Chapter 8
A Review of Marine and Coastal Ecosystem Services Data and Tools to Incorporate This into Decision-Making

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8.1 Introduction

One of the five guiding principles of the UK Government's 2005 Sustainable Development Strategy "Securing the Future" is to use sound science responsibly to underpin the activities of government departments and organisations. The principle promotes an evidence-based approach to decision-making and policy development

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through each stage, from identifying and monitoring environmental issues, to the consideration of all available policy options, development of the most appropriate management response and subsequent evaluation of policy effectiveness.

It is critical therefore to invest in research for new data and to develop the ability to discriminate between evidence which is reliable and useful, and that which is not. These data need to be made publicly available to ensure transparency in the decision-making process, to encourage open and rigorous public debate and to avoid unnecessary duplication of research. Accessible and user-friendly tools and guidance are then needed to apply that data for decision-making in a consistent, relevant and rigorous approach (Scott et al. 2014).

Historically, marine policy, management and data collection have focussed primarily on environmental concerns. However, if policies are to be successful, both in terms of uptake and achieving their desired goals, it is increasingly accepted that they should also take into account social and economic factors (see Chap. 2, Defra 2011; United Nations 1987). Ecosystem services assessment aims to provide a more holistic view of the value that the marine environment provides to human beings and how this value may be impacted by policy decisions.

Ecosystem services research requires a large range of environmental, social and economic information to inform the various levels of the assessment framework (see Chap. 2). Environmental information is needed on the distribution and status of coastal and marine features (e.g. habitats and species, sea space, sea water, substratum) along with an understanding of the ecological processes that influence them in order to appreciate the flow of final services. In order to then assess human wellbeing derived from these final services (i.e. goods and benefits in Chap. 2) information is needed on the value of the marine environment to human wellbeing, and where and how this value is extracted.

As a consequence, in the commercial and academic arenas, the application of coastal and marine ecosystem services research to the understanding and management of the environment is a rapidly growing field (Liquete et al. 2013). However, the availability of data and tools to apply such thinking to decision-making is also key. The Marine Environmental Data and Information Network (MEDIN)[1] is an open partnership which promotes sharing of, and improved access to, marine data in the UK. The MEDIN datasets for natural science data are comprehensive and well developed, but deficient in terms of social and economic data.

The first part of this chapter focusses on the findings of a project carried out by several of this chapter's authors which developed and analysed a metadata[2] catalogue of relevant UK marine social and economic data (MMO and Marine Scotland 2012a[3]), hereafter referred to as "the catalogue". This includes data measuring the impacts on wellbeing as well as financial values or economic activity associated with uses of the coastal zone. Issues regarding the interpretation of socio-economic

[1] http://www.oceannet.org/

[2] Metadata are essentially data which describe the data, for example where and how the data were collected, the format and location of data etc.

[3] www.scotland.gov.uk/Resource/0041/00412950.xls

data are discussed, specifically including how to handle uncertainty within data and how to utilise qualitative data.

Secondly, the chapter provides a review of the tools that may facilitate the incorporation of ecosystem services data into decision-making. This is a summary of a more detailed project based in the UK (MMO and Marine Scotland 2012b) although many of the findings and recommendations for the future research agenda apply globally. Finally a series of recommendations is put forward for future research.

8.2 Detailed Analysis of Data Availability by Ecosystem Service Category

This section provides an overview of data availability by ecosystem category focussing on the final goods and benefits derived from the coastal and marine environment (see Table 8.1). There are a number of data gaps related not just to social and economic data, but also the availability of environmental data on which to interpret and apply economic data (for example, the abundance and distribution of species used for fish feed and fertiliser).

Given that the methodologies for the valuation of some goods and benefits are still in development, it is difficult to even assess what datasets might be required. For example, the economic value of the sea's ability to assimilate waste is complicated as it is partly dependent on demand (i.e. how much waste needs to be assimilated by the environment) and partly dependent on supply (i.e. the capacity of environmental processes and components to store, break down and regulate particular volumes, concentrations and types of waste). Datasets on the demand for waste management includes annual information on the location, volume, intensity, and monitoring of regulated discharge of wastewater and the disposal of hazardous and non-hazardous waste. Much of this information is managed by either the relevant environment agencies (EA, SEPA and NIEA) or Cefas (licensed disposal sites for dredged material). Datasets on the supply of natural waste management services is more disparate and relates to the distribution and quality of ecosystem components such as saltmarshes, benthic sediments and bacterio-plankton that store and breakdown contaminants and pollutants.

There are no spatial layers describing the distribution of educational marine resources as data sources are too disparate and would require significant time and budgets to collate; related values therefore remain a large data gap. It may however be particularly important at a local-scale, e.g. places such as Plymouth where marine research forms a large part of the local economy.

