local Stewardship		
	Region	SEE	N&W &W	SC	SEE	N&W &W	SC	SEE	N&W &W	SC	SEE	N&W &W	SC	SEE	N&W &W	SC	SEE	N&W &W	SC
Wild fish/shelfish/seaweed		-1	1	5	-5	1	6	1	1	1	-18	-18	-13	20	20	20	12	13	13
Cultured fish/shelfish/seaweed		7	9	16	2	5	13	-2	2	5	1	16	18	3	10	10	10	9	14
Genetic resources		1	4	4	-1	0	2	-6	10	-8	-14	-14	-14	0	0	0	6	8	8
Climate regulation		1	4	3	1	2	4	-5	2	-8	-16	-18	-18	18	10	10	-3	-3	-2
Natural hazard protection		5	6	3	2	3	4	-9	-6	-4	-10	2	-2	18	10	10	5	7	7
Waste breakdown/detoxification		2	4	4	3	4	4	-9	-7	-5	-12	-4	-4	1	10	10	5	8	5
Meaningful places - Socially valued seascapes		3	8	7	2	6	9	8	5	7	-18	-5	-9	1	10	10	8	8	8

Figure 4.S.5 Expert opinions about the relative change in delivery of marine ecosystem services under five different scenarios in three British sub-regions: South East England (SEE); North and West England and Wales (N&W); and Scotland (S). Green is positive (good, max. score +20); white is relatively little change; and orange is negative (bad, max score -20). The Go with the Flow scenario was assessed by the group before (Baseline 1) and after (Baseline 2) the deliberations. Since marine systems are open and heavily influenced by global and regional policies, a Global Community scenario was devised and tested (emphasising wider international factors and increased globalisation of governance in the maritime environment), rather than the Nature@Work and Green and Pleasant Land scenarios designed for terrestrial environments. All other scenarios are those from the UK NEA.

Two key policy implications can be drawn from these results. The first is the importance of sustaining present trends in marine environmental management. The second is what can be learnt from the alternative scenarios that might be applied technically (i.e. without major socio-economic alterations) within the Baseline scenario. An example would be the increased use of locally managed 'soft engineering' of coastlines, augmenting carbon sinks and improving the resilience of coastal ecosystems and communities to sea-level rise.

These are *products* of the workshop. In addition, the workshop *process* may also lead to benefits. When the alternative scenarios result in strong deviations - for better or worse - from the baseline, they stimulate discussion about the societal (and economic) conditions that might improve the provision of ecosystem services. Of course, trying to adopt such conditions might be though desirable or undesirable for other reasons, but opening up new ground for discussion sheds light on present management policies and might lead to innovatory proposals for sustaining marine ecosystems.

4.S.4 Indicators of ecosystem services change

Within the DPSWR framework a set of practicable ecosystem indicators is required and these reflect *State changes* and *Welfare impacts* relating to ecosystem services supply. Indicators are of two sorts, trend/trajectory indicators reflecting state, and indicators associated with absolute limits for compliance reflecting performance. All indicators should meet operational requirements, such as being SMART, and be grounded within the ecosystem service and management frameworks. The data requirement of indicators is recognised and examples of data sources for the UK marine environment are identified.

Further consideration is given to six ecosystem services comprising fisheries and aquaculture, sea defence, prevention of coastal erosion, carbon sequestration/storage, tourism and nature watching, and education, and two broader concepts comprising biodiversity and cultural assets. These were selected for consistency with the review of economic valuation studies (Section 4.S.6) and demonstrate how multiple indicators are necessary to capture the complexity of the marine system associated with even single ecosystem services and to detect change over time in their service provision. In the case of sea defence, for example, a range of indicators related to state and/or performance would be needed to reflect natural hazard protection, natural hazard regulation and many ecosystem components and processes that are connected with *State changes* and *Welfare impacts* on that service provision (Figure 4.S.6).

