Options for Delivering Ecosystem-Based Marine Management

The ODEMM Approach to Analysing the Costs & Benefits of Marine Management

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Authors: Salman Hussain[1], Corinne Baulcomb[1], Helen Bloomfield[2], Anne Böhnke-Henrichs[3], Fiona Culhane[2], Abdulai Fofana[1], Chris Frid[2], Rudolf de Groot[3], George Halkos[4], Rebecca Koss[2] and Leonie Robinson[2]

[1] Land Economy, Environment & Society Research Group, SRUC, Edinburgh UK.
[2] School of Environmental Science, University of Liverpool, UK.
[3] Environmental Systems Analysis, Wageningen UR, Netherlands.
[4] Department of Economics, University of Thessaly, Greece.

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1 Introduction

Cost-Benefit Analysis

The primary purpose of the economics work package within ODEMM was to explore the costs and benefits implied by the adoption of new marine management efforts that were directed at a particular MSFD high level descriptor. The over-arching framework selected for the economic analysis was that of cost-benefit analysis (CBA). CBA is an economic decision-support tool that evaluates the changes in costs and benefits that occur when a Management Option (MO) is applied, typically measuring these changes in monetary terms. CBA is a decision-making tool that can inform policy-making (Hussain and Gundimeda, 2011) because it can be used to compare different management options.

In the context of ODEMM, there was a need to apply CBA to the analysis of MOs that were developed in accordance with the ecosystem approach (EA). EA is a managed response to anthropogenic impacts on marine ecosystems, aiming to facilitate the protection, recovery, and sustainable use of marine ecosystems. In attempting to mitigate such impacts, operationalising any management option is likely to entail trade-offs in the sense that there are some sectors that will realise net benefits from the application of a particular management option and others that will incur net losses. There are winners and losers even *within* a body of stakeholders (e.g. fishermen). Furthermore, one significant broad stakeholder group is 'wider society,' and it is important to capture these broader social welfare changes arising from any MO[1]. The application of CBA to the evaluation of multi-sector MOs allows researchers to better understand the range of socio-economic trade-offs implied by pursuing ecosystem-based management (EBM).

The entry point for the CBA analysis in ODEMM is to presume that any MO is indeed feasible, and that as a consequence, there is the potential for its implementation to have an impact on the state of the ecosystem (and the state of the economy). The rationale for assessing individual MOs or a suite of options applied concurrently (a 'management scenario') is, under the EC MSFD, based on the need to reduce the risk of failing to meet good environmental status (GES) across a range of specific descriptors. The economic assessment, however, is not directly linked to GES. A MO that changes the state of the marine ecosystem (*towards* GES, or such that the final state *is* GES) is assessed in economic terms based on how the change in state that is associated with the MO affects the delivery of marine *ecosystem services* (ESs).

The concept of ESs provides a mechanism for people to understand how our existence is linked with the natural environment, and they have been defined as "the direct and indirect contributions of ecosystems to human well-being" (de Groot et al., 2010; Böhnke-Henrichs et al., 2013). We discuss the range of ESs that are relevant in marine ecosystems in detail below, but in terms of CBA more broadly, ODEMM uses ESs as a unit-of-account for assessing the *incremental* changes that arise when the state of the ecosystem changes. Note here that we refer to 'changes' as opposed to simply 'benefits'. The way that we carry out our analysis is to consider each ES in turn and assess, where possible, whether the supply of a particular ES will be higher or lower (and the extent of change) when comparing one MO with another.

In CBA, the analysis of benefits and costs is based on *marginal changes*. By this we mean that the effect of a MO depends on what the state of the ecosystem and the economy would be *in the absence of that particular management option*. In ODEMM, this focus on marginal change has been expressed in terms of Business-As-Usual (BAU) and Business-As-Usual + (BAU+). In some ODEMM case studies, there was more than one BAU+ scenario (see Annex 1 for a summary of management scenarios explored across a range of regional case studies).

[1] The constituency of affected stakeholder groups links back to *governance* in the sense that authorities charged with consulting on the particular MO have to balance the potentially conflicting views voiced by the various stakeholders. This can in turn influence which MOs are feasible in governance terms.

What we were typically looking at in ODEMM then is *trade-off analysis* – not only in terms of a trade-off between stakeholders affected by operationalising a management option but also trade-offs *between ESs*. A MO might for instance be the establishment of a new network of MPAs. This may realise positive changes in some cultural ESs linked to biodiversity conservation but might also imply a short-run reduction in fish catch (and thus the ES termed 'sea food'), depending on the specifics of the MO. In order to allow this trade-off analysis to be carried out appropriately, ODEMM has developed a typology of ESs. This is discussed in Section 2 of this report.

Pathways to Impact

It is also important to note that the approach adopted in ODEMM allows for the consideration of different *pathways* to changes in ES delivery. Consider Figure 1. Restriction of activities by the fisheries sector, for example, will directly impact upon the ES of Sea Food. In this case, the linkage is directly from the MO to a sector and directly to an ES (i.e. arrows 4a→5a). In the case of the cultural ESs, however, the chain of impact is mediated by changes in ecological components (i.e. arrows 4b→2→5b).

Because of the linkages between ecological components and ESs, one of the main tasks within the Economics work has been the investigation of the relative contribution of ecosystem components to different ESs: how these linkages can be identified and utilised, what is known about them, and what is not known. This is discussed further in Section 3.

