Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

An ecosystem approach to marine planning – a summary of selected tools, examples & guidance.

The Ecosystem Approach is widely promoted for all manner of environmental, resource and activity management processes and projects. The Convention on Biological Diversity defined it as *"a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"*, adopting twelve principles[1] for its application (a plain English interpretation is shown); these can be captured by three broad themes:

- Involving people
- Understanding how nature works
- Valuing nature's services / recognising the benefits of nature

Various guides and web-resources advise marine planners and their governing bodies how to go about their work, including:

- UNESCO: Step-By-Step Guide to MSP for Ecosystem-Based Management (Ehler and Douvere, 2009); Good Practice Guide[2]; Guide to Evaluating MSPs (Ehler, 2014)
- The MSP Concierge[3]
- The Nature Conservancy MSP guide (Beck *et al.*, 2009)
- MSP Quality Management Systems (Cormier *et al.*, 2015)
- PlanCoast Handbook (Schultz-Kehden *et al.*, 2008)

The ecosystem approach is central to these guides. Promoting and embedding the concept and principles is key (e.g. Laffoley *et al.*, 2004; Douvere, 2008; ABPMER, 2010; Williamson, 2010; Farmer *et al.*, 2012; Kidd *et al.*, 2012), but marine planners also need support for practical implementation.

However, there can be no single 'how to' guide for an ecosystem approach to marine planning. The appropriate range of tools, methods and information will vary according to the scenarios of the plan area.

Plain-English Principles of the Ecosystem Approach

*-**We are all in the same boat:** Acknowledge the rights of all to share decisions over the care of nature and natural resources*

*-**Local is best:** Allow decisions to be led locally, as far as practicable*

*-**Think of others:** Take care to consider the effects on others, including neighbouring ecosystems*

*-**Only reward good practice:** Use economic tools to support the care and wise use of nature, and avoid perverse incentives*

*-**The health of ecosystems is paramount:** Give priority to natural systems (and their long term benefits) above individual species*

*-**Don't over-exploit:** Keep any use of natural systems to limits well within their capacity for renewal/recovery*

*-**Choose the right scale:** Draw boundaries and timescales to match natural processes and minimize adverse effects*

*-**Look well ahead:** Treat long term stability as a key objective - not just short term benefits*

*-**Be sensitive and flexible:** Adapt the pattern of any use as natural systems change, both naturally and under pressure*

*-**Remember our place in nature:** Respect and value all nature – and for its own sake, as well as for the uses we can make of it*

*-**Value all knowledge and perspectives:** Gather and share information from all sources to understand our relationship with nature*

*-**Engage everyone:** Try to get the benefit of input from all relevant interests, at all levels, when making decisions*

by Simon Pepper

Neither can it be said that a plan simply 'has' or 'has not' taken this approach. The process of planning and the legal requirements regarding conservation designations mean that, *to some extent*, all plans will take an ecosystem approach. But the efficacy of an ecosystem approach could vary greatly and improve with each iteration of a plan: from very basic considerations with limited sustainability benefits, to advanced approaches with extensive

[1] CBD Guidelines for the Ecosystem Approach https://www.cbd.int/doc/publications/ea-text-en.pdf
[2] UNESCO MSP Good Practice Guide http://www.unesco-ioc-marinesp.be/msp_good_practice
[3] MSP Concierge - http://msp.naturalcapitalproject.org/msp_concierge_master/

benefits. Marine planners must choose from a broad suite of potential tools, applying and adapting according to circumstances in their area. Some available tools have not been designed with an ecosystem approach in mind, but may nevertheless be applied in a manner appropriate to the ecosystem approach principles.

Some collations and commentaries on available tools exist elsewhere for conservation and planning practitioners. References are provided, avoiding duplication of content. Existing resources include:

- The NEAT Tree[4], providing a useful online resource generated through the UK National Ecosystem Assessment Follow-On (UKNEAFO) projects.
- The Ecosystem-Based Management Tools Network[5]
- Selecting Decision Support Tools for Marine Spatial Planning (Center for Ocean Solutions, 2011)
- MSP in the context of the Convention of Biological Diversity (SCBD, 2012)
- Options for Delivering Ecosystem-Based Marine Management (ODEMM)[6]

This document draws attention to and provides some commentary on selected available planning tools, guidance and relevant examples. Only the strategic stages of the planning process are considered here; there is overlap, but other tools are relevant for an ecosystem approach at the 'project' level (i.e. within EIA).

The ecosystem approach is complementary to the requirements of the Strategic Environmental Assessment (SEA) Directive[7]. As such, the two processes should not be seen as independent, but can be strongly inter-linked and mutually beneficial for informing effective policy direction.

This is not a comprehensive review, nor does it make specific recommendations of one tool over another; many other tools and examples are available and tool choice will be particular to circumstances. Potentially transferrable examples from non-planning uses, and from terrestrial and freshwater environments, are included. Tools, examples and studies are categorised as follows, although there are many linkages between these:

1. Involving people
2. Mapping habitats and species
3. Assessing environmental status
4. Ecosystem services: Assessing, mapping, valuing and integrating in planning
5. Identifying conflicts and opportunities for planning
6. Cumulative Assessments
7. Futures / Scenario tools
8. Assessing trade-offs and predicting policy impacts
9. Approaches to zoning
10. Other resources

Symbols indicate:
(a) which of the three themes of the ecosystem approach the tool/example primarily relates to, and
(b) potential for direct use by planners Vs specialist/scientist-led support
These allocations may vary with how tools are applied and the experience of planners.

= Involving people
= Understanding how nature works
= Valuing nature's services

= Planner-led
= Specialist/scientist-led

Some planner-led processes are likely to also require specialist support.

[4] NEAT Tree http://neat.ecosystemsknowledge.net/index.html
[5] EBM Tools Network https://www.ebmtoolsdatabase.org/ and https://ebmtoolsdatabase.org/resource/coastal-and-marine-spatial-planning-tools
[6] ODEMM http://odemm.com/content/home
[7] See http://www.snh.gov.uk/planning-and-development/environmental-assessment/sea/

1. INVOLVING PEOPLE

The involvement of relevant stakeholders, including the general public, is fundamental to the principles of the ecosystem approach. Stakeholder consultation is often a requirement of legislation, performed to gather feedback on draft plans or at other key milestones. However, the involvement of people should be integral to the process rather than as a bolt-on step. Use of any of the methods described in this document should involve people to some degree, although there is variation in the extent to which this (a) is balanced with science-led processes or deliberative processes with experts, and (b) is intended to directly inform policy development, as opposed to generating stakeholder support for the inclusion of ecosystem considerations in policy decisions.

Several useful materials already exist, summarising different methods that can be readily applied in the marine planning context. Participatory methods are particularly encouraged, but may be undertaken in simple or complex fashions. See:

- The NEAT Tree[8] summary and detailed literature review of 'engagement tools'
- Guides to participatory and deliberative techniques to support the monetary and non-monetary valuation of ecosystem services (Fish *et al*., 2011a), and to participatory and deliberative techniques to embed an ecosystems approach into decision making (Fish *et al*., 2011b).
- Friedrich *et al.* (2015) provide guidance on using the ecosystem assessment process in the VALMER project (see Section 4) as a tool for stakeholder engagement.
- The 'Talking about our place' toolkit[9], helping communities explore what they value about their local area.

E-participation in planning – Feucht and Pitkänen, 2007

Internet-based participation of the general public and stakeholders enables their involvement at early stages of the planning process. These should not replace the face-to-face open public meetings typical at later stages in a planning process, but can help avoid criticisms that sometimes arise about limited engagement. Specific tools and interfaces can be tailored accordingly; this study presents three case-studies to provide insight to the method.