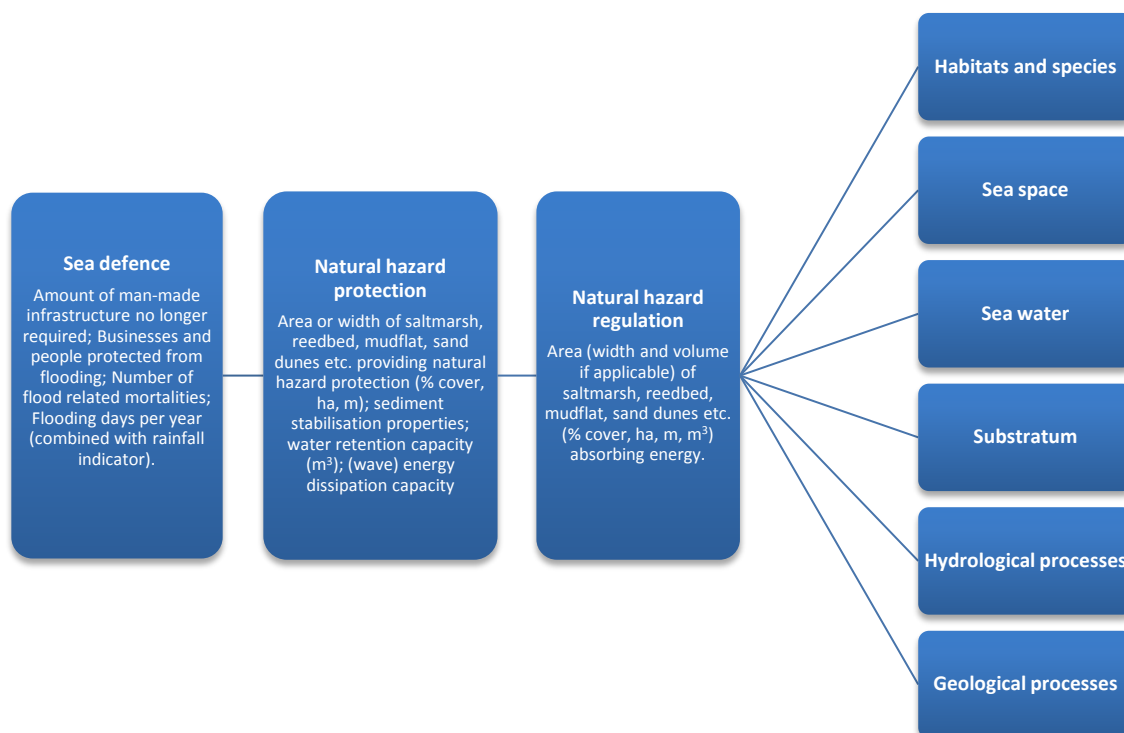


Figure 3.S.6. Sea defence indicators at the level of goods/benefits, final ecosystem services, intermediate ecosystem services, and system structure and processes.

Two case studies on marine protected areas (MPAs) and managed realignment sites show the importance of site-specific data sources in relation to the practicable operation of ecosystem service indicators. MPA designations require a suite of ecosystem service indicators to support selection, monitoring and evaluation of associated management measures as illustrated by site-specific evidence presented for Lundy No Take Zone and Skomer Marine Nature Reserve. Data availability would likely be constraining if prior designations were absent. In the case of managed realignment sites, salt marsh habitat is recognised as providing a number of ecosystem services requiring a suite

of indicators depending on the key characteristics of the site’s ecosystem components and processes and the focus of site management.

Although our focus here has been on ecosystem service indicators relating to the quantification and monitoring of change in provision, the indicators identified could also be applied to test for compliance against a given policy instrument such as Good Environmental Status as required under the Marine Strategy Framework Directive (MSFD). Ecosystem service and the proposed MSFD indicators are thought to be consistent though reflecting different contexts.

4.S.5 Models as tools in the DSS

The scoping, scenarios and indicators components of the DSS all need to be underpinned by as good a scientific knowledge base as is feasible and which can be tested through the use of models. Models offer a way to coherently synthesise and test our understanding of the environment, analyse changes in ecosystems with complex and non-linear interactions, and forecast future changes. Such models range from conceptual frameworks, through models developed based on correlations between variables in existing data sets, to models based on fundamental physical and chemical theory. While models of physical processes such as tides and water circulation can generally be developed from mathematical principles, as biological systems are included, the models require more data and parameterisation of processes. The inclusion of human activity adds a considerable layer of complexity and often requires the inclusion of expert judgement.