Furthermore, no single data-layer exists on the location of naturally-occurring coastal defence features although environmental data exist on the location of saltmarshes and shallow subtidal sandbanks, for example, which might enable such a layer to be produced. The economic value of such features has been estimated at national scale (Jones et al. 2011) and there are some more specific case studies

Table 8.1 Gaps in evidence on ecosystem goods and benefits

Service group	Final ecosystem service	Goods/benefits[a]	Status of information on value and distribution and issues
Provisioning Service	Fish, shellfish and other wild/farmed species etc.	Food: fish, shellfish, algae, *Salicornia* and other wild/farmed food	MMO and Marine Scotland Science, Fishermap in England, Scotmap in Scotland and FishMap Môn in Wales, ICES reporting, Cefas, Defra, Inshore Fisheries and Conservation Authorities (IFCAs), Seafish, also derived layers in CP2, MCZ regional projects, MSFD assessments
		Fish feed (wild/farmed/bait)	Data available from Fish Producer Organisations and Seafish but economic value poorly known as difficult to separate landings from that for human consumption
		Fertiliser and biofuels	Economic value poorly known and from disparate sources – see Jones et al. (2011) for overview
	Ornamental materials (shells)	Ornaments	Economic value unknown
	Aquaria materials (fish, seaweeds)	Aquaria	Economic value unknown
	Genetic resources	Medicines and blue biotechnology	Value unknown. See Jones et al. (2011) for overview
Regulating Service	Climate regulation	Healthy climate	Disparate sources of research on the scale of carbon sequestration and storage although unit values agreed
	Natural hazard protection	Sea defence Prevention of coastal erosion	Economic value estimated: raw data exists, e.g. on the distribution of natural features that provide natural hazard protection to collate a spatial layer of values
	Clean water and sediments	Waste burial, removal and neutralisation	Quantities of waste stored and broken down has been estimated for some habitats or marine features but economic value poorly known for reasons given in text (see Austen et al. 2011)

(continued)

Table 8.1 (continued)

Service group	Final ecosystem service	Goods/benefits[a]	Status of information on value and distribution and issues
Cultural Service	Places and seascapes	Opportunities for tourism and nature watching (including recreation)	Social and economic data includes participation and visitor numbers and the related economic turnover from the sector. There are 31 spatial layers that might be used to spatially allocate these values
		Spiritual and cultural wellbeing	Economic value unknown
		Aesthetic and inspirational benefits	Economic value unknown
		Human health	Economic value unknown
		Education, research, knowledge	Datasets highly disparate and incomplete (see below)

[a] Dark grey = minimal social and economic or value data; Grey = some data, but insufficient to support impending policy needs; Unshaded = reasonable, but not perfect, data coverage

(see Chap. 10 and 11). There is also guidance documents on assessing the costs of flood risk (Environment Agency 2010) and a number of examples of the application of the guidance.

Defra is conducting a study due to finish in 2015 to provide valuation of regulating, provisioning and cultural benefits that would arise from targets set under Marine Strategy Framework Directive (MSFD). The UK NEA Follow-on Phase has conducted a series of valuation studies for MPAs as well as local studies on a wide range of services (Kenter et al. 2014). There are also a wide variety of EU funded studies including VECTORS,[4] ValMER,[5] and ODEMM.[6] Finally, information on blue biotechnology and medicines may be available now through online access to licences and university registers of research. All of this future information may inevitably be useful for marine planning purposes in understanding the wider economic value of marine plan areas.

[4] http://www.marine-vectors.eu/

[5] http://www.valmer.eu/

[6] http://www.liv.ac.uk/odemm/

8.3 An Overview and Analysis of Marine and Coastal Ecosystem Services Data

8.3.1 Overview by Data Type

Ecosystem services related studies recorded in the catalogue, included the benefits of natural and man-made coastal defences, marine protected areas and water quality. However, there were very few ecosystem service specific studies, and few of these were original primary valuation studies (see Chap. 6).

Data on some ecosystem services were covered by social and economic datasets in the catalogue under categories such as fisheries and education. However, it is important to note that these datasets do not mean that all management, policy and academic needs can be met. For example there are extensive and readily available fishery datasets but less consistent data to enable assessments on whether stocks are being fished sustainably.