Keypad polling[10]

Although more associated with audience participation TV game-shows, use of this equipment can be a powerful tool for reaping anonymous responses to targeted questions within a participatory process. The technique could enhance the engagement of stakeholders, inform planners and decision-makers of stakeholder views, inform the direction of discussions and help achieve lasting and supported (or at least understood) decisions. A recording of a webinar demonstration provides an example of this system in use[11]. Hardware and software can be acquired from many retailers,

[8] http://neat.ecosystemsknowledge.net/engagement-tools.html
[9] http://www.snh.gov.uk/docs/B1117673.pdf
[10] https://ebmtoolsdatabase.org/tool/keypad-polling
[11] https://ebmtoolsdatabase.org/resource/webinar-demonstration-anyware-polling

although the proliferation of smart phones and other personal devices may reduce the need for dedicated hardware.

Open OceanMap[12]

The tool described is only supported in parts of the USA and Caribbean, but a similar approach to gathering citizen and sectoral stakeholder data could be adopted to support marine planning in Scotland. The potential for success of marine planning is widely regarded as being limited by our knowledge of the marine environment, including basic information on species and habitat distribution and condition. Such data collection tools could have a valuable role to play for effective marine planning, in particular harnessing the knowledge of commercial and recreational fishers.

SeaSketch[13]

This web-based and interactive GIS tool provides a facility for stakeholders and planners alike to view data/information, to sketch, share and propose possible spatial management solutions, and consider analytical feedback. The website details many diverse applications this tool can be used for within marine planning.

CORPORATES project[14]

Using a particular scenario, Scott *et al*. (2016) tested some participatory methods for considering the value of ecosystem services to a wide range of stakeholders. The process helped identify perceptions of the spatial context and stakeholder values of ecosystem benefits, then linking these to ecosystem services. These methods alone may be unlikely to lead to policy development, with more academic exercises likely to be required to explore the implications of alternative development/activity/protection scenarios for ecosystem services and benefits. However, the method may be used in conjunction with more deliberative methods or in the early 'visioning' stage of a marine planning process. It can also be effective in enhancing stakeholder appreciation for the ecosystem service concept and its place in a planning system.

MSP Challenge Game[15]

This interactive gaming-approach provides an engaging way of exploring marine planning issues with a wide range of stakeholders. Players can adopt the roles of others or themselves. The currently available games are hypothetical and used for building familiarity and interest in the issues relevant to marine planning and the solutions it can offer. However, adapted versions for real-life planning may be feasible.

12 https://ebmtoolsdatabase.org/tool/open-oceanmap
13 http://www.seasketch.org/home.html
14 http://www.corporatesproject.co.uk/
15 http://www.mspchallenge.info/

2. MAPPING HABITATS AND SPECIES

Benthic habitats and species have important functional roles in ecosystems, and many are sensitive and/or vulnerable to anthropogenic pressures. Mapping the distribution and extent (and if possible the quality) of different benthic habitats and species aggregations is therefore a very valuable step for marine planners, enabling the development of planning policies that take account of sensitivities (or perhaps can allow for recovery of degraded areas). However, understanding the distribution species and habitats (physical and biological compositions) in sufficient detail presents a major challenge to marine planners. Small areas can be surveyed and mapped in great detail, thereby supporting detailed spatial planning. This can be useful if areas of likely sensitivity and exposure to relevant pressures can be identified (see Section 5), but the expense of doing so means that such approaches are likely to be limited to selected near-shore areas and designated sites. Shucksmith and Kelly (2014) provide a useful examination of principles, processes and caveats for the collection, mapping and application of biophysical data in MSP.

Of course, the mapping of important areas may also be applied to mobile species (seabirds, fish and marine mammals). Data and funding challenges also abound here, but such information may nevertheless be useful for informing later evaluation of planning issues and options.

Some mapping projects use available survey data in conjunction with scientific knowledge that relates species life-history traits to properties of the marine environment, building predictive models and subsequently using survey data to validate models. There are many approaches to predictive mapping for habitats and species (including mobile species), some of which are highlighted below, but all must be used with an understanding of the limitations of the data. Some more complex methods of predictive habitat modelling have potential for wider use (e.g. Gormley *et al.*, 2013), but may require further scientific advances and testing.

Mapping European Seabed Habitats (MESH)[16]

The MESH website includes a Guide to Marine Habitat Mapping, detailing the use of physical environmental data and biological sampling to build and assess confidence in predictive seabed habitat maps. The methods have been applied at large geographical scales (e.g. UKSeaMap[17]).

Similar approaches have been taken at more regional scales in Scotland (e.g. Tresadern, 2008; Foster-Smith, 2010), easing use of targeted survey work for ground-truthing the results. Application at even lesser (local) scales is also possible and may lend itself to greater detail or confidence in outputs, but the quality of the output remains dependent on (a) the accuracy and precision of the input data, and (b) sufficient spatial coverage of ground-truthing. Similar methods are also used for broadscale mapping of seabed habitats within marine designated sites, with more detailed survey often being required for spatially detailed approaches to activity management.

Biogenic habitats in Shetland – updating historic data – Shermeldine *et al*., 2014

Work to map and close to scallop dredging areas of maerl and horse mussel bed was initiated by the local fishing industry but has since been incorporated within the Shetland Marine Spatial Plan. In

[16] MESH http://www.emodnet-seabedhabitats.eu/default.aspx?page=1616
[17] UKSeaMap http://jncc.defra.gov.uk/page-5534

2010 twenty-two voluntary closed areas were established on a precautionary basis according to historical data. The closed areas received legal protection in 2011. Detailed surveys were conducted with a combination of a hull-mounted multi-beam backscatter system, with ground-truthing using a drop-down camera system. The updated knowledge of the presence, extent and distribution of the habitats allowed assessment of and refinement to closed area boundaries. The work demonstrates the importance of detailed survey to update records and inform management measures to a fine geographic scale, but that starting from the use of historic data can provide a reasonable basis to initiate work and prioritise specific locations for detailed survey.

Fish spawning and nursery grounds

Coull *et al.* (1998) provided an extensive set of maps indicating possible nursery and spawning grounds for a suite of marine fish species in British waters. Ellis *et al.* (2012) provided updates to this information for some species. Both of these resources have been used to inform assessments of the vulnerability of marine fish populations to individual proposed developments. They could also be used readily for more strategic applications within marine planning, although any use of these should be mindful of the limitations of the information – spawning and nursery grounds are not static in space or time so, while these maps can support an evaluation of risk to marine fish interests, they provide an indicative rather an absolute understanding of important areas for fish.

In Scotland new work is providing further updates[18] specifically in relation to nursery ground habitat for 0-group fish (fish in the first year of their life). It applies information about the environment and catch records to build models that predict the relative probability of aggregations of these fish. The mapped products (available on National Marine Plan interactive (NMPi) have potential to inform both strategic marine planning as well as decisions on specific development/management issues. The accompanying report (Aires *et al.*, 2014) provides important information on the use and limitations of the information. Similar work has been conducted in parts of England, developing and validating models of Essential Fish Habitat, with the specific intention for application within marine planning (MMO, 2016).

Seal density mapping[19]

Data from telemetry tags attached to seals have been collated and extrapolated to generate these maps of mean 'at-sea usage' (seals per 5 x 5 km square, including confidence estimates). These figures have also been combined with counts at seal haul-outs to give 'total' density figures, although these are intended for use in considering land-based impacts upon seals. The associated report (Jones *et al.*, 2013) details limitations of the data and caveats for its use but, provided users are mindful of these, such information provides a useful basis for examining relevant strategic marine planning issues and options.

Falkland Islands Marine Megafauna and MSP – Augé *et al.*, 2015

This workshop report was part of a larger Marine Spatial Planning Project for the Falkland Islands[20]. It examines methodologies for transparent, consistent and scientifically robust data compilation, mapping and analysis of data to distinguish key areas for marine megafauna. Tracking, sighting and

[18] See http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/fish-fisheries/fsm
[19] http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/seal-density
[20] See http://south-atlantic-research.org/research/current-research/marine-spatial-planning

colony data were considered. Challenges arise due to gaps and uncertainties in the data, but the authors recognise the role of marine planning in identifying such gaps, prioritising survey and monitoring to inform future plan iterations.