No single model can address all of the requirements of the marine NEA, but a range of models using several different sorts of approaches are available that can tackle many different components of the marine/coastal ecosystem and contribute to the UK NEA. Predictions of future changes in the ecosystem require several models and are still dependent on the definition of future scenarios. Thus the models support rather than replace scientific evaluation and judgement. In **Table 4.S.1**, we tabulate selected final ecosystem services and the goods and benefits and link them to the types of models that can contribute to the effective management of these services.

Table 4.S.1. Final ecosystem services, goods and benefits and models that can help provide information on these

Final Ecosystem Services	Goods and Benefits	Types of Models (see section 4.5 of WP4 Report)
Fish and shellfish	Food	Wild Fisheries – fisheries yield models, biogeochemical models, end-to-end, hydrodynamic and sediment transport models, climate change models, integrative tools –Bayesian networks and spread-sheet. Aquaculture – biogeochemical models, farm and water-body scale models
Algae & seaweed	Fertiliser	Macro-algae models, biogeochemical models
Ornamental material	Ornaments	
Genetic Resources	Medicines and	

	blue technology	
Climate Regulation	Healthy climate	Biogeochemical models (C sequestration), climate change models, hydrodynamic models, Bayesian networks and spread-sheet.
Natural Hazard Protection	Prevention of coastal erosion and sea defence	Storm surge models, sea level rise models, sediment transport models, hydrodynamic models, Bayesian networks and spread-sheet.
Clean water and sediments		Biogeochemical models, hydrodynamic models, sediment transport models, land use models, Bayesian networks and spread-sheet.
Places and seascapes	Tourism, spiritual and cultural well-being, aesthetic benefits, education	Bayesian networks and spread-sheet, Models of intermediate complexity built using the approach of Box 4.3 in WP4 report.

Our survey of modelling capabilities has shown that while significant progress has been made across a range of environmental contexts, the efforts so far to link terrestrial catchments to coastal and marine environments have been limited. While estuaries are important components in such a ‘coupled’ approach their complexity is such that the models that do exist are site specific, or are ‘box’ models without spatial representation.

We take a closer look below at how progress might be pragmatically made to better link nutrient flows from catchments to estuaries and coastal waters and the consequences for ecosystem services provision. There are several options to link the terrestrial and marine environment. The UK geography is not suited to the approach of nested models to represent land-estuary-sea dynamics, so that a simpler approach using estuarine box models is suggested. A box model is a model without spatial representation, which captures the main dynamics as a function of time and ‘forcings’. The following non-exclusive options for linking land to sea are possible with varying degrees of effort:

1. A simple but effective coupling can be achieved by using results from the NEA land-use model (flow and nutrients) as direct input into marine models, replacing the riverine observational data. This can be achieved in the short run, and would allow for a better simulation of current and future marine coastal conditions.
2. A more comprehensive approach, taking into account estuarine processes, would be to couple the NEA land-use model to an estuarine box model based on estuarine classification (Prandle, 2010a; 2010b) and simplified nutrient processes. This would require some development of estuarine box models and could be included as part of the pre-processing of nutrient data before application to the marine model. A simplified representation of nutrient cycling could be based on the results of the Joint Nutrient Study (JONUS) programme, taking into account river flow, sediment availability, percentage of intertidal area and other estuarine characteristics.
3. A fully coupled approach would be to include the estuarine box model as an extension of the marine model, allowing for both marine and land-based influences on estuarine processes. This would require model development of both the estuarine and marine models, and would take

into account any marine representation of the estuary based on model resolution (i.e. a fine scale marine model will spatially cover more of an estuary than a coarse scale marine model, causing the estuarine box model to represent a smaller area).

Model outputs could be integrated in a Bayesian network model to investigate possible changes on pressures (such as nutrient inputs) and ecosystem services under different scenarios. This can also be further integrated with a socio-economic component and be fed into a valuation assessment of ecosystem services and appraisal of management options.