There are few social datasets but these are generally very comprehensive, freely available, national datasets, such as those held by Office for National Statistics (ONS) and Economic and Social Data Service (ESDS) with internationally recognised protocols and standards for data collection and management. However, ONS data may be restricted to a particular spatial scale, e.g. local authority level, with a charge for the provision of more detailed economic data at smaller local scales. In addition, although the ONS and ESDS published datasets are very comprehensive they do not hold a lot of information specifically related to the coastal and marine environment. A number of complex assumptions are required in order to apply the data to marine policy and planning at the appropriate sectoral and geographical scales. For example, national data on tourism will not distinguish between that directly related to coastal and marine activities and other activities, and careful assumptions are often needed to utilise such data. The MMO, with steer from Marine Scotland, conducted a project to explore whether and how ONS data could be interpreted to be more applicable to marine planning (MMO 2014). Unpublished data accessible through the ONS service Nomis and directly from the ONS for a fee should provide much of the necessary information to support marine planning.

The review also collated datasets on the geographic location of social and economic activities and infrastructure, both marine and coastal. This locational and other supporting data (e.g. habitat and species data) can, for example, provide an understanding of the spatial distribution of values. Scotland's marine atlas holds the most up to date information on the location of activities in Scottish waters and the MMO have published a Master Data Register, an extensive list of locational datasets for England used in marine planning[7] The Crown Estate also provide access to their related activity data on the Marine Data Exchange.[8] The availability of social and economic data specific to Wales is less clear although some data are likely accessible

[7] https://www.gov.uk/government/publications/master-data-register

[8] www.marinedataexchange.co.uk/

through the Welsh Government's online statistics and research portal.[9] Marine social and economic data for Northern Ireland is not held in a central place and may only be accessible through each individual government department.

8.3.2 Spatial Scale of Data

The catalogue was primarily focussed on collecting national level datasets. However, exercises such as Strategic Environmental Assessment (SEA), marine planning and Marine Protected Area (MPA) projects have provided a number of regional datasets. It is worth noting that more local datasets may also be available from site specific Environmental Impact Assessments (EIA), Local Authority projects (particularly with respect to tourism and recreation) and local conservation group projects, for example, valuation studies of reserves managed by the Royal Society for the Protection of Birds.

Furthermore, the available data are not always at the appropriate spatial scale. Data are either (1) collated at a national level, making coastal and marine-specific and spatially-allocated assessments difficult or (2) collated at a local or site-specific level, often for a single activity, making it difficult to scale up for national level assessments. There are a number of initiatives trying to improve this evidence base: The Pembrokeshire Coastal Forum have mapped economic values to areas of coastal recreation and tourism in two pilot areas of Pembrokeshire[10] and the MMO have compiled spatial data specifically on coastal recreation activities[11] and looked at ways to better utilise existing tourism data (MMO 2014).

8.3.3 Temporal Distribution of Data

Temporal information regarding the datasets was poorly recorded in the metadata and therefore difficult to assess without delving further in to each individual dataset. Of the social and economic datasets 60 % of metadata provided time series information. Given multiple changes in organisations over time it can be difficult to trace historical data. A significant number of the social and economic datasets were collected as part of one-off projects which were funded to support marine management and influence future policy, for example Charting Progress 2 (CP2), Scotland's Marine Atlas, the National Ecosystem Assessment (NEA) and MPA projects. Even those projects that are updated regularly may be dependent on and vulnerable to funding from internal memberships, for example the British Marine Federation economic reports on recreational boating activity. Social datasets were particularly disparate and often held in individual project reports.

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[9] http://wales.gov.uk/statistics-and-research/?lang=en

[10] http://www.walesactivitymapping.org.uk/economic-valuation/

[11] http://webarchive.nationalarchives.gov.uk/20140108121958/http:/www.marinemanagement.org.uk/evidence/1043.htm

8.3.4 Application/Utilisation of Data

As noted above, a large number of datasets were produced for specific applications in decision-making. However, explicit evidence of the direct application of the data in policy development and marine management can be unclear and specific information on how the data have been used may only be available from the supporting documents, if at all.

Integrating understanding of limitations and knowledge gaps as well as being clear about how data are used in marine management and policy could result in more effective and efficient research, contributing to shared understanding between regulatory and academic sectors. Increasingly, regulators now publish their decision making process and the evidence used to increase transparency. The MMO and Marine Scotland also prepare metadata catalogues for all planning evidence work and provide access to data used (where it is legal to do so) so that others can explore and re-use data.

Complementary work is currently underway within the MEDIN community to assign Digital Object Identifiers (DOI's) to datasets to improve the tracking of their use (Socha 2013; BODC Published Data Library[12]). The UK government has committed to increasing transparency of data generally through its open data strategy[13] and the development and promotion of the Open Government Licence (OGL) for public sector information. Additionally there are marine specific data sharing processes required to support the Marine Strategy Framework Directive (MSFD) and Common Fisheries Policy (CFP) commitments.