Seabird tracking

The Royal Society for the Protection of Birds (RSPB) have been carrying out tagging and tracking of seabird movements through their FAME and STAR[21] projects. When data become available it should be possible to interrogate mapped data to consider key areas or routes used by various seabird species.

Sedimentary habitat model - Galparsoro *et al*., 2013

This study describes a process driven benthic sedimentary habitat model, defining and mapping habitat classes that reflect different structural and functional characteristics of the benthos. It also allows anomalies in benthic community structure caused by human pressures to be detected, and it can describe the potential presence of particularly sensitive and/or tolerant species. The work has primarily been done with a view to monitoring seafloor integrity and biodiversity descriptors under the Marine Strategy Framework Directive (MSFD), but the authors explicitly identify the potential for environmental status assessment and activity management applications within marine planning. It is also noted that similar modelling could be conducted for non-sedimentary habitats.

Sandeel habitat suitability – Greenstreet *et al*., 2010

Sandeel are an example of a species of clear importance to ecosystem functioning, being particularly important as prey to many seabird species and a key dietary component for many marine mammals and predatory fish. While there is no longer an extensive sandeel fishery in Scottish waters, the sandeel is an important prey species for many other commercially harvested species.

These values, combined with the strong habitat preferences of the species, make it a strong candidate for the development of spatial management/policies. Existing or broadscale data on sedimentary particle size will help narrow the identification of potential sandeel habitat within a region, but further local mapping of habitat suitability would inform more specific polices and measures.

Greenstreet *et al*. (2010) describe a method that combines hydroacoustic seabed survey with grab sampling techniques to allow finer scale understanding of the distribution of prime, suitable and unsuitable substrates. It is possible that similar techniques could be developed for other key habitats or sensitive species with particular habitat requirements**.**

[21] http://www.rspb.org.uk/whatwedo/projects/details/365020-tracking-seabirds-to-inform-conservation-of-the-marine-environment-

3. ASSESSING ENVIRONMENTAL STATUS

An assessment of the status of the environment should be amongst the first exercises within marine planning. Plan area assessments should ideally be set in the context of broader-scale assessments, as many ecosystem components are unlikely to be constrained to the specific planning region under consideration. For instance, environmental status assessments for Scottish marine regions should be set in the context of information for Scotland, the UK and Europe, making use of existing reporting at those scales (it may also be possible to compartmentalise some of the data for use at the plan-area scale). It may also be relevant to put assessments in the context of biogeographic regions where that is meaningful for particular species or habitats (i.e. North Sea, or the North-East Atlantic). Assessments should also make appropriate links to adjacent marine regions and terrestrial areas.

A rudimentary assessment of ecosystem health would examine (using indicators and proxies where necessary) the distribution, presence, abundance and condition of ecosystem components: the species and habitats, and key physical and chemical parameters, including trend information. The focus below is on more holistic assessment tools that may supplement more traditional methods, but there remains great potential for scientific progress. Ecosystem services are considered separately (see Section 4) as they have a particular purpose in linking the natural capital of the environment to the subsequent benefits for human society and economy.

DEVOTES indicator-based biodiversity assessment – Andersen *et al.*, 2014

A Danish prototype tool used for an assessment in line with MSFD reporting requirements, this relatively simplistic tool integrates multiple aspects of biodiversity into indicators with associated numerical target values. Biodiversity Quality Ratios (BQRs) were generated for local areas (i.e. fjord scale) where data allowed, then averaged across larger areas. BQRs were also generated separately for four categories: (i) broad-scale habitats, (ii) communities, (iii) species and (iv) supporting indicators. The latter provide a supplementary means of identifying indirect indicators (proxies) of biological change (e.g. eutrophication). Three classifications for outputs were used, (1) "*unaffected by human activities*", (2) "*moderately affected by human activities*", or (3) "*significantly affected by human activities*". A non-statistical method for estimating confidence in the threshold values, data and number of indicators are an important part of the method.

This method requires expert judgement and some effort to generate indicators and quantitative thresholds but seeks to reflect the complexity of biodiversity responses to human pressures. The tool can function even where data coverage is incomplete, highlighting poor confidence to inform future survey work. This method is transparent in its presentation of deficiencies and has merit as an interim tool until more data-intensive approaches are possible.

Biological valuation – Derous *et al.*, 2007

This general guide to biological valuation that can be displayed in map form explicitly aims to provide a scientifically objective approach, as opposed to other methods employing stakeholder participatory methods or expert judgement. Results indicate relative biological value of subzones within a plan area to inform identification of appropriate risk-management or spatial planning approaches; the authors stress that the intention is not to identify 'hotspots' for protected area proposals. The primary valuation criteria were 'rarity', 'aggregation' and 'fitness consequences'. Secondary 'modifying' criteria account for the relative 'naturalness' and 'proportional importance' of an area.

The method stops short of including the sensitivity/resilience of biodiversity, which would need to be captured by a subsequent assessment stage to inform appropriate policy options. It would also require some careful tailoring to specific applications, for example ensuring compatibility with existing spatial designations. There are difficulties around use of some of the criteria (such as rarity); these are discussed in the report.

The concept of this approach is idealistic in terms of data availability. Its use would likely highlight large data gaps and levels of uncertainty in parts of a plan area. This outcome may be useful in itself, highlighting priority areas for survey, but for policy development in the near term may be unlikely to yield benefits over use of more intuitive/expert-judgement methods.

Integrating ecosystem components for assessing status – Borja *et al*., 2014, 2016

Understanding the status of ecosystem components and the processes that link those components is central to an ecosystem approach to informing planning policies. However, for communication purposes it can also be useful to integrate this complex information in to a small number of statements about ecosystem health.

These reviews appraise different methods for integrating assessments of ecosystem components into simplified statements of ecosystem health that are more readily communicated to managers, stakeholders and the public. Although many of the examples given relate to reporting requirements at scale greater than most marine planning areas (e.g. under the MSFD), many of the approaches described, the relative advantages and disadvantages, and the principles and recommendations provided, could be applied to smaller-scale environmental assessment processes.

The article highlights circumstances in which particular methods are appropriate or inappropriate. It also balances some of the realities of data availability, the challenges of agreeing indicator weightings and the need to retain sufficient information on the ecosystem components to guide meaningful management decisions.

Kupschus *et al*. (in press) elaborate on the principles and practical issues regarding the implementation of a monitoring framework that supports an ecosystem approach to management. Understanding the key processes linking ecosystem components is fundamental to an ecosystem approach, facilitating an understanding of not only ecosystem change, but also its causes. A shift to a properly integrated ecosystem monitoring programme requires a degree of top-down coordination.

Ecopath[22]

Ecopath is the first in a series of models for assessing the ecosystem impacts of fisheries. While the later model components (Ecosim and Ecospace) can be used to simulate fisheries management scenarios (see Section 7), Ecopath presents a snapshot in time of aspects of the ecosystem as influenced by fisheries activity and environmental changes (i.e. climate change). It can provide an indication of ecosystem health, with a variety of indicators built in to the model. While focussed on fisheries impacts, as fisheries are a major source of historical and current ecosystem impacts for

[22] http://www.ecopath.org/

many areas, this has potential value to marine planners if used in conjunction with broader assessment methods. However, its use requires an understanding of its limitations and access to specialist support. The software website provides links to many useful publications; Christensen and Walters (2004) review the methods, capabilities and limitations.

[Ecopath is just one of many available ecosystem models that seek to explain patterns in data. MRAG Americas (2009; see appendices) describe a range of other tools, explaining different model categories – minimum realistic models (spatial and non-spatial); aggregate ecosystem models; dynamic whole ecosystem models.]