4.S.6 Economic and social appraisal

The application of economic and social appraisal of projects, policies, programmes or courses of action in the coastal context can only take place after policy issues have been identified and highlighted within given spatial and temporal scales, and scenarios and evaluative criteria have been established and legitimised within the dialogue process. Once agreed, the policy issues and scenarios chosen then provide the backdrop and framework in which economic and social appraisal can take place. Thus the effect of management options/choices on ecosystem services can be evaluated and any trade-offs among services made explicit. However, this is not a one-way process. Ideally, feedback should occur between all stages of the assessment process and the deliberative procedures set up with stakeholders, since concerns that are thrown up by the dialogue can help to refine the policy issues, leading to 'acceptable' interventions and scenarios that resonate with most stakeholders and interest groups.

The evaluation of options and trade-offs involves an estimation of their impacts in terms of welfare/wellbeing consequences for society. These impacts can relate to changes in the provision of ecosystem final services and goods (which could include, for example, the carbon storage functions of coastal mudflats) and other, more conventional goods (such as commercial fish catch or shellfish harvested from coastal mudflats). Primarily, economic assessments are concerned with those impacts on goods that can be valued in monetary terms. However, this does not mean that all impacts can be incorporated into such an analysis – it may not be possible to value all impacts in this way, because of practical or ethical considerations. Hence we consider that economic assessment provides just one strand of an overall integrated (sustainability) analysis, with other strands being supplied by trade-off assessments from social and deliberative as well as ecological perspectives (see balance sheet approach, Section 4.S.7). It is also the case that the sustainable provision of the flow of final services and related goods and benefits depends on the maintenance of ecosystem processes with adequate carrying capacity and resistance and resilience characteristics. Given the prevailing uncertainties surrounding environmental change and its consequences a precautionary approach and regulatory regime are also necessary for effective adaptive management.

The core of the economic assessment process is to determine how changes in ecosystem services provision are translated into changes in welfare (which can be positive or negative, i.e. benefits or costs). This is achieved by, where possible, placing a monetary value on those changes and aggregating these values together to arrive at an overall change in value for the environmental and policy scenarios considered.

In the economic literature, a number of issues can be identified as key to the appropriate economic valuation of ecosystem services. These are: spatial and policy context explicitness, marginality, the double-counting trap, non-linearities in benefits, and threshold effects (see **Figure 4.S.7**).

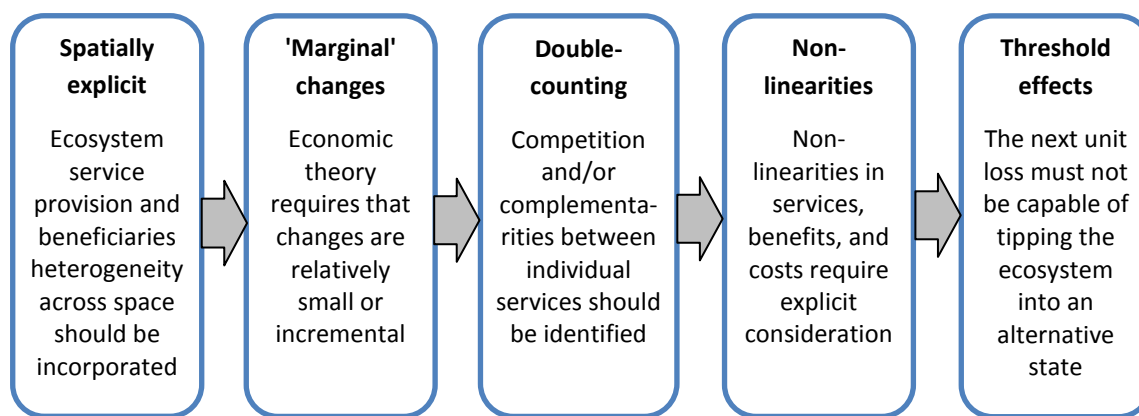


Figure 4.S.7. Ecosystem Services Sequential Steps: A framework for appropriate economic valuation. Source: Morse-Jones *et al.* (2008).

Therefore to be most useful for policy, services must be assessed within their appropriate spatial and policy context and economic valuation should provide marginal estimates of value (avoiding double counting) that can feed into decisions at the appropriate scale, which recognise possible non-linearities and are precautionary in terms of respecting wherever feasible the bounds of safe minimum standards (MEA, 2005; Turner *et al.*, 2003).