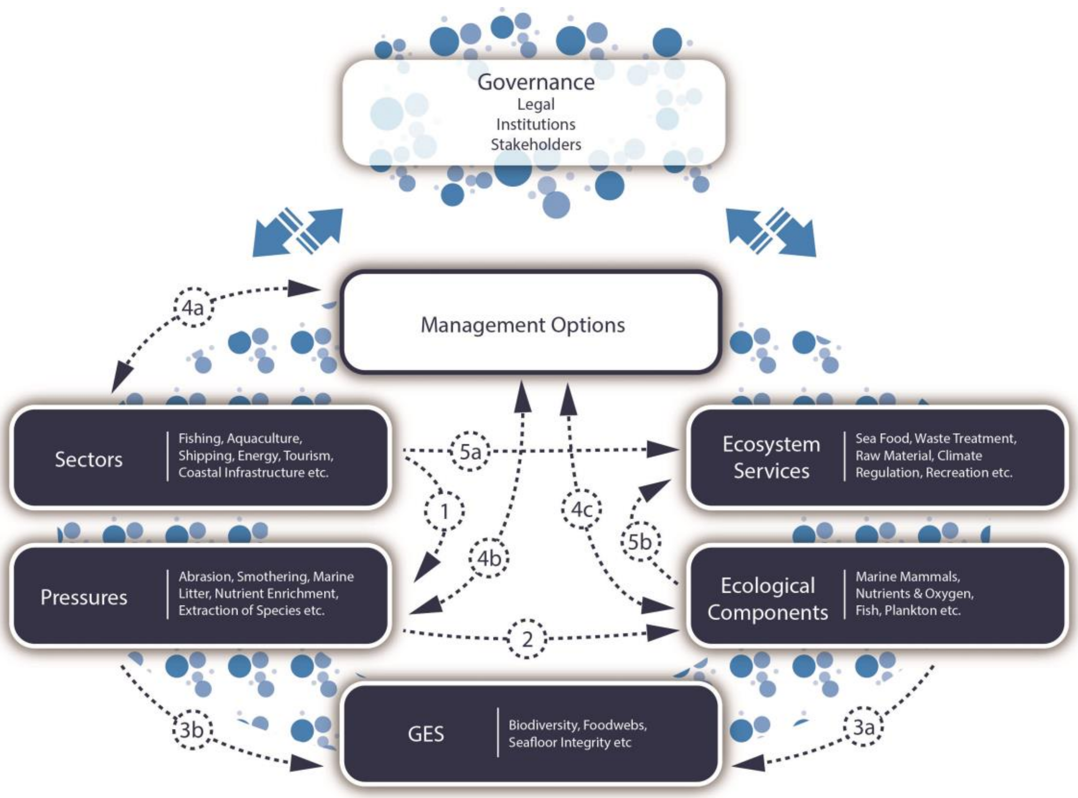


Figure 1 Appraisal of management options takes into consideration the potential implications for ecosystem services provisioning and the cost of implementing management options

Benefit Analysis

This assessment of change in ES supply arising from changes in the activities of sectors and in the state of ecological components as a part of any given BAU+ scenario is, by nature, a bio-physical analysis. In contrast, the assessment in changes in human welfare is, by nature, an economic analysis.

Consequently, it was necessary to design the typology of ESs such that it could transition from a bio-physical analysis to an economic analysis that focuses on the *human benefits* provided by marine ecosystem.

There is considerable variability, however, in the extent to which the benefits arising from applying CBA are measurable, and also in the extent to which they can be valued in monetary terms. For instance changes in fish stocks have a relatively direct market value whereas other benefits (such as a feeling of wellbeing arising from the aesthetics of the marine landscape) are much less tangible. In economic terms, changes in ecosystems can realise *welfare effects* even if these changes do not have a direct market price. For instance, marine habitats might provide inspiration for art or provide opportunities for leisure and recreation that people do not pay for directly in the market (e.g. there is no charge to swim in the sea, and yet it is clear that people value such access). Some elements of these benefits afforded to us might be marketed (e.g. the price for a painting that has been inspired by the ocean, or the premium that we may pay for a hotel with a sea view or direct access to a beach), but the ability to use what are termed 'surrogate markets' is limited, and approaches that rely on these surrogate markets only partially capture relevant benefits (Edwards-Jones et al., 2000; Hussain and Gundimeda, 2011).

This has led to the development of economic methodologies that allow one to value the non-marketed benefits that nature provides. ODEMM has contributed significantly to this evidence base, and key results are set out in Section 4.

Cost Analysis

The assessment of costs is similar to that of the assessment of benefits in that there needs to be a coherent *typology* of costs (that includes all elements whilst avoiding double-counting) and also the categorisation of *marginal* costs. The former is typically split between one-off and on-going costs, and between those costs borne by industry and those by the regulator. In terms of focusing on marginality, it is important to consider what cost elements are truly additional. For instance, some regulatory interventions that might be proposed as MOs for the MSFD might *already* be implemented under the auspices of other EC Directives such as the Water Framework Directive. This applies for instance in our assessment in ODEMM of measures to reduce nutrient loading in the Baltic Sea. It would, therefore, not be appropriate to consider those costs to be a part of the implementation of the MSFD.

A typology for the assessment of costs is set out in Section 5. Section 6 provides a synopsis and highlights ODEMM's key achievements in this area of work as well as data gaps and avenues for future research. Throughout this report, we use individual examples from case study regions.

