A FRAMEWORK FOR THE OPERATIONAL ASSESSMENT OF MARINE ECOSYSTEM SERVICES

VALMER WP1 GUIDELINES DOCUMENT

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1. Aims and Objectives

The VALMER project is an eleven partner, €4.7 million project co-funded by the INTERREG IV A Channel programme through the European Regional Development Fund, which aimed to examine how improved marine ecosystem services assessment can support effective and informed marine management and planning.

The project has 6 work packages which can be explored online at www.valmer.eu. The aim of work package 1 was to assess and value marine ecosystems. This work package was divided into two sections:

1.1 Developing an operational framework for assessing and valuing marine ecosystem services (1 September 2012 – 31 March 2015).

The purpose of this action was to review existing approaches to ecosystem service assessment and valuation and propose a coherent approach to monetary and non-monetary assessment and valuation. This was achieved through collaborative working between social scientists, economists, ecologists and environmental managers to enable best practice to be exchanged at a scale appropriate to the Channel area. The deliverables from this action include a set of guidelines for assessing and valuing marine ecosystem services (as presented here) and a report from a best practice exchange workshop held in Brest in 2012. The materials presented during this workshop can be consulted online at the following link:
http://www.umr-amure.fr/valmer_workshop/index-valmer-wwp1.htm

1.2 Trialling ecosystem service assessments and valuations at pilot study locations (1 October 2012 – 30 September 2014).

This action established six pilot study locations at various spatial scales that are representative of a range of common Channel ecosystem services. The Guidelines developed in Action 1.1 were applied to the pilot study sites and relevant valuations for ecosystem services were determined at those sites. Full case study reports and the results of the trials can be found in the Valmer WP4 Report titled "Advice note for using ecosystem service assessment to support marine governance". The deliverable from this action 1.2 was a synthesis of lessons learned and recommendations (see Valmer WP1 Report on "Ecosystem Service Assessment in Practice: Lessons Learned") tailored to the needs of practitioners, enabled by a final workshop in Brest in February 2015.

The VALMER Guidelines document was initially developed to provide a standardised approach to valuation of marine ecosystem services in support of management, so that this approach could be applied in the six case pilot study areas. However it has now been redrafted to provide a broadly applicable “best practice” manual providing a fully validated set of guidelines supported by six case study applications.

The Guidelines document addresses the following topics: it summarizes the history and the basic principles of the Ecosystem Services approach (part 2); it presents and discusses the general definitions and concepts which may be applied for characterising marine and coastal ecological functions and ecosystem services (part 3); it proposes a framework which is intended to help scientists and practitioners to develop marine ecosystem assessments frameworks that may be useful for management purposes, including information regarding tools, methods and case study applications (part 4); finally, it presents the application of various assessment methods in the 6 study sites together with a discussion of their pros and cons according to the context of use (part 5).

The VALMER framework for the operational assessment of marine and coastal ecosystem services, which is presented in the part 4 of this guidelines document, provides a structure to guide practitioners in undertaking comprehensive, transparent and appropriate MES assessments. It does not, however, provide a set of rigid and prescriptive rules that are applicable in their entirety to all circumstances. MES assessments are context dependent, as the needs of managers and stakeholders, the services about which they are concerned, and the resources available for the assessment are highly variable. This necessitates a flexible guidance framework.

The VALMER framework for marine and coastal ecosystem services assessment is an approach which deals not only with ecological and economic valuation methods. Some important issues will arise at this stage of the implementation of the assessment process, which are related to but beyond the scope of ecological and economic expertise alone. These issues concern mainly the engagement of stakeholder, the building of scenarios and the analysis of governance and institutional changes. Other work packages of the VALMER project present in-depth developments regarding these topics, in particular WP3 (Valmer WP3 Report on “Building site based scenarios: tools and approaches for implementation from the VALMER project”) and WP4 (Valmer WP4 Report on “Improving stakeholder engagement in marine management through ecosystem service assessment”), and should be seen as key accompaniments to this document.

2. Background to the Ecosystem Service Approach

The ecosystem services approach has first been elaborated by ecologists who were concerned by critical environmental problems, and was formalised in the 1970s for the purpose of political advising[1]. Since the 1990s, as they became convinced of the persuasive power of monetisation of Nature for conservation purposes, natural scientists and economists joined their efforts in order to estimate the "value" of ecosystem services or their contribution to human well-being (Gómez-Baggethun et al., 2010). A remarkable milestone in this process appeared to be the 1997 paper on "The value of the world's ecosystem services and natural capital" published in the journal Nature by R. Costanza et al. Ecosystem services have fed a lot of scientific debates and projects, which strengthened the interdisciplinary collaborations between natural scientists - mostly ecologists, and social scientists - mostly economists. Within the decision-making sphere, the ecosystem services approach has been popularised by the publication in 2005 of the results of the Millennium Ecosystem Assessment (MEA, 2005), a study carried out by 1300 scientists from around the world under the umbrella of the United Nations Environment Program (UNEP). This work stimulated the interest of high-level politicians toward in particular the economic significance of the global loss of biological diversity[2] and opened the way for initiatives such as TEEB (The Economics of Ecosystems and Biodiversity), again under the umbrella of the UNEP (TEEB, 2010), and COPI (Costs of Policy Inaction), a study for the European Commission (Braat and ten Brik, 2010).

2.1. Review of concepts and definitions

Ecosystem services are the benefits people obtain from ecosystems. The classification of ecosystem services adopted by the MEA distinguishes the following four categories: provisioning services, regulating services, cultural services and supporting services (MEA 2005). **Provisioning services** are the products obtained from ecosystems, including food derived from animals, plants and microbs, biological material for medicines or food additives, material such as wood and energy derived from biological material. **Regulating services** are the benefits obtained from the regulation of ecosystem processes, including climate and water regulation, erosion control, water purification and waste treatment, regulation of human diseases, biological control and storm protection. **Cultural services** are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. At last, **supporting services** are those that are necessary for the production of all other ecosystem services; they differ from the formers in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people.

[1] The origin of the concept can be traced back to the 'Study of Critical Environmental Problem' (SCEP), a report prepared in the Summer of 1970 by about 40 scientists and professionals from various disciplines under the supervision of Carroll L. Wilson, MIT Professor of Management, and William H. Matthews from the MIT Political Science Department (Mooney and Ehrlich 1997). The SCEP contains a first typology of 'environmental services': "pest control, insect pollination, fisheries, climate regulation, soil retention, flood control, soil formation, cycling of matter, composition of the atmosphere" (SCEP, 1970, pp. 122-125).

[2] This interest was formulated in the decisions of the "Potsdam Initiative-Biological Diversity 2010", which arose from a meeting between the Environment Ministers of the G8 countries and of Brazil, China, India, Mexico and South Africa, the European Commissioner responsible for the Environment and senior officials from the United Nations and the IUCN (The World Conservation Union) (Braat, 2012).

The strengths of the Ecosystem Services Approach are the following:

- It is a clear logical framework based on a comprehensive list of ecosystem services organised into four categories.
- The concept of ecosystem services is equally meaningful to the social sciences and to the natural sciences.
- It provides a benchmark for analysing the interactions and trade-offs between environment conservation issues and economic development issues.
- It helps developing scenarios through which interdependencies between political choices, nature conservation goals, human uses and well-being can be highlighted.

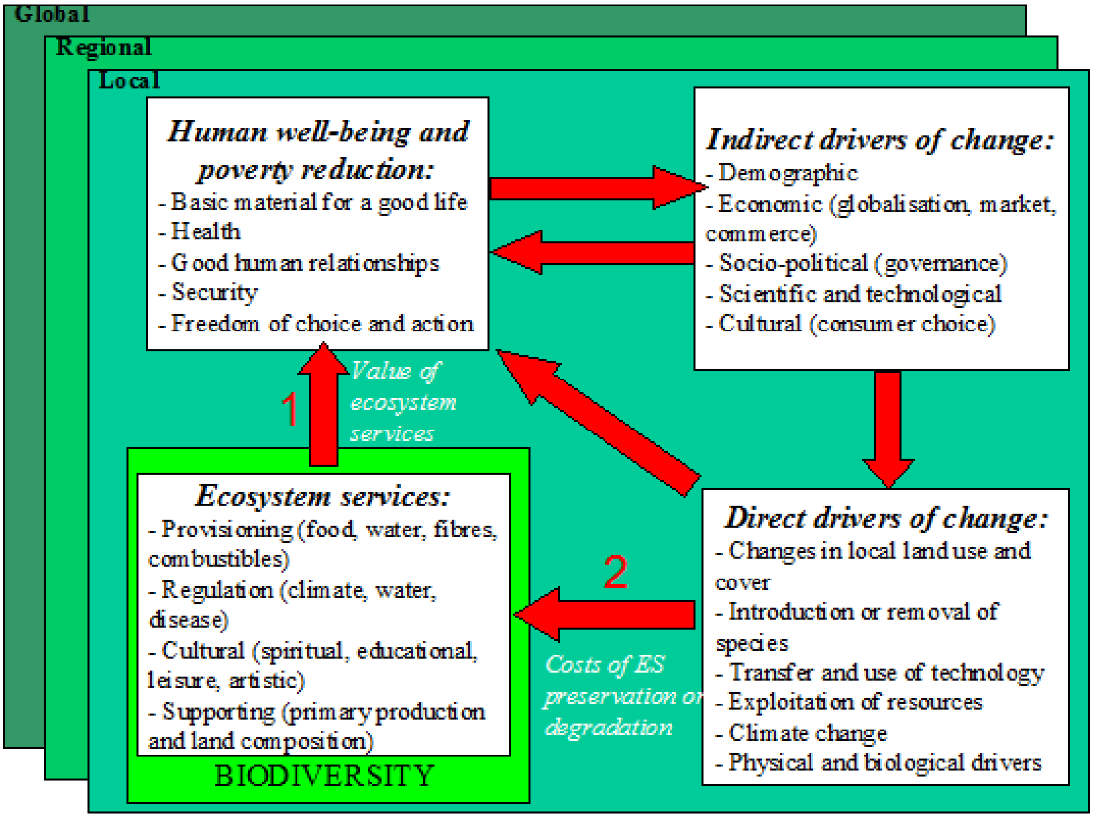

Figure 1. Ecosystem services and Human well-being (adapted from MEA 2005)

2.2. Existing frameworks

The first reference framework for Ecosystem Services Assessment has been produced through the **Millennium Ecosystem Assessment** (MEA). The conceptual framework of the MEA places human well-being as the central focus for assessment while recognizing that biodiversity and ecosystems also have intrinsic value and that people take decisions concerning ecosystems based on considerations of both well-being and intrinsic value (MEA 2003). The MA conceptual framework assumes that a dynamic interaction exists between people and ecosystems, with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being (Figure 1).

The MEA framework is presented with recommendations regarding the importance of multi-scale and multicriteria approaches, the consideration of multidimensional aspects of decision-making, but also the integration of various forms of knowledge and the participation of stakeholders due to the effect of any assessment on their relative power or perception. However, the general framework pictured in Figure 1 points *de facto* most of the attention to economic valuation, as emphasized by arrow 1, which links ES and human well-being through the value of ecosystem and arrow 2, which links human drivers of changes to ES though the costs of preservation or the losses of benefits.

Following initiatives such as the Stern Review on the Economics of Climate Change (Stern, 2006) and the Cost of Policy Inaction study initiated by the European Commission (Braat and ten Brink, 2008), the **TEEB initiative** intended to bring ecosystem services in the policy arena with a clear economic connotation (Braat and De Groot 2012). Basically, the TEEB framework is an extension of the so-called cascade model published by Haines-Young and Potschin (2009), which is based on an "unidirectional downward flow" from ecological functions to ecosystem services and human well-being. The TEEB framework added positive feed-backs via institutions, judgments, management and restoration (Figure 2). The TEEB provided a two-steps approach for ES assessment in support of decision-making: first identify and assess ES, mostly based on changes in ES values related to land-cover changes, and second estimate and demonstrate the value of ES. This second step aims at revealing the full costs and benefits of ecosystem uses and at promoting economic mechanisms that incorporate the values of ecosystems into decision-making, through incentives and price signals.

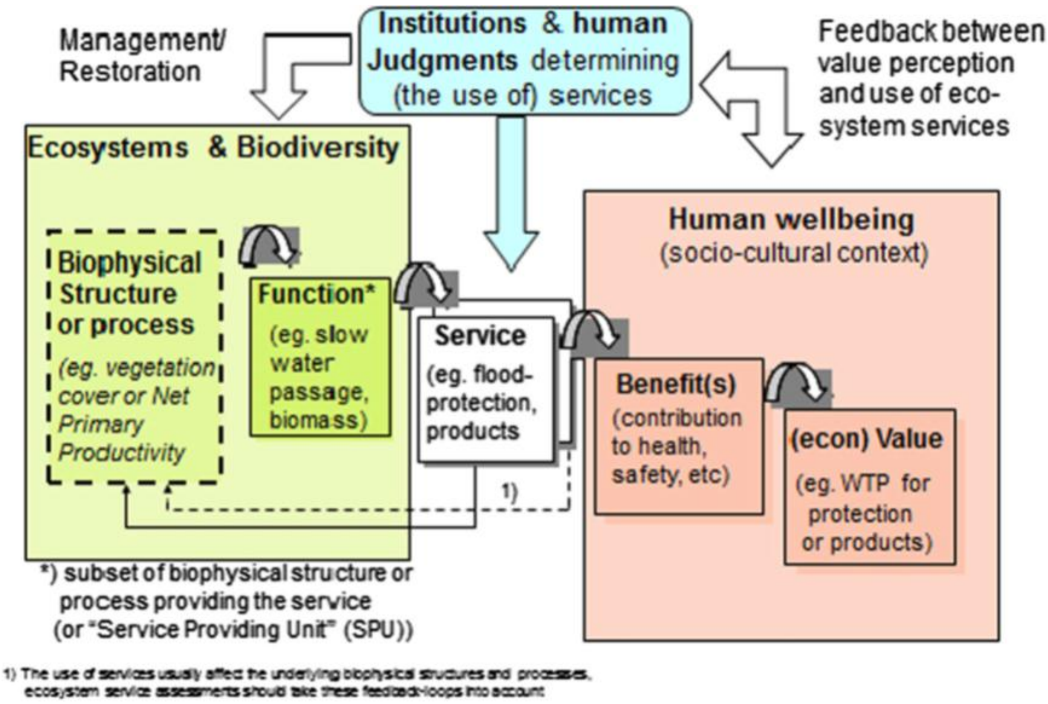

Figure 2. Ecosystem services within the frame of "The Economics of Ecosystems and Biodiversity"

From the point of view of economists, the concept of ecosystem services is very linked to the one of natural capital: the flow of ecosystem services may be seen as the 'dividends' (benefits) that the society receives from natural capital (TEEB 2010). Hence, the value that the society associates to ES depends on the status of the natural capital: the more the natural capital is rare the highest is its marginal value, which is the value of an additional unit of natural capital (Figure 3). The figure 3 reveals where the threshold for strong sustainability appears (for a given ecosystem or habitat): the amount of natural capital that has to be preserved (because it is not substitutable or because its destruction would generate irreversible adverse effects) corresponds to an inelastic demand (vertical demand curve), that is where the marginal value could be infinite and the preservation of nature non-negotiable. In other words, some (amount of) natural assets or some (level of) ecosystem services have an infinite value, and the benefits they provide cannot be estimated.

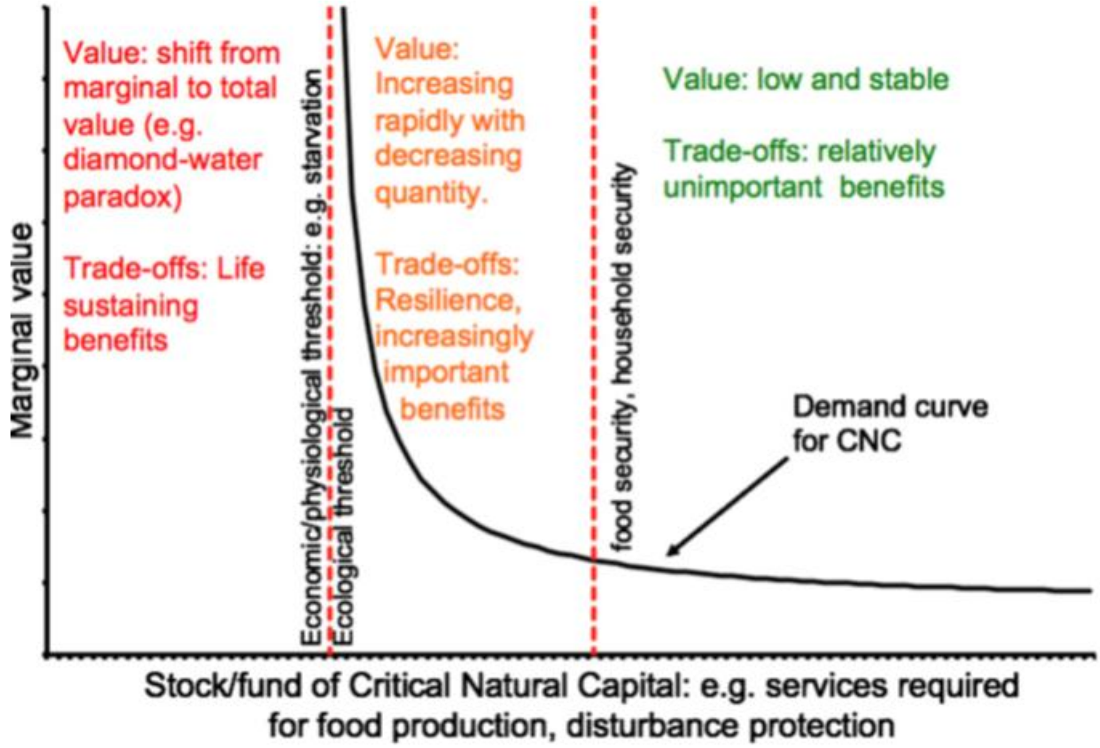

Figure 3. The demand curve (marginal value) for Ecosystem Services (Farley 2012)

Thus, the economic valuation of ecosystem services is to be implemented for defining the scope and target of use and conservation trade-offs, within the limits of what is substitutable or reversible. This may be formalized by considering two categories of values. The first category is the ‘insurance value’ which reflects the ability of the ecosystem to face variability and to absorb shocks (Balmford et al 2002, Turner et al 2003); it is closely related to the resilience of the ecosystem, which depends on ecological infrastructure and processing capability. This value is better acknowledged through the precautionary approach or the setting of safe minimum standards than through monetary valuation. The second category is the ‘output value’ which corresponds to the aggregated flows of benefits provided by the ecosystem in a given state. The output value is commonly referred to as the Total Economic Value (TEV), which encompasses use values and non-use values (Table 1).

Table 1. Components of the Total Economic Value (TEEB 2010).

Value Type	Sub-type	Meaning
Use values	Direct use value	Results from direct human use of biodiversity, be it consumptive (fisheries, aquaculture) or non-consumptive (recreation, culture).
	Indirect use value	Derived from the regulation services provided by species and ecosystems
	Option value	Relates to the importance that people give to the future availability of ecosystem services for personal benefit.
Non use values	Bequest value	Value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (intergenerational equity concerns).
	Altruist value	Value attached by individuals to the fact that other people of the present generation have access to the benefits provided by species and ecosystems (intragenerational equity concerns).
	Existence value	Value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist.

The output (or instrumental) values may be estimated with neoclassical economics methods. In general, these methods do not integrate distributional issues: political science methods can address this problem by considering a justice criterion (Figure 4). All these methods are based on the measurement or revelation of individual preferences. While the flow of services generates benefits, the preservation of ecosystem resilience (insurance value) generates maintenance costs: however, for the reasons mentioned above, it would be conceptually wrong to compare resilience maintenance costs to ecosystem benefits as for a conventional cost-benefit analysis.

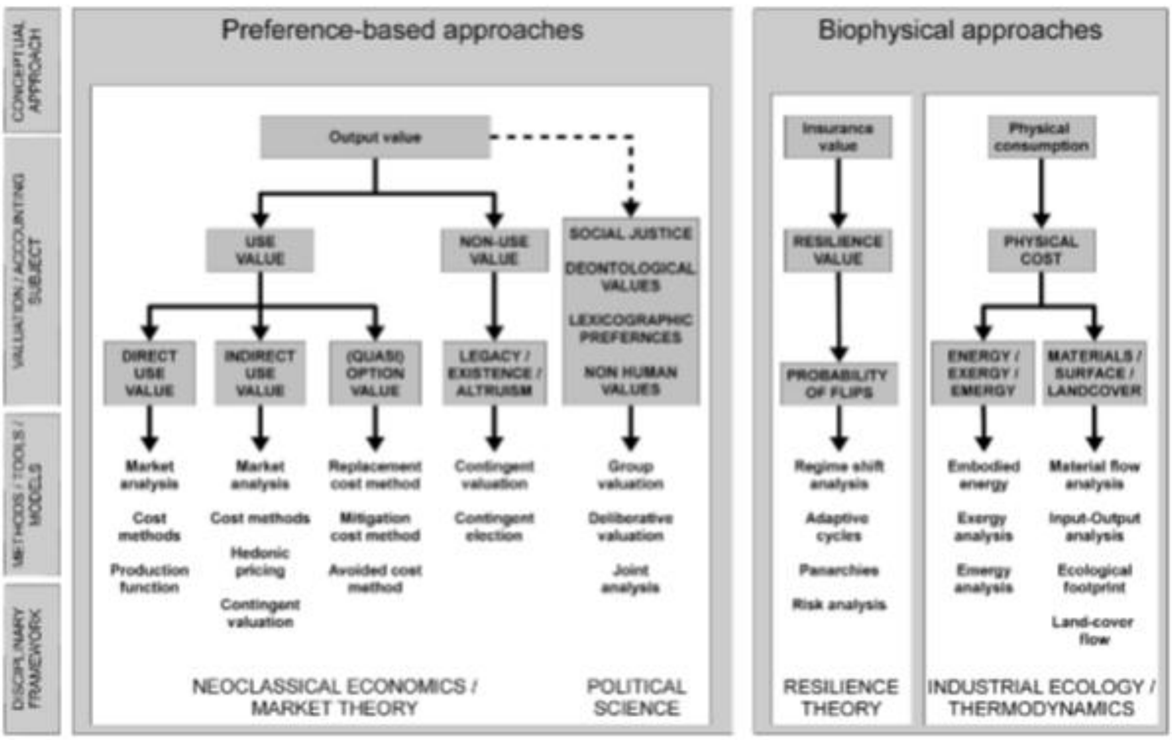

Figure 4. Approaches for estimating Ecosystem Services values (TEEB 2010).

In practice, valuation is needed when a choice has to be made, *i.e.* when natural capital or ecosystem services are becoming scarcer: at this stage, the marginal value of ES increases rapidly, especially because of rising awareness of the less tangible values (aesthetical, cultural, ethical). It is therefore recommended to use a variety of valuation approaches, as hybridizing approaches may overcome disadvantages of particular valuation methods (TEEB 2010).

2.3. Limitations

Ecosystem services assessment has inspired a large amount of economic literature drawing upon Costanza et al (1997), with the aim of building reliable valuation methods. At a rather global scale, the focus on monetary valuation has contributed to attract political support for ecosystem conservation and favoured initiatives such as TEEB (Gómez-Baggethun et al 2010, Liu et al 2010). However, the validity of ES valuation at global or local scales remains a controversial issue. Multi-scale, multi-criteria and multidimensional assessments as recommended by MEA and TEEB are very rare. The focus on monetary valuation has raised criticisms related to the excessive use of the benefit transfer methods or the spreading of numbers without contextual elements. These limits of the economic valuation of ES are reflected in the academic literature: examples of effective use of ES economic valuation in support of decision-making represent a very low share of the work (Figure 5).