Landscape & Seascape Assessment

Human perception of the ecosystem, and how we interact with it, includes aspects of landscape and seascape. Landscape and seascape assessments do not solely relate to visual aesthetics, but also the character and interactions of the natural and/or man-made qualities of an area. In the context of marine planning, this is most relevant close to the shore and in the immediate hinterland; coastal characterisation methods provide a means of capturing the relevant information.

Coastal characterisation can be done at different levels of detail; coarser assessments can cover wider geographic areas. SNH Coastal Character Assessment Guidance (in preparation) describes:

- National coastal character types. National characterisation has already been conducted for the entire Scottish coastline, providing a highly strategic level of characterisation. Most Scottish Marine Regions are divided into a small number of coastal types.
- Regional coastal character. This tier is still relatively coarse, identifying obvious variation in the physical form of the coast and providing a potentially useful basis for some strategic planning and for considering targeted finer scale characterisation.
- Local coastal character. Characterised areas are smaller in size and considered in a finer level of detail, subdividing an area in to typologies with strong identities (i.e. specific bays / sections of coast or lochs with a similar characters). They are usually mapped at 1:50,000 scale. This scale of characterisation could be focussed on areas of likely development interest for informing planning policy. Local coastal character assessments have been conducted for some parts of the Scottish coast, such as the Firth of Clyde (Grant *et al*., 2013), which also including a character description at the higher regional tier. Similar work is underway for Shetland, Orkney and the North Caithness coast

Landscape/seascape capacity studies can build on previous character assessment work to explore the capacity or sensitivities of an area to a particular development type. They can inform project-level licensing and consenting decisions, but may also be done more strategically to inform marine plan policies. Typically this will focus at local scales (e.g. a bay or sea loch) with likely development interest and sensitivities. Detailed guidance and examples are available:

- Landscape capacity studies in Scotland: a review and guide to good practice (Grant *et al*., 2010)
- SNH Landscape capacity study toolkit[23]
- Landscape/seascape carrying capacity for aquaculture (Grant, 2006)
- Orkney landscape capacity study for aquaculture: Scapa Flow and Wide Firth (Horner and Maclennan, 2011)

[23] http://www.snh.gov.uk/docs/B858929.pdf

4. ECOSYSTEM SERVICES: ASSESSING, MAPPING & VALUING

Information about ecosystem services (including benefits subsequently arising for human society and economy) should facilitate the adoption of policies for the maintenance or improvement of the extent or condition of natural capital underlying those services. Mapping supports the formation of spatial policies, while valuation methods (monetary or non-monetary) aid deeper reflection of relative importance (Borger *et al*. (2014) provide a useful review). The terms 'natural capital' or 'natural assets' refer to the naturally occurring stock or features from which services emerge and flow to the human beneficiaries. Despite substantial progress, challenges remain for the application of these concepts in policy-development (Guerry *et al*., 2015).

Ecosystem service assessments can also inform individual project/licensing decisions (e.g. Everard and Waters, 2013) but here we focus on strategic application during plan-making, supporting a positive, proactive and long-term approach to the avoidance of conflicts and optimisation of synergies between sectoral interests and ecosystem health.

Unfortunately the state of knowledge about the marine environment is relatively under-developed when compared with terrestrial systems (Medcalf *et al*., 2012). This is partly due to the expense and practical difficulties of marine survey, but also the variability and dynamism of natural marine systems. As the provision of data and scientific understanding improves, so should the detail of ecosystem service assessments. As is appropriate in the interim, many of the methods described below allow the progression of assessment work despite data limitations.

Some specific tools and examples are identified below. The Ecosystem Services Partnership provides a wealth of further information, directing users to toolkits, guidelines, forums and other resources for science, policy and practice. This may provide a useful gateway for planners, with a Methods Navigator available to help select appropriate methods for particular purposes.

More advanced and standardised methods for mapping and assessing marine ecosystems and their services are likely to emerge. The EU MAES (Mapping & Assessment of Ecosystems and their Services) Working Group are progressing a marine pilot to strengthen approaches to: (a) defining ecosystem typologies and their interactions, (b) identifying appropriate assessment scales, (c) identifying ecosystem services and assessment methodologies, and (d) identifying data constraints and potential solutions.

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)[24] √xy;

Designed for use with ArcGIS software, biophysical data is used to estimate services and their value; depending on the data available, this may be done at multiple geographic scales. InVEST provides a suite of accessible and flexible tools to assess baseline conditions, and ecosystem costs and benefits, under different scenarios of natural resource management; they can also be used for scenario assessment (see Section 7). There are many available models within InVEST, including models addressing carbon storage, recreation, fisheries, water quality, aquaculture, wind energy and scenic quality. Although indirect impacts, changes in human behaviour, the interaction of human activities and feedback between ecosystem services are generally not modelled with this tool, it has considerable capacity as a tool for marine planning. The design of the tool allows focus

[24] http://www.naturalcapitalproject.org/invest/

on specific ecosystem services and supports the user in addressing issues of data availability and scientific uncertainty. Critical evaluation of this and some other decision-making tools is available (see MMO & Marine Scotland, 2012; MMO, 2014). Marine application of the InVEST tool is embedded within guidance provided in the MSP Concierge[25].

VALMER[26]

The VALMER project developed and tested a marine ecosystem services assessment (MESA) approach to informing marine planning/governance. Within the documentation are many examples from case studies in the Western Channel between England and France. Useful outputs include:

- Dodds *et al*. (2015) provide a useful short advice note on the implementation of ecosystem services assessments at different stages of the planning process, highlighting examples.
- Outputs of Work Package 1 provide (a) general recommendations for mobilising expertise and engaging with stakeholders during a MESA, and (b) detailed recommendations on a process for focussing the scope and methodologies for a MESA. A separate report summarises useful lessons learned from trialling this framework. While this is not a guide to MESA, the framework provides a logical and auditable process to identify ecosystem service issues for planning, to prioritise those issues, and to identify assessment methods. This may be of particular use in areas where the issues are complex, but in other areas these decisions (especially issue identification & prioritisation) may be reached more intuitively.
- An e-learning module[27] based on the process applied in VALMER, covering the assessment framework, to assessments and valuations, scenario-building (see Section 7) and stakeholder engagement (see Section 1). This provides basic knowledge for marine planners and detailed guidance on carrying out a MESA.

NEAT Ecosystem (Services) Assessment Guidance[28]

This guidance addresses the assessment of ecosystem services to inform the development of plans or strategies. It is not specific to the marine or coastal environments, but the principles may be applied. While this guidance provides a useful framework and a logical breakdown of the exercises involved in an ecosystem services assessment, it does not provide practical advice on how to deliver these exercises.

NEAT Mapping Ecosystem Services[29]

This guidance doesn't give specific detail about how to carry out mapping of ecosystem services. However, it is closely linked to a separate piece of work 'GIS Tools for Stocks and Flows of Ecosystem Services' (see below) and provides numerous references to more detailed methodological examples. Note that this field of work is rapidly evolving; there are many different methodologies possible, but calls have been made for a standardised approach. Most research and guidance in this field relates to terrestrial ecosystems, but the principles can apply equally for the marine environment. However, challenges around data availability and resolution are more

[25] http://msp.naturalcapitalproject.org/msp_concierge_master/
[26] http://www.valmer.eu
[27] E-learning module http://www.marine-ecosystem-services.eu/en
[28] http://neat.ecosystemsknowledge.net/ecosystem-assessment-tool.html
[29] http://neat.ecosystemsknowledge.net/ecosystem-mapping-tool.html

problematic for many marine ecosystem services, so planners and the supporting scientific communities should focus initial attention on ecosystem services intuitively identified as priorities for management or policy development.

The guidance includes clear articulation of the uses for ecosystem services mapping and key aspects for informing these uses. It notes the importance of mapping (a) ecosystem functions that generate services, (b) ecosystem service beneficiaries and (c) ecosystem service flow pathways between (a) and (b), as these aspects may occur at different locations, over different extents and/or with different temporal patterns. Mapping areas that present the greatest opportunities and/or risks for ecosystem services is a useful secondary output, as is mapping of any historical changes or long-term trends that can help identify opportunities for intervention.