8.4 Interpretation of Ecosystem Services Data

The previous sections highlight the diversity in quality and sources of the social and economic datasets. The correct interpretation of these data is essential if they are to be used both efficiently and effectively. Two aspects of interpretation are covered in depth in this section: uncertainty, and utilisation of qualitative data. Other aspects of valuation are covered elsewhere in the book (see Chap. 4).

8.4.1 Addressing Uncertainty in Ecosystem Services Data

In general, information on uncertainties in social and economic data is poorly recorded in the metadata, for example, information on years when surveys were not carried out, or information that the current dataset is undergoing review and is soon to be updated. However, such information is critical in the interpretation of the data.

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[12] https://www.bodc.ac.uk/data/published_data_library/

[13] www.data.gov.uk/

With respect to ecosystem services there are many sources of uncertainty: in the distribution and quality of ecosystem components, understanding of economic value and the links between changes in ecosystem function or extent and consequent changes in service flows/benefits. Analysis of ecosystem services (whether for ‘financial’, ‘market’ or ‘non-market’ impacts) involves three steps:

(i) qualitative analysis that identifies the links between the changes in ecosystem function/extent and consequent changes in service flows/benefits
(ii) quantitative analysis that produces biophysical and other data about this linkage
(iii) economic analysis (market and/or non-market) that also takes account of the social and economic characteristics of the affected human population.

There are gaps and uncertainties in each of these three steps. For example in the first step, we may not know the link between the change in the ecosystem and the change in the associated services.

The knowledge gaps in step (i) naturally continue in step (ii) as an unknown impact cannot be quantified. Even for known impacts, data may not exist, or data may exist in one location for one change context but may need to be ‘transferred’ to other locations/contexts. This transference introduces uncertainty, the scale of which would depend on the similarities between the two locations or contexts (see Chap. 4 and 10).

Step (iii) could suffer from three types of uncertainty. First, the value data may not exist or may not be specific to the location or context of interest. Second, the value data may exist but may not be robust (e.g. survey data may come from very small samples and may be for very specific changes that limit the transferability of the results). Third, the value data may exist and be robust but is often incomplete. It is rarely possible, even when primary valuation research is commissioned, to have monetary value estimates for each type and scale of ecosystem service change. Therefore, the third step of the analysis, the appraisal, tends to produce results expressed in monetary and non-monetary units. The methods with which non-monetary estimates are obtained and the extent to which they are included in marine management, decision making and policy appraisal also contribute to the uncertainty surrounding the results. Integration of research about valuing the environment (HM Government 2011a, 2013; Saunders et al. 2010a) into analysis and decision making should reduce this type of uncertainty.

A final type of uncertainty stems from the scope of analysis. In most social and economic analyses (in all three steps) to date, the focus is usually on one pressure that causes ecosystem changes. If the same resource or service is subject to multiple on-going pressures, or to combinations of threats (natural or human induced), then an analysis focusing the baseline assessment on just one pressure could miss the dangers associated with the overall impacts. For example, when determining the impacts of aggregates extraction on fisheries it may be necessary to consider not only the direct impacts of extraction on fish habitats, but the bigger picture of threats facing fish populations, including overfishing, climate change and the availability of alternative habitats. Not doing so will lead to uncertainty in the results. Similarly most analyses do not take note of ‘cumulative’ impacts over time.

Factors that lead to uncertainty in individual economic value estimates include: the size of the impact being valued; the permanence of the impact; the affected (human) population; the valuation function; the timescale over which valuation occurs; and the discount rate (see Chap. 4).

8.4.1.1 Handling Uncertainty in the Decision Making Context

Uncertainty (both in terms of gaps in data and uncertainty around the existing data) is inevitable. How much of an obstacle uncertainty is to efficient decision-making depends on (i) how easy it is to handle uncertainty in the decision making context; and (ii) how robust the data need to be for the purposes of a given decision-making context. To increase transparency and trust in decision-making, it is crucial to make clear what the evidence tells us, and what the uncertainties are. For this, the meta-data of the data used (or available) should be presented.

The level of uncertainty around an estimate can be gauged by undertaking sensitivity analysis, which involves re-estimating the economic analysis (e.g. CBA) using of a range of values for the parameters that represents a range around the true value. This is done by varying one parameter at a time to assess the effect on the result, which may be most appropriate when there are only a small number of parameters of concern. It is important to test as many assumptions as possible to see how different options fare in each run and what the net outcomes are.

Once the level of uncertainty has been determined, there are several methods available for clarifying the potential implications of this uncertainty for a given decision making context. The aim of these methods is to assist the marine manager or policy maker in understanding what uncertainty means in a specific context, and how to minimise the potential negative implications of this uncertainty. This requires good communication between the manager or decision/policy maker and the data provider. In addition, a number of more technical methods are available, including ‘minimax’ which selects between different options, having run the analysis under several different assumptions, so that the regret of making a wrong choice (selecting the wrong option) is minimised. ‘Regret’ in this context is defined as the difference between the net present value of the chosen option and that of other options.