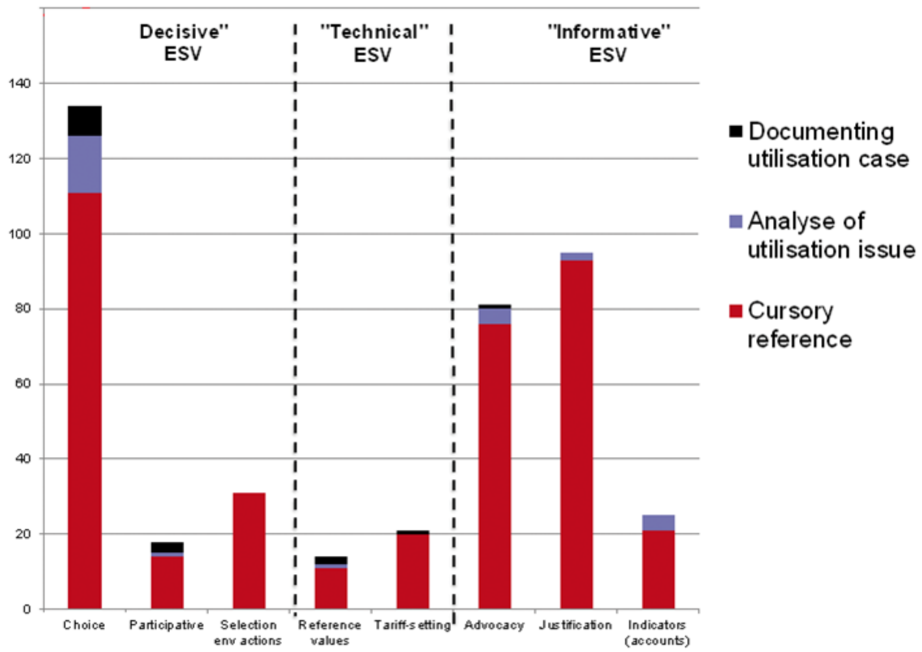

Figure 5. Use of ES economic valuation as treated in the literature (Laurans et al 2013)

In addition to these well-known pitfalls of ES economic valuation as regards its effective use in support of ecosystem management, ES assessments have mostly concerned terrestrial ecosystem and have not been so much developed in the marine field. New research is thus needed, firstly in order to properly identify and characterize marine ES and secondly in order to provide ES assessment frameworks which should be efficient and useful for designing future marine policies, in particular in the prospect of the European call for an ecosystem-based approach for marine integrated policies which appears in the Marine Strategy Framework Directive.

3. Ecosystem Service Assessment in the marine environment: concepts and definitions

A first aim of this section is to provide a series of admitted references and nomenclatures which can be used for describing with the accurate level of precision the marine ecosystem and the related social system which will be scrutinised (paragraph 3.1). This attention paid to terms and categories is fundamental for two reasons. First, the ecosystem services approach bring together concepts which come from several disciplines of natural and social sciences, while being implemented by researchers, managers and stakeholders from various backgrounds: therefore, shared conceptual and analytical frameworks are needed for building a common language (Granek et al, 2010). Second, the clarification of the terms used for objects, processes and concepts will facilitate the comparability of studies, and also the preparation of the quantitative valuation step which requires that the main attributes of the social-ecological system to be assessed have been carefully specified.

Another objective of the characterisation of marine ES is to provide a conceptual representation of ecosystem services in relation to the ecosystem which delivers them and the people who benefit from them. Basically, as far as complex ecological processes and social issues may be concerned, the ecosystem services approach gains from being enlarged to a system approach (paragraph 3.2). From this perspective, ecosystem services should be placed within the broader representation of a complete social-ecological system. Even if the complex dynamics of ecological and social processes are not a first concern for the ecosystem services approach, it is necessary to understand how and why the trade-offs between ecosystem services are generated or challenged by these processes. This is the reason why the implementation of the ecosystem services approach requires characterising with the accurate precision level not only the habitats, functions and services, but also the uses and institutions which fail within the scope of the ES assessment.

3.1. Natural habitats, ecological functions and marine ecosystem services

Ecosystem services are basically the benefits people obtain from ecosystems (MEA 2005); however the links between the biophysical features of ecosystems and the social benefits they deliver is not so easy to establish. Ecosystems may be characterised by their organisation (stock, structure, infrastructure, pattern and capital), their operation (flows, functioning, processes) and their outcomes for Humans (goods and services, income and benefits) (Fisher et al. 2009). A simple way to capture the organisation of ecosystem is to describe habitats, which can be classified using international multi-tiered nomenclatures. Originally defined as the physical and chemical environment in which a species or an assemblage of species lives, habitats are now defined in European Directives as recognizable spaces which can be distinguished by their abiotic characteristics and associated biological assemblages (ICES, 2001). A first step in the services evaluation is then habitat mapping. Classification becomes more complex when it comes to ecological functions and ecosystem services.

Nomenclature for habitats

The European Nature Information System (EUNIS) habitat classification is a pan-European system, which covers all types of natural and artificial habitats, both aquatic and terrestrial; the system was developed through the collaboration of a wide range of scientists and conservation managers, by the analysis of empirical data sets, and the review of other classifications and scientific literature (Fraschetti 2008). EUNIS classification is organised into hierarchical levels: the current version of the classification starts at level 1, where 'Marine habitats' are defined and distinguished from different continental habitats[3], up to level 6 (Galparsoro et al. 2012). The criteria for defining marine habitats up to level 2 are presented in Figure 6. Levels 2 and 3 are based only on physical features while biological assemblages are explicitly required to reach Level 4 (Table 2). This level allows for coupling marine habitats as previously defined with ecological functions and ecosystem services without including excessive details. ES assessment in VALMER should be based on EUNIS Level 4 classification as a tradeoff between the current knowledge on ecosystem functioning and marine habitats and the need to discriminate spatially the valuation of ecosystem services (see Appendix 1). As EUNIS typology is a hierarchical system, it can be used for habitat mapping at different spatial scales.

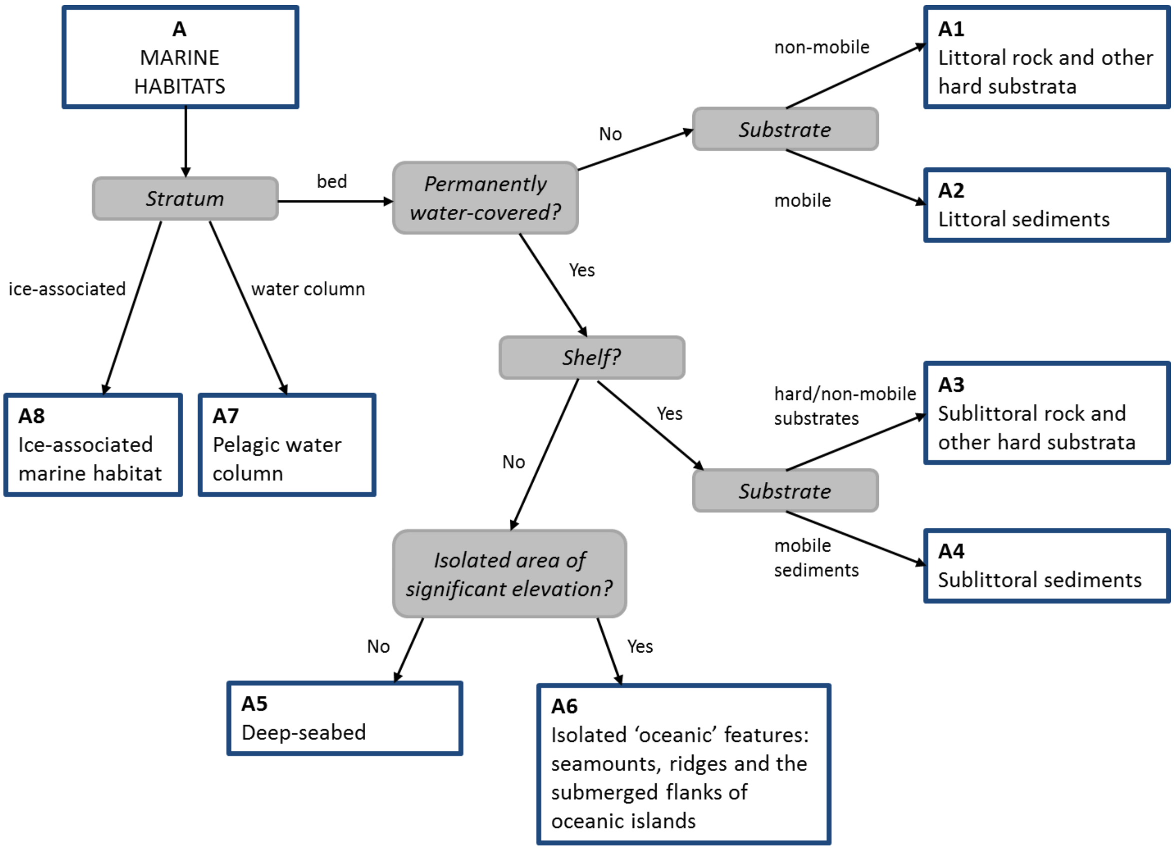

Figure 6. EUNIS habitat classification: criteria to define marine habitats at Level 2.

Source: http://eunis.eea.europa.eu/habitats-diagram.jsp?habCode=A

[3] One of the 10 others level 1 categories is named "coastal habitats". Coastal habitats are those above spring high tide limit (or above mean water level in non-tidal waters) occupying coastal features and characterised by their proximity to the sea, including coastal dunes and wooded coastal dunes, beaches and cliffs.

Table 2. Illustration of the hierarchical structure of the EUNIS habitat classification for one habitat, up to levels 4 and 5.

A. Marine habitats
A2 Littoral sediment
A2.2 Littoral sand and muddy sand
A2.24 Polychaete/bivalve-dominated fine sand shore
A2.242 [*Cerastoderma edule*] and polychaetes in littoral muddy sand

Do natural habitat, ecological functions and ecosystem services always match?

Habitat classification constitutes a well admitted starting-point for describing ecosystems. However, one habitat remains a place where many biophysical processes occur and a system which provides several ecological functions: thus, within a whole ES assessment framework, one habitat may contribute to several functions and services while a service may depend on several functions and habitats. Relationships between habitats, functions and services are then multiple, complex and non bijective. An important step in the qualitative assessment of ES in a given study site is therefore to identify the major ecological functions and the main ecosystem services which are an issue for ecological social concerns. Table 3 provides a list of biological functions and their definitions. Each of these ecological functions may generate a series of ecosystem services. Figure 7 depicts the way ecological functions and ecosystem goods and services are the most likely to interact.

Table 3. List of beneficial ecological functions and their definitions. Some ecological processes that influence the functions are provided. (Modified from TEEB, 2009; Fletcher et al., 2011).

Category	Definition
Primary production	Production of biomass by photosynthetic autotroph organisms (e.g. macroalgae, plants) Processes: photosynthesis
Secondary production	Production of biomass by animal heterotroph organisms Processes: consumption, assimilation, excretion, growth, mortality
Biological control	Biotic interactions resulting in a decrease of species abundance by diseases, parasites or invasive species Processes: diseases, parasitism, commensalism, phoresia
Food-web dynamics	Interactions between species related to food consumption through bottom-up or top-down control Processes: predator-prey interactions
Formation of species habitat	Provision of the physical properties of the habitats necessary for the survival of a species Processes: growth of reef-building organisms, hydrodynamism
Nurseries/spawning grounds	Provision of the physical properties of the habitats necessary for the survival of certain stages of the life cycle Processes: larval dispersal, spawning behaviour
Species richness/Genetic diversity	Diversity between and within species Processes: environmental filter, dispersal, biotic interactions, migration, mutation, drift
Stocking and waste of pollutants	Storage, removal or alteration of organic and inorganic pollutants from the ecosystems including the water column Processes: bioturbation, bioremediation, bacterial activity
Biogeochemical cycles	Modification and transport of carbon and nutrients through biogeochemical processes Processes: mineralization, calcification, respiration, excretion, photosynthesis, bioturbation
Erosion and sediment stability	Control of the processes leading to erosion or deposit of sediment Processes: bioturbation, biofilm formation, development sediment stabilizers
Formation of physical barriers	Formation of physical structures that attenuate the energy of currents and waves Processes: production of physical structures by marine organisms
Formation of pleasant landscapes and seascapes	Formation of seascapes or landscapes that are attractive for people Processes: not relevant

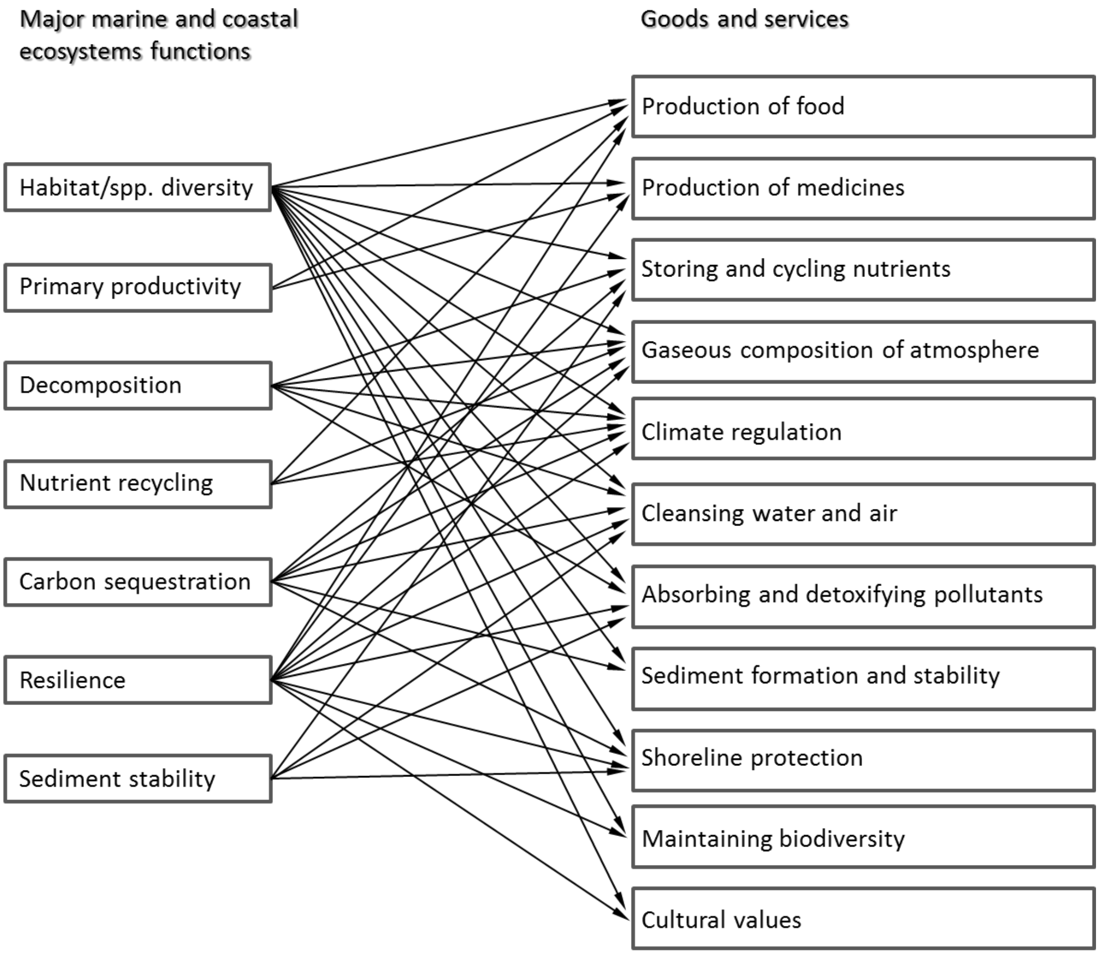

Figure 7. Ecological functions and ecosystem services (Townsend et al. 2011)

Another way for disentangling the complexity of the relationships between ecosystems, their features and the services they may deliver is to use a framework which clearly separates fundamental biophysical processes, ecological functions, final services and benefits (see Table 4). The link between ecosystem functions and ecological processes is not very explicit and varies among studies. While some sources used both terms indifferently (e.g. MEA), other sources (e.g. TEEB, Fletcher et al., 2011) defined ecological processes or core ecosystem processes as the basic physical, chemical or ecological processes which occur within ecosystems (e.g. photosynthesis, fluxes of nutrients, competition), and ecosystem functions or beneficial ecosystem processes as specific ecosystem processes that underpin the capacity of an ecosystem to provide goods and services. According to this classification, biophysical processes include parameters and regimes which define the fundamental features of the ecosystems, ecological functions are the "intermediate services" which result from the interactions between biota and their physical environment or among different biota, and the final services are these ecosystem services that different user groups will be able to capture as benefits for themselves. In this classification, the conventional "ecosystem services" category is thus equivalent to the "final services", which are "demand-oriented" in that sense that there exist due to the demand of at least one clearly identified user group. On the other hand, "intermediate services" are these ecological functions which may be observed but which are not necessarily transformed into a benefit for a given portion of society.

Table 4. List of Biophysical processes, Ecological functions, Ecosystem services and Benefits.

Biophysical features and processes	**Ecological functions (intermediate services)**	**Ecosystem services (final services)**	**Benefits (for the society or some user groups)**
-Hydrology -Nutrients -Oxygen -Temperature -pH & salinity -Depth -Exposure -Density -Turbidity -Light -Wind, wave & tides	-Primary production -Competition for food & space -Population control -Biologically mediated habitats -Resilience & resistance -Microbial loops -Carbon fixation -Biomodification of sediments -Delivery and settlement of organisms	-Food provision -Raw materials -Bioremediation of waste -Residential/industrial water supply -Disturbance prevention -Transport & navigation[4] -Energy (wave, wind, tidal)	-Fishing harvest and fish consumption -Raw material harvesting and consumption -Damage avoidance for public health -Damage avoidance for private properties -Risk mitigation -Leisure & recreation -Feel good or warm glow -Existence and option use value

Source: Atkins et al. 2011, Beaumont et al. 2007, Boyd and Banzhaf 2007, Fisher et al. 2009.

Main categories of services provided by marine ecosystems

Besides these necessary distinctions between habitats, processes, ecological functions, ecosystem services and benefits, it remains helpful to dispatch ecosystem services according to the conventional classification of the Millennium Ecosystem Assessment (MEA 2003). Table 5 presents the main categories of goods, services and benefits provided by marine and coastal ecosystems, according to the literature review published by Liquete et al. (2013). An extensive list of Marine ES which are found in the literature and the complete table by Liquete et al., including more details on specific components, are presented in Appendix 2.

Table 5. MEA classification of Marine and Coastal Ecosystem Services (Liquete et al. 2013)

	Marine Ecosystem Services	**Specific components**
Provisioning services	Food provision	Fishing activities (either commercial or subsistence fishing) and aquaculture
	Water storage and provision	Water use for desalination plants, industrial cooling processes or coastal aquaculture
	Biotic materials and biofuels	Medicinal, ornamental and other industrial resources (oil and fishmeal); biomass to produce energy

[4] The inclusion of “transport and navigation” as ES services is a controversial issue.

Regulation and maintenance services	Water purification	Treatment of human wastes through dilution, sedimentation, trapping or sequestration, etc
	Air quality regulation	Absorption by vegetal or water bodies of air pollutants like particulate matter, ozone or sulphur dioxide
	Coastal protection	Natural defense of the coastal zone against inundation and erosion from waves, storms or sea level rise
	Climate regulation	Sequestration by the ocean of greenhouse and climate active gases
	Weather regulation	Influence of coastal vegetation and wetlands on air moisture or the formation of clouds
	Ocean nourishment	Natural cycling processes leading to the availability of nutrients in the seawater for the production of organic matter
	Life cycle maintenance	The maintenance of key habitats that act as nurseries, spawning areas or migratory routes
	Biological regulation	Control of fish pathogens, biological control on the spread of vector borne human diseases
Cultural services	Symbolic and aesthetic values	Contribution to local identity, value of charismatic habitats and species such as coral reefs or marine mammals
	Recreation and tourism	Coastal activities (bathing, snorkeling, scuba diving) and offshore activities (sailing, recreational fishing, whale watching)
	Cognitive effects	Inspiration for arts and applications, material for research and education, information and awareness

3.2. A system view of ecosystem services

For the purpose of assessing the ecosystem services delivered by complex marine social-ecological systems, we propose to build a framework which considers the cross-relationships between natural habitats, ecological functions, stakeholders, ecological services and management institutions. Most of empirical works on ES assessment have adopted the cascade approach (Haynes-Young and Potschin 2009) which draws a linear relationship between habitats, functions, services, benefits and values. However, ecological functions and ecosystem services are not so easy to define, while economic values depend heavily on the actual uses of ecosystem services and the current management system. In addition, monetary values apply to services only, while a multicriteria valuation framework, which would account for the particular concerns of stakeholders and institutions, could also provide a disaggregated assessment of the status of habitats, functions and services. Basically, fundamental concepts from system science, such as adaptation and feedback loops, have proved to be helpful for understanding the robustness of ecological functions as well as the ability of social change to maintain ecosystem services (Levin and Lubchenco 2008).

Why stakeholders and institutions matter

Most of the authors who have questioned the contribution of the ecosystem services approach to environmental policies emphasize both the role of human activities and institutions in the status of the ecosystems and the feedback that the perception of the ecosystem through human judgement exerts on institutions and stakeholder behaviours (Braat and de Groot 2012, Carpenter et al 2009, Daily et al 2009, Turner and Daily 2008). If natural habitats and ecological functions could be seen as some kinds of purely natural components of the ecosystems, the very existence of ecosystem services depend on the way humans express their demand for the benefits of Nature. According to Turner and Daily (p.28), "*stakeholder perceptions, property-rights and institutional arrangements are thus important components of any scheme to capture benefits on a practical and lasting basis*".

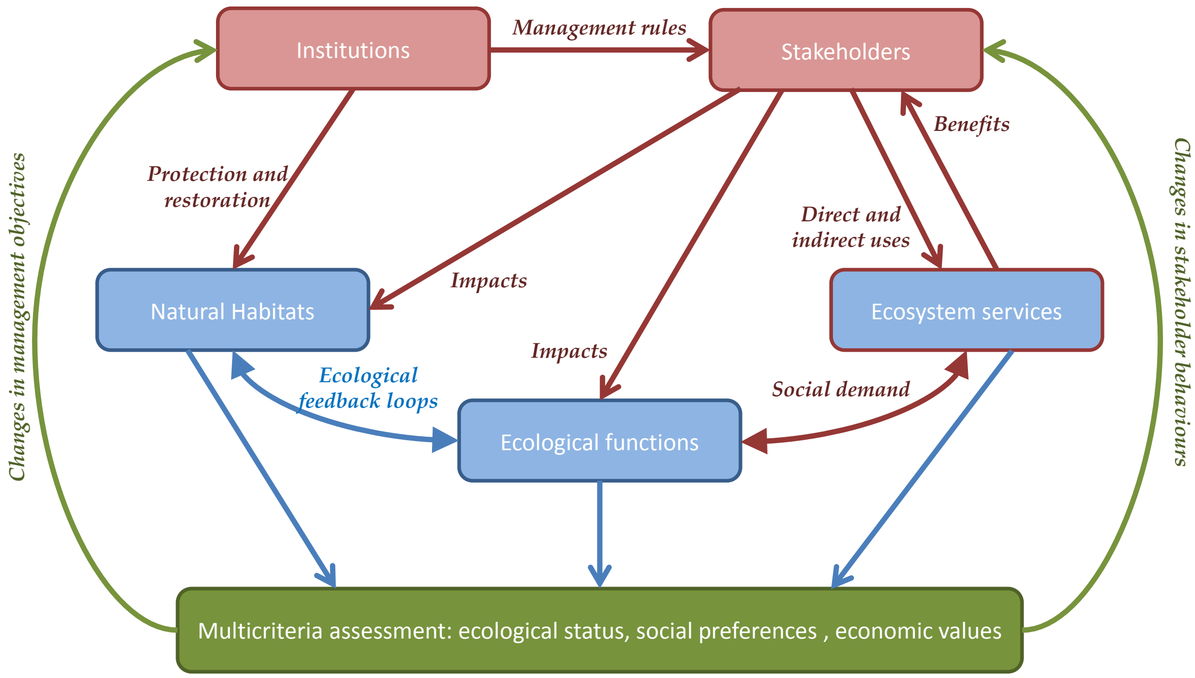

Figure 8. A system view of ecosystem services at the local level. Our own elaboration after Braat and de Groot 2012, Carpenter et al 2009, Daily et al 2009, Turner and Daily 2008.