GIS Tools for Stocks and Flows of Ecosystem Services[30]

This short document provides a generic workflow for conducting a map-based assessment of ecosystem service stocks and flow pathways, highlighting stages at which key considerations and decisions should be made. An important distinction is made between the two main types of models that can be applied in mapping ecosystem services:

(1) Empirical (or at least semi-empirical) methods that rely on a strong evidence-base and ample data, providing outputs with defensible scientific credibility. An example in this category is InVEST, which is discussed above.
(2) Methods relying to a large degree on expert knowledge rather than extensive collection, collation and analysis of environmental data. Modern approaches to this method often involve developing a graphical representation of the relationships between the drivers and supply of ecosystem services and benefits, termed a 'belief network'. An example in this category includes ARIES, which is discussed further below.

In reality, knowledge and data are rarely optimal for delivery of a completely empirical approach, so some degree of expert knowledge is likely to be required.

Natural Capital Asset Check[31]

This tool helps users interrogate particular natural assets and the ecosystem services they provide, identifying 'red flags' and relevant information to support policy development. Tool flexibility allows detailed or light touch approaches, so it can be used to help prioritise issues for more detailed analysis, or for conducting that detailed analysis.

The templates provide a logical series of questions under five steps (1. The asset → 2. Integrity of the asset → 3. Performance of the asset → 4. Asset criticalities → 5. Asset check summary), guiding constructive consideration of potentially complex issues. The templates also provide opportunities to record uncertainties and knowledge gaps, as well providing an audit trail of expert judgements made. However, users may wish to tailor the templates slightly to remove some repetition across the different steps and to simplify some of the questions and language used. Useful examples of completed asset check templates may be found in reporting under the UK NEAFO[32].

[30] http://neat.ecosystemsknowledge.net/pdfs/GIS_ecosystem_proofed_tool.pdf
[31] http://neat.ecosystemsknowledge.net/NCAC-tool.html
[32] http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=dNp%2bvIjmXi4%3d&tabid=82

The Local Environment and Economic Development (LEED) Toolkit[33]

Although designed for use by Local Enterprise Partnerships, this toolkit is sufficiently generic that it would function well within any planning process. It starts from the premise that *the relationship between the economy and the environment is important to economic, as well as environmental, planning.* The tool guides users to give specific focus to economic targets, evaluating their environmental dependencies in a defined region and identifying opportunities, threats and potential solutions relevant to those dependencies. In doing so, this tool only considers ecosystem services which give rise to economic benefits, rather than the cultural, societal or health benefits that other ecosystem services provide.

The tool-user can choose from three levels of use depending on the purpose of the exercise and the availability of resources. Estimates are provided for the staff time required at each level. Users can start with Level 1 and then decide on the need, value and potential for continuing with subsequent levels. The tool includes suggested templates and workshop agendas, which can be tailored accordingly.

- Level 1 is focussed on a one-day stakeholder workshop to increase understanding of the economy's relationship with the environment and to identify a list of opportunities and threats for the dependencies in this relationship, and potential approaches to addressing these.
- Level 2 involves a more formal research process, putting the previous list of opportunities and threats through systematic checking with key partners and experts.
- Level 3 returns to the primary evidence sources to provide a stronger, more objective evidence base for confirming or adding to the list of opportunities and threats.

Complete understanding of economy-environment relationships is unlikely, but the more detailed evaluations will better support decisions in the context of uncertainty, being explicit about strengths and weaknesses in the evidence. This also supports ranking of opportunities and threats for management action.

Prioritisation of ecosystem services and indicators – Werner *et al*. 2014

It is unlikely to be possible to evaluate all ecosystem services for consideration of appropriate plan policies. This study provides a beneficial and flexible methodology for prioritising key ecosystem services within a region and identifying the most effective indicators for ongoing monitoring of those key services. As such, it is useful not only for identifying key issues for policy development within plans (therefore also relating to Sections 5 and 6 of this document) but also for informing the allocation of limited funds to a monitoring programme. The method could be adapted in many ways to suit particular circumstances, such as different division of ecological components, or the involvement of additional stakeholders during evaluation of ecosystem services or setting of indicator assessment criteria.

ARIES (Artificial Intelligence for Ecosystem Services)[34]

A web-based tool for assessing and valuing ecosystem services, but also for examining different development/use scenarios. Simple or complex models can be built, with mapped outputs. Open source data is available within the tool but UK data is currently limited. However, GIS data can be

[33] http://ecosystemsknowledge.net/apply/local-economy/LEED
[34] http://www.ariesonline.org/

uploaded for analysis, with the model addressing data limitations by providing a measure of uncertainty in outputs. This tool has had little application to the marine environment so far; a project is underway in Madagascar, also linking with land-based models to reveal interactions across the land-sea interface. Critical evaluation of this and some other decision-making tools is available (see MMO & Marine Scotland, 2012; MMO, 2014). Villa *et al*. (2014) provide useful further information, including the benefits and limitations of ARIES.

Participatory and deliberative techniques in valuation

Several of the above methods employ participatory techniques (see Section 1). Fish *et al*. (2011a) provide a guide to using these within the context of monetary and non-monetary valuation of ecosystem services. This can be useful to supplement data-led valuation methods, but may also be a valid alternative in the absence of appropriate data or science.

Ecosystem service mapping - Severn estuary and Bristol Channel – Ashley, 2014

This study identified and assessed selected ecosystem services and associated activities in the Greater Severn Estuary. Services were mapped and potential valuation approaches explored. The project adapted methodologies for ecosystem service classification from the Millennium Ecosystem Assessment and the UK National Ecosystem Assessment (NEA), and valuation methodologies from TEEB manuals[35] and UK NEA. Limitations are identified and further work is suggested by the authors, with a view to better information resources to inform marine management and conservation.

Cultural ecosystem services framework – SNH, 2015

This working paper provides useful background and practical advice for incorporating data and knowledge of cultural ecosystem services into ecosystem approaches to planning, policy and practical applications. While most of the examples relate to terrestrial environments, the principles and approaches can apply equally to marine systems. Guidance on information sources, analysis techniques, mapping and valuing are included.

Mapping cultural dimension of marine ecosystem services – ICES, 2013

This workshop report delves deeper in discussing ways of incorporating cultural values in to the marine planning process. Different sections address (a) codifying and collecting cultural values for MSP, (b) methods for identifying marine places of socio-cultural importance, (c) rating impacts on cultural places of importance and (d) mapping spatially relevant information. The approaches described could be applied at different scales and help uncover evidence-based approaches to addressing this challenging theme.

Assessing blue carbon stores

Burrows *et al*. (2014) reviewed carbon budgets and blue carbon stores in the marine and coastal environments of Scotland, considering organic and inorganic, living and non-living materials. At this broad scale it provided a coarse but useful appreciation of the relative carbon storage potential of different habitat types and considered their overall contribution to carbon budgets according to

[35] http://www.teebweb.org/resources/guidance-manual-for-teeb-country-studies/

available information on the extent of those habitats. Current work is conducting a more detailed inventory of blue carbon stores within the Scottish Marine Protected Area (MPA) network. Similar exercises for regional plan areas, or sub-areas, would provide a useful basis for considering policies to protect the integrity of key blue carbon stores.

5. IDENTIFYING CONFLICTS AND OPPORTUNITIES FOR PLANNING

Information and spatial data on developments, activities, uses and other interests (current and future projections) is fundamental to the identification of key issues for planning, requiring frequent update and re-evaluation. Any single plan cannot address all issues and opportunities for a given area simultaneously, but the iterative process should prioritise key issues for sustainability. Adopting a risk-management framework (see Cormier *et al*., 2013) can help appropriate prioritisation of issues in both the identification of key planning issues and the evaluation of policy trade-offs.