4.S.6.1 Ecosystem services flow values

The distinction between ecosystem services stocks and flows has also to be reflected in the economic valuation approach adopted. The paper in the journal *Nature* by Costanza *et al.* (1997) estimated the value of global ecosystem services at \$33 trillion and this led to a protracted debate and controversy over the ‘true’ value of the natural environment. The value of nature is a multidimensional concept which includes monetary value but also more qualitative measures. The complete ‘commodification’ of nature is an ever present danger to be avoided according to critics of monetary valuation. The position adopted here is that many (but not all) ecosystem services can be meaningfully expressed in monetary terms and that this type of calculus has ‘political’ purchase which can be used to further conservation efforts in the real world. It is important to be able to quantify and evaluate gains or losses in stock assets and consequent service flows (analogous to net GDP).¹ In economic analysis, we seek to determine marginal economic value as it relates to an incremental increase in a set of ecosystem services over time and space. So in the case of blue carbon in Europe, for example, future economic losses from a possible continued decline (up to 2060) in salt marsh and sea grass areas have been estimated at between US\$4 million to US\$500 million, using a range of Social Cost of Carbon estimates (US\$5-312) (Luisetti *et al.*, 2013). When the ecosystem final services value relates only to non-market services, it can be combined with GDP (in the same way as relevant pollution and other externalities are internalised) to yield a more green GDP measure, or contribute in discounted form to the construction of stock of wealth accounts. The studies reviewed in this report all provide estimates of the value per year, i.e. flow values. But a separate and complementary ecosystem services account or index may also be a worthwhile objective. Overall, the future goal should be to measure and value both service flows and to predict changes in stocks (ecosystem health) which condition future flows, because the monitoring of stock and flow positions can support sustainable management.

¹ GDP reflects the financial (market) value of all final goods and services produced within a country within a certain period. Net Domestic Product (net GDP) is GDP net of the depreciation on capital goods, and thereby reflects how much capital has been consumed over the year.

4.S.6.2 Valuation Studies Review.

The academic literature on environmental valuation provides evidence of the welfare and wellbeing that society derives from coastal and marine ecosystem services. We performed a review of the existing international literature in search of monetary value estimates that can be used in the assessments of these goods and benefits in the UK. Emphasis was put on reviewing economic, non-market benefits. In total, we found 208 international studies published since 2000 in the peer-reviewed academic literature, of which 25 provide UK-based value estimates.

Different coastal and marine habitat types provide a range of ecosystem goods and benefits. In the assessment of the total economic value of marine and coastal habitat changes, one would ideally use reliable value estimates for each habitat-benefit combination. The literature provides useful estimates of benefits of sea defence and carbon sequestration by salt marshes, and recreation at beaches and along the coast, that can be used in benefit transfer exercises and scenario analysis. However, the review of these 25 UK studies reveals considerable gaps, including those ecosystem benefits deemed important by experts (see **Table 4.S.2**). The main gaps relate to the biodiversity and seascape (non-use) values and benefits of research and education of the majority of coastal and marine habitats. Moreover, for some of the typical GB habitats, such as machair, sea cliffs, cold water coral reefs, and rocky bottom areas, no studies are available, whilst comprehensive analyses of the benefits and goods provided by estuaries and intertidal wetlands are also unavailable.

Table 4.S.2. Importance of ecosystem services per coastal and marine habitat and the availability of UK-based valuation studies. Red: services of high importance with no relevant valuation studies; Orange: important services with one valuation study, or services of medium importance with no valuation studies; Yellow: important services with two or more valuation study or services of medium importance with one valuation study; White: services of low importance or services of medium importance with two or more valuation studies.

	Products	Sea defence	Erosion prevention	Healthy climate	Tourism and nature watching	Education research	Aesthetic: property \$	Spiritual/aesthetic: wild species, seascapes
Dunes	0	2	0	1	1	0	0	1
Beaches	0	1	1	0	4	0	0	0
Sea cliffs	0	0	0	0	1	0	0	0
Machair	0	0	0	0	0	0	0	0
Lagoons	0	0	0	0	0	0	0	0
Marshes	1	4	0	4	1	0	0	1
Mudflats	0	2	0	2	1	0	0	0
Inter. wetland	0	0	0	0	0	0	0	1
Seagrass beds	0	0	0	1	0	0	0	0
Kelp forest	0	0	0	1	0	0	0	0

Estuaries	0	0	0	0	0	0	0	0
Cold water coral reefs	0	0	0	0	0	0	0	0
Rocky bottom	0	0	0	0	0	0	0	0
Coastal shelf	3	0	0	1	5	1	0	2
Open ocean	0	0	0	0	0	0	0	0

§ Property related aesthetic values are not included in Table 11.3 of UK NEA 2011.