Building on the works by these authors, Figure 8 presents a very simple framework which places the ecosystem services approach within a system view. Basically, ecosystem services depend on natural habitats and ecological functions, but they exist as long as there is a social demand for the benefits the later may provide. This demand is expressed by stakeholders, which are responsible of direct and indirect uses of ecosystem services, but also of impacts on habitats and ecological functions. In response to these sometimes negative effects of human activities, institutions have been designed for managing uses and mitigating impacts. For many practical reasons, including for the purpose of improving ecosystem governance through realistic management options, it may appear useful to determine who are the beneficiaries of ecosystem services as well as who are responsible for the impacts.

This framework is designed for assessing ecosystem services at the local scale, therefore the contribution of ecosystem services to human well-being is left aside, as it is a broader question which should be addressed at the global scale. On the other hand, a multicriteria assessment framework which includes ecological status descriptors, social preferences indicators and monetary values would contribute to a first appraisal of the contribution of local ecosystem services to human well-being. Furthermore, the criteria associated with these ecological, social and economic indicators are expected to inform the judgements that the society will form regarding the situation, what is likely to affect the current consensus and trends regarding policy objectives and stakeholder behaviours.

Nomenclatures for stakeholders and management bodies

The proposed nomenclature for identifying stakeholders and management bodies is presented in Appendix 3. It is based on the works that have been carried out in the field of Integrated Costal Zone Management. The private economic agents who use or impact ecosystem services may belong to the primary sector (agriculture, fisheries, etc.), the secondary sector (food processing, energy industry, etc.), the tertiary sector (tourist industry) and the non productive private sector (landowners, real estate owners). The public productive sector is represented by managers of settlements which may affect or preserve ecosystem services such as harbours, waste water treatment plants, cultural infrastructure or other public services such as restoration projects. Some stakeholders may have particular claims regarding ecosystem services through their involvement in lobbying or any kind of associative movement. At last, institutions which may contribute to the management of ecosystem services encompass the European, State or Local authorities which intervene in the domain of Sea and Fisheries management, Agriculture, Water, Environment, Energy, Land and Spatial planning, and also expertise providers such as Research institutes.

3.3. Indicators for the assessment of marine ES

Any assessment framework should include a minimum set of indicators to represent the multiple facets of ecosystem services and the related complexity of biophysical processes and social issues (Carpenter et al 2006). Ecosystem service indicators are statistics or other forms of information including maps, which communicate the characteristics of ecosystem services in a form that is easily understood and applied by diverse audiences; ecosystem service indicators relay information about the overall magnitude and trends in ecosystem services (UNEP 2009). Because of the difficultly in measuring the flow of benefits from some regulating and cultural services, it may be necessary to rely on proxy indicators for some ecosystem services, in particular for some regulating and cultural services. In principle, indicators of ecosystem services ideally convey information about the *flow* of service, which corresponds to the benefits people receive (UNEP 2009). However, it may be necessary to consider *stock* or *status* indicators for the purpose of an integrated assessment framework which would consider not only ecosystem services, but although ecological functions.

At the present time, there is now scientific consensus yet regarding such a minimal set of indicators for assessing marine ecosystem services. In the context of the VALMER project, it is suggested that indicators should be selected, within the lists provided hereafter (Table 6), by the study site team together with the end-users (managers, stakeholders), who may prefer particular indicators or metrics, depending on the scope of the assessment and their judgement criteria. Whatever the aim of the ES assessment, it remains necessary to distinguish *supply* and *demand* indicators. Supply indicators characterize the ability of the ecosystem to deliver a particular flow service: in that case the service may be actual (the default) or potential. Demand indicators characterize the requirement or concern of human population, subject to economic and social circumstances: in that case, the service may be direct (the default) or indirect. According to the above definitions, monetary values of ES are always demand indicators, subject to a particular social and economic context. Appendix 4 provides the list of indicators that was used in the PNMI case study site for kelp forest ES.

Table 6. Supply and Demand indicators for Marine ES assessment.

Marine and coastal ES	Specific components	Supply indicator	Demand indicator
Food provision	Fisheries and aquaculture	Fish landings and production (volume)	Fish consumption Employment and revenue in fishing industry *(indirect)*
Water storage and provision	Industrial use of seawater	Sea water use settlements	Marine water consumption
Biotic materials and biofuels	Medicinal sector	Production of material used for medicines	Consumption of medicines using marine material
	Ornamental resources	Production of ornamental living material from the sea	Consumption of ornamental living material from the sea
	Energy resources	Production of marine biomass for fuel	Consumption of marine biomass for fuel
Water purification	Treatment of human waste		Water quality standard
Air quality regulation	Absorption of pollutant		Air quality standards (for all pollutants except CO2)
Coastal protection	Natural defense	Mangrove or coral reefs extension	
Climate regulation	Carbon sequestration	Carbon stock exchange Carbon sequestration capacity *(potential)*	Value of carbon sequestration capacity
Weather regulation	*No example found*	*No example found*	*No example found*
Ocean nourishment	Nutrient and organic matters	Primary productivity Algal biomass	Value of organic matter production
Life cycle maintenance	Maintenance of habitats	Biodiversity indicators (habitats extension or status, diversity of species)	
Biological regulation	*No example found*	*No example found*	*No example found*
Symbolic and aesthetic values	Heritage	No of UNESCO heritage sites *(potential)* No of sites or species used for cultural events *(potential)*	No of persons placing high values on Sea *(potential)*
Symbolic and aesthetic values	Aesthetic value		Frequentation for Nature based motivation
Recreation and tourism	Recreational activities (non market activities)		No of tourists
	Recreational fishing		No of recreational fishers Value of recreational fisheries
	Tourism industry (market activities)	Protected or preserved area for ecotourism *(potential)*	No of tourists Expenses of tourists Employment and revenue in tourism industry *(indirect)*
Cognitive effects		No of actions for education or research *(potential)*	

Source: Our own elaboration after UNEP 2009 and Liquete et al. 2013.

4. The VALMER operational framework for Marine Ecosystem Service Assessment (MESA)

The VALMER operational framework for marine ecosystem service assessment which is proposed in this section results from the consultation of the most relevant available knowledge on the current pitfalls of ES assessment, in particular as regards marine applications. In particular, a panel of scientists and practitioners, who participated to the VALMER WP1 international workshop in Brest from 6 to 8 November 2012, helped us to understand why it was necessary to provide a complete framework, in addition to assessment methods and tools, for operational purposes.

Prior to undertaking an ecosystem service assessment it is critically important to consider why this assessment is being undertaken, who and what it is being undertaken for, and how best to go about the assessment in the given circumstances. This initial preparatory step is frequently over looked with the result being an inefficient use of resources and poorly used MES assessments (Laurans et al. 2013). In addition to this, careful considerations should be given to the available means, knowledge and expertise that will be available for carrying out the assessment, considering that depending on its aim, the MESA may mobilize not only quantitative ecological and economic methods, but also skills in working with stakeholders and delivering communicable outputs. At last, for the purpose of defining the aim, scope and expected output of the marine ecosystem service assessment, it will be necessary, due to practical reasons, to focus on what is meaningful and feasible.

The VALMER operational framework for marine ecosystem service assessment is based on two sets of recommendations. The first set of recommendations is a general reminder of the numerous reasons why any meaningful ES assessment should explicitly present itself as a social process, which remains by nature subjective, context-dependent, incomplete, and should be carried out in an iterative way. During these iterations, the scientific team in charge of the MESA should re-adapt permanently for mobilizing accurate expertise and engaging efficiently with the stakeholders who are expected to use the outputs. These recommendations are detailed in section 4.1

The second set of recommendations contains the logical steps to be followed for implementing operational MESA in practice. This second set consists in following a “Triage Process” which is intended to help defining the aim, scope, methods and tool of the MESA so that it will be both meaningful (interpretable), useful (in relation to management concern, needs and projects) and feasible (according to the available knowledge and means). This Triage Process is detailed in Section 4.2.

Finally, in Section 4.3 case study applications of the Triage process are detailed. Further information on the Triage can also be found at (Pendleton et al 2015).The case study information is mostly dedicated to stage 2 of the Triage which the rest of the case study reports being available in the Valmer WP4 Report “Advice note for using ecosystem service assessment to support marine governance”.

4.1. General recommendations: mobilising accurate expertise for engaging efficiently with stakeholders

4.1.1. Assessment process and stakeholder engagement

Work in partnership

It is important to engage as early as possible with the decision makers who will use the valuation information. Decision makers are defined as those with responsibility for initiating actions and so, depending on the context, may be, for example, national officials developing policy, or local organisations implementing awareness campaigns. Stakeholders are defined as those with an interest in the issue: decision makers will be a subset of the stakeholder group.

All the responsibility for applying valuation data does not lie with the decision maker; deciding whether valuation is what is needed to answer the management question (and how results can and should be used) should be a joint process between the decision maker and those undertaking the valuation, and should include a written agreement to detail the requirements and expectations of both parties. A personal relationship should be built with the decision makers through frequent communication.

Use social science methods

Stakeholder engagement can take a number of forms, including providing information to them, requesting that they share data and knowledge, or through their active participation throughout the project. Social science has developed methodologies and tools for engaging with stakeholders, and the best practice should be applied. When ES valuation is carried out for a research project, it should be clear when the research project is expected to feed existing stakeholder forums and when stakeholder groups must be convened in the context of the research project.

Communicate appropriately

Communicating the concepts of ecosystem services and valuation will require different techniques and tools depending on the target audience.

4.1.2. Assessment content

Decide upon the management issue to be addressed

The requirements of the stakeholders are central to the process, but it is also important to consider what is actually needed to inform management decisions, and also what, practically, can be undertaken in terms of valuation. The approach and methods for ES assessment may differ depending on the stage of the management process at which valuation is needed.

Define the scope of ecosystem service valuation

There are many contexts in which ecosystem service valuation is worthwhile, including in illuminating people's dependency on the environment in order to build collective understanding, which may, in the long term, affect perceptions of public policy. However, the objective of assessment may concern more immediate, management-driven change. In practice, the definition of the scope of the ES valuation in relation to its aim and the target audience may be carried out following a "Triage process" (see practical recommendations).

Develop realistic and coherent scenarios of ecosystem service change

The management scenarios considered as part of the valuation process should address multiple policies in a coherent manner. The type of scenario (whether comparing alternative management actions or building visions of alternative futures) will depend on the context and stakeholder perspective. When assessing change in ecosystem services due to management actions, the cross-effects of various thematic policies should be considered (for instance the cross-effects of the Water Framework Directive and the Marine Strategy Framework Directive for coastal ecosystems). The current state of the regulation which affects ecosystem services should be explicitly taken into account in order to estimate the effects of a marginal change in environmental or sectoral policies.

Explore and quantify ecosystem service metrics that are meaningful

Value can be expressed in a number of metrics (e.g. monetary, output, use and cultural measures), and a monetary value may not always be meaningful to the stakeholder. Also, a monetary value may not have the greatest impact: if passive use is the only value available, the issue may be better addressed by natural science or conservation arguments rather than valuation. It is difficult to predict *a priori* how different individuals or stakeholder groups will react to different metrics, as it will depend on their motivation. VALMER should discuss possible metrics, and where appropriate consider testing metrics using focus groups or other social science methods. To date, that has not been any systematic assessment of which metrics are preferred by particular people or in particular situations so this must be assessed on a case by case basis. Similarly, preferences for aggregate values or for narrative descriptions will also vary from stakeholder to stakeholder.

Tailor valuation outputs to the audience

The need to communicate appropriately with stakeholders continues throughout the process. The output required by stakeholders and decision makers will vary between individuals and situations. There is no single magic bullet that will work for everyone. There is a place for both headline figures (to make a point in a short time) and narratives that provide broader qualitative assessments. As a general rule, outputs should be clear, concise, and short. However, whatever the format of the output, it is essential that strong supporting evidence is also available: decision makers will have to defend actions enacted on the basis of the valuation. Uncertainty within the valuation must also be communicated effectively, and guidelines for doing so already exist: for example, the categories and definitions used by the Intergovernmental Panel on Climate Change.

Publish on the whole approach

Few examples exist within the peer-reviewed literature that detail how valuation has actually been used in practice. In general, studies refer to how valuation results could or might be used. It is therefore important to publish details of how the work has been applied.

4.1.3. Science needs for valuation

Consider different scales

The scale of the valuation should consider the extent of the socio-economic system impacted, the scales of the ecological functions that support the service being considered, and the sensitivity of the valuation method used and how these relate to the scale of the proposed management action.

Avoid unnecessary complexity

Initially, simpler scenarios of ecosystem change, and more straightforward models, will help researchers and stakeholders develop familiarity and expertise in ecosystem service valuation. Keeping complexity to a minimum will also help to mitigate uncertainty, and generate more robust outputs. Initial valuation efforts should focus on direct relationships between management action and changes in ecosystems, ecosystem services and values. As VALMER valuations better quantify ecosystem service values (and changes in values), it will become clear where a better understanding of complexity may be needed.

Create new primary data

Empirical studies are essential for the continued improvement of the ecosystem service valuation discipline as a whole. Where socio-economic data is unavailable for a case study site, the aim should be to create new data rather than applying benefits transfer. Data that already exists from similar sites and situations may have some value nonetheless, in providing an indication of likely empirical results and directing specific data collection needs.

Address natural science issues

Natural scientists do not fully understand the complex linkages between ecological processes and the ecosystem services they generate, or the impact that management actions will have on processes and services. These data gaps restrict what can be attempted in terms of ecosystem service assessment, valuation and management. Biophysical modelling is therefore an important area of work on which to focus. Data gaps also arise due to the traditional separation of the relevant disciplines: natural scientist concentrate on functions and processes, while economists and other social scientists focus on people, with minimal overlap. This needs to be addressed if ecosystem service valuation is to become truly interdisciplinary.

Make knowledge gaps and uncertainty explicit

In order to avoid too much additional research in ecology or economics, the focus should not be on accuracy of data in each field but on developing data that are appropriate for integrated assessment: coupled biophysical and human models have the potential to be useful tools in this process. Another way to overcome the lack of knowledge is to follow an iterative process between the global understanding of ES and the focus on key ecological processes or social issues. Face-to-face discussions involving natural and social scientists during which the specific ES are discussed from both the ecological and economic perspectives are useful in improving mutual understanding, exploring linkages and identifying data gaps. Where significant uncertainty remains, assumptions made and confidence assessments should be included as an integral part of the ES valuation outputs.

Be aware of context dependency

Economists understand that benefit transfer methods must be undertaken with caution, but may have less appreciation of the context dependency of ecological patterns and processes. However, the same procedures for data transposition apply. Where natural science data is not available for a case study site, any attempt to use natural science data from another area should only be undertaken after careful consideration of the biogeochemical parameters of both the case study site and the area from which the data was obtained.

4.2. The Triage process: agreeing the purpose, scope, methods and tools for the Marine Ecosystem Services Assessment

The assessment and valuation of MES can promote understanding of the services provided by the marine environment, and determine values for the benefits arising from them, in the context of changing levels of pressure and alternative management scenarios. These possibilities make the approach attractive to stakeholders and decision makers. However, there are alternative approaches that can be used in making natural resource management decisions. It is important to decide at an early stage whether an MES assessment is the most appropriate approach in specific situation, and also to determine where effort should be focused to make the best use of limited resources. Thus, once the stakeholders are engaged, it is valuable to understand the overarching purposes of the assessment and then to consider in more detail how the assessment should be undertaken.

The principle of the Triage process is to provide a procedure for delimiting the scope of a potential MES quantitative assessment using a step-wise process to refine the initial broad-scale analysis and to consider, as objectively as possible, the relevance of MES assessment and valuation in a particular situation. The Triage aims to identify the policy issues for which an MES assessment is expected to provide new insights, the parts of the system to be considered in relation to these policy issues, the sensitivity of the considered marine ES to natural or social factors of changes, the appropriate methods for valuation and finally the feasibility of an MES assessment in practice. Basically, the Triage process consists in three sequences: *i)* a preliminary delimitation of the scope of the ES assessment in relation to its general aims; *ii)* a refinement of the scope of the ES assessment in support of scenarios building and policy design; *iii)* the choice of methods, tools and means for ES assessment in response to management needs (Figure 9). In practice, the Triage process requires sequential consideration of a series of 9 questions, which are described in more detail below.

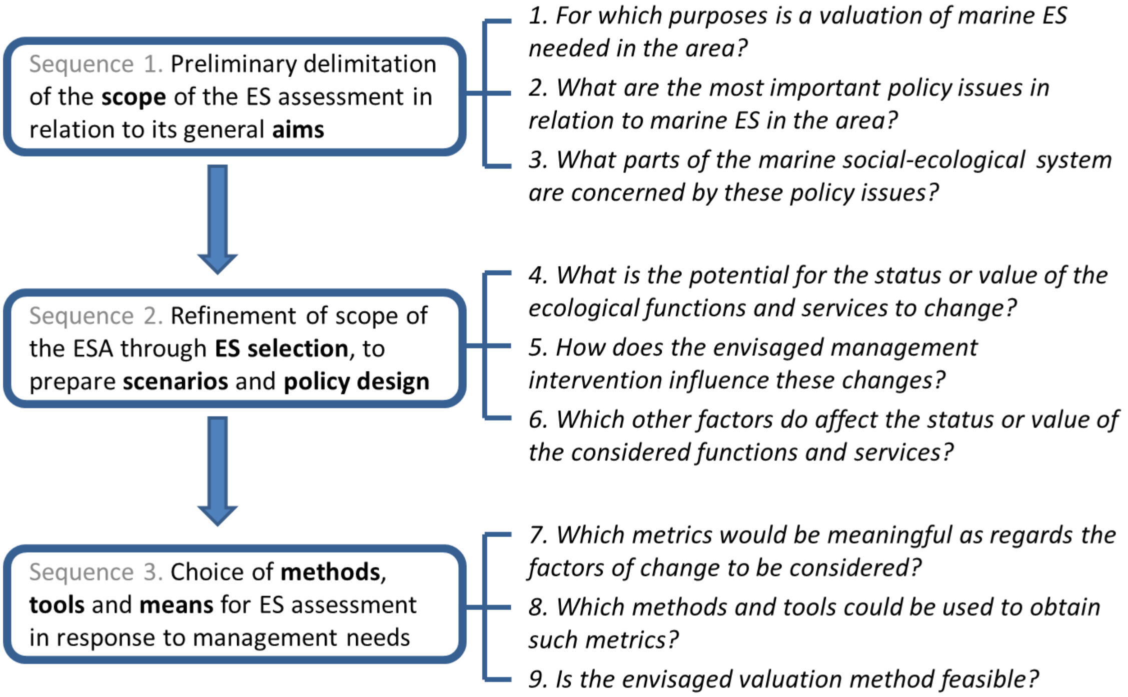

Figure 9. A schematic representation of the Triage process

4.2.1. Triage Sequence 1. Preliminary delimitation of the scope of the ES assessment in relation to its general aims

1. For which purposes is a valuation of MES needed in the area?

This first question relates to the operational needs of the stakeholders who envisage using a marine ES assessment. Following the classification by Laurans et al. (2013), three categories of MESA expected uses could be considered: 1) informative uses, 2) decisive uses and 3) technical uses. Examples of informative uses include: to improve and integrate knowledge, to provide initial diagnosis for marine management, to raise awareness of particularly issues or of the value of the marine environment more generally. Examples of decisive uses include: to explore possible changes in the ecosystems or human pressures, to compare operational management options, to facilitate trade-offs, and to search ways for increasing welfare of concerned populations. Examples of technical use include: to design a new marine and coastal policy and to design management options.

2. What are the most important policy issues in relation to marine ES in the area?

The policy issue may be linked to the impacts of particular activities, the claims of certain stakeholders or the possible change in collective rules. It is necessary to be precise when defining the policy issue, and to establish a hierarchy when several policy issues are of interest. Where several options exist, a process for prioritising the policy issues can be implemented. For instance it is possible to ask stakeholders to give a score (high, moderate, low) to the different issues and then deliberate for gathering a selection of the more relevant issues.

3. What parts of the marine social-ecological system are concerned by these policy issues?

This stage of the Triage process requires specification and selection of the ecosystem components, functions and services that relate to the defined policy issues, as well as the identification of the stakeholders and institutions whose actions are concerned by these policy issues.

4.2.2. Triage Sequence 2. Refinement of scope of the ES assessment in support of scenarios building and policy design

1. What is the potential for the status or value of ecological functions and services to change?

The purpose of this question is to estimate whether the considered ecological functions or ecosystem services are likely to experiment significant changes in the future. Such changes may be the result of on-going natural processes or the evolution of human pressures on the ecosystems, due to new practices, new technologies or new activities. In a first step, the estimate of potential for change can be based on expert knowledge and consensus.

2. How does the envisaged management intervention influence these changes?

If the specific management action is unlikely to have a significant influence on the value then there is little purpose in a valuation assessment. Factors such as the likelihood of the policy coming into effect, and where responsibility for making the decision lies should also be considered. It is also important to take account of the resistance and resilience of the system providing the service. If the change in value will be very small (for example carbon sequestration on a local scale) or the benefit is very robust (e.g. aggregate extraction) then there is very limited justification for continuing with the valuation.

3. Which other factors do affect the status or value of the considered functions and services?

The next stage of the Triage is to assess the influence of wider social, economic, environmental and political issues, particularly those beyond the control of local management structures (such as climate change or national policies). Where these wider issues have a more significant impact on the value than the proposed local change, any expected change in value from local management action is unlikely to be realised.

In order to sort the ecosystem services which should be assessed in the context of scenario or policy design, it is recommended to address the later three questions simultaneously. Each service could be given a score (high, moderate, low) in response to each questions based on relevant criteria (Table 7). The total scores for each service, and how it scores for each question, can then feed into the decision-making process. For example, where the Ecosystem Services on which a proposed study will focus have already been defined, the Triage scoring can be used to justify (or to reject) the use of an MES assessment approach. Alternatively, where a number of possibilities for empirical research exist, the relative scores can be used to identify the where limited resources would be best applied.

Table 7. Criteria for scoring each question of the Sequence 2 in the Triage process

	Potential for the Ecosystem Service value to change	Influence of management on Ecosystem Service change	Other factors affecting the Ecosystem Service
High	Service is sensitive to impacts and value change will be large	Management will have a large influence on value, a strong probability of coming into effect and is locally driven	Local environmental factors have the strongest influence on value
Moderate	Service is sensitive to impacts and value change will be small *OR* Service is robust and value change will be large	Management will have a large influence on value and at least a reasonable probability of coming into effect, but is not locally driven *OR* Management will have a moderate influence on value, at least a reasonable probability of coming into effect and is locally driven	Other factors (social, economic, political, global environmental change) have a similar influence on value to that of local environmental factors
Low	Service is robust and value change will be small	Management will have a small influence on value and/or a low probability of coming into effect	Other factors have the strongest influence on value

4.2.3. Triage Sequence 3. Choice of methods, tools and means for ES assessment in response to management needs

1. Which metrics would be meaningful as regards the factors of change to be considered?

Depending on the factors of change, different types of metrics could be meaningful: changes related to ecological status should require biophysical metrics, changes affecting human activities may be expressed in terms of monetary values or jobs, and changes related to trade-offs may require to assess social perception. In most cases, a mix of indicators from different categories could turn out to be what stakeholders are looking for. The key determinant for meaningfulness is to clearly express what each indicator is referring to as regards the various possible characteristics of one ecosystem services (effective or potential, supply, demand, perception by a given social group).

2. Which methods and tools could be used to obtain such metrics?

Once the metrics and indicators for estimating the changes in ecosystem services have been chosen, valuation methods should be selected accordingly. The method is also linked to the aim of the assessment and the stage of the management process it is intended to support. Broad objectives associated with early management stages like initial diagnosis and policy design may require large-scope assessment methods while more operational objectives like management option comparison could require more focused methods. Valuation methodologies using ecological, economic and social indicators are numerous (see Appendix 2), and can provide single indicators, multicriteria assessment or integrated assessment. They are more or less powerful depending of the number of ecosystem services to be included in the assessment.