2 The ODEMM typology of Marine Ecosystem Services

The concept of ESs provides a mechanism for people to understand how our existence is linked with the natural environment (MA, 2005). The need for a typology of ESs arises so as to ensure that all these benefits are made explicit as any omission of benefit categories leads to a systemic under-representation of the benefits arising from measures aimed at conserving nature. The core principle is to make the benefits visible, to remove what is otherwise a pro-extractive, contra-conservation bias in decision-making. But there is also a corollary to this argument in that the typology must be designed so as to avoid double-counting.

The Economics of Ecosystems and Biodiversity (TEEB) study (TEEB 2010) has developed such a typology, following (but modifying) the framework used in the Millennium Ecosystem Assessment (MA, 2005). There are four main categories of services: (1) provisioning services such as sea fish for human consumption; (2) regulating services such as gas and climate regulation; (3) supporting/habitat services (e.g. sea grass beds providing a nursery habitat for juvenile fish); and (4) cultural/amenity services such as leisure and recreation.

The typologies in TEEB (2010) and MA (2005) are both constructed from a terrestrial ecosystem perspective; Beaumont et al. (2008) argue that marine ecosystems have been marginalised. Costanza et al. (1997) values global ecosystem services and natural capital at US$16-54 trillion per annum and this remains arguably the most significant publication in the valuation literature. Notwithstanding the methodological controversies as to the actual estimates reported, the *ratio* of marine/terrestrial ecosystem service values is noteworthy, with marine ecosystems providing around two-thirds of the global aggregate. If this is coupled with the evidence to support the contention that this service provisioning is threatened (e.g. Halpern et al., 2008) then the need for a service typology that is framed for marine ecosystems and that is internally consistent (i.e. a typology that avoids double-counting) follows. Boyd and Banzhaf (2007) go so far as to argue that a lack of internal consistency, particularly as it relates to the non-provisioning services, has severely constrained the adoption and operational use of the ecosystem service typologies published to date in the literature.

Böhnke-Henrichs et al. (2013) present an analysis carried out for ODEMM that reviews and then develops currently-available typologies. Although there are a couple of extant marine-focused (Beaumont et al., 2007; Atkins et al., 2011), the MA (2005) and TEEB (2010) typologies remain ubiquitous in the policy arena. This would not be problematic were the differences between these dominant typologies and marine-focused to be semantic (e.g. defining 'Sea Food' as a marine-specific ES rather than 'Food', or the removal of inapplicable services such as 'Pollination' and 'Maintenance of soil fertility'). The more substantive issue is where to draw the boundaries around a service so as to avoid double counting, and to allow for the analysis of trade-offs between services. For instance, extracting fish for 'Sea Food' reduces their abundance and this could affect opportunities for 'Recreation and Leisure' for those wishing to go snorkelling or diving. It may also have consequences in terms of the provision of the 'less tangible' cultural services. These boundary issues are not unique to marine ecosystems but the potential for double-counting is greater in some cases as compared to terrestrial ecosystems because of the (literal) fluidity of the system.

The scientific rationale for the categorisation of ESs in the ODEMM typology is set out in Böhnke-Henrichs et al. (2013). Figures 2-5 set out summary ES cards that were developed for the ODEMM Road shows for the four regional seas in October and November 2013. Using these cards (and Böhnke-Henrichs et al., 2013) allows decision-makers to begin to identify those ESs that are likely to be priorities in their particular decision-making context. The ODEMM ES cards are available to download for use of the typology from www.odemm.com/content/cost-and-benefits-analyses.

Figure 2 Summary Ecosystem Service cards – 'Provisioning' services

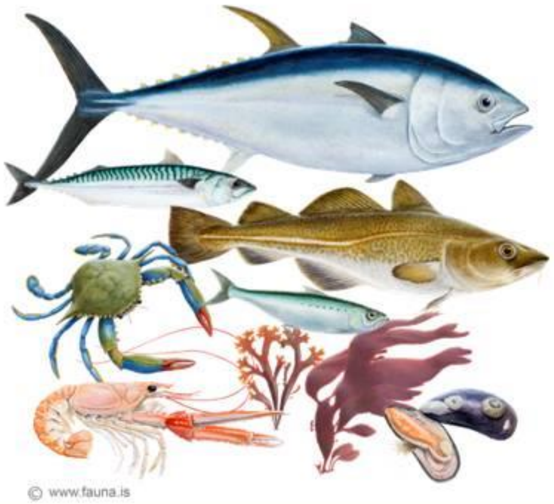
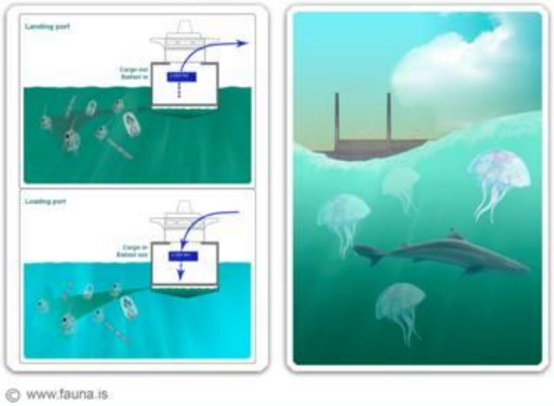
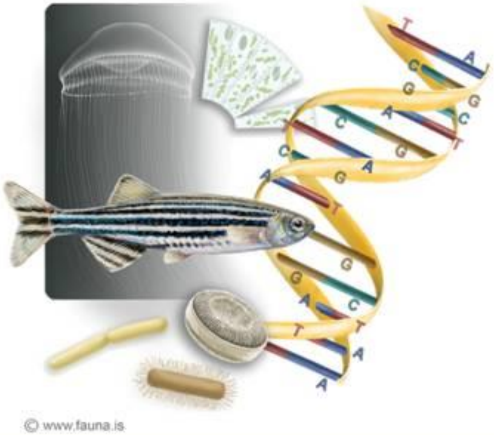
PROVISIONING SERVICE	PROVISIONING SERVICE	PROVISIONING SERVICE
SEAFOOD	**SEA WATER**	**RAW MATERIALS**
Examples Fish, Shellfish, Seaweed	**Examples** Seawater used in shipping, Industrial cooling, Desalinization	**Examples** Algae (non-food), Sand of biogenic origin
		