When there are multiple parameters, each with significant uncertainties, Monte Carlo Analysis allows for these uncertainties to be assessed simultaneously in a single procedure. Monte Carlo Analysis relies on repeated random sampling to compute uncertainty estimates. Over a given domain of possible values (the range of values and the probability distribution across this range), repeated iterations generate a best estimate for the valuation and a confidence interval within which this value is expected to lie. In certain distributions (e.g. normal or triangular) the probability assigned to extreme values is very small, but their inclusion is necessary to ensure a true representation of the degree of uncertainty surrounding the estimate.

A strategic approach to use, especially when probabilities are not known, is the switching analysis. This helps answer the question ‘How wrong does the analysis need to be for the results (the selected option) to be different, in other words, for the positive net present value for an option to become negative?' The switching value (in percentage) for benefits can be estimated simply by deducting the present value of benefits from the present value of costs and dividing the resulting amount by present value of benefits, and vice versa for switching value for costs. The higher the percentage value the less influence an individual (an uncertain or absent) factor has on the results. Note that this analysis does not change the level of certainty in the results, but presents the 'comfort zone' around them.

8.4.1.2 How Much Uncertainty Is Acceptable?

In terms of how much uncertainty is acceptable, there is no theoretical benchmark against which a given uncertainty level can be judged. For risk information, when the probability and/or magnitude of change is known, the smaller the probability is the better. For uncertainty, this is left to how risk averse the decision context can afford to be; one way for decision makers to assess this are the costs of making a wrong decision (see above). It also depends on the phase of the policy or decision-making cycle in which the assessment is carried out (Brouwer 2008). Risk and coping with uncertainty guidance is provided in the UK Green Book (HM Treasury 2011).

There is no method of reducing uncertainty to zero, and as a result it is important to ensure stakeholder engagement and ownership of a decision, together with all its uncertainties. This can only be achieved if stakeholders are involved in a decision from the start and work together to address uncertainty and its impacts (e.g. commission new research, agree on assumptions to be tested in sensitivity analysis etc.) rather than use uncertainty as a reason for disagreement.

If the level of uncertainty is considered unacceptable, a valid option should be to delay the decision making until further relevant data can be collected. In Wales, for example, the recommendations for a network of Marine Conservation Zones (MCZs) have been delayed until more is understood about the potential ecosystem benefits and economic impacts (see Chap. 9). If the decision cannot be further delayed, the reasons for progressing despite uncertainty should be clearly communicated to all parties. In practical terms, economic valuation and CBA deal with risk (i.e. where probabilities are known) reasonably well, and with ambiguity (known outcomes, unknown probabilities) to some extent, through calculation of expected values and various forms of sensitivity analysis. However, economic methods are more limited where possible outcomes are unknown (see Chap. 2). In these cases, concepts of 'safe minimum standards' can be used for aspects of the natural environment that need to be safeguarded because they have critical functions that cannot be substituted or they are near critical limits (Barbier et al. 1990). Unfortunately in most cases it is not possible to identify such limits, and in some cases a highly precautionary approach may not be acceptable due to a disproportionate cost limitation on development.

8.4.2 *Utilisation of Qualitative Data*

Qualitative data play a unique role in environmental management, but are often misused, misinterpreted or taken out of the context. Qualitative data does exist[14] and is accessible, but their use and meaning differ substantially from that traditionally collected for economic assessments.

How sectors, communities, or individuals respond to valuation, in the complex real life context of social, cultural and political action is at the heart of qualitative research. Detailed studies on valuation in a social context can highlight the potential consequences of implementation of an ecosystem service style policy instrument e.g. payments for ecosystem services, green taxes or positive subsidies. How valuations can actually be utilised and what their full consequences are can only be assessed by deliberative means, based on contextual analysis of the relevant political, social, and economic system, its networks and its stakeholders (see Chap. 2). These questions are likely to be controversial and result in public debate, resulting in winners and losers, and shifts in the allocation of resources.

While qualitative research is limited in terms of informing a measurable value for a particular ecosystem service (and often contests the utility of such approaches), its benefit lies in understanding how society responds to a particular policy instrument or scenario. Qualitative approaches may provide insight into the deeper and significant social values that are attached to seascape which are critical for political negotiation and implementation of policy.