The options for reliable benefit transfer, both of UK and overseas studies, which report specific values to other comparable habitats may be limited as relatively recent studies are often scarce. Moreover, not all value estimates are suitable for benefit estimation of scenarios, as some values represent non-marginal values. Finally, the valuation studies tend to use different valuation methods, which implies that the results are not directly comparable and cannot be directly added up.

Our review results provide some guidance on the prioritisation of future efforts in primary valuation research. It clearly shows that more primary valuation studies are needed for valid and reliable assessment of the social welfare provided by coastal and marine ecosystem services.

4.S.7 'Balance sheets' appraisal approach

If cost-benefit analysis (CBA) or related methods are to continue to play a role in the policy process, then a more explicit focus on distributional issues (i.e. who gains and who loses from environmental change and consequent policy responses) is required. A two-stage approach needs to be adopted in which the spread of costs and benefits across different affected individuals and groups in society needs to be accounted for and a weighting procedure applied. Project appraisals funded by economic development agencies have routinely included distributional weights but this practice has not been common place in other public sector applications. As a minimum, the way in which the CBA 'accounts' are set out and formatted needs to be changed in order to incorporate and highlight financial transfers and the distributional impact of costs and benefits across stakeholders. Krutilla (2005) has set out a tableau format which disaggregates the benefits and costs of a project or policy among stakeholders and records all inter-stakeholder financial transfers. It also serves to illuminate key issues such as the level of aggregation adopted and the project/policy accounting boundary.

Changing the accounts format is a necessary first step in distributional analysis, but Kristrom (2005) has gone further and put forward a 'hierarchy of options approach' in which explicit distributional weighting is applied, based on a rule that requires higher weights on all costs and benefits accruing to socially disadvantaged or below average income groups. Alternatively, explicit distributional weights can be introduced to reflect the degree of inequality aversion present in society, by examining past public policy decisions, or the prevailing marginal rates of income tax (Atkinson *et al.*, 2000).

Any DSS that is put in place to assist in evaluating the gains and losses involved in marine planning and management will need to encompass a wide diversity of impacts and different stakeholder perspectives. The balance sheets approach set out below (see **Figure 4.S.8**) is a pragmatic attempt to provide a format within which the complexity of real world decision making and trade-offs can be examined. It sets out three complementary components (balance sheets) which can be seen as

‘roughly comparable’ sets of findings with overlaps and linkages. The aim would therefore be to determine the ‘best’ combination of data, methods and analysis, depending on the actual activity and context under appraisal (Turner, 2011).