3. Is the envisaged valuation method feasible?

Finally, the manpower and cost requirements for evaluating different services can vary considerably depending on the methods proposed, and must be explicitly considered. Where resources for primary data collection are limited, the availability of supporting data (both ecological and socio-economic) will also have a strong influence on the scope of an MES assessment.

4.2.4. Comments on the Triage process implementation

The Triage process can be implemented in a context where the first set of general recommendations on accurate expertise mobilisation and stakeholder engagement are carefully taken into account. From this perspective, the general recommendations together with the Triage process form a flexible and operational framework to guide scientists and practitioners in undertaking comprehensive, transparent and appropriate MES assessments. This framework should not be seen as set of rigid and prescriptive rules that are applicable in their entirety to all circumstances. MES assessments are context dependent, as the needs of managers and stakeholders, the services about which they are concerned, and the resources available for the assessment are highly variable. This necessitates a flexible guidance framework which allows for adapting to particular situations and also to evolving needs and circumstances. It may happen that a first implementation of the framework could lead managers to better understand the real meanings of the ES approach and to change their view on how they can use this approach for operational purposes.

The three sequences of the Triage process and its 9 questions are thus not necessarily to be implemented in a systematic way. For instance, when sequence 1 reveals that the assessment pursues a broad objective, *e.g.* to improve knowledge of ecosystem services or to provide an initial diagnosis on particular policy issues, sequence 2 could be omitted, but sequence 3 on methods and means remains useful. On the other hand, when stakeholders have already a clear view of the aim and scope of the assessment because they intend to compare management options which are on their agendas (end of sequence 1), they should however consider carefully sequence 2 on the factors of change before entering into the section of assessment methods through sequence 3.

The term 'value' is used all along the Triage process because valuation (monetary or otherwise) is often the ultimate purpose of a MES assessment. However, the Triage remains appropriate where the MES assessment intends only to quantify the level of service provision. In such cases 'service delivery' should be substituted for 'value'. Also, the list above describes the core of the Triage, but it should not be considered exhaustive. There is room in this flexible framework for considering other factors, knowledge and expertise, such has how the MES assessment would complement other work begin undertaken locally, or the relevance of the findings beyond the study site.

4.3. Implementing the Triage process in practice: UK and French examples

To test the validity of the Triage process it was applied in case study areas in the UK and France, and played a key role in determining the bounds of, and approach to, the ESA in these areas. The approach to application was, as detailed above, quite flexible and varied somewhat between the two case study areas. This is perceived to be a strength of the approach and demonstrates the adaptability and value of the Triage process. The case studies focus on sequence 1 and 2 of the Triage, with full details of the case study reports and results available in the Valmer WP3 and WP4 reports.

4.3.1. Extensive case study: The North Devon Biosphere Reserve

Background

The first trial of the Triage process was undertaken at VALMER's North Devon Biosphere Reserve (NDBR) case study site. An initial consultation identified the priorities of interested members of the public and stakeholder groups. These discussions produced a shortlist of potential foci for an MES assessment:

- support for managed retreat within the estuary and the associated creation of saltmarsh habitats;
- poor water quality, particularly the loss of blue flag status on beaches;
- concerns over jetskiiers outside their designated area and kitesurfers impacting on nesting and roosting birds;
- the impact of the Atlantic Array offshore wind farm on the seascape (particularly views of Lundy) and conflicts with the Area of Outstanding Natural Beauty status;
- fisheries production, in particular the role of benthic habitats in supporting commercial fisheries (e.g. skate), and changes in scallop dredging intensity;

The Triage process was then applied in two ways: a deliberative process involving experts (the NDBR Coordinator and environmental economists), and a survey to determine the individual opinion of local stakeholders.

Expert opinion

The scores resulting from the expert deliberation (Table 8; further details of the justification for each score provided are given in Appendix 5) suggested that recreation would not be an appropriate focus for the study, because the change in value is likely to be small, external factors may have a larger influence than the local concerns and there is limited capacity for collecting stated preference data. Water quality is an important marine issue (as a result of the effects on ecology and recreation), and valuing waste remediation presents an interesting potential topic for VALMER as it requires addressing the need to integrate natural science information into the economic assessment. However, the change in value of the marine ecosystem service is likely to be small and is unlikely to be affected by policy, as this will target the land-based sources of pollution rather than expanding the waste carrying capacity of the marine ecosystem.

Estuarine habitats scored moderately well, but the change in the value of the service in not expected to be large, and so a focus here may not be the most cost-effective use of the project effort. Conversely, the loss of visual amenity caused by the Atlantic Array is likely to result in a large change in value, as this benefit is very important to people. This issue also scored highly in terms of the influence of external factors, and only manmade developments such as the offshore wind farm are likely to have a significant influence on that value. However, the score given in the policy category was only moderate. This was because there is a lack of local control over the policy decision: there is no certainty that a valuation assessment submitted as part of the consultation process will have any influence on the decision. Also, reduced visual amenity (whether quantified through valuation or otherwise highlighted) is just one of many factors that will be considered during the consenting process. The limited capacity for collecting stated preference data is also reduces the feasibility of undertaking a comprehensive assessment.

Table 8. Scores in each category for the shortlisted management concerns based on expert opinion

High Medium Low

	Likely use of value in policy decisions	Potential for value to change	Influence of external factors	Feasibility
Saltmarsh creation	High	Medium	Medium	High
Water quality	Low	Low	Medium	High
Fish habitat	High	High	Medium	High
Disturbance	Medium	Low	Low	Medium
Atlantic Array	Medium	High	High	Medium

The combination of service vulnerability and local importance produced a high score for valuing the contribution made by benthic habitats to fisheries production. This service also scored highly for the influence of policy because management measures can directly affect service provision and can be locally led. The valuation of benthic habitats was given a moderate score for the influence of external factors on the value of the service, as the ability of the habitats to sustain the service can be affected by changes in the physical parameters of the water column (such as temperature) or changes in the species present. A study of the subtidal habitats would also be feasible, and particularly as strong natural science expertise was available within the project. Benthic habitats were therefore recommended as the most appropriate focus for the valuation study.

Stakeholder survey

The views of NDBR stakeholders were also sought, through an online survey. Responses were received from 42% of those invited to take part, and represented a good cross-section of stakeholders. Most respondents engaged with the marine environment of the NDBR along the coast (Figure 10a), but they had a range of interests including fisheries, conservation and recreation (Figure 10b) and respondents represented local government, other public bodies and local stakeholder groups in decision-making about the NDBR (Figure 10c).

Respondents were asked to answer five questions for each of the shortlisted concerns, which were in three categories:

Likely use of value in policy decisions

- What is the likelihood of the proposed policy coming into effect?
- How much responsibility for the policy decision lies with local organisations and institutions?

Potential for value to change

- How much will the proposed policy affect the delivery of the benefit?
- How big do you think any change in the value of the benefit will be as a result of the proposed policy?

Influence of external factors

- How much influence do external factors beyond the control of the policy have in determining the value of the service?

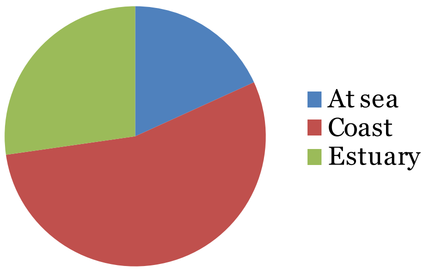

Figure 10a. The proportion of respondents who most engage with the NDBR's marine environment at each location

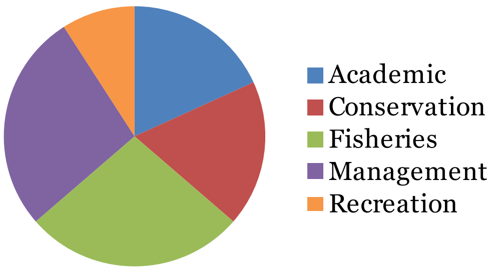

Figure 10b. The proportion of respondents with a particular interest in the NDBR's marine environment

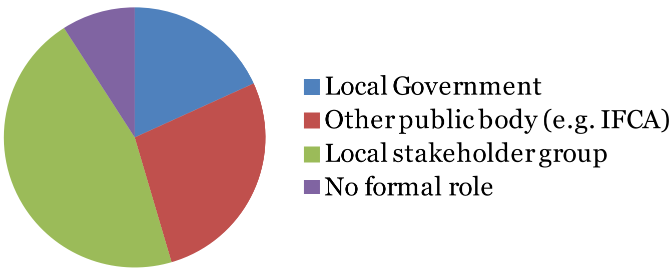

Figure 10c. The proportion of respondents with a particular role in decision-making related to the NDBR's marine environment

Respondents were not asked to judge the feasibility of an MES assessment for each of the management issues, as they did not have a sufficiently detailed understanding of the project. Answers were given on a three-point scale, and these were averaged to provide a score (high, medium or low) in each of the three categories for each management issue. Two different measures of the average were used, the mean (Table 9) and the median (Table 10). In both cases, the highest scores were given to the role of subtidal benthic habitats in supporting fisheries, again suggesting that this would be the most appropriate focus for an MES assessment in the NDBR.

Table 9. The mean score for each management concern

High Medium Low

	Likely use of value in policy decisions	Potential for value to change	Influence of external factors
Saltmarsh creation	High	Medium	Medium
Water quality	Medium	Medium	Low
Fish habitat	High	High	Medium
Disturbance	High	Medium	Low
Atlantic Array	Medium	High	Medium

Table 10. The median score for each management concern

High Medium Low

	Likely use of value in policy decisions	Potential for value to change	Influence of external factors
Saltmarsh creation	High	Medium	Low
Water quality	Medium	Medium	Medium
Fish habitat	High	High	Medium
Disturbance	High	Low	Medium
Atlantic Array	Medium	High	Low

Discussion

The Triage process continues to evolve, but the pilot exercise in North Devon has demonstrated that it is a useful tool for characterising the criteria that should be considered in decision-making, and hence ranking a shortlist of options. It should be remembered, however, that the Triage is a scoping process and is not intended as a mechanism that will generate a statistically robust 'right' answer.

As part of the evolution of the technique, the assessment criteria used varied slightly between the expert and stakeholder groups: the experts considered value changes more generically, while the stakeholders were asked questions related specifically to particularly policy interventions. This may account for some of the observed differences in the scores provided. Also, there were differences in expertise between the groups: the environmental economists have a more thorough understanding of MES valuation and its potential for change, while the stakeholders possess stronger local knowledge on service provision and policy.

These differences in expertise and understanding support the recommendation that a deliberative context is used in implementing the Triage, involving a discussion between MES experts and local stakeholders in order to appropriately integrate all the necessary information. It is possible to implement the Triage through a survey, but this is less satisfactory, because it provides no opportunity to discuss the issues, and the outcome may vary depending on how the data is processed, decreasing the transparency and objectivity of the approach.

The case study also showed that two services may have the same overall Triage score but different scores in the individual categories. Where these ties occur, a process for weighting the Triage categories is required, which may be context specific. To use an example from the expert deliberation in the case study, if the feasibility category is left aside, then the role of benthic habitats in supporting commercial fisheries and the impact on the seascape of the Atlantic Array offshore wind farm scored equally (two 'high' and one 'medium' score). It is suggested that, in this context, the policy implications (for which the Atlantic Array received a reduced score) are more important than the external factors likely to affect the value (the lower score for the benthic habitats). This is because those factors affecting the fisheries production assessment (climate change, invasive species, fisheries subsidies) are mostly long-term, gradual changes, so their effect on management interventions proposed for the near future is likely to be small. The uncertainty around the use of a value for visual amenity in the policy-making process is of more immediate concern, especially because the research may not be completed within the timescale of the consultation process: the stated preference surveys that would be used take considerable time to prepare as there are several stages in development of the questionnaire, which all require public engagement.

4.3.2. Implementation of the Triage process in the French study sites

A first round dedicated to a preliminary implementation of the Triage process on the three French sites was carried out during a two days session in June 2013, with a core group of managers and experts in ecology and economics for each case study. The session was organized as follows:

- At first, the Triage process was briefly presented
- Participants chose the questions of the Triage it would be possible to address at this stage
- The answers to the questions were adopted following a deliberative process

Following the presentation of the Triage process, and according to time constraints, it was decided to focus on the Sequence 1, question 1 (purposes of the marine ES valuation in the area) and question 2 (most important policy issues in relation to marine ES in the area) and to Sequence 2, question 1 (what are the potential for the status or value of the ecological functions and services to change).

Purposes of the valuation of the Marine ES in the French study sites

The three French study sites have reached different stages of their management process. The Normand-Breton Gulf study site (GNB, *"Golfe Normand-Breton"*) is at an early stage of the management process as consultations of the stakeholders are still on going in the prospect of creating a Marine Park in the area. The Iroise Sea study site is at a very advanced stage as the Natural Marine Park of the Iroise Sea (PNMI, *"Parc Naturel de la Mer d'Iroise"*) was created in 2007 and its management plan was adopted in 2010; it includes access rules for kelp harvesting and fishing which should evolved toward a higher protection level. The Gulf of Morbihan study site (GM, *"Golfe du Morbihan"*) is at an intermediary stage as regards marine management: the management body (SIAGM, *"Syndicat Intercommunal d'Aménagement du Golfe du Morbihan"*) is in charge of a Natural Park which encompasses 38 municipalities and aims to be extended at sea where a Natura 2000 area for seagrass beds has already been defined. The variety of stages of development of the marine ecosystem management processes lead to different purposes for ES valuation (Table 11).

Table 11. Identification and ranking of the Marine ES Assessment purposes in the French study sites

Purposes of Marine ES Assessment	GNB	PNMI	GM
Improve knowledge		2	2
Integrate knowledge	2		2
Initial diagnosis	1		
Raising awareness	2		1
Anticipating future changes	1		
Facilitate trade-offs	2	3	3
Designing management options	2		3
Compare management options		1	
Increasing well-being			

1 = main purpose ; 2 = secondary purpose ; 3 = complementary purpose

Each study site tried to sort the main purpose (scored 1), secondary purposes (scored 2) and complementary purposes (scored 3). In the PNMI study site, the assessment of ES provided by kelp habitats will at first be used for comparing management options; however this comparison of management options will necessitate improved knowledge on the variety of services delivered by kelps, while knowledge improvement of ES is expected to facilitate trade-offs when the most protective management measures would to be envisaged. The GNB study site being in a preliminary phase as regards marine ecosystems management, the assessment of ES should contribute to two equally important purposes: the initial diagnosis of the area, which should be based on further knowledge integration and is expected to contribute to awareness raising in support of a Marine Natural Park creation, and the anticipation of future changes is expected to contribute to the definition of the main objectives of this future Park, while facilitating trade-offs as regards these local marine policy. In the Gulfe of Morbihan, the ES assessment will be used for raising awareness regarding the role of seagrass beds in the local social-ecological system, based on improved and more integrated knowledge regarding ES delivered by seagrass in the prospect of designing future management options which will necessitate new trade-offs among stakeholders.

Most important policy issues in relation to marine ES in the French study sites

Once the aim of the marine ES was identified and structured into a set of main, secondary and complementary purposes, study site teams were asked to formulate the policy issues which are related to the considered ES in their area. Not surprisingly, the policy issues in the PNMI and the GM study sites focused on the ecological and social concerns related to kelp habitats and seagrass beds respectively, while the GNB study site identified a wide range of policy issues, from the protection of marine biodiversity to the development of new activities and the consequences of population growth on ecosystem services (table 12).

Table 12. Examples of policy issues identification in the French study sites, during the first round of the triage implementation

GNB Policy Issues	PNMI Policy Issues	GM Policy Issues
Need for biodiversity conservation	Conservation of rare species and ecosystems	Seagrass protection needs
Control of invasive species	Preservation of traditions associated with kelps	Seagrass good ecological status definition
Impacts of fisheries and aquaculture on habitats	Cohabitation of fishing gears	Ecological functions of seagrass are broader than birds protection
Demand for recreative infrastructure	Seasonal protection need vs secured industry supply	Shellfish farming impacts on seagrass
Urbanisation of coastal zone	Economic development of kelp industry	Shellfish farming socio-economic development
Renewable energy development	Boom of industrial product price (Pharmaceutics MNF)	Social perceptions of seagrass protection
Development of aggregate extraction	Local perceptions of environmental impacts	
Reaching MSY for fish stocks		
Maintening and restoring water quality		

It was not possible to rank these ecological and social concerns at this stage, also because the study site teams felt not to be legitimate for carrying out such an appraisal. However, a hierarchy of policy issues is to be provided when ecological and social concerns are numerous and diverse. This means that GNB is certainly the study site where a selection in the policy issues will have to be done, preferably through stakeholder consultation. For all sites, the next important step will be to link ecological and social concerns with the various categories of services provided by the considered marine ecosystem (what is to be done through question 3 of the sequence 1 of the Triage process).

Identifying the potential for the status or the value of ES to change in the French study sites

In the GNB study site, where the scope of the ES assessment purposes is broad (initial diagnosis and possible changes exploration), a list of up to 20 factors of changes was drawn up. Obviously, a sound consideration of all these factors will not be feasible: as a consequence, scenarios will focus on particularly sensitive habitats, key economic factors (for instance the installation of wind-farms or changes in fishing or shellfish farming practices) or important social concerns (for instance cultural values associated with some particular habitats or services). However, the sorting of the factors of change which are of the highest interest will be the result of a dedicated stakeholder meeting.

In the PNMI study site, the intrinsic ecological dynamics of kelp habitats is not a matter of concern, but the significant factors of changes are rather to be found in economic and institutional changes. The kelp processing industry is developing rapidly worldwide and also in Brittany, which drives a rising demand for kelp fishing in the PNMI area. This particular economic context results in projects for building new boats with increased capacities and for harvesting more kelp species. In response to this economic drivers of change, management measures are envisaged for controlling kelp harvesting while achieving balanced trade-offs between the services delivered by kelps.

In the GM study site, a preliminary attempt to link each of the ES delivered by seagrass bed and the current factors of changes was carried out (Table 13). The exercise was made complicated because of the uncertainties which remain as regards the status and dynamics of many of the services which are delivered by seagrass beds in this particular area. However, based on the available knowledge at this stage of the process, it was possible to identify that the spatial dynamics of the seagrass beds on the one hand and the changes in perceptions as regards cultural services on the other hand could be considered as the main expected changes in the future.

Table 13. Factors of changes affecting ES delivered by seagrass beds in the Morbihan Gulf

Ecosystem Services	Probability for changes to happen
Biodiversity	Spatial dynamics of seagrass beds
Rare species Seahorses	
Rare species Birds	
Nursery (IS)	
Fisheries (FS)	Cattlefish harvesting industry development
Recreational fishing	
Primary production (IS)	
Shellfish farming (FS)	Removal of shellfish farming from seagrass
Water purification	
Carbon sequestration	Carbon release due to seagrass destruction
Birds watching	Changes in perception; active and passive uses
Recreational activities	Low interest due to water turbidity
Landscape and seascape	Changes in perception

low *may happen* *likely to happen*

The second round for the implementation of the triage process in the French study sites was initiated during a two day workshop in December 2013, always with a core group of managers and experts in ecology and economics for each case study. This workshop confirmed the results of the first round as regards the aim and broad scope of the assessments, and then it focused on the implementation of the second sequence of the triage and on the choice of the assessment method.

Which ES should be assessed and quantified in the French study sites?

The choice of the ES to be assessed was expected to be defined by scoring the answers to the three questions of the sequence two of the triage (see table 7 in the paragraph 4.2.2.). This sequence benefited from literature reviews which were carried out meanwhile in each study sites. However, sequence 2 was implemented with various difficulties: it works well in the PNMI, as one habitat with multiple ES was considered; it was more complicated in the GNB because of the number of habitats, so it was decided to consider only a set of critical factors of change; it was also complicated in the Morbihan Gulf, because ES were scored equal due to persistent lack of knowledge.

In order to go further in the identification of ES to be assessed, each study site adopted its own approach and participative process. MG organised a workshop to gather the most advanced knowledge regarding the ES delivered by seagrass bed. GNB used the results of the sequence 2 of the triage (which sorted the combinations of ES and habitats of main interests considering the current social and environmental issues) to define two major topics that could be addressed through narrative scenarios (participative approach, focus groups). The PNMI was able to score each of the possible ES delivered by kelp forests (see table 14). Based on this list, PNMI study site went further in the identification of meaningful indicators, what produced new insights for organizing the indicators sets already built for the PNMI management plan.

Which methods could be used to assess marine ES in the French study sites?

Finally, some choices were made regarding possible valuation methods which could be used in relation to the aim of the assessment and the policy issues. In order to feed the initial diagnosis of marine ES in the GNB study site, a spatial representation of habitats has been developed in order to develop INVEST models on habitat vulnerability and activities overlapping, and a system of ecological accounting will also be developed in order to link the main ES and the local economy. In addition, the importance of fishing and shellfish farming activities in the GNB will lead to the building of multicriteria assessment frameworks for this kind of provisioning services. In the PNMI study site, the focus on the need for controlling the increase in kelp exploitation intensity will lead to the building of the system dynamic model of kelp ecosystem services under human pressures in order to simulate management options; however it is anticipated that not all the indicators identified for the selected ES will be responsive to the simulation model. At last, in the Gulf of Morbihan, the role of social perception of seagrass bed contribution to various ES in the design of future management options may lead to the implementation of survey methods based on choice experiment or conjoint analysis.

Table 14. Outputs of the Sequence 2 of the triage in the PNMI study site

Marine and coastal ES		Code	MES	Potential for the ES value to change	Influence of management on ES change	Others factors affecting the ES	Final score
Provisioning services	Food provision	P1	Abalone commercial fisheries (diving)	1	2	3	2,00
		P2	Angling commercial fisheries	2	3	2	2,33
		P3	Lobster commercial fisheries (fish pots)	1	1	3	1,67
		P4	Alginates for food industry	NA	NA	NA	
		P5	Kelp aquaculture (Laminaria)	3	3	1	2,33
	Biotic materials and biofuels	P6	Biofuel	*potential*	*potential*	*potential*	
		P7	Crop fertilizer & pest management	3	2	1	2,00
		P8	Alginates	3	3	1	2,33
		P9	Molecule for medecines (non alginate)	2	1	3	2,00
		P10	Molecule for cosmetics (non alginate)	2	1	3	2,00
		P11	DS Bycatch (SP)	2	2	2	2,00
Maintenance and regulation services	Coastal protection	R1	Natural coastal defense	2	2	1	1,67
	Ocean nourishment	M1	Strong primary productivity	2	1	1	1,33
	Life cycle maintenance	M2	Improvement of kelp resilience	2	2	2	2,00
		M3	Support strong biodiversity (diversité de l'habitat)	2	3	1	2,00
		M4.1	Key habitats for commercial fishes (pollock and seabass)	1	2	3	2,00
		M4.2	Key habitats for abalone	2	3	2	2,33
		M4.3	Key habitats for European lobster	1	1	3	1,67
		M4.4	Key habitats for bottle-nose dolphins (refuge and hunting area)	2	2	2	2,00
		M4.5	Key habitats for grey seals	2	2	2	2,00
		M4.6	Key habitats for seabirds (Shelter / Sternes)	2	2	2	2,00
Cultural services	Symbolic and aesthetic values	C1	Traditional activity	1	1	2	1,33
		C2	Remarkable marine and seascape	2	2	1	1,67
		C3	Remarkable species	2	3	1	2,00
	Recreation and tourism	C4	Recreational fishing (shell, crustacean & fish)	3	2	1	2,00
		C5	Ecotourism (sea life and seascape watching)	2	3	2	2,33
	Cognitive effects	C7	Material for research	3	2	1	2,00
		C8	Material for arts	1	1	3	1,67
		C9	School excursion / awareness campaign	2	1	3	2,00

5. Methods and tools for the assessment of Marine Ecosystem Services: Application in 6 case study sites

Numerous methods can be used to assess marine ecosystem services. Basically, these methods belong to natural sciences or social sciences, and for some of them try to cross concepts and principles from both realms. A systematic review of the MES assessment methods has been recently carried out by the US Environmental Protection Agency (EPA 2009); a summary of this report is provided in Appendix 6. This last section of the guidelines document develops the presentation of the sets of methodologies which have been implemented in the VALMER case study sites. These sets of methodologies include: ecological assessment methods (habitats-functions-services relationship assessment, sensitivity assessment), social sciences methods (interviews, surveys, multi-criteria analysis), economic methods (transport costs, choice experiment, ecosystem accounting, Bayesian belief networks) and cross-methods (INVEST, system dynamic modelling).