All available marine fauna and flora extracted from coastal/marine environments for the specific purpose of human consumption as food	*Marine water in oceans, seas and inland seas that is extracted for use in human industry and economic activity*	*The extraction of any biogenic material from coastal/marine environments*

Figure 2 Summary Ecosystem Service cards – 'Provisioning' services (continued)

PROVISIONING SERVICE

GENETIC RESOURCES

Examples
Use of marine flora/fauna-derived genetic material to improve crop resistance



The provision/extraction of genetic material from marine flora and fauna for use in non-marine, non-medicinal contexts

PROVISIONING SERVICE

MEDICINAL RESOURCES

Examples
Marine-derived pharmaceuticals; Marine/coastal derived salt-water used for health purposes

Any material that is extracted from the coastal/marine environment for its ability to provide medicinal benefits

PROVISIONING SERVICE

ORNAMENTAL RESOURCES

Examples
Shells, Aquarium fish, Pearls, Coral

Any material extracted for use in decoration, fashion, handicrafts, souvenirs, etc.

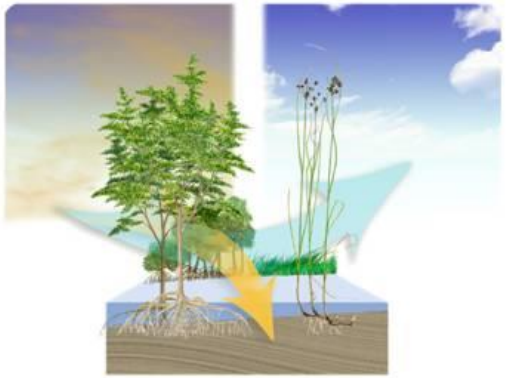
Figure 3 Summary Ecosystem Service cards – ‘Regulating’ services

REGULATING SERVICE

AIR PURIFICATION

Examples

The removal from the air of pollutants like fine dust and particular matter, sulphur dioxide, carbon dioxide, etc.



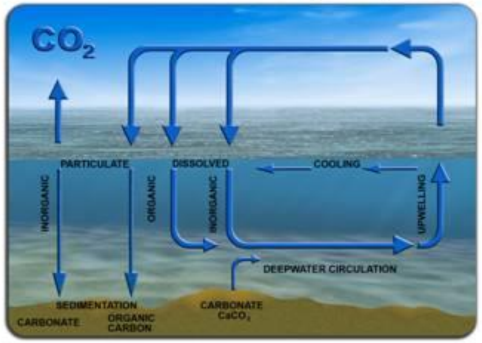
The removal from the air of anthropogenic pollutants by a coastal/marine ecosystem

REGULATING SERVICE

CLIMATE REGULATION

Examples

Production, consumption and use by marine organisms of gases such as carbon dioxide, water vapour, nitrous oxides, methane and dimethyl sulphide



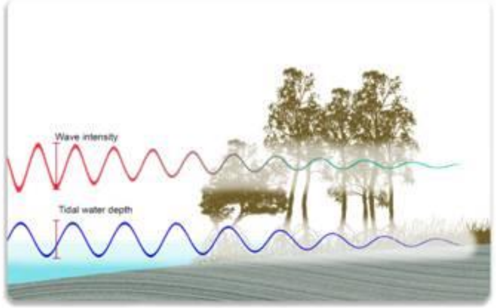
The contribution of biotic elements of coastal/marine ecosystems to the maintenance of a favourable climate

REGULATING SERVICE

DISTURBANCE PREVENTION AND MODERATION

Examples

The reduction in the intensity or and/or damage caused by environmental disturbances resulting directly from marine ecosystem structures like salt marshes, sea grass beds and mangroves



The contribution of marine ecosystem structures to the dampening of the intensity of environmental disturbances

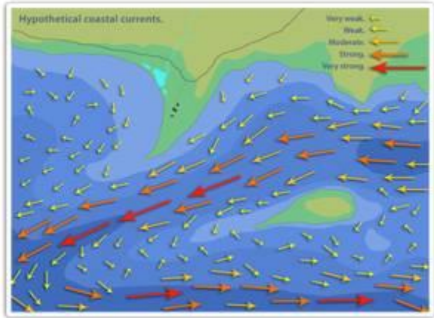
Figure 3 Summary Ecosystem Service cards – ‘Regulating’ services (continued)

REGULATING SERVICE

REGULATION OF WATER FLOWS

Examples

Effect of macro-algae on localized current intensity; Maintenance of deep channels used for shipping by coastal currents