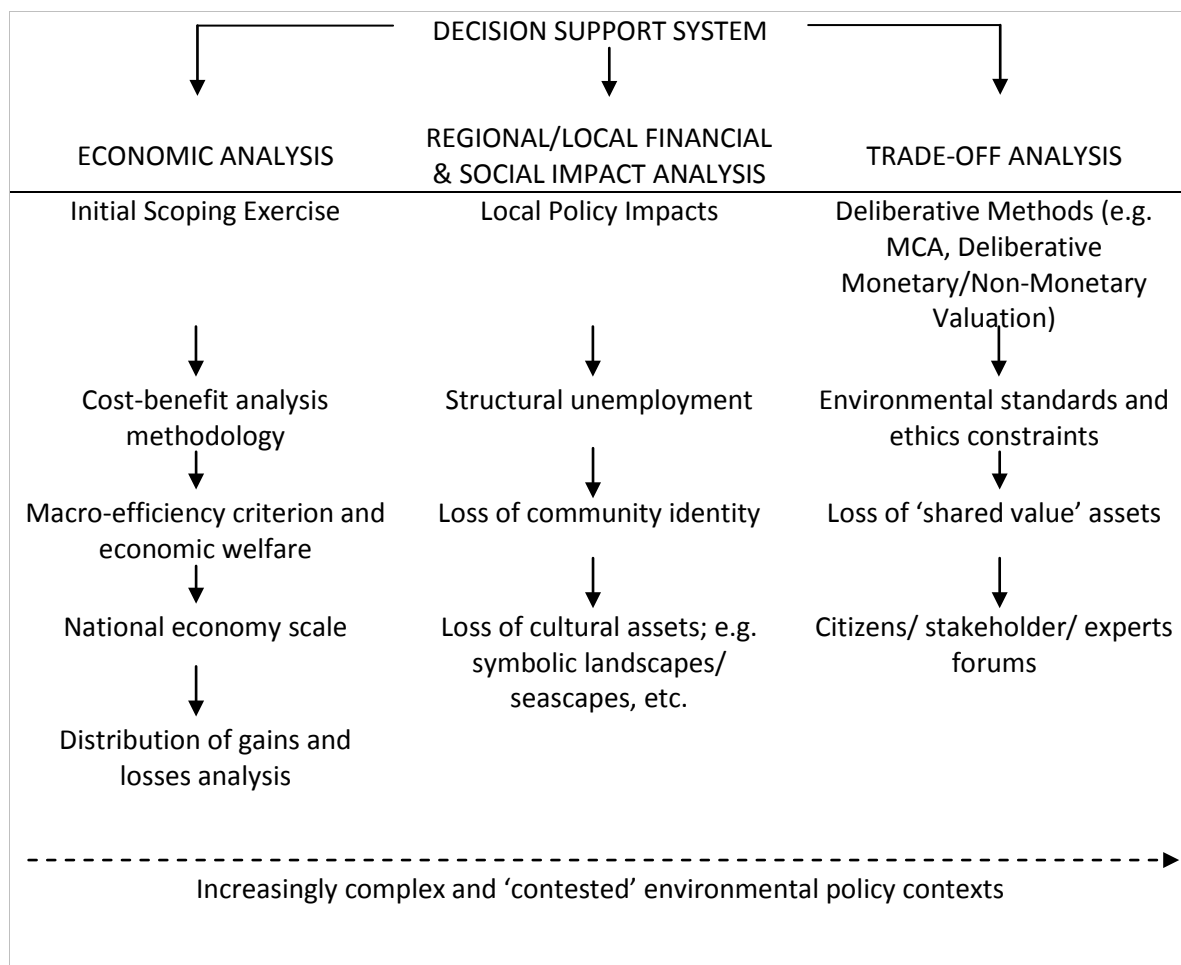


Figure 4.S.8. Policy Appraisal Balance Sheets.

In the Balance Sheets Approach, the three balance sheets are envisaged to try to give some guidelines for steering a reasonably objective course through ‘contested’ policy contexts, and these are illustrated in Figure 4.S.8.

1. Economic (monetary) CBA using a conventional economic efficiency criterion (macro UK economy efficiency), but augmented with a distributional analysis of impacts and possible equity weighting;
2. Regional and local financial impacts and policy analysis, covering impacts like local unemployment, loss of community identity and related financial multiplier effects which often raise issues of compensation; and
3. Trade-off analysis and (non-monetary) evaluation, better suited to dealing with collective or shared values across wider society such as, for example, intrinsic value in biodiversity, cultural assets value etc.

The analytical sequence of the balance sheet approach would begin with an economic cost benefit scoping analysis and then proceed to include the other balance sheets depending on the context and the type of issue under scrutiny. The aim would not be to aggregate the results of each balance sheet but to present the policy process with the set of findings in as transparent a way as possible. Given the range of data that relates to the marine environment and related socio-economic activities, there is a pressing need to agree broad categories of data which can illuminate the

economic, social and environmental dimensions of environmental change in the marine context. The balance sheets approach aims to achieve this by separating out, in the first instance, economic data and analysis. So in the first column of Figure 4.S.8, economic data is covered and is guided by the criterion of macro-economic efficiency and informed by market-based data, WTP data and cost data (including second best data such as gross value added (GVA), etc). A key link to the second column in Figure 4.S.8 is provided at the bottom of the first column when the issue of the distribution of costs and benefits is raised, i.e. who gains and who loses from any change. In MSFD terms we are now shifting from an economic appraisal (enabled via CBA or cost-effectiveness analysis, CEA) into a wider social appraisal. The second column of Figure 4.S.8 expands on the sort of data and issues that are best classified as social effects with a spatial boundary (local/regional) condition imposed on the analysis. The final column of Figure 4.S.8 continues the social analysis but now encompasses values and impacts that are often expressed at the national scale with a variety of underlying ethical criteria. Clearly the columns overlap but the aim is to give some logical sequence to a decision support method(s) and process which is trying to scope and analyse real world (often 'wicked') economic and socio-political issues and inevitable trade-offs.