5.1. Ecological assessment methods

5.1.1. Habitats-functions-services relationship assessment

In most cases, MESA is required in the context of a marine policy which may target the protection of marine habitats and biodiversity. Such policies are better informed by assessments which highlight the most important habitats or the key ecological functions for delivering ecosystem services. However, even if it is often referred to in the "cascade approach" (see Figure 2 in section 1), the relationships between habitat, functions and services within marine ecosystems are not well known and understood. A step forward in that direction was attempted in the Normand-Breton Gulf (GNB) study site, which proposed a first overview of the services delivered by the diverse habitats of this site in the prospect of the creation of new MPA.

Being part of an initial diagnosis, this exercise tried to identify and assess the contribution of all the habitats to key ecological functions and services. The identification phase raised the issue of the appropriate scale, considering habitat heterogeneity and knowledge gaps. It appeared feasible to produce a complete map of the diverse soft-sediment habitats of the site using EUNIS classification level 4; however, this map was based on a set of oceanographic data collected over more than 40 years, what indicates that the current status of some habitats may remain doubtful (Figure 11).

The second step of this work consisted in linking those habitats with functions and services based on the available knowledge. The ecological functions were assessed using a large variety of sources. Peer-reviewed papers were used first, some of them concerning a smaller part of the GNB (Mont-Saint-Michel Bay), comparable close areas (English Channel like the Bay of Morlaix) or more distant areas (North-East Atlantic like the Bay of Arcachon). Other sources included reports, unpublished in-situ observations or simple expert judgment. This variety and heterogeneity of sources led the ecologists from the study site team to propose a confidence interval for the assessment of ecological functions based on three criteria: 1) the quality of information sources, considering the nature of the source (peer-reviewed papers, reports, expert judgement) and the nature of the data (field observations, modeling results), 2) the applicability of evidence, according to the nature of the habitat and the location (increasing distance from Gulf Normand-Breton to English Channel and North-East Atlantic), and 3) the degree of concordance, which depend on the number of observations and the range of values.

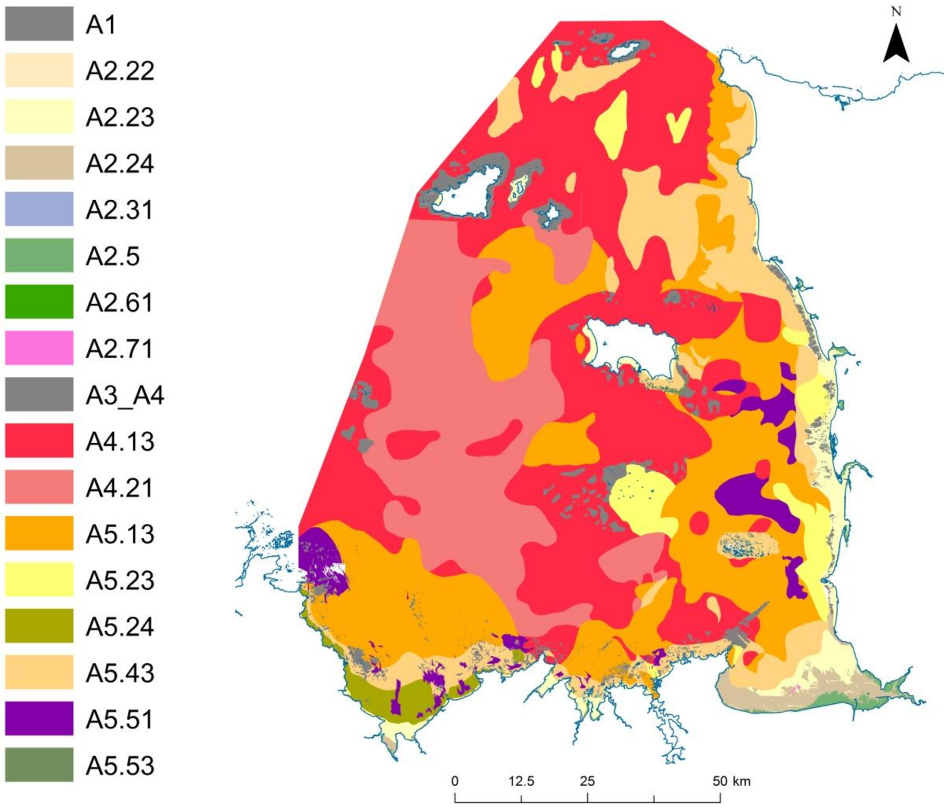

Figure 11. Benthic habitats of the Normand-Breton Gulf, EUNIS classification level 4

The ecological assessment of the GNB highlighted the importance of four categories of habitats (Table 15), coastal saltmarshes and saline reedbeds (A2.5), littoral and sub-littoral seagrass beds (A2.61 and A5.53), heterogeneous sediments in the infralittoral zone (A5.24, A5.43) and maerl beds (A5.51). The main functions which these habitats deliver are gross primary production, secondary production, habitat provision, nurseries, stocking and waste of pollutants, nitrogen cycling, calcification and respiration.

The link between habitats and services was also assessed using different sources including the previous functions assessment, some general ecological rules, quantitative estimates of food production and recreative activities at the scale of the GNB. The global estimates of fish production and recreative activities were allocated among the different habitats based on the expert judgement. This analysis revealed the major role of (i) intertidal habitats for shellfish farming, recreative activities but also for other cultural services, (ii) coarse sand and gravel habitats for commercial fishing and consequently to the cultural heritage in relation with fishing activities, (iii) saltmarsh for traditional activities, and (iv) offshore habitats in the provision of nurseries and the ocean nourishment. The analysis suggested also the possible contribution of nearshore habitats to the regulation of water quality and coastal protection and the possible negative effects of some habitats on some services (e.g. act as a source of CO2).

Table 15. Main ecological functions delivered by the various habitats of the Normand-Breton Gulf according to the following color code: white: not meaningful; light yellow: negligible; yellow: low; orange: moderate; red: high; nd: not determined

	A2.22	A2.23	A2.24	A2.31	A2.5	A2.61	A2.71	A4.13	A4.21	A5.13	A5.23	A5.24	A5.43	A5.51	A5.53
Gross primary production (gC. m^{-2}. y^{-1})	~ 0	~ 10	23.5- 50	135	675-1350	189-852	nd	~ 1	~ 1	< 1	0-10	6-200	31	241	111-2599
Secondary production (gC. m^{-2}. y^{-1})	0-5	4-15	4-15	15-30	0-5	25-30	nd	5-20	20-100	1.5-7	2.2-9.3	10-15	75-110	10	12-125
Habitat provision															
Nurseries (Σ Nb of species x importance)		5	2	9	3					3	2	8	9	3	6
Spawning grounds (Σ Nb of species x importance)								2	2	3		3	3	3	2
Stocking and waste of pollutants															
Nitrogen cycling (µmol. m^{-2}. h^{-1})	~ 0	2-10 (2-4)	80-160 (4-60)	160-240 (15-56)	~ 0	<0	nd	40	120	40	70-200	130-300	210	53-226	Sink ?
Calcification (gCaCO$_3$. m^{-2}. an^{-1})	~ 0	~ 0	10-120		~ 0		nd		682			69-104	515	490	
Respiration (gC. m^{-2}. y^{-1})	~ 0	~30	30-100	110	nd	832-936	nd		204		60		180-440	407	54-1400
Erosion and sediment stability															
Formation of physical barriers															

This attempt to fill the knowledge gaps concerning the habitats-functions-services relationships in marine ecosystems produced the following insights. Carrying out such an analysis based on literature review and exchanges with experts is time-consuming, but it generates no additional costs from field observations and experimentations. However, available knowledge may not be sufficient to assess the current status of all the habitats. Large gaps in functional ecology prevent from properly assessing the role of the main habitats in regulation services: this is due to lack of basic data, the limitations of data collected for other purposes and also spatial heterogeneity in ecological functions. As it remains difficult to assess all the relationships between habitats and functions or services, it is clearly needed to focus on some major functions and services according to the management issues. Finally, the analysis of the habitats-functions-services relationships, although complicated, may help to move further from a static vision toward a dynamic system, taking into account the changes in the services delivery in response to human pressures. More work is also need to better understand the cumulative effects of pressure on ecological functions and ecosystem services.

5.1.2. Sensitivity assessment

Sensitivity assessments involve the collation of existing information on key characteristics of a species or habitat and its response to environmental change, and the presentation of this information in a format that is accessible to decision makers (Hiscock and Tyler-Waters, 2006). Certain key concepts are fundamental to the sensitivity assessment approach, as defined by Tillin et al. (2010) (Table 16).

Sensitivity assessments are widely used to evaluate the expected extent to which changes in certain pressures will affect particular species or habitats. If MES assessments are to become widely used in decision making, then the approach must provide information to help decision makers understand how changing levels of pressure affect the delivery of particular services and benefits. Various methods for sensitivity assessments may be carried out: a synthesis of existing research, empirical approaches or a mix of both approaches.

One approach to assessing the sensitivity of MES to pressure changes is to build on existing work that has described both the ecosystem services, goods and benefits provided by marine and coastal habitats, and also on the sensitivity of these habitats to pressures. This is appropriate for a broad-based assessment that aims to provide an indication of the sensitivity of a suite of services to a range of pressures at generic levels of intensity.

Table 16. Key definitions in sensitivity assessment (from Tillin et al. (2010))

Term	Definition
Sensitivity	A measure of tolerance (or intolerance) to changes in environmental conditions
Resistance	Response to change whether element can absorb disturbance or stress without changing character
Resilience	The ability of a system to recover from disturbance or stress
Vulnerability	A measure of the degree of exposure of a receptor to a pressure to which it is sensitive
Pressure	The mechanism through which an activity has an effect on any part of the ecosystem. The nature of the pressure is determined by the activity type, intensity and distribution
Impact	The effects (or consequences) of a pressure on a component
Exposure	The action of a pressure on a receptor, with regard to the extent, magnitude and duration of the pressure

The limitations of the synthesis approach may require a more empirical assessment in order to determine the sensitivity of particular MES in a specific situation. Two further empirical approaches to MES sensitivity assessment may be therefore suggested: i) a habitat-based approach, which follows a broadly similar method to the synthesis approach but is more specific to a local context and mix together expert and scientific knowledge; and ii) a benefit-based approach for situations in which there is no suitable existing information, such as when the direct linkages between certain habitats or species and a particular benefit are not clear. However, the benefit-based approach does not longer rely on ecological knowledge but on social demand.

The empirical approach for habitats and MES sensitivity assessment was applied in the NDBR, GNB and Poole Harbour case study sites. Table 17 provides an example of a matrix which presents for a series of habitats, the sensitivity of three regulation services to fishing gears and aggregate extraction in NDBR. Of course, interpreting the results requires a precautionary principle as the scientific knowledge is not always suitable for the case and the expert judgments not comprehensive. A similar approach was undertaken in the GNB study site (Cabral et al. 2014). In the Poole Harbour case study site, the focus was on cultural service (recreation) for which linkages between habitats/species and service provision were not clear. In this case, a benefit-based approach was chosen where sensitivity was assessed in terms of how user participation might be affected by changes to the environment within Poole Harbour. The approach required data generated by surveys, which are presented in the next section on "social science methods".

Table 17. The sensitivity of selected subtidal sedimentary habitats of the NDBR to different fishing gears and to aggregate extraction

	Contribution	Scallop dredges	Demersal trawls	Static gear (pots)	Aggregate extraction
Coarse sands and gravels characterised by large/long lived bivalves		High	High	Low	High
Nursery Habitat (3)	Low				
Food Web (3)	Significant				
Carbon sequestration (1)	Low				
Stable subtidal fine sands		Low	Medium	Low	High
Nursery Habitat (3)	Low				
Food Web (3)	Significant				
Carbon sequestration (1)	Low				
Subtidal stable muddy sands, sandy muds and muds		Medium	Low	Low	High
Nursery Habitat (3)	Significant				
Food Web (3)	Significant				
Carbon sequestration (1)	Moderate				
Dynamic, shallow water fine sands		Low	Medium	Low	Low
Nursery Habitat (3)	Significant				
Food Web (3)	Significant				
Carbon sequestration (1)	Negligible				
Stable, species rich mixed sediments		Medium	Medium	Low	High
Nursery Habitat (3)	Significant				
Food Web (3)	Significant				
Carbon sequestration (1)	Moderate				
Unstable cobbles, pebbles, gravels		Low	Medium	Low	Medium
Nursery Habitat (3)	Negligible				
Food Web (3)	Low				
Carbon sequestration (1)	Negligible				

Scale of contribution to supply of ecosystem service relative to other species/habitats: Significant Moderate Low Negligible

Confidence in evidence: 3 UK-related, peer-reviewed literature 2 Grey or overseas literature 1 Expert opinion

Sensitivity: High Medium Low Activity unlikely to occur

5.2. Social science methods

5.2.1. Surveys, interviews and focus groups

Surveys, interviews and focus groups are typical social science methods which aim at eliciting preferences of people for a given state of the environment, and provide also useful information on the practices of the stakeholders with regards ecosystems or their perception of the possible changes and main issues to be dealt with by policy-makers. The Gulf of Morbihan study site used a combination of all the three methods. In a context of high scientific uncertainty, a series of 50 interviews and 9 focus group workshops was used to gather information regarding the perception of the ecosystem services provided by seagrass beds (Figure 12). In addition, a survey was carried out to elicit the preferences of people living in 34 municipalities within the Natural Regional Park of the Gulf of Morbihan for prioritising policy intervention (Figure 13); the survey concerned 611 respondents who filled a face to face questionnaire in the street. Later on, the same survey included a choice experiment on policy alternatives (see paragraph 5.3.3).

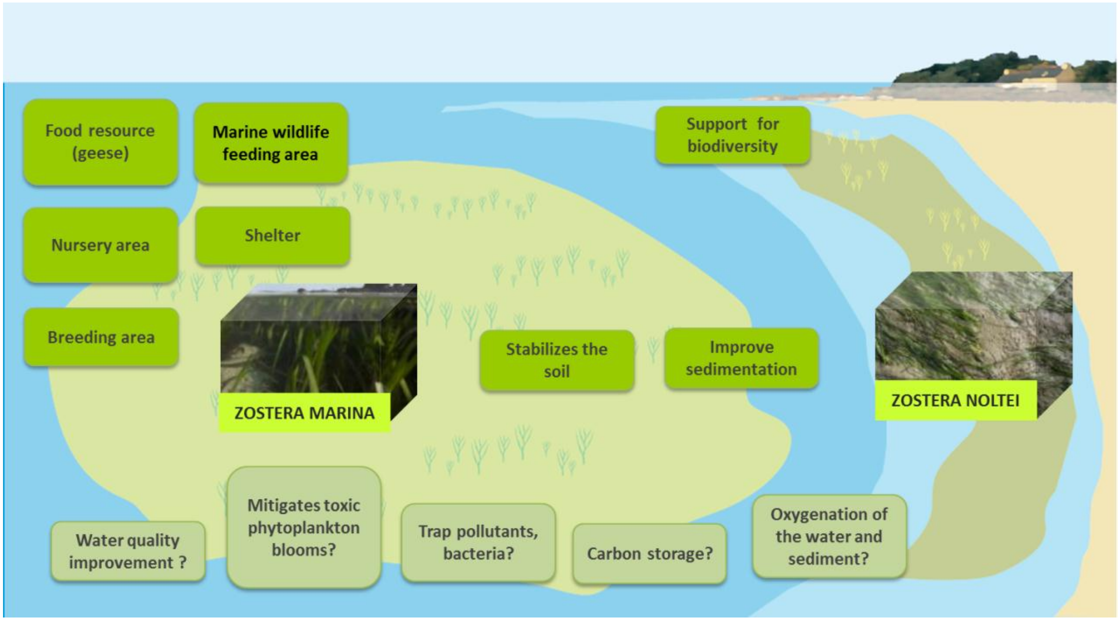

Figure 12. Functions and services delivered by seagrass beds in the Gulf of Morbihan

In the Gulf of Morbihan study site, the interviews with key stakeholders highlighted the variety of perceptions regarding seagrass ecological functions and services, as well as the unequal conservation of the territory memory among people. Focus groups were useful for revealing lack of knowledge and managers priorities; they demonstrated also that maps, even incomplete, are useful to stimulate discussion and lead participants to formalise their views. The survey helped to prioritise policy interventions; it demonstrated however that people are not aware of seagrass ecological functions and that gaining support for seagrass conservation policies would require to spread information toward the general public.

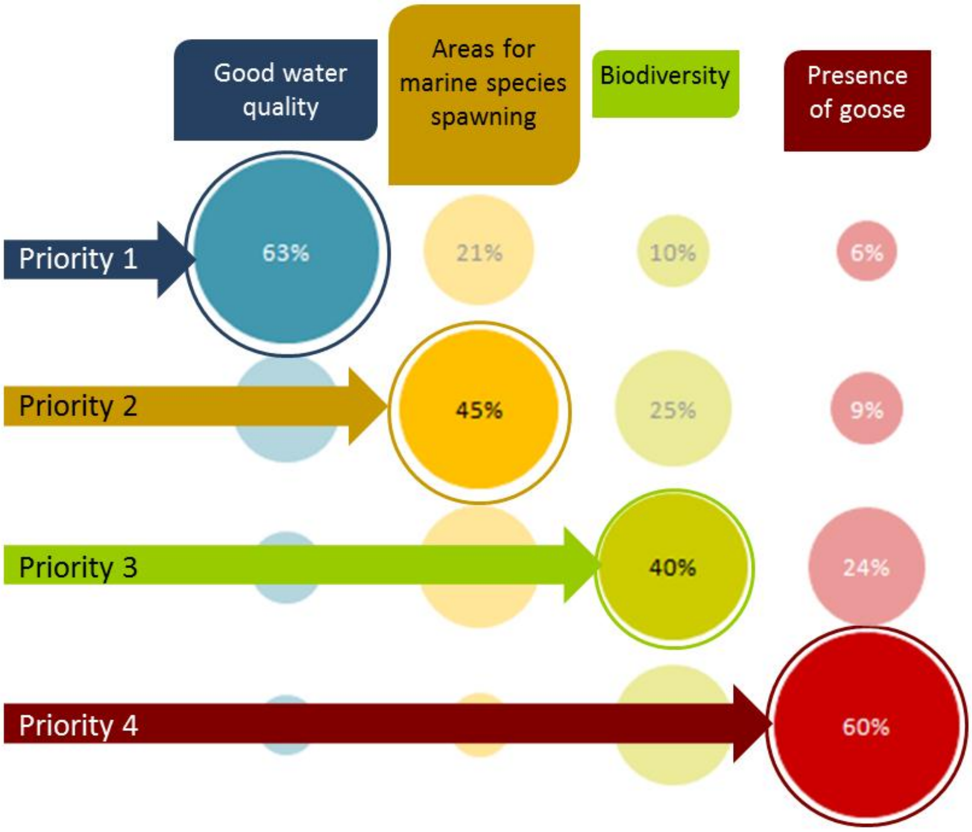

Figure 13. Main priorities for policy intervention with respect to the broad categories of ES delivered by seagrass beds in the Gulf of Morbihan

Survey methods were again used for the Plymouth Sound to Fowey case study in order to investigate the cultural services provided by this part of South East Cornwall (Willis et al., 2014). The responses showed a clear link between reported wellbeing and the frequency of visits to the coast: wellbeing was significantly lower for those who 'almost never' spend time in/on the sea and at the coast compared to those who spend time there more frequently. Over half of the respondents strongly agreed that being in the area helped them to: feel calm and relaxed; clear their head and think; feel closer to nature; and feel refreshed and revitalised.

Respondents were also asked to identify on a map three key areas that were significant or valuable to them ("green dots"), and a further three that they felt were under threat or challenged ("red dots") and to provide associated narrative details. The information was amalgamated into 'hotspot' maps showing the density of green or red dots in particular areas (Figure 14). The significant and valuable places tended to be particularly associated with history and cultural heritage, childhood memories and family experiences, aesthetic value, recreation and leisure. Places identified as challenged or under threat had poor environmental quality, were at risk of flooding, or had lost their 'traditional feel' due to modern developments and second home ownership.

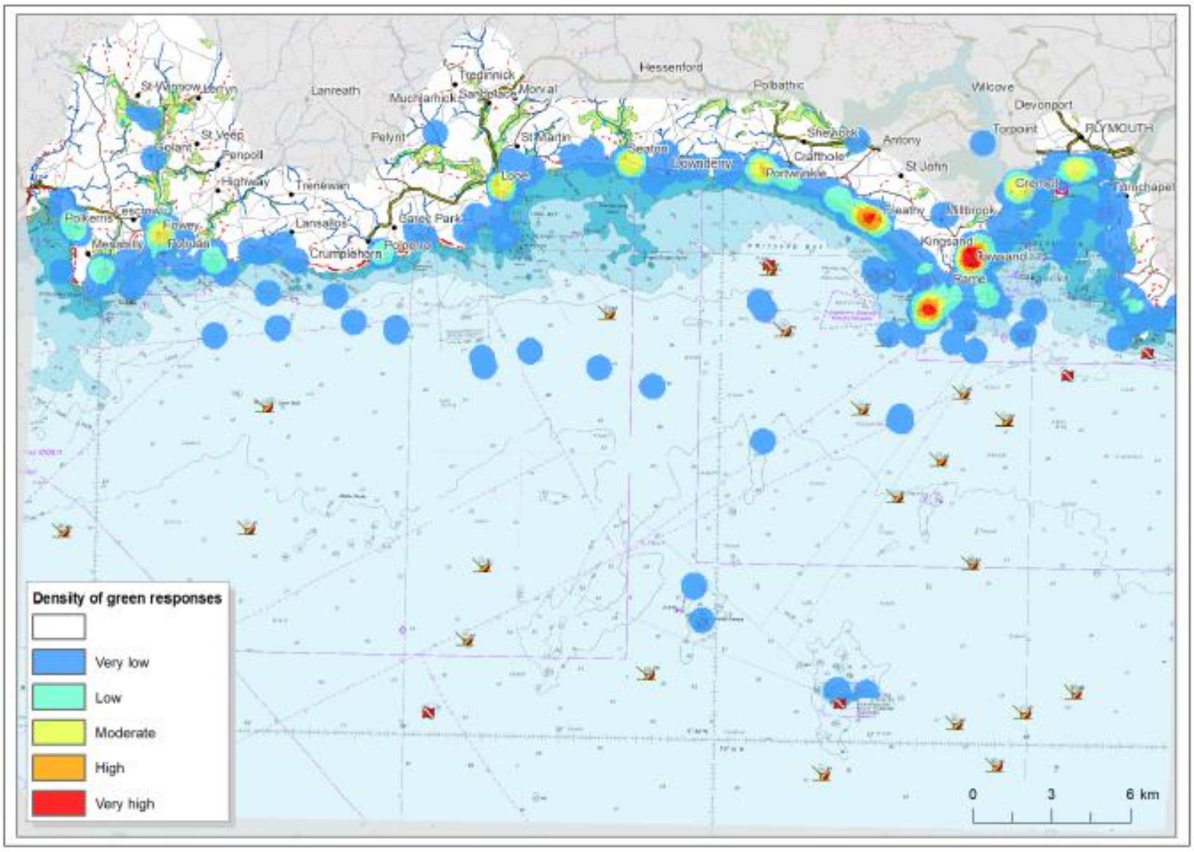

Figure 14. Significant and valuable places in the Sound to Fowey case study identified by survey respondents

5.2.2. Multi-criteria analysis

The Analytic Hierarchy Process (AHP) is an example of a multi-criteria analysis (MCA) methodology. MCA techniques are often used to support decision making as they provide a formal framework in which different characteristics or options can be compared and relative preferences for them expressed, typically using weighting, ranking or scoring methods. In an AHP assessment, survey respondents are asked to compare different attributes two at a time, expressing on a scale of 1 to 9 how much they prefer one attribute over the other. The AHP method was chosen in this study because i) it is very commonly used in environmental science for assessing the preferences of multiple individuals, and ii) the pairwise comparisons used can generate more accurate relative weights than other ranking or rating methods.