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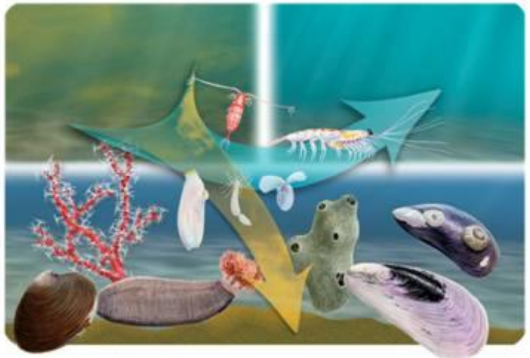
The contribution of marine/coastal ecosystems to the maintenance of localized coastal current structures

REGULATING SERVICE

WASTE TREATMENT

Examples

Breakdown of chemical pollutants by marine microorganisms; filtering of coastal water by shell fish



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The bioremediation of anthropogenic pollutants by coastal/marine ecosystems

REGULATING SERVICE

COASTAL EROSION PROTECTION

Examples

Maintenance of coastal dunes by coastal vegetation; reduction in scouring potential that results for near-shore macro-algal forests

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The contribution of coastal/marine ecosystems to Coastal Erosion Prevention

Figure 3 Summary Ecosystem Service cards – ‘Regulating’ services (continued)

REGULATING SERVICE

BIOLOGICAL CONTROL

Examples

Role that top predators play in limiting populations of opportunistic species like jellyfish and squid

Contribution of marine/coastal ecosystems to the maintenance of natural healthy population dynamics to support ecosystem resilience by maintaining food web structure and flows

Figure 4 Summary Ecosystem Service cards – 'Habitat' services

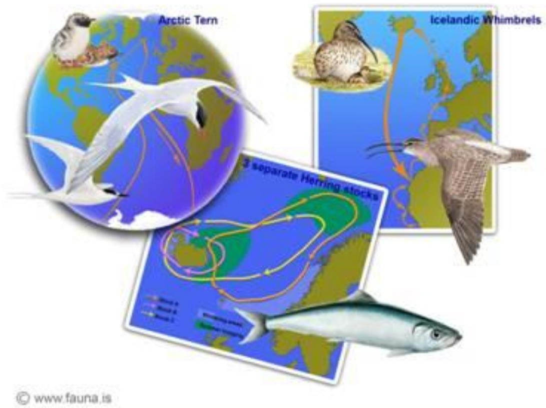
HABITAT	HABITAT
LIFECYCLE MAINTENANCE	**GENE POOL PROTECTION**
Examples Reproductive habitat of species that attain commercial or non-market value elsewhere	**Examples** Inter- and intra-specific genetic diversity that is supported by marine ecosystems that enhances adaptability of species to environmental changes
	
The contribution of a particular habitat to migratory species' populations through the provision of essential habitat for reproduction and juvenile maturation	*The contribution of marine habitats to the maintenance of viable gene pools through natural selection/evolutionary processes*

Figure 5 Summary Ecosystem Service cards – ‘Cultural and Amenity’ services

CULTURAL & AMENITY

RECREATION AND LEISURE

Examples
Bird/whale watching, Beachcombing, Sailing, Recreational fishing,

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The provision of opportunities for Recreation and Leisure that depend on a particular state of marine/coastal ecosystems

CULTURAL & AMENITY

AESTHETIC INFORMATION

Examples
Particular aesthetic dimensions of a sea-scape or a beach-scape that emotionally resonate with individual

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The contribution marine/coastal ecosystems make to the existence of a surface or subsurface sea-scapes

CULTURAL & AMENITY

INSPIRATION FOR CULTURE, ART AND DESIGN

Examples
Use of marine landscape as a motif in paintings; Use of marine features (e.g waves) in jewellery; Inspiration for films (e.g. Jaws, Finding Nemo)

The contribution marine/coastal ecosystems make to environmental features that inspire elements of culture, art, and/or design

Figure 5 Summary Ecosystem Service cards – 'Cultural and Amenity' services (continued)

CULTURAL & AMENITY	CULTURAL & AMENITY	CULTURAL & AMENITY
SPIRITUAL EXPERIENCE **Examples** Several Greek and Roman gods were connected to the sea; the fish is a prominent Christian symbol; marine organisms play an important role in various indigenous communities' religion	**INFORMATION FOR COGNITATIVE DEVELOPMENT** **Examples** Environmental education of children & adults; development of surfaces to reduce marine biofouling based on examples in marine environments	**CULTURAL HERITAGE AND IDENTITY** **Examples** Animals of specific cultural relevance; cultural 'functions' of the sea in daily community life
		
The contribution marine/coastal ecosystems make to formal religious experiences	*The contribution marine/coastal ecosystems make to education, research, etc.*	*The contribution marine/coastal ecosystems make to cultural traditions and folklore*

3 Linking Management Options to Change in the Supply of Individual Ecosystem Services

The ODEMM approach links up MOs with Sectors, Pressures, Ecological Components and Ecosystem Services (Figure 1). Detailed one-to-one linkages have been specified between most aspects of this framework, including between the different ecological components (seabirds, habitat types, demersal fish etc.) and the full list of ESs presented in the Böhnke-Henrichs et al. (2013) typology (see example in Figure 6 below). This means that it is possible to extract the relevant links for any scenario and to see which ESs have the potential to be affected by that scenario (see description and link to full documentation of ODEMM's linkage framework (White et al., 2013) as well as downloadable matrices for all links, at www.odemm.com/content/linkage-framework).