A number of studies have explored 'intangible' values of communities towards the sea (e.g. Potts et al. 2011, 2012, 2014; Gee and Burkhard 2010). These data show that societal perspectives that emphasise aesthetic as well as practical aspects of the seas and non-market ecosystem services (e.g. climate regulation and scenery) are rated as important as economic maritime activities. However, as expected, countries vary in their views on particular services with significant differences in interpretation of relative importance, highlighting that analyses should consider the national and cultural context. Such qualitative data illustrates that coastal and marine values captured through economic metrics are not necessarily those of most importance to individuals and there is a clear research challenge in including some of the less easily quantified aspects of the marine environment in planning and decision making.

Data on non-market values around cultural ecosystem services are a case in point in terms of a lack of clear methodological guidelines, definitions or applications (Potts et al. 2014). There is a substantial need to expand, standardise and improve qualitative approaches so that they can complement and augment quantitative estimates.

Uncertainty surrounds the qualitative methodological processes used to determine values (methodological uncertainty) which are themselves subject to considerable debate. Furthermore qualitative data underpinning cultural ecosystem services are inherently context dependent, rich, and non-transferable to the broader

[14] For example the Ecosystem Services Indicators Database produced by the World Resources Institute holds both qualitative and quantitative data on ES indicators including examples of aesthetic and spiritual indicators. See: http://www.esindicators.org/

context. Caution should be used in extrapolation of qualitative datasets that cover deliberations over the meaning of place, power and context, and, while critical for understanding the application of the ecosystem services approach, contribute more to theoretical development rather than longitudinal assessment.

Including qualitative data in a metadatabase, such as the one explored here, is fraught with difficulty as qualitative data often do not fit into the set keywords and categories. However, this information is of key importance and further efforts must be made to describe datasets of a qualitative nature.

8.5 Tools

This section provides a general overview of the different types of tools (as part of the DSS, see Chap. 2), their functions and application throughout the planning process, their various strengths and weaknesses and data requirements.

Tools have a number of different functions throughout the marine policy development and licensing process including:

- Understanding the problem that needs management;
- Data mapping and visualisation;
- Development of policy or development options;
- Selection of sites to meet policy or development objectives;
- Assessment of the economic and social impacts of policy and development options;
- Monitoring and evaluation of policy objectives, targets and licensing conditions.

A summary of the various processes that might be involved under each function is provided in Table 8.2. Examples of applications are given from a regulatory perspective under marine planning and a developer's perspective under marine project development. Some of the tool functions are dependent on each other, for example, development of policy options (and underlying policy objectives) requires an understanding of the issue that needs managing, and site selection tools require mapping and visualisation routines. Processes involved in the development of plan and project options and Impact Assessments should aim to identify objectives, key issues and useful indicators to assist in the development of monitoring programmes. It is also worth noting that some of these tools are required throughout the decision-making process, for example, tools for mapping and visualising data will be important throughout the planning process for communication and stakeholder engagement.

The tool functions may involve both spatial and temporal models and to various degrees may help to:

- Incorporate data from ecological, economic, and social systems;
- Clearly assess management alternatives and trade-offs;
- Facilitate stakeholder participation and collaboration, community outreach and engagement;
- Evaluate progress towards management objectives.

Table 8.2 A summary of the processes involved for each tool function and relevant planning and licensing applications

		Examples in marine and coastal management	
Tool function	Processes involved	Marine planning stages – regulator led aspects	Marine project stages – developer led aspects
Understanding the problem	Identify issues, constraints and future conditions, baseline assessment (dynamic and spatial)	Before planning starts – assessing why a plan is needed	What is the need for the project? Is an EIA required?
Data mapping and visualisation	Gather metadata and data, QA data, identify confidence levels, map data, make data available	Stakeholder engagement, Ongoing plan communication	Stakeholder engagement, Ongoing project communication
Development of options	Define objectives, explore scenarios, develop alternative management measures or project options	Plan development	Project development including early feasibility studies
Site selection tools	Define site criteria, explore scenarios, develop alternative spatial configurations, resolve spatial constraints	Refine any spatial aspects of the plan	Refine any spatial aspects of the project
Impact assessment	Evaluate the costs and benefits, strengths and weaknesses of baseline and alternative options	Sustainability Appraisal of the plan	EIA of the project
Monitoring and assessment	Gather monitoring data, assess performance indicators and evaluate plan/project	Plan monitoring and review	Post-consent monitoring and review

Table 8.3 provides examples of the tools that are available under their various functions. The focus is on tools available in the UK although the review also extended to products available internationally. Links to all of the tools listed can be sourced from the report (MMO and Marine Scotland 2012b).

Overall, there are a large number of tools available for mapping and visualising data ranging from published reports to web-based maps that allow users to manipulate existing data and stakeholders to add their own data. Most of the government-led online web tools are secured with long-term funding to ensure that the initial investment in developing the tool and the effort made by stakeholders to populate it with data are protected.