In Poole Harbour, the AHP assessment was used in a two-step process. Firstly, respondents were asked to express the relative importance to them of:

- the environment (described to them as the underlying features that shape Poole Harbour as well as other elements of the natural environment),
- facilities (the availability of built infrastructure such as car parks, slipways, shops)
- cost factors (how much it costs to use the infrastructure and facilities)

An example of an AHP comparison as presented to respondents is shown in Figure 15. The process was then repeated for three specific environmental attributes: views of the coastline, wildlife, and water quality. The results demonstrated that equal preference was given to cost factors and the facilities available, but importance of the environment was significantly higher (Figure 16a). Within the environmental characteristics, wildlife was most important (Figure 16b),and there was a small, but significant, preference for views over water quality. This finding was not driven solely by the inclusion of birdwatchers, as the relative rankings were unchanged when watersports users only were considered.

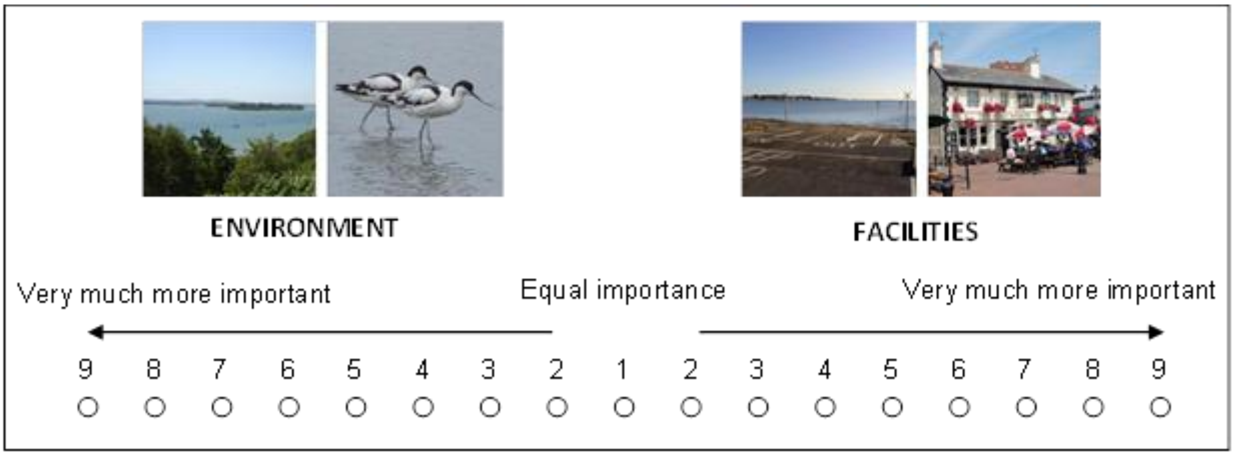

Figure 15. An example of an AHP comparison

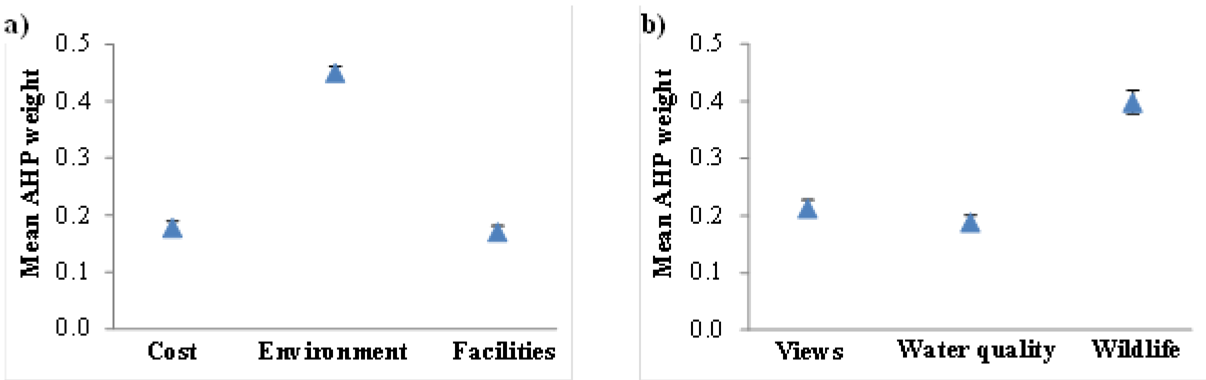

Figure 16. Geometric mean and 95% confidence interval for the AHP weights of all respondents (n=528) for a) the characteristics of Poole Harbour and b) different environmental characteristics

5.3. Economic methods

5.3.1. Travel costs method

A key aim of the Poole Harbour case study was to provide a monetary value for selected recreational activities, as monetary values can be used to demonstrate the potential economic implications of management actions and so can support decision-making. The Travel Cost Method was used, which is an example of a revealed preference technique: values are calculated based on information about how people actually behave. In the case of the Travel Cost Method, the value to a respondent of a particular location is based on the amount they are prepared to spend on travel to get there. The value of the recreational activities in Poole Harbour was determined primarily by considering the distance travelled (as calculated based on their home post code) and the mode of transport used by each respondent, with factors such as whether they travelled to multiple destinations or had multiple purposes for their visit also taken into account. In addition to the cost of their travel, respondents were also asked about additional costs they incurred during their trip, to provide information about their local spending on items such as food, accommodation, car parking, permits, slipway use, tuition and equipment. Count data was also collected to determine the number of participants undertaking each activity. This was combined with the information on spend per person to determine the total annual spending by participants in each activity (Figure 17).

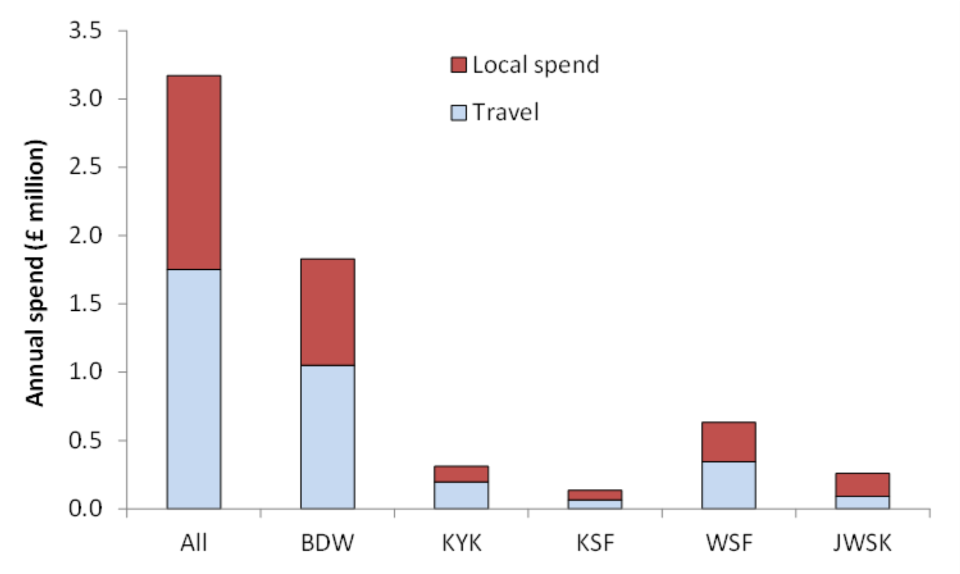

Figure 17. The annual spend per year (£millions) for all activities combined and for the individual pursuits: birdwatching (BDW), kayak/canoing (KYK), kitesurfing (KSF),windsurfing (WSF) and jet/waterskiing (JWSK)

5.3.2. Ecosystem accounting

In 2012, a satellite account called the "System of environmental-economic accounting Central Framework" (SEEA-CF, 2012) was published by the United-Nations in order to incorporate the environmental assets in the national accounts and to estimate the defensive expenditures. The conventional accounting indicators are adjusted in order to take into account the depletion of natural resources and produce an adjusted Gross Domestic Product (GDP), also called "green GDP". However, the SEEA focuses on natural resources, considered as well identified and separated economic goods. An experiment was carried out by the United-Nations to extend the SEEA to ecosystems: The SEEA Experimental Ecosystem Accounting (SEEA-EEA, 2012). The SEEA-EEA focuses on asset accountings; therefore, one of the major challenges of the SEEA EEA remains to define monetary valuation methods to provide a monetary value of ES which would be consistent with the accounting approach. Indeed, the ES approach has not solved all the methodological problems raised by the monetary valuation of natural capital. For this reason, a complementary approach was adopted within the VALMER project: we developed an ecosystem satellite account, which encompasses the activities using or maintaining the ecosystem services and estimates all the resources and expenditures of these activities. For the second type of activities, it can be referred to one existing functional account of the SEEA-CF, which values the different means implemented by a society in order to avoid environmental degradation or to maintain or to increase the production of ecosystem services. Ideally, this satellite account of activities using or maintaining ES should be complemented by a physical account which would provide indicators of the ecological input used by these activities or the ecological outputs they may produce (Figure 18). Contrary to the SEEA-EEA, the environmental degradation would not be valued in monetary units, but in physical units. This approach was applied to the Normand-Breton Gulf study site.

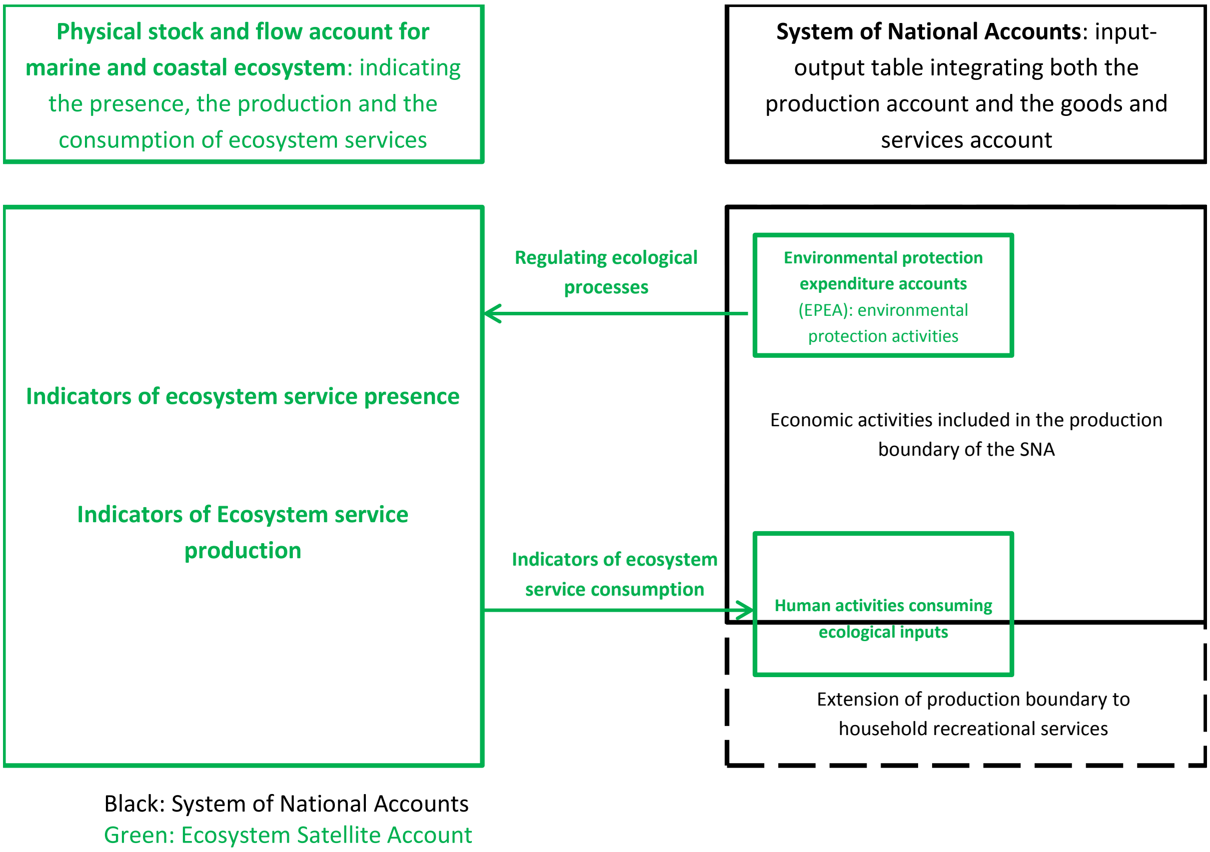

Figure 18. Ecosystem satellite accounting: incorporating ES in the SEEA-Central Framework

An important issue for the integration of ecosystems in the SEEA is the assessment of ecosystem cultural services. Most of those services are obtained through a process of "production for own use" by the households. It is thus necessary to extend the production boundary of the System of National Account in order to integrate those activities. In the GNB study site, a survey was carried out to estimates the means that households dedicate to the production of the recreational ecosystem services they consume: it necessitates preparation time, travel, materials, etc. The valuation of this production means (including time) served as the basis for estimating the total production value of their recreational activity, part of which being used for consuming cultural ES. The consumption time was divided into different types of ES consumption (recreational fishing, seascape) and other recreational activities (sport). The production value of recreational activities allowing individuals to consume cultural ES was finally estimated as a proportional share of the real consumption time. Finally, this contributed to a comprehensive picture of the ES targeted, for use or maintenance, by human activities in the Normand-Breton Gulf for the year 2013 (Figure 19 and Appendix 7). In a first implementation stage, this ecosystem accounting approach necessitates methodological developments, which may be time consuming, however the approach can be easily repeated over time in a routine way thereafter and can support marine management policies which build on the ES approach for balancing uses and conservation.

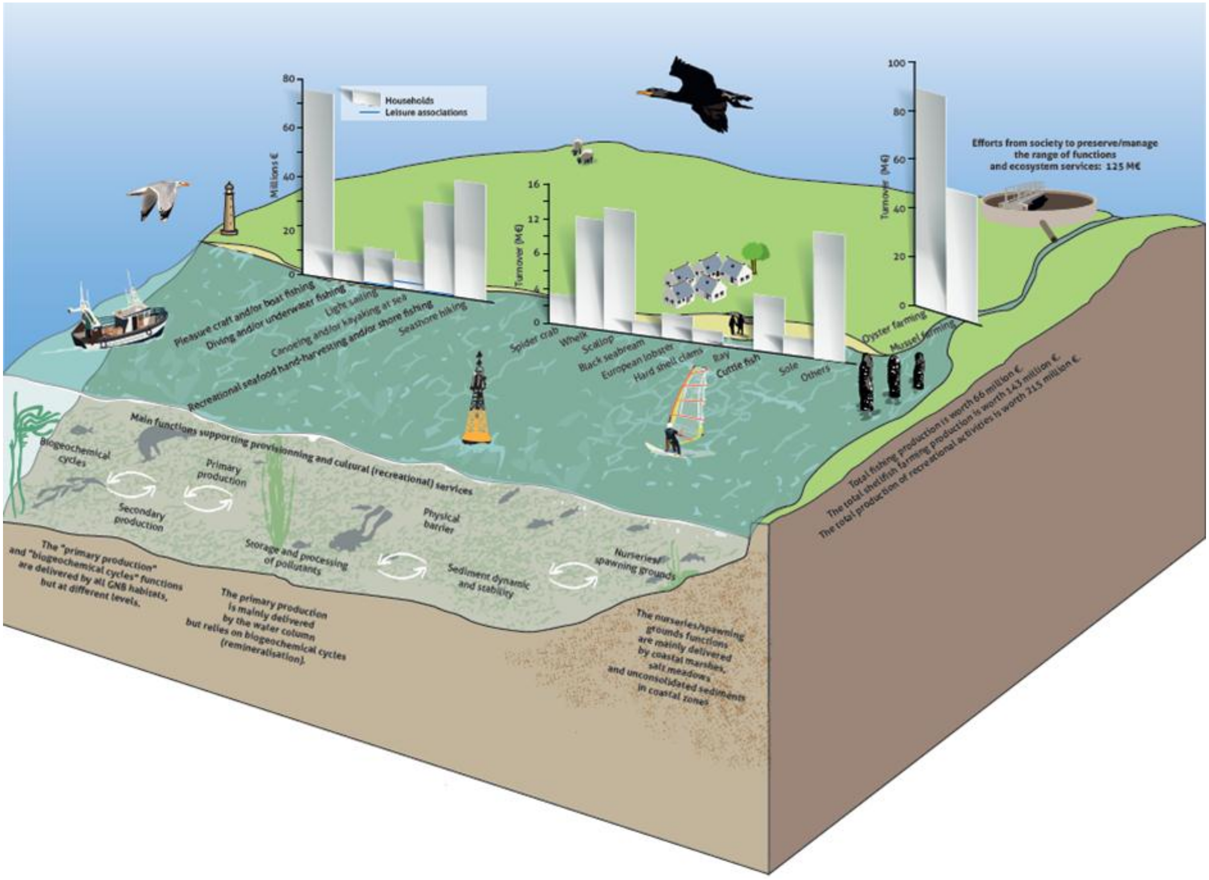

Figure 19. Production value of the activities producing and/or consuming ecosystem services in the Normand-Breton Gulf (2013)

5.3.3. Choice experiment

Choice experiment may help to reveal people preferences for ES. The method consists in asking respondents to select one among a limited number of scenarios, the experiment being repeated several times with the same respondent. Within each scenario, the attributes of the ecosystem vary. This method was used in the Gulf of Morbihan in order to estimate the preferences for seagrass conservation. Due to persistent knowledge uncertainties, the choice experiment applied to a very broad view of seagrass ES: comparing the ecological status of the ecosystem, considering various levels of constraints on activities and associated public expenditures. Each of the 611 respondents was asked 8 times to select one among three scenarios made of three attributes, the first scenario being always the 'business as usual' projection (Figure 20). The answers to the questionnaires are then processed with econometric models. In the Gulf of Morbihan, the preference of the interviewees goes to an improvement of the seagrass ecological status through increased constraints on activities but without additional money devoted to this management policy.

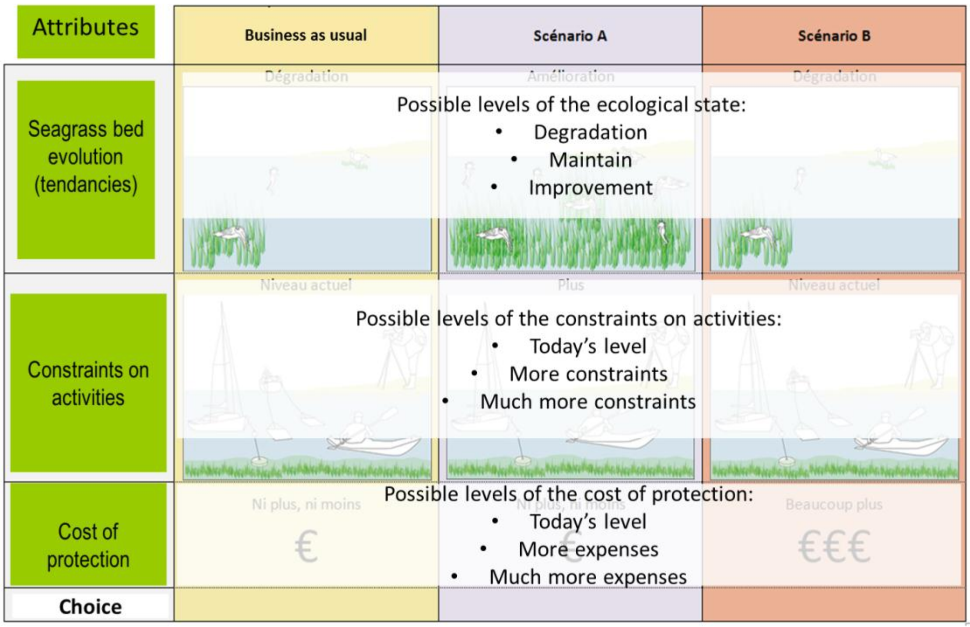

Figure 20. Scenarios on seagrass evoluation used for the choice experiment in Gulf of Morbihan

5.4. Cross methods

5.4.1. INVEST

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a suite of software models used to map and value the goods and services, which has been developed by the Natural Capital Project at the Stanford University. InVEST currently includes 17 models among which the following are applicable to marine environments: "Blue Carbon" quantifies and values carbon storage and sequestration in coastal ecosystems; "Coastal Protection" quantifies and values the benefits of nearshore habitats for coastal protection; "Coastal Vulnerability" assesses the relative risk to coastal areas from storms; "Habitat Risk Assessment" evaluates the risk to marine or terrestrial habitats from anthropogenic factors; "Marine Fish Aquaculture" estimates the harvest weight and value of farmed salmon; "Marine Water Quality" models concentration of pollutants at sea; "Offshore Wind Energy" measures the electricity generation potential of wind over ocean and large lake surfaces; "Scenic Quality" maps the visibility of features across a landscape or seascape; "Wave Energy" models and values harvested energy from wave power facilities.

The InVEST habitat risk assessment (HRA) model was applied as part of the initial diagnosis of the ES delivered by the Normand-Breton Gulf. This model allows users to assess the risk posed to coastal and marine habitats by human activities and the potential consequences of exposure for the delivery of environmental services and biodiversity. The likelihood of exposure of the habitat to the stressor and the consequence of this exposure was done using expert knowledge by assigning a rating to a set of criteria for each attribute. The results showed that, as expected, the near shore areas exhibit higher risk values, which means that these habitats are more exposed to pressures unlike the habitats in the offshore areas (Figure 21).

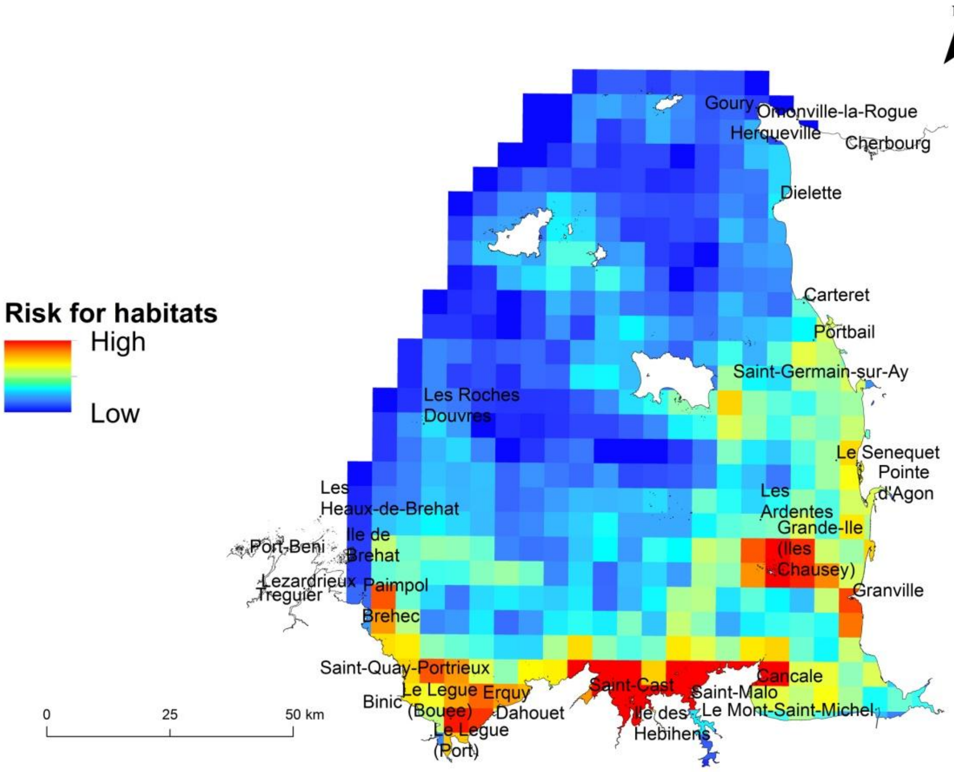

Figure 21. Cumulative habitat risk in the Normand-Breton Gulf

5.4.2. Bayesian belief networks

A Bayesian Belief Network (BBN) model was used to examine the effects of current fishing pressure and hypothetical management scenarios on the subtidal sediments in the North Devon Biosphere Reserve (NDBR) (Langmead et al., 2015). Three ecosystem services were considered: nursery habitats for commercial fish and shellfish, waste processing and carbon storage. The habitats across the NDBR were divided into six broad habitat types and mapped. The potential contribution of each habitat type to the supply of each service was determined using a four-point qualitative scale (negligible, low, moderate, significant), with the results based on a literature review (nursery habitats), empirical evaluation of community bioturbation potential (waste processing), and considering the sediment mud content (carbon storage). The sensitivity of the services to key pressures was also determined (see Section 5.1.2, above). Information on existing levels of fishing activity was combined with the sensitivity information to model the current supply of each ecosystem service in each Ikm2 grid cell across the area. The model was then run again based on the change in pressures that would be exerted by three management scenarios: the establishment of marine protected areas, aggregate extraction and the development of extensive mussel aquaculture. The scenarios included the implications of these scenarios for the displacement of fishing effort. The model outputs suggested that ecosystem service supply increased within the proposed MPA sites, although a decrease in service delivery was observed in the adjacent areas to which fishing effort was displaced (Figure 22). Both the aggregate extraction and aquaculture scenarios resulted in a decrease in nursery habitat, but the latter also showed potential large increases in carbon storage and waste processing.