While conflicts or incompatibilities with short/medium-term economic implications are likely to be at the top of the agenda for many stakeholders, planners should also dedicate time to identifying (a) opportunities for improvement or enhancement of sector productivity/ sustainability, ecosystem health or societal well-being, including through synergies and co-locations, and (b) strategic issues for which proper attention could avoid future conflicts.

For identifying opportunities for potential ecosystem enhancement/recovery, other than the identification of designated sites, approaches in the marine environment are relatively undeveloped. Habitat restoration and enhancement are less common in the marine environment than terrestrially, partly due to the financial and practical limitations of such intervention. Consequently, while there are some habitats for which this can be relevant (particularly in the near-shore/coastal environment), opportunities for ecosystem improvements are most likely to arise from the management or exclusion of damaging activities or developments. Mazik *et al.* (2015) reviewed the recovery potential (including potential interventional measures) of selected marine biodiversity features of Scotland. In the context of marine planning, such opportunities are more likely to have traction with stakeholders and regulators where there is (a) a contribution to legislative or policy commitments (e.g. OSPAR, Scottish Biodiversity Strategy), and/or (b) a win:win scenario, whereby the measures are likely to boost ecosystem services and subsequent benefits for societal or economic interests.

Cumulative assessments are addressed in Section 6. They are important for identifying existing and potential planning issues and opportunities in a multi-sectoral and whole-ecosystem manner.

Sensitivity tools – FEAST[36] and MarLIN[37]

Both of these resources provide access to a wealth of information about the sensitivity of a wide array of marine species and habitats to anthropogenic pressures arising from different human activities. The sensitivity of a given feature is comprised of both its resistance (consequence of the initial impact) and resilience (recovery from the impact). Consequently, such information should be integral to identifying and prioritising (a) existing and potential conflicts between human activity/development and valuable ecosystem components, and (b) opportunities to support the recovery of valuable ecosystem components.

[36] http://www.marine.scotland.gov.uk/FEAST/
[37] http://www.marlin.ac.uk/evidence

Evaluating existing zoning / spatial measures – Boyes *et al*., 2005, 2007

A useful process for a marine planner is to examine existing spatial measures, categorising them according to the different levels of restriction and describing how effectively the current measures contribute to the objectives of the plan. In this example from the Irish Sea, existing spatial measures were categorised in a hierarchy of: 1. General Use Zones (sub-categories: 1A, Minimal Management; 1B, Targeted Management), 2. Conservation Priority Zones, 3. Exclusion Zones (sub-categories: 3A, Limited Exclusion; 3B, Significant Exclusion), 4. Protected Zone. Mapping such measures alongside information on known or potential conflicts/compatibilities/opportunities would likely be a useful visual aid for considering new spatial policies.

The Local Environment and Economic Development (LEED) Toolkit[38]

This toolkit is described under Section 4, but is also of relevance for identifying inter-dependencies and threats between economic sectors and the environment.

Interaction matrices and mapping conflicts/compatibilities

It is useful to identify past, existing and possible future interactions between sectors and between sectors and other interests (e.g. environment or cultural heritage). Interactions may be negative (conflicts), positive or neutral. A matrix approach can be used to identify these interactions in principle but, to inform appropriate policy, planners should map these interactions within their plan area.

Previous projects have produced interactions matrices and, although they have mostly not progressed to the mapping of interactions, they demonstrate useful experience in matrix development and presentation. These include:

- Clyde Forum for the Clyde SSMEI pilot[39]
- Sound of Mull SSMEI pilot[40]
- Tay Estuary Forum[41]

Different matrix-building methodologies may be applicable to different situations and scales. Consideration should be given to the data/information needs for the mapping of matrix results and therefore what the appropriate area for focus would be (e.g. local areas of intuitively higher use/sensitivity may be preferable to region-wide interaction mapping).

Fisheries management opportunities

Not all human activities at sea or on adjacent coasts are controlled by licensing and consenting regimes. Of the other activities, commercial fisheries are the most pervasive economic activity in our marine environment, with some parts of the industry having particular impacts on marine ecosystems. While marine planning can seek to protect sustainable 'non-licensable' activities from conflicts with other licensed developments, it is also important that marine plans exert influence on the management of these other activities, with a view to achievement of the broader marine plan

[38] http://ecosystemsknowledge.net/apply/local-economy/LEED
[39] http://www.clydeforum.com/marine-planning
[40] http://www.acba.org.uk/info/sectoral-interactions.pdf
[41] https://sites.dundee.ac.uk/tef/wp-content/uploads/sites/9/2014/04/Sectoral-Interactions-on-the-Tay-report1.pdf

objectives. However, management of fisheries has not typically been well integrated with the planning and management of other activities and developments. While the delivery of fisheries management measures is likely to continue to be delivered through fishery-specific regulation, planners may identify particular issues and opportunities for the attention of fisheries managers. To this end, tools such as the Ecological Risk Assessment of the Effects of Commercial Fishing (ERAEF; Cotter and Lart, 2011), or those available through the FAOs Ecosystem Approach to Fisheries (EAF) toolbox[42], may be used in conjunction with other planning tools to inform progress towards fisheries sustainability in a way that is cognisant of all other developments and activities, and the collective influence of these on the ecosystem.

[42] http://www.fao.org/fishery/eaf-net/toolbox/en

6. CUMULATIVE ASSESSMENTS

The core purpose of marine planning is to progress beyond single-development or single-sector management decisions, instead adopting a strategic and plan-led approach across all marine sectoral, social and environmental interests simultaneously. Analysis of cumulative pressures, effects or impacts should therefore reflect this complexity.

Cumulative Impact Assessment (CIA) should be carried out in the environmental assessment of individual development proposals, evaluating impacts of a proposal when taken in conjunction with other developments and activities. Such project-specific CIA is likely to focus on very detailed and (to the extent possible) quantitative analysis, whereas cumulative assessments for planning policy are likely to be more strategic. Ultimately, examination of cumulative risks within strategic planning should lead to policies that improve the likely acceptability of individual development proposals.

The following types of cumulative assessment can be taken as steps towards a comprehensive CIA, but simpler strategic consideration of cumulative issues can be undertaken by following just the first (cumulative pressures), or first and second (pressures and effects). Application of any or all steps are more effective if it is recognised (a) where the spatial range of a pressure extends beyond the footprint of the activity or development (including pressures arising from land-based activities), and (b) temporal aspects of the pressure, such as duration, frequency of recurrence, and any diurnal or seasonal patterns. Note that terms such as 'pressures', 'effects, and 'impacts' are defined inconsistently in the literature, for both project-level and plan level assessments, which has potential to confuse. Here we align closely with definitions used by Judd *et al*. (2015) and consider only strategic plan-level assessments.

Cumulative pressures assessment

This involves an understanding of where activities occur and the scale and intensity of subsequent physical or chemical changes (pressures). There is no analysis of what the biological or ecological response (effects) or consequences (impacts) would be, but pressure information can still provide information for making logical inferences about where the most impacted or most natural areas are. This can aid in the identification of spatially defined areas for policy options. Subsequent deliberation of the implications of cumulative pressures can be aided considerably by understanding the distribution and or abundance/condition of biodiversity and geodiversity features, but this is not necessarily inherently included in pressure mapping.

The Shetland Marine Plan has included a mapping exercise that approximately meets this definition of cumulative pressures assessment (Kelly *et al.,* 2013, 2014), including a 'weighted-sum' tool to generate a single map of cumulative pressures (as opposed to separate maps for different pressure-types). This adds assumptions to the assessment output, but has merits in terms of its application to strategic planning policy. This example provides a further extension to basic pressure assessment, modifying outputs by filtering against criteria that rank according to the likelihood of interaction, frequency of activity, confidence in activity data and timescale to ecosystem recovery. The latter criterion for ecosystem recovery is coarse; it is not related to the location or specific sensitivities of biodiversity or geodiversity features/processes, as per the cumulative effects assessments described below.