4.S.8 Conclusions/key findings

Coastal zone environmental changes have been defined in management terms to include direct and indirect influences from adjacent river basins and catchments, estuaries and coastal seas extending out to the continental shelf. This continuum concept is compatible with the NEA **ecosystem services framework** which seeks to encompass ecosystem structure, processes, services and goods/benefits (in welfare terms).

The **high level principles of adaptive management (AM)**, which is a 'learning by doing' approach, are advocated as the best way to cope with the diverse and dynamic environmental change and its often uncertain consequences experienced in coastal zones. AM also requires a **practical decision support system (DSS)** focused on specific issues and decision making contexts with a number of sequential but overlapping components. The sequencing can be altered to suit the different contexts and issues under investigation. The main components of the DSS are: a scoping method, scenario analysis, a scheme for functionally related indicators of change in ecosystem services supply, a toolbox (including models) for scientific, economic and social appraisal of options and trade-offs, formatting of data assumptions and findings, and monitoring and review procedures.

The **DPSWR scoping framework** combined with scenario analysis plus the appropriate indicators set, can identify causal trends in coastal environmental change, monitor them and relate these to outcomes (within the 'Welfare impacts' stage of the DPWSR) in terms of ecosystem services provision over time. In order to apply economic and social appraisal methods the scoping process must be focused down to 'key' contexts and issues and possible trade-off situations.

Five **marine futures scenarios** (related to the NEA 2011 scenarios) were successfully tested in an expert workshop in order to identify changes in ecosystem services supply by 2060. The general conclusion (with some regional variation) was that the UK marine ecosystems would prove resilient to temporary shocks. It was also felt that the supply of some services would increase if prevailing environmental planning/management regimes were maintained over the long run.

It has been possible to derive a **practicable set of indicators** for the ecosystem services within the NEA framework. Further consideration was given to six ecosystem services, fisheries and aquaculture, sea defence, prevention of coastal erosion, carbon sequestration and storage, tourism and nature watching, and education, and two broader concepts comprising biodiversity and cultural assets. **Figure 4.S.6** illustrates appropriate indicators for the sea defence service. The indicators were

applied to marine protected areas and managed realignment sites contexts to show ‘in part’ the importance of site-specific data sources. Links with the MSFD indicators are recognised.

No single model can address all the needs of AM and the ecosystem services DSS, but a range of **models** are available to address the different parts of the marine/coastal environment (see Table 4.S.1). A number of pragmatic strategies are available, for example, to link the NEA land use change model to models for estuarine and coastal areas in order to assess the consequences for ecosystem services as climate and other parameters (e.g. nutrient flows from catchments) change.

The **review of existing UK coastal/marine services valuation studies** covering important habitats and ecosystem goods and benefits has served to highlight a number of data gaps. Two key conclusions from this review therefore are that more primary valuation studies need to be conducted and that benefits transfer is not a panacea in this context (see Table 4.S.2). Where no recent UK valuation studies are available, the use of any available older or international studies may be considered. However, both temporal and cultural bias constraints remain formidable challenges for any benefits transfer exercise using data more than a decade old and spatially more distant than a rough boundary around Northern Europe.

While a number of methods and tools exist for **economic and social appraisal**, a new formatting approach labelled the **‘Balance sheet’ procedure** has been advocated. Under this format, blocks of data are brought together in separate but overlapping ‘balance sheets’ and progress through the three main ‘balances’ is determined by the type of policy/context that is under appraisal scrutiny. In simple terms the more ‘wicked’ the problem the greater the probability that all three ‘balances’ will need to be populated with data of varying types and trade-offs considered.

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