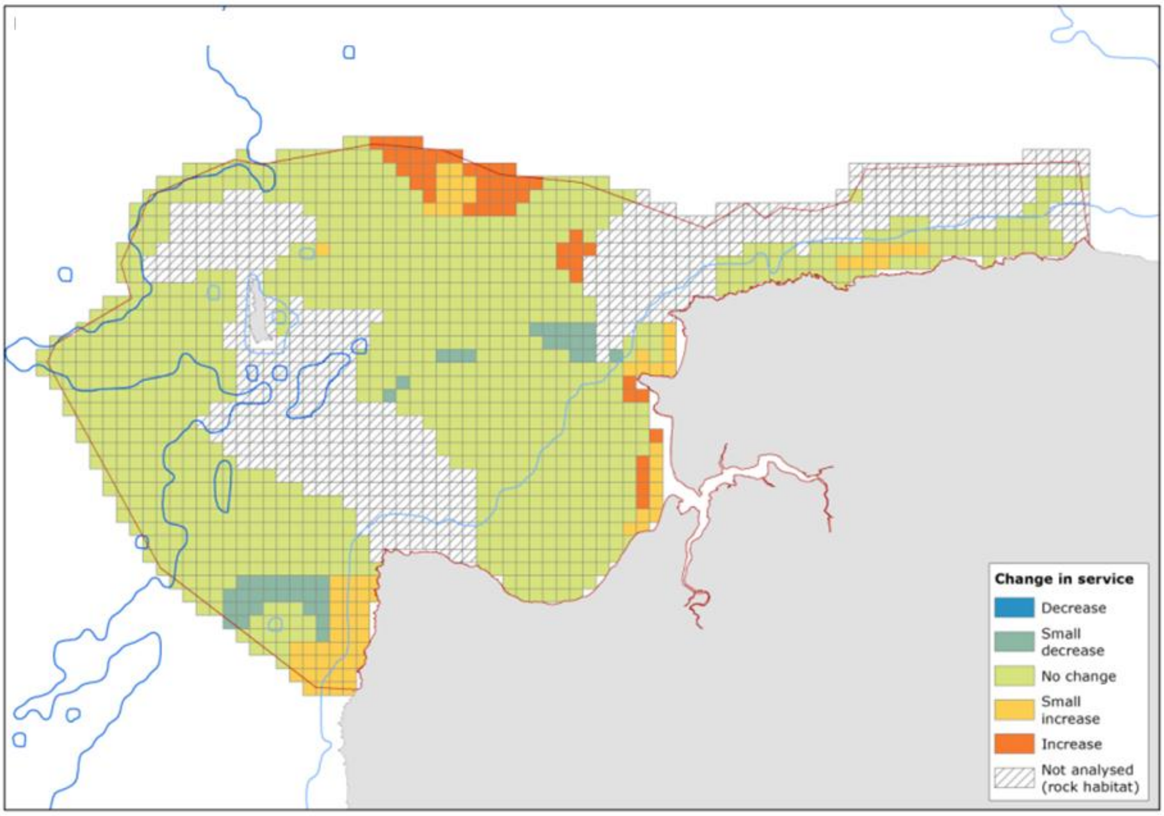

Figure 22. Model output showing the change in combined ES following the establishment of marine protected areas

5.4.4. System dynamic modelling

System dynamic modeling has become one of the most suitable approaches for dealing with environmental sustainability problems, as it makes social-ecological interactions central to a systems approach, thus facilitating interdisciplinary collaboration (Boulanger and Bréchet 2005). System dynamic models present known limits and weaknesses. First, these models are not well adapted to dealing with multiple levels or scales, except when several models are combined. Second, they cannot easily take uncertainty into account, as they are based on fixed relations between variables while consuming a high number of coefficients. For these reasons, they are highly sensitive to the assumptions formulated during the parameterization step. Nevertheless, a system dynamic model is useful whenever sufficient data are available to feed it, as it allows for communication between stakeholders and scientists, making it a preferable instrument for the integrated assessment of environmental problems and the simulation of exploratory scenarios, as distinct from predictive or normative scenarios (Mongruel et al. 2013).

In the Nature Marine Park of the Iroise Sea case study site (PNMI) a system dynamic model was developed to simulate kelp forest management options, using the most advanced available knowledge through expert participation and stakeholder interviews. This participative socio-ecosystem modelling aimed at representing the kelp forest ecosystem and its services according to a "REFUGE" projection, which includes Resources and Ecological Functions, Uses and Governance (Figure 23).

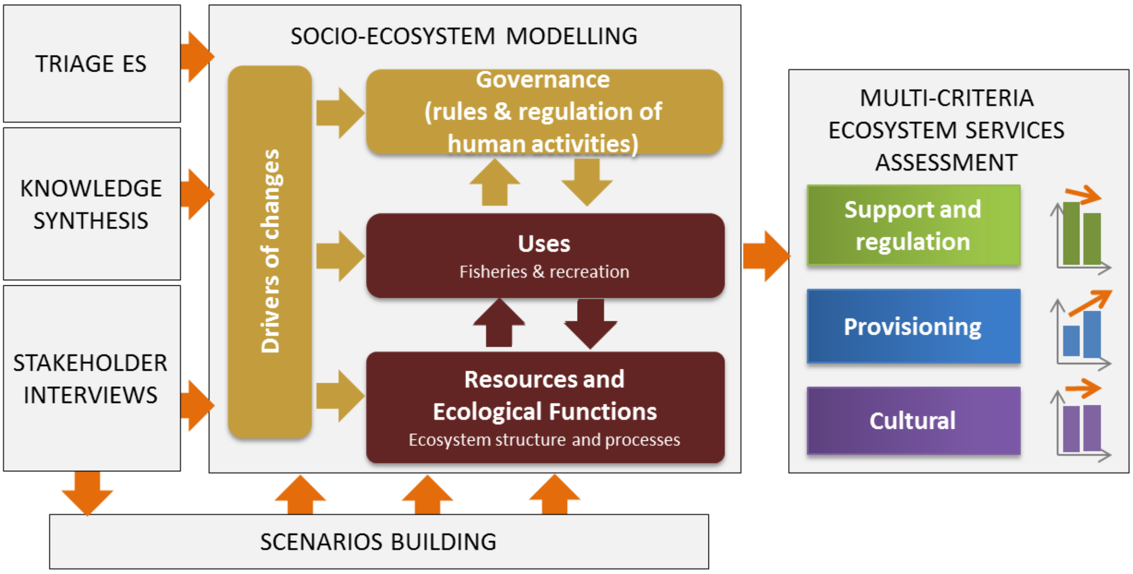

Figure 23. Modelling approach in the PNMI case study site

The "Resources and Ecological Functions" component of the model is based on a population dynamic model of kelp, the "Uses" component is a bio-economic model of kelp harvesting, and the "Governance" component encompasses access rules which can be modified for comparing management options. The model is able to estimate a series of parameters for a multicriteria assessment. For instance, the "Resources and Ecological Functions" component simulates kelp biomass and kelp plants size: the first parameter is then connected with the kelp exploitation module which estimates economic indicators, and the second one can be used to assess other key ecological functions such as support function for biodiversity, other commercial species or emblematic species (Figure 24). This kind of model is able to highlight the trade-offs involved by management options, taking into account the dynamic of ecological and social processes and the interconnectedness of marine ES.

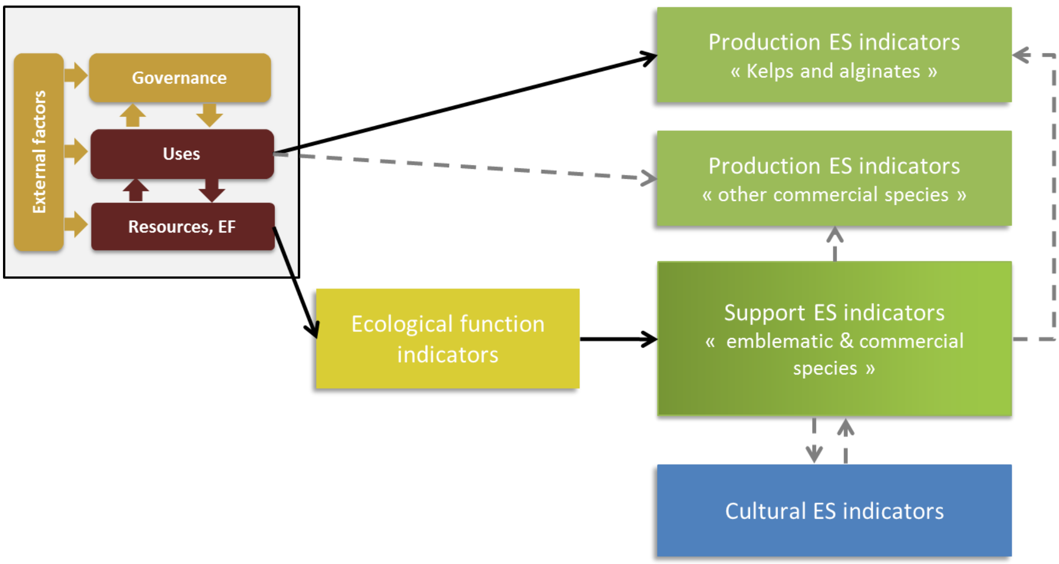

Figure 24. ES indicators simulated by the kelp forest system dynamic model

6. Concluding comments

This Guidelines document is focused on providing the fundamental background information essential to undertaking a MESA (sections 2 and 3) and also a novel operational framework for undertaking a MESA (section 4). The framework is deliberately flexible as exemplified by the case study applications (section 5). With regard to undertaking a MESA the available resources, environmental setting, managerial needs and overarching context will always be highly variable, and it is essential that any framework reflects this requirement. However, it is the case that some level of guidance and structure is required in order to enable an efficient process of MESA, and it is such Guidance which this report has aimed to produce.

The Guidelines report should be read in accompaniment with the other VALMER outputs which present some other insights or details concerning the implementation of the Valmer operational framework for marine ES assessment presented in this guidelines document. These additional reports and documents dealing with the VALMER methodology for marine ES assessment, its implementation in the case study sites and the results obtained, include:

Valmer WP1 Report on “Ecosystem Service Assessment in Practice: Lessons Learned”

Valmer WP2 Report on “Practical approaches to the management of marine social and economic data”

Valmer WP3 Report on “Building site based scenarios: tools and approaches for implementation from the VALMER project”

Valmer WP4 Report titled “Advice note for using ecosystem service assessment to support marine governance”

Valmer WP4 Report on “Improving stakeholder engagement in marine management through ecosystem service assessment”

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Appendices

Appendix 1. Nomenclature for marine habitats at EUNIS Level 4. Application to the Channel.

A Marine habitats

A1 Littoral rock and other hard substrata

A1.1 High energy littoral rock

A1.11 *[Mytilus edulis] and/or barnacle communities*

A1.12 *Robust fucoid and/or red seaweed communities*

A1.15 *Fucoid in tide-swept conditions*

A1.2 Moderate energy littoral rock

A1.21 *Barnacles and fucoids on moderately exposed shores*

A1.22 *[Mytilus edulis] and fucoids on moderately exposed shores*

A1.3 Low energy littoral rock

A1.31 *Fucoids on sheltered marine shores*

A1.32 *Fucoids in variable salinity*

A1.33 *Red algal turf in lower eulittoral, sheltered from wave action*

A1.4 Features of littoral rock

A1.41 *Communities of littoral rockpools*

A1.42 *Communities of rockpools in the supralittoral zone*

A1.43 *Brackish permanent pools in the geolittoral zone*

A1.44 *Communities of littoral caves and overhangs*

A1.45 *Ephemeral green or red seaweeds on non-mobile substrata*

A2 Littoral sediment

A2.1 Littoral coarse sediment

A2.11 *Shingle (pebble) and gravel shores*

A2.12 *Estuarine coarse sediment shores*

A2.2 Littoral sand and muddy sand

A2.21 *Strandline*

A2.22 *Barren or amphipod-dominated mobile sand shores*

A2.23 *Polychaete/amphipod-dominated fine sand shores*

A2.24 *Polychaete/bivalve-dominated muddy sand shores*

A2.3 Littoral mud

A2.31 *Polychaete/bivalve-dominated mid estuarine mud shores*

A2.32 *Polychaete/oligochaete-dominated upper estuarine mud shores*

A2.33 *Marine mud shores*

A2.34 *[Corophium] spp. in soft mud shores*

A2.4 Littoral mixed sediments

A2.41 *[Hediste diversicolor] dominated gravelly sand mud shores*

A2.42 *Species-rich mixed sediment shores*

A2.43 *Species-poor mixed sediment shores*

A2.5 Coastal saltmarshes and saline reedbeds

A2.51 *Saltmarsh driftlines*

A2.52 *Upper saltmarshes*

A2.53 *Mid-upper saltmarshes and saline and brackish reed, rush and sedge beds*

A2.54 *Low-mid saltmarshes*

A2.55 *Pioneer saltmarshes*

A2.6 Littoral sediments dominated by aquatic angiosperms

A2.61 *Seagrass beds on littoral sediments*

A2.7 Littoral biogenic reefs

A2.71 *Littoral [Sabellaria] reefs*

A2.72 *Littoral [Mytilus edulis] beds on sediment*

A2.8 Features of littoral sediment

A2.82 *Ephemeral green or red seaweeds on mobile substrata*

A3 Infralittoral rock and other hard substrata

A3.1 Atlantic and Mediterranean moderate energy infralittoral rock

A3.11 *Kelp with cushion fauna and/or foliose red seaweeds*

A3.12 *Sediment-affected or disturbed kelp and seaweed communities*

A3.14 *Encrusting algal communities*

A3.15 *Frondose algal communities*

A3.2 Atlantic and Mediterranean moderate energy infralittoral rock

A3.21 *Kelp and red seaweeds*

A3.22 *Kelp and seaweed communities in tide-swept sheltered conditions*

A3.24 *Faunal communities on moderate energy infralittoral rock*

A3.3 Atlantic and Mediterranean low energy infralittoral rock

A3.31 *Silted kelp on low energy infralittoral rock with full salinity*

A3.32 *Kelp in variable salinity on low energy infralittoral rock*

A3.34 *Submerged fucoids, green or red seaweeds*

A3.35 *Faunal communities on low energy infralittoral rock*

A3.7 Features of infralittoral rock

A3.71 *Robust faunal cushions and crusts in surge gullies and caves*

A3.72 *Infralittoral fouling seaweed communities*

A4 Circalittoral rock and other hard substrate

A4.1 Atlantic and Mediterranean high energy circalittoral rock

A4.11 *Very tide-swept faunal communities on circalittoral rock*

A4.12 *Sponge communities on deep circalittoral rock*

A4.13 *Mixed faunal turfed communities on circalittoral rock*

A4.2 Atlantic and Mediterranean moderate energy circalittoral rock

A4.21 *Echinoderms and crustose communities on circalittoral rock*

A4.22 *[Sabellaria] reefs on circalittoral rock*

A4.23 *Communities on soft circalittoral rock*

A4.24 *Mussel beds on circalittoral rock*

A4.27 *Faunal communities on deep moderate energy circalittoral rock*

A4.3 Atlantic and Mediterranean low energy circalittoral rock

A4.31 *Brachiopod and ascidian communities on circalittoral rock*

A4.33 *Faunal communities on deep low energy circalittoral rock*

A4.7 Features of circalittoral rock

A4.71 *Communities and circalittoral caves and overhangs*

A4.72 *Circalittoral fouling communities*

A5 Sublittoral sediment

A5.1 Sublittoral coarse sediment

A5.12 *Infralittoral coarse sediment*

A5.13 *Circalittoral coarse sediment*

A5.14 *Deep circalittoral coarse sediment*

A5.2 Sublittoral sand

A5.22 *Sublittoral sand in variable salinity*

A5.23 *Infralittoral fine sand*

A5.24 *Infralittoral muddy sand*

A5.25 *Circalittoral fine sand*

A5.26 *Circalittoral muddy sand*

A5.27 *Deep circalittoral sand*

A5.3 Sublittoral mud

A5.32 *Sublittoral mud in variable salinity (estuaries)*

A5.33 *Infralittoral sandy mud*

A5.34 *Infralittoral fine mud*

A5.35 *Circalittoral sandy mud*

A5.36 *Circalittoral fine mud*

A5.37 *Deep circalittoral mud*

A5.4 Sublittoral mixed sediments

A5.42 *Sublittoral mixed sediment in variable salinity (estuaries)*

A5.43 *Infralittoral mixed sediments*

A5.44 *Circalittoral mixed sediments*

A5.45 *Deep mixed sediments*

A5.5 Sublittoral macrophyte-dominated sediment

A5.51 *Maerl beds*

A5.52 *Kelp and seaweed communities on sublittoral sediment*

A5.53 *Sublittoral seagrass beds*

A5.54 *Angiosperm communities in reduced salinity*

A5.6 Sublittoral biogenic reefs

A5.61 *Sublittoral polychaete worms reefs on sediment*

A5.62 *Sublittoral mussel beds on sediment*

Appendix 2. Classification of marine and coastal ecosystem services (MCES) used in the literature review by Liquete et al (2013)

	MCES	Marine or coastal specific component	General definition
Provisioning services	Food provision	a. Fishing activities (including shellfishing) industrial or artisanal (either commercial or subsistence fishing). In general, fisheries are reported as total landings or catch per unit effort and, sometimes, corresponding jobs. b. Aquaculture is the farming of aquatic organisms, including fish, crustaceans, mollusks, seaweeds and algae.	*The provision of biomass for human consumption and the conditions to grow it. It mostly relates to cropping, animal husbandry and fisheries.*
	Water storage and provision	a. Water abstraction in marine and coastal environments is mostly associated to coastal lakes, deltaic aquifers or desalination plants. b. Marine water may also be used for industrial cooling processes or coastal aquaculture in ponds and raceways.	*The provision of water for human consumption and for other uses.*
	Biotic materials and biofuels	a. This includes medicinal (e.g. drugs, cosmetics), ornamental (e.g. corals, shells) and other commercial or industrial resources (e.g. whale oil, fishmeal, seal leather, algal or plant fertilizers). b. Biomass to produce energy can have a solid form (like wood from mangroves), liquid (like fuels extracted from algal lipids or whale oil) or biogas (from decomposing material).	*The provision of biomass or biotic elements for non-food purposes.*
Regulating services	Water purification	Treatment of human wastes (e.g. nitrogen retention); dilution; sedimentation, trapping or sequestration (e.g. of pesticide residues or industrial pollution); bioremediation (e.g. bioaugmentation after marine oil spills); oxygenation of ''dead zones''; filtration and absorption; remineralisation; decomposition.	*Biochemical and physicochemical processes involved in the removal of wastes and pollutants from the aquatic environment.*
	Air quality regulation	Vegetation (e.g. in mangroves), soil (e.g. in wetlands) and water bodies (e.g. open ocean), due to their physical structure and microbiological composition, absorb air pollutants like particulate matter, ozone or sulphur dioxide.	*Regulation of air pollutants concentration in the lower atmosphere.*
	Coastal protection	Natural defense of the coastal zone against inundation and erosion from waves, storms or sea level rise. Biogenic and geologic structures that form the coastal habitats can disrupt the water movement and, thus, stabilize sediments or create buffering protective zones.	*Protection against floods, droughts, hurricanes and other extreme events. Also, erosion prevention in the coast.*
	Climate regulation	The ocean acts as a sink (and only a very marginal source) for greenhouse and climate active gases. Inorganic carbon is dissolved into the seawater, organic carbon is formed through primary producers, a percentage of which is stored, and a percentage of which is sequestered.	*Regulation of greenhouse and climate active gases. The most common proxies are the uptake, storage and sequestration of carbon dioxide.*
	Weather regulation	For example, the influence of coastal vegetation and wetlands on air moisture and, eventually, on the saturation point and the formation of clouds.	*Influence of ecosystems and habitats on the local weather conditions such as thermoregulation and relative humidity.*
	Ocean nourishment	Natural cycling processes leading to the availability of nutrients in the seawater for the production of organic matter. Pedogenesis could be observed at the margin of certain wetlands and mangroves, depending on hydrodynamic conditions.	*In the terrestrial realm it refers to pedogenesis and soil quality regulation.*
	Life cycle maintenance	The maintenance of key habitats that act as nurseries, spawning areas or migratory routes (e.g. seagrasses, coastal wetlands, coral reefs, mangroves). These habitats and the connectivity among them are crucial for the successful life cycle of species. This also includes pollination (e.g. mangrove pollination), and seed and gamete dispersal by organisms. This service guarantees the maintenance of genetic diversity or gene pool protection.	*Biological and physical support to facilitate the healthy and diverse reproduction of species.*
	Biological regulation	Control of fish pathogens especially in aquaculture installations; role of cleaner fishes in coral reefs; biological control on the spread of vector borne human diseases; control of potentially invasive species.	*Biological control of pests mostly linked to the protection of crops and animal production that may affect commercial activities and human health.*
Cultural services	Symbolic and aesthetic values	Coastal communities have always shown strong bonds to the sea due to the local identity. Natural and cultural sites linked to traditions and religion are numerous in the coastal zone. Both coastal and inland societies value the existence and beauty of charismatic habitats and species such as coral reefs or marine mammals.	*Exaltation of senses and emotions by landscapes, habitats or species.*
	Recreation and tourism	The appeal of marine ecosystems is usually linked to wilderness, sports, or iconic landscapes and species. It can be related to coastal activities (e.g. bathing, sunbathing, snorkeling, scuba diving) and offshore activities (e.g. sailing, recreational fishing, whale watching).	*Opportunities that the natural environment provide for relaxation and amusement.*
	Cognitive effects	Inspiration for arts and applications (e.g. architecture designs inspired in marine shells, medical applications replicating marine organic compounds). Material for research and education (e.g. discoveries of new deep sea species). Information and awareness (e.g. respect for nature through the observation of marine wild life).	*Trigger of mental processes like knowing, developing, perceiving, or being aware resulting from natural landscapes or living organisms.*

Appendix 3. Nomenclature for the identification of stakeholders and management bodies

For each type of activity or stakeholder, tick (for yes) or ignore in the column B and add specifications and comments in columns C and D

Activity domain and stakeholders (individuals or organisations)	Study site name	Specifications Economic and social role	Comments Links with Ecosystem services
Private economic sectors	*Who are the private economic agents who use or impact ES in your study site?*		
Primary sector			
Fisheries			
Aquaculture			
Agriculture			
Forestry			
Secundary sector			
Food processing			
Energy industry			
Biotechnology			
Other industries (polluting industries)			
Tertiary sector			
Hotels and campsites			
Vacation homes			
Restaurants, pubs			
Tourism services (transportation, sport)			
Other services			
Non productive private sector			
Land owners			
Real estate owners			
Public productive sector	*Are ES in your study site used, affected or preserved by any type of public settlements?*		
Harbour infrastructures and services			
Energy production			
Water treatment plants			
Hydrological settlements (dams)			
Roads, railroads and airports			
Cultural infrastructures (parks, museums)			
Other public services			
Entertainment and citizenship	*Are there some particular claims concerning ES in your study site?*		
Recreational fishermen			
Landscape tourists			
Beach visitors			
Consumers of other public goods			
Consumers of private goods			
Consumers of private services			
Environment lobbyists			
Social and economic lobbyists			
Industrial lobbyists			
Public management bodies	*What are the management bodies whose action apply to ES in your study site?*		
Fish and Sea management body			
Agriculture management body			
Water management body			
Environment management bodies			
Energy policy			
Land management and spatial planning			
Research institutes			
Towns authorities			
Counties authorities			
Region authorities			
State authorities			
European authorities			

References: list of activity domain and stakeholders in the coastal zone adapted from studies by Cisin-Sain (1998), Leafe et al. (1998), Turner (2000), Ledoux and Turner (2002), Smith (2002), Buanes et al. (2004)

Appendix 4. Selection and estimation of indicators for kelp ES in the PNMI study site

Figure A4-1. Potential indicators for the Support, Provisioning and Cultural kelp ES.