Cumulative effects assessment

This progresses from pressure mapping to include consideration of the response (sensitivities – see Section 5) of features of the environment, with the mapping of effects informed by the distribution of biodiversity and geodiversity features (the resolution of this information and the extent to which taxon/habitats are grouped depends on the available information and the scale of the assessment area). This stops short of detailed quantitative analysis of biological or ecological impacts, but applies an understanding of feature sensitivity to inform subsequent deliberative processes (e.g. risk assessment) that can inform spatial policies.

Judd *et al*. (2015) provide a set of principles and a framework for this method. Robinson *et al*. (2013) also provide a clear and useful methodology which can be applied at any geographic scale; this method is nested within a broader suite of tools described by ODEMM[43]. Although the application of these has been at European regional seas scale (e.g. Greater North Sea), most may be adaptable for application in finer scale marine planning exercises. However, the availability of environmental data may mean that such an assessment would be best delivered by appropriate grouping of taxa and use of relatively coarse biotope levels. In turn, cumulative effects assessments may be most effective at the scale of multiple Scottish planning regions, which may also align better with biogeographic zones (e.g. east coast, west coast, north coast).

In 2008 the US National Center for Ecological Analysis and Synthesis (NCEAS) published a global map of human impacts[44]. Since then they have supported several regional scale applications of their method. The methodological details of Kappel *et al*. (2012) could be adjusted or updated for marine planning applications in Scotland. More information is available at *SeaPlan*[45].

Cumulative impacts assessment (CIA)

This goes further by also identifying measurable changes to species or habitats, therefore applying understanding of biological response to change (sensitivity) alongside information on pressure magnitude and how the arising impacts may accumulate additively or synergistically. This could in theory result in more detailed or policy-ready conclusions, but usually involves modelling or calculations that are subject to many assumptions and uncertainties. It is unlikely that such an approach will have regular applicability to strategic planning. An example of this approach is described by Ban *et al*. (2010)

[43] http://odemm.com/content/home
[44] https://www.nceas.ucsb.edu/globalmarine
[45] http://www.seaplan.org/blog/project/cumulative-impacts/

7. FUTURE / SCENARIOS TOOLS

Future or scenario tools may draw upon or be used within other tools described within this document. Their application within the context of an ecosystem approach to marine planning could take three general forms:

1. Forecasting change, whether environmental, economic or social, to understand the future conditions which a plan needs to account for.
2. Deliberation over planning outcome options, facilitating stakeholder articulation of preferences by presenting feasible alternative futures/scenarios rather than a blank canvas.
3. Working backwards from a stated future vision or objective, to understand the steps and policy detail required to achieve that vision.

The use of such methods can become a driver for seeking change through a plan-led process. They should help to ensure that policy direction is focussed on long-term sustainability, avoiding the temptation for policies to solely serve short-term economic aspirations.

These tools are likely to be particularly applicable during the identification of issues and opportunities for planning (Section 5), the assessment of trade-offs (Section 8) and approaches to zoning (Section 9). The involvement of stakeholders (Section 1) is likely to be fundamental to the use of futures/scenario tools.

The NEAT Tree[46] provides useful background, literature review, summaries and evaluations of such tools. It does so in the context of ecosystem services, but the tools are applicable to broader aspects of planning and the ecosystem approach.

A few other relevant tools are identified below.

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)[47]

Described in more detail in Section 4, the InVEST tool also supports scenario assessment and trade-off analysis. It can compare multiple scenarios within one model and can be used at multiple geographic scales. This adds value to its potential for use in both strategic planning and specific activity management applications, but users should note its limitations in relation to modelling indirect effects and changes in human behaviour.

Ecosim and Ecospace[48]

Ecopath has been highlighted above (Section 3) as holding potential for informing environmental status assessments in relation to fisheries impacts. Extensions to this model are called Ecosim and Ecospace. Ecosim analyses add a temporally dynamic simulation capability so that model parameters can be manipulated for forecasting or to present future management scenarios. Ecospace then adds a spatial mapping element by assigning different species groups to different

[46] http://neat.ecosystemsknowledge.net/futures-tools.html
[47] http://www.naturalcapitalproject.org/invest/
[48] http://www.ecopath.org/

habitats and allowing simulation of spatial restrictions on fisheries. This furthers the potential for deliberations over forecasts and scenarios to inform spatial policies. While these models do not accommodate impacts from non-fisheries activities, as fisheries are a major source of historical and current ecosystem impacts for many areas, outputs have potential value to marine planners. However, their use is technically demanding, requiring an understanding of the limitations and access to specialist support. The software website provides links to many useful publications, including a User Guide that identifies pitfalls; Christensen and Walters (2004) also review the methods, capabilities and limitations.

Integration of Spatial Information for Simulation of Fisheries (ISIS-fish)[49] ;

This modelling process also allows simulation of different spatial management options for fisheries regulation. As for Ecopath and Ecosim it is limited by having a single-sector focus, but marine planners may apply the outputs in a multi-sector context. It is also likely that specialist input is required; users require understanding of the complex coding and of the limitations of the model.

[Ecosim, Ecospace and ISIS-fish are just a few of many available ecosystem models that seek to simulate the consequences of defined changes in impacts or management. MRAG Americas (2009; see appendices) describe a range of other tools, explaining different model categories – minimum realistic models (spatial and non-spatial); aggregate ecosystem models; dynamic whole ecosystem models.]

[49] http://www.isis-fish.org/en/

8. ASSESSING TRADE-OFFS AND PREDICTING POLICY IMPACTS

Analysis of trade-offs and policy impacts should improve the transparency of policy and management decisions. They should also help avoid unnecessary (and often entrenched) conflicts around perceived but weak conflicts, so subsequent debate can focus on more pressing issues (White *et al*., 2012). The subsequent priorities and decision-rules that can then be established in planning policy should therefore limit the occurrence of contentious decisions having to be made in the course of development licensing and activity management decisions (by which point considerable investments may be at risk).

Such analyses and decisions will often need to be made in the face of uncertainties or imperfect knowledge of the underlying issues. Planners should not be deterred from reaching judgements in these situations, but ensure an appropriate risk-based approach is adopted. Some methods are better suited to accommodating the acknowledgement of uncertainties or information on relative risk. For decisions relating to conflicts with natural heritage interests, risk-based approaches still need to comply with legislative requirements.

MMO and MS (2012; pp 28-32) provide an overview of methods, highlighting limitations, benefits and data needs for each. The following may have particularly useful application within marine planning, and indeed some are incorporated within many of the tools/examples described above:

- Cost Benefit Analysis
- Cost-Effectiveness Analysis
- Multi-Criteria Assessment
- Trade-off analysis

MMO and MS (2012; pp 32-38) also critique some specific tools (applying some of the above generic methods) that could be explored for use within marine planning.

Outputs of Work package 10[50] of the UKNEAFO project included useful non-specialist guidance on methods for cost-benefit analysis and multi-criteria assessment.

Decision Support System (DSS) Toolbox – Turner *et al*., 2014 √xy;

This review describes a toolbox that adopts some of the above methods in relation to marine and coastal ecosystem services, and proposes a 'balance sheet approach' to evaluating the trade-offs of marine plan policy options.

ODEMM (Options for Delivering Ecosystem-Based Marine Management)[51] √xy;

The outputs of this project provide a suite of decision-support tools. It includes tools that allow assessment of policy impacts and trade-offs, but which are designed to follow-on from the other assessment tools aimed at understanding pressures, interactions and ecological risk. Application of the tools has so far been at the scale of European regional seas, but could likely be adapted for application to smaller-scale marine planning.