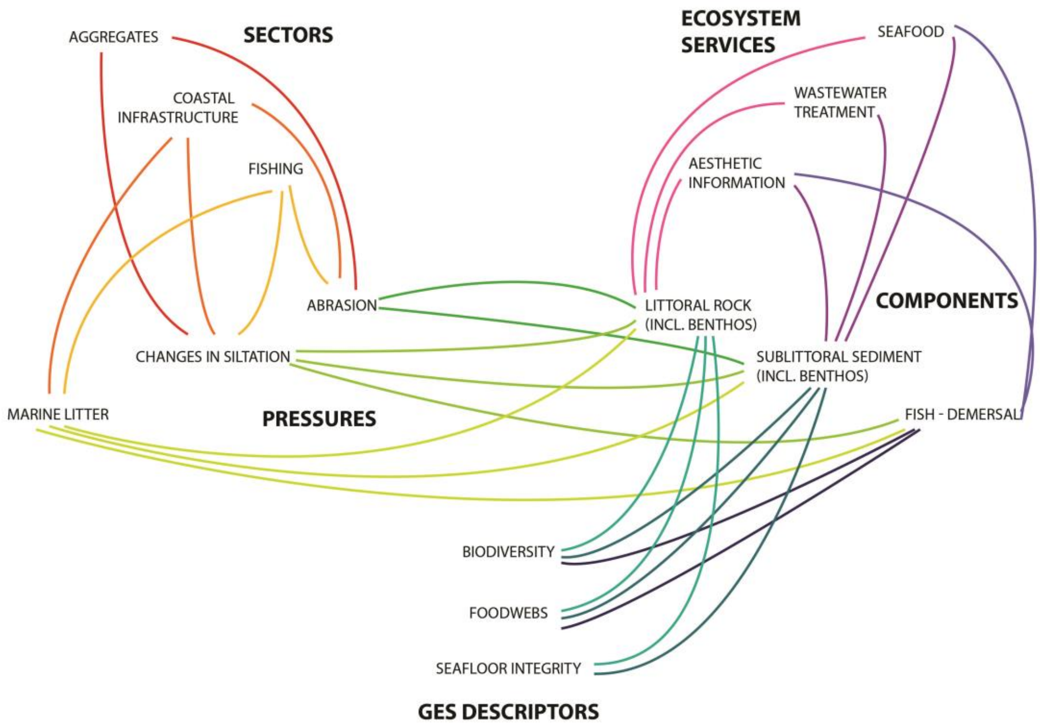

Figure 6 An illustration of the full linkage framework showing linkages between a subset of elements of the ecosystem.

Knowing the qualitative links between these different aspects of the ecosystem provides the structure within which management options can be explored. ODEMM went on to examine the ways in which change in ecosystem service supply (resulting from application of MOs) could be estimated and these are described in sections 3.1 and 3.2 below.

3.1 Exploring the potential to quantify change in ES supply as a result of applying MOs

In a series of regional sea case studies, the effects of applying a range of MOs (BAU+) were compared with the do nothing scenario (BAU) in terms of any resultant change in the state of ecological components over a set time period (Akoglu, 2013; Baltic Sea Case Study, 2013; Bloomfield et al., 2013; Papadopoulou et al., 2013; for a summary of results across case studies see Paijmans et al., (2013)). These case studies were framed around the potential to improve the state of particular objectives of the MSFD.

ODEMM ecologists and economists then worked together to explore the potential to quantify how the effects of applying MOs in each case study translated into any change in the supply of linked ecosystem services. In all cases it was assumed that change in ES supply could arise either as a direct effect of a change in ecosystem state and/or as a direct consequence of the management applied. For example, a number of the case studies included some form of MO that restricted the amount or type of fishing occurring; in these scenarios, one would anticipate that there could be a short-term change in supply in the ES Seafood as a direct consequence of the management applied, in addition to the longer-term realisation of changes in supply resulting from the recovery of depleted fish stocks. Full details of these assessments are given in individual regional case study reports available on www.liv.ac.uk/odemm/data/, but a tabulated cross-regional overview of the findings, in terms of the ability to quantify change in ES supply under each scenario, can be found in Annex I to this report. A summary of the findings from this work is given below.

Main Findings from ES case study work in ODEMM:

1. There are many data and/or knowledge gaps in terms of the ability to undertake quantitative analysis of the likely change in ES supply resulting from application of MOs (see light green, yellow and orange cells in Table A1.3, Annex I). In many cases, even though experts were confident that there was likely a link between ecological components and ESs (see White et al., (2013) linkages work), they were unable to predict how the change in state of specific ecological components (resulting from application of MOs) would result in a change of supply of specific ESs. Difficulties arose here for a number of reasons.
    - For some ESs there is little understanding of how change in state of any particular ecological component manifests itself in a change in supply of the ES, and there is little information available to establish even how the contribution to supply of the ES differs between different components of the ecosystem (e.g. what their relative contributions might be).
    - In other cases, we might understand (qualitatively at least) the relative contributions of different components of the ecosystem to the supply of an ES (see Table 3 for an example of qualitative weighting of relative contributions of ecological components to ESs), but we have no means of translating this into a quantification of the magnitude and timeframe over which the supply of the ES would change following change in state of the relevant ecological components.
    - In some cases, there was not sufficient detail within the management scenarios explored to quantify or even identify which ecological components would be affected at a level of detail that would allow for the links to ESs affected to be identified.
    - There were few cases where it was possible to predict direct consequences of applying management on the supply of ESs. This was often because the level of detail required to do this was not provided in the management scenarios evaluated. For example, a case study may have explored how application of MPAs could broadly reduce impacted areas of seafloor habitats, but there was no means of estimating how the fishing sector would be affected by this, certainly in terms of the extent to which this might affect a change in supply of the ES Seafood.
2. It was clear that ‘Sea food’ and ‘Raw material – fish meal and fish oil’ are the Ecosystem Services that we are best able to work with in terms of a quantification of the change in supply (=dark green cells across most case studies in Table A1.3, Annex I), due to relatively well developed fishery models and indicators. The majority of “unknowns” (orange cells in Table A1.3, Annex I) fell in the Cultural and Habitat ESs. For Cultural Services it is generally not yet well understood how supply of these ESs is linked with individual ECs never-mind how a change in state of any one EC might translate into a change in supply of the linked Cultural Service. For habitat services issues arose in terms of the level of detail required to understand how the change in supply would be manifested, even where links to ecological components were broadly understood.
3. There were, however, quite a few cases where the experts were confident that there would be no effect of the management option applied on the supply of particular ESs (grey cells in Table A1.3, Annex I). This helps to narrow down the scope of assessments still required to conduct a full ecosystem services trade off analysis. Overall, the case study affecting the state of coastal habitats (the Mediterranean case study) was seen to have known effects on the broadest range of ecosystem services, whereas there were many more ESs that experts were sure would not be affected in case studies aimed either at improving the state of fish stocks/foodwebs (Baltic and Black Sea), or