	State	Potential supply	Actual supply	Demand
Key habitats supporting - strong biodiversity - commercial species - emblematic species	Total biomass MSFD & WFD index	Life cycle maintenance capacity	No of individuals	MSFD & WFD standards
Kelp harvesting & Alginates	Total biomass	Maximum sustainable harvest	Production Total landings CPUE	No fishermen No months in act. Wage/Min. wage Net return
Commercial fisheries (abalone, European lobster, seabass, pollock)	Total biomass	Maximum sustainable yield		
Local identity through remarkable species (grey seal, bottle-nose dolphin and European shag)	No of individuals	Not relevant	No of individuals	No of people who attach significance to these species
Ecotourism (sea life watching)	Presence of species with stated recreational value	Maximum sustainable No of tourists	No of tourists	No of tourists
Local identity through traditional activity (kelp harvesting)	Presence of kelp harvesting activity	Not relevant	No of cultural activities in relation to kelp harvesting	No of visitors in cultural events

Figure A4-2. Initial assessment (2013) of the Support, Provisioning and Cultural kelp ES.

	State	Potential supply	Actual supply	Demand
Key habitats supporting - strong biodiversity - commercial species - emblematic species	510 000 T	Life cycle maintenance capacity	Grey seals: 130 BN dolphin: 35 EU shag: 531	
Kelp harvesting & Alginates	510 000 T	180 000 T	52 000 T ~4.6 T/harv. hours	25 harvesters 123 month 2.7 42 500 €
Commercial fisheries (abalone, European lobster, seabass, pollock)				
Local identity through remarkable species (grey seal, bottle-nose dolphin and European shag)	Grey seals: 130 BN dolphin: 35 EU shag: 531		Grey seals: 130 BN dolphin: 35 EU shag: 531	
Ecotourism (sea life watching)	Grey seals: Yes BN dolphin: Yes EU shag: Yes		Up to 3000 visitors/mesh	Up to 3000 visitors/mesh
Local identity through traditional activity (kelp harvesting)	Yes		2 museum exhibitions 1 kelp fest !	16 752 visitors

Appendix 5. Review of the suitability of valuation in addressing specific stakeholder concerns, using the Triage framework in the North Devon Biosphere Reserve (NDBR)

Key to category score: Low (red) Moderate (amber) High (green)

Valuation Theme and Specific Context	Influence of policy on change in value	Potential for the value to change	Lack of other factors affecting the value service	Feasibility
SEASCAPE *Service:* Visual amenity *Policy issue*: The impact of the Atlantic Array on the AONB and views of Lundy.	[Moderate] • The policy decision (to permit or reject the development) is fundamental to the change in value. • However, this decision will not be taken locally. • In addition, the VALMER timeframe may not match the timetable of the consultation process. • Also, a range of costs and benefits will be considered during the licensing process, of which visual amenity is just one.	[High] • The seascape is very important to people and so impacts upon it are likely to significantly change the value of the service.	[High] • Manmade developments such as offshore wind farms are the main impact on the service.	[Moderate] • Adequate identification of the seascape character and the impacts of the Array should be the responsibility of the developer (through the Environmental Statement) and VALMER effort could be better focussed elsewhere. • The field is comparatively well researched.
BENTHIC HABITATS *Service:* Fisheries production (from food web and nursery habitat processes). *Policy issue*: Implementation of Marine Conservation Zones or wider voluntary agreements and changes in scallop dredging.	[High] • Management measures (to alter levels of impact) will have a direct effect on the value of the service. • The issue of habitat protection in fisheries management has been debated for some time, and economic arguments will provide a useful new perspective. • The designation of Marine Conservation Zone is taking place at a national level, but measures such as expanding voluntary agreements (e.g. the "Skate Box") can be led locally.	[High] • Benthic habitats are sensitive to impacts, and fisheries contribute to economic and cultural values.	[Moderate] • The role of benthic habitats in fisheries production can be affected by external factors including climate change and the introduction of invasive species. • Market factors and political intervention (e.g. subsidies) affect the value of fisheries.	[High] • The strong natural science capacity within the VALMER team will also ensure proper understanding of ecological linkages required to support valuation techniques.

Valuation Theme and Specific Context	Influence of policy on change in value	Potential for the value to change	Lack of other factors affecting the value	Feasibility
ESTUARINE HABITATS *Service(s):* Remediation of waste, carbon sequestration *Policy issue:* Managed retreat within the estuary	• Management measures (to increase the area of saltmarsh) will have a direct effect on the value of the service.	• Estuarine habitats are sensitive to impacts, but local-scale values for carbon sequestration are very small. • Also, the saltmarsh created will replace agricultural land (used primarily for grazing) so the lost remediation and sequestration services from that land must be considered.	• The ability of habitats and species to neutralise and sequester waste can be affected by external factors including climate change and the introduction of invasive species. • Carbon prices are affected by market forces and Government policy (e.g. the carbon price floor).	• As with the benthic habitats theme, the very strong natural science capacity within the VALMER team will provide a solid ecological basis for valuations.
WATER QUALITY *Service:* Remediation of waste *Policy issue(s)*: Loss of Blue Flag status, and the implementation of the Water Framework Directive and Marine Strategy Framework Directive.	• Policies directed at water quality improvements are most likely to focus on the source of the pollution input (agriculture, combined sewer overflow outfalls), so the suppy and value of the marine ecosystem service will not change.	• A small change in value is expected, as dilution is the main marine influence on water pollution from riverine inputs. • Substitute recreational sites are also available.	• The ability of habitats and species to neutralise and sequester waste can be affected by external factors including climate change and the introduction of invasive species.	• There is very strong natural science capacity within the VALMER team, providing the opportunity to assess the value of species and habitats in maintaining water quality (as opposed to the more comparatively well studied field of determining willingness to pay to reduce, for example, poor visibility).
RECREATION 1. *Service:* Birdwatching, existence value (birds) *Policy issue*: Disturbance of birds by kitesurfers. 2. *Service:* Recreation (general) *Policy issue*: Disturbance of other users by jetskiiers outside their zone.	• Defined policy measures (such as improved education and enforcement) could reduce the problem and restore the value of the service. • However, this is not a current management priority.	• The change in value is likely to be small, due to the availability of substitute sites (for both birds and people) in the area.	• Recreation choices are influenced by a range of factors, and wider issues (such as climate and the economic downturn) may have a more significant effect on the value of recreation in North Devon.	• There is some expertise in this area, but limited capacity for primary data gathering, which would be necessary to value recreational services

Appendix 6. Social and economic methods for the assessment of Ecosystem Services

Equally important to understanding the sensitivity behind the delivery of ecosystem services is the understanding of the social and economic benefits arising from ecosystem services. Social and economic assessment methods can be organised through different ways; stated preferences VS revealed preferences, deliberative process VS authoritarian, group based method VS individual based method, multiple attributes VS single attribute. We give below some definition of assessment methods which allow for capturing the values of ecosystem services. These definitions come, for a large part, from the Environmental Protection Agency report entitled *Valuing the protection of ecological systems and services* (EPA 2009).

1. Measures of attitudes, preferences, and intentions

Social-psychological approaches allow to characterize and measure the values people hold, express, and advocate with respect to changes in ecological states or their personal and social consequences. These methods elicit value-relevant perceptions and judgments, typically expressed as choices, rankings, or ratings among presented sets of alternative ecosystems protection policies and may include comparisons with potentially competing social and economic goals. Individuals making these judgments may respond on their own behalf or on behalf of others. The basis for judgments can be changes in individual well-being or in civic, ethical, or moral obligations.

Survey questions eliciting information about attitudes, preferences, and intentions are most often presented in a verbal format. Assessments can be well-conveyed in perceptual surveys and conjoint surveys (e.g., requiring choices among alternatives that combine multiple attributes). Surveys are based on *quantitative* analyses of responses from large representative samples.

Narrative methods based on unstructured individual interviews and small samples of informants and analyze responses *qualitatively*.

Focus groups can be used to elicit information about values and preferences from small groups of relevant members of the public engaging in *group discussion* led by a facilitator.

Behavioral observation methods elicit values information through observations of *behavioral responses* by individuals interacting with either actual or computer-simulated environments. Observing how the activities of people change as environmental conditions change can reveal information about the importance of these changes to those people.

2. Economic methods

Economic valuation methods seek to measure the trade-offs individuals are willing to make for ecological improvements or to avoid ecological degradation, given the constraints they face.

They are based on the utilitarian concept of total economic value (TEV) of the environment, an expression of the many ways through which people benefit from the environment. As put in Barbier (1997), TEV distinguishes between use value and non-use values, use values involving some interactions between human and Nature whereas non-use values do not and rely mostly on its continued existence. Use values are either direct (e.g. people benefit directly from the use of seashore for recreation) or indirect (e.g. the regulatory ecological functions of the ocean and their impacts on climate change). Use values also consider actual uses and potential future uses (option use). The TEV framework, as applied to the marine and coastal environment, is illustrated in Table 1

Tableau 1 - Classification of Total Economic Value for Marine Environment (adapted from Barbier 1997)

Uses Values			Non-Use Values
Direct Use Value	Indirect Use Value	Option Value	Existence Value
Fish Recreation Esthetics Transport Wildlife harvesting	Climate stabilisation	Potential future uses	Biodiversity Bequest Values Culture, heritage

Tradeoffs people are willing to make is captured through the economic notion of "willingness to pay" (WTP), i.e. the amount of money the people would agree to pay in order to benefit from a given ecological improvement or to avoid some specific ecological degradation, in order to maintain a given level of satisfaction. WTP can be computed through the use of prices for some ecological services. However, most ecological services are unmarketed and specific economic valuation methods are therefore required.

In order to assess WTP, one can either carry ad hoc studies, or rely on previous values of WTP in the existing literature. Economic valuation methods involving ad hoc studies are classified into revealed preference (RP) methods and stated preference (SP) methods. RP methods rely on actual individuals' behaviour to elicit preferences for ecosystem services. Preferences are revealed indirectly, i.e. through the purchase of a market good which is associated with the given ecosystem service. The strength of this group of methods is that they rely on historical data. Their weaknesses are that they only capture use values and do not allow eliciting preferences for changes in ecosystem services beyond the range of historical experience. SP methods allow estimating benefits of changes in ecosystem services beyond the range of experience. Their strength is that they capture both use and non-use values. Their weakness is that they are based on intended behaviour, which may differ from what individuals' would actually do. These two groups of methods can be combined in order to exploit their contrasting strengths while minimizing their weaknesses.

3. Revealed preference methods:

Travel cost method (including applications using random utility models) use information about how much people implicitly or explicitly pay to visit locations with specific environmental attributes including, specific levels of ecosystem services, to infer how much they value changes in those attributes. Type of measured value: Recreational use value.

For more information see:
In French: http://www.economie.eaufrance.fr/IMG/pdf/05-M05_Guide_de_BP_pour_la_mise_en_oeuvre_de_la_MCT.pdf
In English: http://www.ecosystemvaluation.org/travel_costs.htm

Hedonic pricing uses information about how much people pay for houses or other directly-purchased items with specific environmental attributes (e.g., visibility, proximity to amenities or disamenities) to infer how much they value changes in those attributes. Type of measured value: Residential use value

For more information see:
In French: http://www.economie.eaufrance.fr/IMG/pdf/05-M01_Guide_de_BP_pour_la_mise_en_oeuvre_de_la_MPH.pdf
In English: http://www.ecosystemvaluation.org/hedonic_pricing.htm

Averting-behavior methods use observations on how much people spend to avoid adverse effects, including environmental effects to infer how much they value or are willing to pay for the improvements those expenditures yield.

For more information see:
In English: http://www.ecosystemvaluation.org/cost_avoided.htm

4. Stated preference method:

Contingent valuation directly elicits values through surveys by asking people about their willingness to pay for a given ecosystem service. Types of measured values: use and non-use values.

For more information see:
In French: http://www.economie.eaufrance.fr/IMG/pdf/05-M04_Guide_de_BP_pour_la_mise_en_oeuvre_de_la_MEC.pdf
In English: http://www.ecosystemvaluation.org/contingent_valuation.htm

Contingent behaviour directly elicits values through surveys by asking people about their hypothetical behaviour towards a given ecosystem service

Choice experiment successively presents a number of choice sets to respondents and asks them to choose their preferred scenario. Each choice set consists of two or three scenarios related to the good under valuation. This good is defined by its key attributes (or characteristics) and the levels that these attributes take, where one attribute is price.

For more information, see:
In French: http://www.developpement-durable.gouv.fr/IMG/pdf/ED49.pdf
In English: http://www.ecosystemvaluation.org/contingent_choice.htm

5. Benefit transfer

Benefit transfer method estimates the economic values of ecosystem services using existing estimates from studies completed for another location or issue. The critical part of benefit transfer consists in adapting the value derived from existing studies to some other context. The strength of benefit transfer is that it is a cheaper and faster way to compute economic value, compared to an original site-specific valuation study. The weakness is that it relies upon the availability and the accuracy of previous studies on the same issue.

For more information, see:
In French: http://www.insee.fr/fr/ffc/docs_ffc/es336d.pdf
In English: http://www.ecosystemvaluation.org/benefit_transfer.htm

6. Civic valuation

Civic valuation seeks to measure the values that people place on changes in ecosystems or ecosystem services when explicitly considering or acting in their role as citizens.

Referenda or initiatives can provide information about how members of the *voting* population value a particular governmental action involving the environment, given a particular means of financing the associated expenditure. Individuals may also consider what the community as a whole stands to gain or lose if the proposal is adopted.

Citizen valuation juries are given *extensive information* and, after a *lengthy discussion*, usually asked to agree on a common value or make a group decision. Citizen juries can develop a ranking of alternative options for achieving a given goal. Their estimates would reflect *community-based values* rather than economic values.

7. Ecosystem benefit indicators and biophysical ranking methods

Ecosystem benefit indicators offer quantitative metrics that are correlated with ecological contributions to human well-being and can serve as indicators for these contributions in a specific setting. They use data to provide information related to the demand for, supply (or scarcity) of ecosystem services. Although the resulting indicators can be correlated with other value measures, such as economic values, they do not themselves provide measures of value. Quantification of ecological changes in biophysical terms allows these changes to be ranked based on individual or aggregate indicators for use in evaluating policy options based on biophysical criteria previously determined to be relevant to human/social well-being.

The **conservation value method** develops a spatially-differentiated index of conservation value across a landscape based on an assessment of rarity, persistence, threat, and other landscape attributes, reflecting the contribution of these attributes to sustained ecosystem diversity and integrity. These values can be used to prioritize land for acquisition, conservation, or other purposes, given relevant biophysical goals. Based on geographic information system (GIS) technology, the method can combine information about a variety of ecosystem characteristics and services across a given landscape and overlay ecological information with other spatial data.

Assess **the lows of energy and materials** through complex ecological systems, economic systems, or both. Ecologists have used these methods to identify the resources or resource-equivalents needed to produce a product or service, using a systems or life-cycle ("cradle to grave") approach. For example, **embodied energy analysis** measures the total energy, direct and indirect, required to produce a good or service. Similarly, **ecological footprint analysis** measures the area of an ecosystem (e.g., the amount of land and/or water) required to support a certain level and type of consumption by an individual or population.

8. Methods using cost as a proxy for value

Fundamental principle in economics is the distinction between benefits and costs. In the context of ecosystem services, economic benefits reflect what is gained by increasing the amount of a given service relative to some baseline, while costs reflect what must be given up in order to achieve that increase. Costs can provide information about benefits or value only under specific and limited conditions. First, there must be multiple ways to produce an equivalent amount and quality of the ecosystem service. Second, the value of the ecosystem service must be greater than or equal to the cost of producing the service via this alternative means, so that society would be better off paying for replacement rather than choosing to forego the ecosystem service.

Habitat equivalency analysis (HEA). HEA seeks to determine the restoration projects that would provide ecosystem or other related services (including capital investments such as boat docks) sufficient to compensate for a loss from a natural-resource injury (e.g., a hazardous waste release or spill). In principle, to determine whether a set of projects provides sufficient compensation for a loss, HEA should determine the tradeoffs required to make the public whole using utility equivalents of the associated losses and gains – i.e., it should use a value-to-value approach. However, in practice HEA is often based on a service-to-service approach specified in biophysical equivalents rather than utility equivalents.

The price of **tradable emissions permits** under cap-and-trade systems will almost never meet the requirements for using cost as a proxy for value. The price of an emission permit in a well-functioning market will reflect the incremental cost of pollution abatement. This price does not reflect the value of pollution reduction unless one of two conditions is met: a) the number of permits is set optimally, so that the incremental cost of pollution equals the incremental benefit of pollution reduction; or b) there are significant purchases of permits for purposes of retiring rather than using the permit, which indicates the willingness-to-pay for pollution reduction by the purchaser.

9. Cross-methods

Natural capital project crosses ecosystem benefit indicators, economic methods (InVEST software) and decision science valuation methods (adaptive co-management). InVEST is a family of tools to map and value the goods and services from nature which are essential for sustaining and fulfilling human life. Values can be expressed through biophysical indicators of ecosystem services or through economic returns. InVEST enables decision-makers to assess the tradeoffs associated with alternative choices and to identify areas where investment in natural capital can enhance human development and conservation in terrestrial, freshwater, and marine ecosystems. InVEST is most effectively used within a decision-making process that starts with stakeholder consultations as suggested in the Natural capital project.

Companion modeling for common pool resources crosses ecosystem benefit indicators, economic methods (CORMAS software, http://cormas.cirad.fr/ComMod/) and decision science valuation methods. The companion modeling approach is a collective learning process that takes place in the interaction between the stakeholders and the models they build together. The implementation of such processes requires to take into account multiple skills and multiple point of view. Modeling is used to clarify and formalize the values and to simulate the evolution of the ecosystem studied. Its collective implementation aims to produce a shared representation of the different values expressed by stakeholders. Collective discussion around the simulation results help to make explicit conflicts between the various values defended by different stakeholders.

Appendix 7. Results of the Ecosystem Accounting in the GNB

Physical indicators of ES in the Normand-Breton Gulf (GNB), 2013 values

Type of ecosystem services	Ecosystem services		State indicators	Indicators of ecosystem service production	Indicators of ecoystem service consumption
Provisioning services	fish, shellfish and crustaceans accessibles to fisheries	Scallop		5 672 t	7 920 t
		black seabream		863 t	894 t
		cuttlefish		2 212 t	2 685 t
		clam		1 154 t	421 t
		whelk		6 748 t	9 038 t
		common sole		234 t	180 t
		ray		527 t	160 t
		european lobster		110 t	207 t
		european spider crab		1 877 t	2 134 t
		other species			3 972 t
	Cultivated oysters and mussels	oysters			25 301 t
		mussels			28 700 t
	Maerls and shell sand accessibles to extractive	Maërls			214 920 t
		shell sand			119 330 t
Cultural services	aesthetic services: seascape landscape	recreational fishing	Surface : 484 km²		2 113 k-hours
		Hiking	Distance of littoral paths: 520 km		8 659 k-hours
		Recreational boating	Surface : 2 322 km²		2 158 k-hours
		Kayaking	Distance of paths for kayaking: 341 km		1 116 k-hours
		Voile légère	Surface : 4 376 km²		1 111 k-hours
		Scuba-diving and underwater fishing	Surface : 17 km², 123 points for scuba-diving		79 k-hours
	aesthetic services: submarine landscape	recreational fishing	Surface : 484 km²		103 k-hours
		Recreational boating	Surface : 2 322 km²		105 k-hours
		Kayaking	Distance of paths for kayaking: 341 km		20 k-hours
		Scuba-diving and underwater fishing	Surface : 17 km², 123 points for scuba-diving		394 k-hours
	recreative services : extraction of halieutic resources	recreational fishing	Surface : 484 km²		2 938 k-hours
		Recreational boating	Surface : 2 322 km²		2 738 k-hours
		Kayaking	Distance of paths for kayaking: 341 km		117 k-hours
		Scuba-diving and underwater fishing	Surface : 17 km², 123 points for scuba-diving		228 k-hours
Regulation services	Climate change				
	Reducing polluant matters				
	Prevention / protection against perturbations				
	Preventing erosion				

Production indicators for fish provisioning services have been estimated following the DCAC methodology.

Economic indicators of ES in the Normand-Breton Gulf (GNB), 2013

Activities aiming at maintening the proudction of ecosystem services	Supply accounting indicators
Management of natural resources	Production : 12 M€ Added value : 7 M€ Intermediate consumptions : 5 M€ Labour (in FTE) : 131
Protection of ecosystems	Production : 113 M€ Added value : 49 M€ Intermediate consumptions : 64 M€ Labour (in FTE) : 537

Budget : 125 M€
Demand accounting indicators

Ecosystem goods and services
Provisioning services
Fish and shellfish accessible to the commercial fishing sector
breeding stock of oysters and mussels
Maerls, shell sand accessible for extraction
algae accessible to à l'algaculture
Regulation and maintenance services
Filtration of polluants
Biodiversity support
Biochemical support, carbon sequestration
Cultural services
Experimental of physical use of ecosystems (animals, fish, landscape ...)
Aesthetics and symbolic values

Activities consuming ecoystem goods and services	Supply accounting indicators	Demand accounting indicators
Fishing activity	Production : 66 M€ Added value : 38 M€ Intermediate cons. : 28 M€ Labour (in FTE) : 917	Intermediate product : 41 M€ Final product : 25 M€
shellfish farming (oyster and mussel farmings)	Production : 143 M€ Added value : 95 M€ Intermediate cons. : 50 M€ Labour (in FTE) : 2078	Intermediate product : 22 M€ Final product : 121 M€
Extractive industry	Production : 0,3 M€ Added value : 0,1 M€ Intermediate cons. : 0,2 M€ Labour (in FTE) : s.	Intermediate product : 0,3 M€ Final product : 0 M€
Algaculture		
Recreational services produced by households for own use	Production : 209 M€ - 276 M€ Added value : 121M€ - 187M€ Intermediate cons. : 89 M€ Travail (en ETP) : 6867	Intermediate product : 0€ Final product : 209 M€ - 276 M€
Recreational services produced by associations	Production : 6 M€ Added value : 4 M€ Intermediate cons. : 2 M€ Labour (in FTE) : 106	Intermediate product : 0€ Final product : 6 M€
Museums and cultural events	Production : N.C. Added value : N.C. Intermediate cons. : N.C. Labour (in FTE) : N.C.	Intermediate product : N.C. Final product : N.C.

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