[50] http://neat.ecosystemsknowledge.net/pdfs/cba_mcda_ecosystem_proofed_tool.pdf.
[51] http://odemm.com/content/home

Efficiency frontiers – White *et al*., 2012

A bioeconomic model is used, extending efficiency frontier methods common in other economic applications for use in a marine spatial planning context. The approach, like others, is not immune from assumptions that can oversimplify model criteria describing ecosystem dynamics and sectoral drivers. It would also benefit from inclusion of indirect benefits of different plan options. However, the structured methodology is appealing in its relative flexibility and simplicity for considering trade-offs and predicting the impacts of policies on multiple sectors/interests, with the paper demonstrating the considerable potential for economic benefits of such approaches within marine planning. As sector values can be characterised in different ways (absolute or percentage terms), it is possible to compare diverse ecosystem benefits. The visualisation methods described could also provide a powerful communication and stakeholder engagement tool, also supporting discussions around the balancing of optimal benefits versus practicality of implementation.

Marine Integrated Decision Analysis System[52]

Tackling the same planning area as White *et al*. (2012), this project took a different approach to trade-off modelling and visualisation, building a model on the Mulitscale Integrated Models of Ecosystem Services (MIMES[53]) framework and developing an interactive, web-based and user-friendly GIS visualisation tool. This more advanced modelling approach can allow attempts to capture some of the complex dynamics of marine ecological systems. However, this itself comes with risks and assumptions, and necessitates extensive specialist knowledge.

Differential-DPSIR – Nobre, 2009

The DPSIR (Driver-Pressure-State-Impact-Response) Framework has been through many iterations and different applications for describing the interactions between society and the environment. While early steps in its application can drive other stages in a planning process (e.g. environmental status assessment), it ultimately seeks to aid decision-making by identifying causal links between environmental condition and socio-economic activity, pointing to steps in the causal chain that could be broken or managed by policy intervention. Gari *et al*. (2015) provide a useful review of its application and evolution, describing many examples and case studies, detailing criticisms and limitations (primarily the over-simplification of pressure-state relationships) but also its merits as demonstrated by its continued use. It has been used in isolation and in conjunction with other tools.

Nobre (2009) describes the differential-DPSIR, an adaptation of the methodology aimed at evaluation of both past and potential future coastal ecosystem management policies. The method provides for explicit links between ecological and economic information relating to the use and management of coastal ecosystems. Development of a DPSIR approach requires some scientific expertise and judgement, but the subsequent synthesis of information for non-scientists is appealing for management deliberations. Most examples of its application have been on relatively small areas with explicit environmental challenges, but it is reported that DPSIR frameworks can be applied at all spatial and temporal scales. The tool may have potential for a range of applications within marine and coastal planning, although awareness of its limitations is important.

[52] http://www.seaplan.org/blog/project/midas/
[53] http://www.seaplan.org/blog/project/mimes/)

9. APPROACHES TO ZONING

Zoning can mean the identification of discrete areas exclusively for particular interests, but zoning approaches can also consider many other 'softer' spatial approaches, including:

- Preferred use areas
- Presumption 'in favour of' or 'against' certain developments/activities/uses
- Spatio-temporal measures, whereby certain activities are only limited at defined times of day/week/month/season.
- Constraints/opportunity mapping

Zoning can also take place in the vertical dimension, influencing activities above, on or below the water's surface, and may also include temporal aspects.

Such spatial approaches can help manage and avoid conflicts across multiple sectors and interests, clarifying requirements and expectations for different sectors and seeking additional benefits for ecosystems and sectoral efficiencies. While zoning for developments with spatially specific licensing requirements cannot guarantee the success of applications, it should facilitate greater investor confidence and ease consenting pathways.

The development of zoning techniques within an ecosystem approach should be strongly linked to a spatial evidence base, such as the mapping of ecosystem components (e.g. species or habitats), ecosystem processes and/or ecosystem services (see Sections 2 and 4).

BALANCE – Ekebom *et al*., 2008

Pages 46-57 of this broad-ranging report describe a zoning approach with four categories, as proposed for the Baltic Sea: 1) The General Use Zone, 2) The Targeted Management Zone, 3) The Exclusive Use Zone, and 4) The Restricted Access Zone. The zoning categories are well defined with clearly stated and detailed objectives and restrictions. These could be readily tailored within other marine planning processes, but demonstrates the potential for a zoning scheme to incorporate a broad suite of management approaches.

Spatial typologies for MSP - Janßen *et al*., 2013

This study describes a data-led process to define spatially distinct parts of the Baltic Sea that, based on their exposure to anthropogenic impacts and their biological and physical characteristics, merit differing approaches to marine planning. The principle of this approach is compared to the demarcation of different types of area in land use planning (e.g. central business districts; industrial areas; wild land). To the degree which available data allows, such an approach may be applied in other areas and at different scales.

Examples of zoning approaches within marine spatial planning:

The following links provide access to a range of marine planning examples around the world, including varied approaches to zoning:

- http://www.unesco-ioc-marinesp.be/msp_around_the_world
- http://www.unesco-ioc-marinesp.be/msp_references

10. OTHER RESOURCES

- Although integral to many of the tools and examples mentioned above, Geographical Information Systems (GIS) are not identified above as a tool in their own right. However, they are likely to be fundamental to many aspects of marine planning. Snickars and Pitkänen (2007) provide a review of how to use GIS tools for marine planning and management.

- MMO (2014) provide some analysis of strengths and weaknesses of selected tools for marine planning in the UK (see pages 38-43 and 119-131). Many of those summarised above are mentioned.

- 'An Evaluation Framework for applying the Ecosystem Approach'[54]: This generic framework should guide the evaluation of policies, plans and planning process against the principles of the ecosystem approach. The UNESCO Guide to Evaluating MSPs (Ehler, 2014) provides more specific guidance.

- Guiding ecological principles for marine spatial planning (Foley *et al*., 2010).

- The Food and Agriculture Organisation (FAO) provide a toolbox for an Ecosystem Approach to Fisheries (EAF)[55]. Fletcher and Bianchi (2014) provide commentary on its use.

- Fletcher *et al*. (2012) tabulate ecosystem services linked to habitats and species protected within the English Marine Conservation Zones (MCZs). Many of the species and habitats identified are also of conservation importance in Scottish waters, within and outwith MPAs; this information may therefore be a useful resource in applying tools such as those identified in Section 4.

- The impacts of climate change on economic sectors, human society and the environment is an increasingly important consideration for marine planning; marine planning should drive mitigation and adaptation measures, making appropriate links with land-based planning. Available specific tools and guidelines that can be readily applied within marine planning relate primarily to adaptation[56], but broader climate change issues could readily be captured within some of the more generic tools described in this document. Scotland's Coastal Change Assessment (CCA)[57] provides a specific tool, mapping erosion and accretion rates with regard to the physical susceptibility of the coast and aids consideration of areas and assets at risk from coastal change.

- Effective coastal planning across the land-sea interface is important for an ecosystem approach to planning because the sectoral, societal and environmental interests relevant to planning are rarely restricted to either just the marine or the terrestrial environment. Indeed, the extent of their interaction is often heightened at this coastal interface. Productive working arrangements and management processes with land-based terrestrial should include collaborative use of planning tools and shared outcomes.

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[54] Evaluation Framework for an Ecosystem Approach - http://www.snh.gov.uk/docs/A1933741.pdf
[55] http://www.fao.org/fishery/eaf-net/toolbox/en
[56] http://ecosystemsknowledge.net/resources/tools-guidelines/climate-change-and-carbon-2
[57] Scotland Coastal Change Assessment - http://www.dynamiccoast.com/

- A video of a presentation supports the publication 'Selecting Decision Support Tools for Marine Spatial Planning'- see www.openchannels.org/webinars/2011/decision-guide-selecting-decision-support-tools-marine-spatial-planning

- There are a number of international examples of marine planning exercises, which apply an ecosystem approach in different was and to varying degrees. UNESCO list marine planning examples from around the world; those from Belgium, Germany, Canada, Australia and parts of the USA and Canada may be of particular interest. See:
    - http://www.unesco-ioc-marinesp.be/msp_around_the_world and
    - http://www.unesco-ioc-marinesp.be/msp_references

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Further comments are welcome from a broad readership and may be used to inform periodic updates to this resource. Please contact chris.leakey@snh.gov.uk

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