A number of tools exist to help policy-makers identify likely policy and plan options from simple mapping exercises to complex and data-intensive simulation models. They are often useful in engaging with stakeholders and exploring the initial outcomes of different management options. There are few examples of such tools being

Table 8.3 Summary of tools

Function	General methods	Example products
Data mapping and visualisation	Web maps Data catalogues Reports	The MMO Marine Planning Portal The Marine Conservation Zone portal National Marine Plan Interactive Marine Scotland Interactive MaRS EVRI (The Environmental Valuation Reference Inventory)
Development of options	Virtual and real world simulations Mapping Modelling of outcomes Initial coarse-level impact assessment	CoastRanger Co$ting Nature Coastal Resilience Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) Multiscale Integrated Models of Ecosystem Services (MIMES) ARtificial Intelligence for Ecosystem Services (ARIES)
Site selection	Geo-spatial modelling Cost optimisation models Mapping of constraints	MaRS Touch-table Marxan Multipurpose Marine Cadastre (MMC) MarineMap
Impact Assessment	Cost-Benefit Analysis (CBA) Cost-Effectiveness Analysis (CEA) Multi-Criteria Assessment (MCA) Trade-off Analysis Life-Cycle Analysis (LCA) Bioeconomic models Risk Assessment	DEFINITE (decisions on a finite set of alternatives) IMPLAN (IMpact analysis for PLANning) InVitro (www.cmar.csiro.au/research/mse/invitro.htm) SolVES (Social Values for Ecosystem Services) (http://solves.cr.usgs.gov) EMDS (Ecosystem-based Management Decision Support) Cumulative Impacts model (www.nceas.ucsb.edu/globalmarine) SPICOSA, ARIES, MIMES, InVEST
Monitoring and Assessment		Marine Integrated Decision Analysis System (MIDAS) Ecosystem Assessment and Reporting Tool (EAR)

used in the licensing process, although they could be used to develop alternatives to the proposed project for consideration in the Environmental Statement.

The tools explored in this review ranged from simple mapping exercises to complex environmental and economic models. The level of complexity required from a tool is generally dependent on the level of risk involved in the decision making process (encompassing social, economic and environmental factors), the spatial scale of a plan or project (i.e. ranging from the development of large zonal wind farms to small coastal marine works) and the temporal scales being considered (ranging from short term to long term projects).

Site selection tools specifically facilitate the development of spatial options to address policy issues. They have had limited application in planning initiatives in the UK to facilitate engagement with stakeholders, because the assumptions used for assigning constraint criteria or cost optimisation models are not always easy to communicate. However, site optimisation models can be useful in engaging with stakeholders and facilitating the design of developments. Good practice guidance could be developed to assist the future application of such tools.

The largest functional area of tool proliferation is in assessing the impact of policies. There are at least seven general methods that are closely related to each other but vary slightly in the level of detail required, the involvement of stakeholders in the process and in the criteria being assessed. They can be broadly compared as follows (see also Chap. 2):

- CBA compares different policy options according to a monetary analysis that may include values of ecosystem services;
- CEA compares policy options according to an objective or outcome unit;
- MCA compares policy options according to scores and weightings rather than monetary units;
- LCA compares policy options according to alternative measures such as energy use or carbon emissions (monetary analysis may later be applied);
- Risk assessment compares policy options according to levels of acceptable risk;
- Bio-economic models compare policy options according to modelled interactions between the environment and human activities; and
- Trade-off analysis compares policy options according to stakeholder consensus often including one or several of the methods above.

Given the number of general approaches to impact assessment, it is not surprising that numerous products have been developed to facilitate decision-making. However, as part of the review, an email and telephone survey of University institutions specialising in marine impact assessment models indicated that there are few products developed specifically for application to the marine environment in the UK, and even fewer that incorporate ecosystem services.

Despite the lack of specific products, there have been several applied projects to provide spatial interpretation of economic values from the marine environment in order to understand the distribution of value throughout the UK and to inform impact assessments of policy options. These projects include CP2 (UKMMAS 2010), the UK NEA (2011), Valuing Change in UK Seas (Saunders et al. 2010b) and the recent baseline developed to inform the Impact Assessment for the Marine Strategy Framework Directive (Defra and Marine Scotland 2012). These projects have made a number of advances in understanding the assumptions and methodologies for spatially presenting economic values that have been agreed at a high level.