improving the state of offshore habitats. This suggests that there will be many cases where the benefits might be quite restricted in terms of coverage of the range of ecosystem services affected, although this tells us nothing of the extent to which this would translate into an overall value change (see Section 4 of this report) that would be required to complete a full costs-benefit analysis.

4. It was challenging to match the scale for the ecosystem management with the scale required for ES assessment (in terms of spatial explicitness). Spatially explicit models of change in state of ecological components are required in order to then match this to spatially resolved changes in the supply of ESs. Spatially explicit modelling of ecosystem changes seems to be extremely challenging at a regional scale, particularly when outcomes must then be translated down to individual countries for an appropriate cost-benefit analysis.

Liquete et al (2013) give a useful summary of the types of indicators available for quantifying either capacity, flow or benefits from ESs in marine and coastal ecosystems. In agreement with the findings summarised above, it is clear also from their work that there are many gaps in this field and that there are few techniques (never mind specific indicators) currently available that can capture how the application of MOs would result in the change in supply (capacity then flow) across all ESs for marine systems. Further investment in this area of research is clearly required, but given the current absence of understanding here, ODEMM went on to develop a more qualitative approach to predict the relative change in ES supply following application of MOs, so that there was at least a means of exploring consequences across all ESs (see 3.2 below). This was deemed important because otherwise decisions made about the selection of MOs are based on assessments of the few relatively well studied ESs (Seafood, Tourism and Recreation; see Section 4) which leaves it likely that full trade-off analysis of benefits cannot be achieved.

3.2 Relative change in ES supply due to reduction in Ecological Risk

The ODEMM research that was focused on the ecological consequences of marine management developed the concept of *Ecological Risk* (for further details see www.odemm.com/content/ecological-risk-assessment; Knights et al., 2013). In theory, the adoption of new management should lead to a reduction in risk, and reductions in risk should be reflected in changes in the identified ecological components (Figure 6). Constructing this full set of linkages allows for changes in ES supply and changes in risk to the ecosystem to be assessed simultaneously. By way of illustration, we set out below the outcomes of this process of linking MOs to changes in ES supply for three hypothetical MOs for the NE Atlantic, simplifying the outcomes for ease of exposition (Tables 1 and 2).

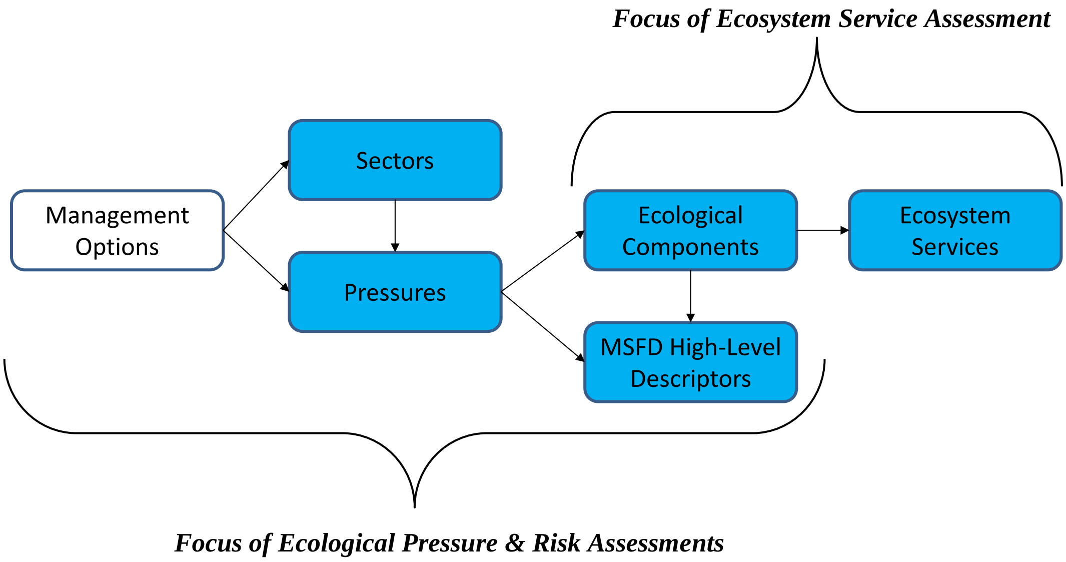

Figure 6 Visualising the connection between the ODEMM risk assessment and the analysis of ecosystem services