Very few of the tools are used to fully investigate options which ensure the sustainable development of the marine environment. For example, there are generally good figures on turnover or GVA for economic activities such as commercial fisheries, but these figures do not adequately capture the flow of economic stocks and whether this return is sustainable. The ability to do this would require bio-economic modelling of each individual managed stock along with indicators of Maximum Sustainable Yield (MSY) and Sustainable Stock Biomass (SSB). This information exists to varying levels of confidence, but agreed methods for the use this raw data to prepare spatially allocated data layers of the "sustainable" economic value of an activity have not yet been explored.

The review has highlighted that limited tools are available for assessing effectiveness of policies and further work should be focused towards tools that help to monitor and assess the achievement of policies, plans or projects and their objectives.

As explained in Sect. 8.4.1, it is important that tools are able to account for uncertainty where the quality of input data or understanding of relationships may be poor, e.g. through (spatially explicit) confidence assessments and sensitivity analyses. A few of the impact assessment tools are known to have this added functionality including MaRS, DEFINITE and EMDS.

The tools explored encompassed a range of data themes, including financial values associated with marine activities and their geographical location. Less common, particularly in the UK, was the inclusion in decision-making tools of indirect economic values (e.g. supply chain data and employment) and social data on the characteristics of coastal communities. This is partly due to the difficulties in geo-referencing data for the marine environment that have been collected according to terrestrial geographies.

8.6 Summary and Recommendations

8.6.1 Data

(i) Data gaps: There is a clear management, policy and academic need for high quality UK-specific marine social and economic data[15] (HM Government 2011b; Liquete et al. 2013). The data available do not necessarily meet all the management, policy and academic requirements. The weaknesses highlighted above should help steer future research requirements. With regard to management there is a need for policy makers, regulators and their advisors to provide more detailed guidance regarding what data they require, and better integration between data collection initiatives and regulatory needs.

(ii) Spatial scale: The catalogue focused on datasets at the national level. However, local information may be held by local councils, site-specific academic research, project-specific environmental impact assessment and monitoring and studies by local conservation groups.

(iii) Links with natural science: Some of the data gaps in ecosystem services are present due to a lack of natural science data and unless we can quantify the changes in the natural environment we cannot value those changes. For example, initial Impact Assessments for MCZs (Defra et al. 2012) were unable to

[15] www.marinemanagement.org.uk/about/documents/strategic-evidence-plan.pdf

quantify beneficial ecosystem service changes without an understanding of the expected environmental change due to MCZ protection measures. The development of a data strategy for the coastal and marine environment should be undertaken with integrated ecosystem serv ices requirements in mind.

(iv) Qualitative data are also required particularly in the field of cultural ecosystem services. Including qualitative data in management, policy and decision making will require further efforts to describe, categorise and publish datasets of a qualitative nature, but could greatly improve the benefits for society.

(v) Central repository: The lack of a dynamic central repository for metadata hinders its usage as datasets are spread across a disparate range of sources making it difficult for any potential user to find the relevant datasets. This is being addressed in the UK through the development of a central MEDIN portal and the encouragement of more open access agreements including the Open Government Licence. This will ensure that the UK is implementing legislation across departments based on a standard social and economic evidence base that can be used with confidence and is regularly reviewed.

(vi) Standardisation of data management approaches: To ensure the data are robust, transparent and defendable, best practice must be applied throughout the data life-cycle, from creation to long-term curation. Such best practice includes the creation of data to meet open, stable, internationally agreed standards and formats. Generating data in this way is critical to facilitate the greatest degree of interoperability and reuse, and to maximise the data's value. To improve accessibility of data a single standard could be promoted and its importance communicated to researchers, managers and policy makers.

(vii) The study reported poor recording of metadata particularly relating to temporal aspects, the standards and protocols applied. The metadata and associated publishing protocols must be given an equal priority, to enable a high degree of visibility to the data, enabling validation and wider utilisation of the data.

8.6.2 Tools

The following recommendations were made to the MMO and Marine Scotland following the review of tools to apply social and economic data to decision-making:

(i) Explore the use of models to develop realistic alternative options for marine planning where this may in turn help to inform the licensing process.

(ii) Develop good practice guidance on the application of site optimisation models in consultation exercises with feedback gathered from stakeholders on the suitability of different site selection tools.

(iii) Investigate the feasibility of adapting existing impact assessment models and guidance for specific use in coastal and marine policy development and incorporating assessments of ecosystem services and human wellbeing.

(iv) Agree methodologies to provide spatial understanding of economic values through targeted workshops with government economists and industry groups.

(v) Support further research towards tools to help monitor and assess the achievement of policies, plans or projects and their objectives, such as the development of anthropogenic pressure benchmarks and associated spatial data layers.
(vi) Support further research to incorporate information on ecosystem services in planning tools.
(vii) Explore new methodologies and tools to better assess the sustainability of marine activities in the coastal and marine environment.

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