What the ODEMM Risk Assessment shows (as reflected in Tables 1 and 2) is the extent to which each MO reduces the overall risk to each Ecological Component (EC). The next step in the analytical process within the context of the economics analysis is to determine how important this risk reduction is in terms of the supply of ESs. In order to do this, we are not *directly* concerned with the individual MOs. Instead, we are concerned with assessing the relative contribution made by each identified ecological component to the supply of each identified ES. The outcomes of this analysis are unique for each regional sea (i.e. the importance of one EC relative to others for (say) the 'Recreation and Leisure' ES might vary depending on local ecological conditions).[2]

In the work done to date by ODEMM, the analysis of the relative contributions of ECs to ESs was conducted using expert judgment. Expert judgment-based inputs can come in a variety of formats; in ODEMM we trialled two approaches in our regional road shows held towards the end of the project. Firstly we used a methodology to demonstrate the identification and specification of the relative contributions of ECs to ESs borrowed from participatory appraisal techniques (see Edwards-Jones et al., 2000) in that we allocated a set number of tokens to a group of stakeholders, and required them to distribute these tokens based on the perceived importance of each EC to a single ES in turn.[3] We also presented the roadshow attendees with results generated by the ODEMM team, where the regional team ecologists had been asked to determine the relative importance of each EC to each ES identified in the typology, scoring them as high, medium, low or not relevant. These designations were then assigned values of 3, 2, 1 and 0, respectively. This scoring exercise allowed the relative contribution of each EC to be standardised *within*, *but not across*, ESs.

For an example, consider ES1 ('Sea food') in Table 3. In this column, there are the following estimates for contributions: (i) 2 cells with a 0 contribution (i.e. the white cells); (ii) 3 cells with a Low contribution that scored 1 each (i.e. the light green cells); (iii) 3 cells with a Medium contribution that scored 2 each (i.e. the moderately green cells); and (iv) 4 cells with a High contribution that scored 3 each (i.e. the dark green cells). Thus, the total score for this single service is 21. Standardising the scores in this column such that the column total is 1 means that every EC with a 'High' relative contribution to the delivery of 'Sea food' received a score of 3/21 (i.e. 0.143). For a comparison, consider ES2 ('Sea Water'). Because the supply of this ES is assumed to be provided by only one EC (i.e. 'water column'), this single dark green cell would take a value of 1.

The methodologies for apportioning relative contribution across ECs within the context of a single ES allow the use of expert judgment (supported by available scientific evidence) to formally link changes in ES supply to changes in marine management. This is achieved as follows: the reductions in the risk associated with each EC are multiplied by the relative contribution scores linking each EC to each ES. The overall results for the NE Atlantic of this process are presented in Table 4.

The results in Table 4 are *indicative*. They highlight the outcomes from linking the ODEMM Risk Assessment with the ODEMM team's assignment of ECs to ESs. There is subjectivity inherent in each of these two steps because in part they each rely on expert judgement (although this is undertaken using objective and transparent criteria such that scores can be easily checked and understood). Thus although the outcomes of each step are 'correct' in terms of the *mechanics* of generating the scores, the actual scores are based on the best available information and as and when better information becomes available scores should be reviewed and updated where necessary (as part of an adaptive management process). This is why we state that the outcomes are indicative and should be viewed as a mechanism for sign-posting research and management options. Despite any inherent subjectivity in the approach, the ODEMM framework captures ecosystem complexity and translates this into a simple metric (i.e. a single figure in each cell of a matrix) that allows comparison across MOs. Participants that attended our road shows trialling these approaches commented that they were pleased to see methods that did try to evaluate the full complexity in the ecosystem, even where results were at first surprising to them.

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[2] It is worth noting that the outcomes of the analysis are unique to the scale of the ODEMM case studies as well. A smaller scale analysis would yield different results

[3] This was the process used in the ODEMM Road shows, using 100 tokens for each ES.

Table 1 Colour Coding & Classification Key for the translation of risk reduction scores from the ecological risk assessment into a category for risk reduction: NE Atlantic ODEMM Road show

Characteristics	Score = 1 (light blue)	Score = 2 (medium blue)	Score = 3 (dark blue)
Categorical Level of Risk Reduction	Low	Medium	High
Original % Risk Reduction Range	< 2%	2% - 4%	> 4%

Table 2 Simplified Risk Reduction Scores with descriptions of Management Options (MOs) given with Table 4: NE Atlantic ODEMM Road show

Eco-component	**MO A**	**MO B**	**MO C**
Littoral Rock *(including benthic flora & fauna)*	1	0	2
Littoral Sediment *(including benthic flora & fauna)*	2	0	1
Infralittoral Rock *(including benthic flora & fauna)*	2	0	2
Circalittoral Rock *(including benthic flora & fauna)*	2	0	3
Sublittoral Sediment *(including benthic flora & fauna)*	3	1	1
Deep Sea Sediment *(including benthic flora & fauna)*	2	2	1
Water column (including plankton)	1	0	2
Demersal Fish	1	2	1
Pelagic Fish	1	0	1
Deep Sea Fish	1	3	1
Marine mammals & Reptiles	1	0	2
Seabirds	1	0	3

Table 3 Assigning contributions of Ecological Components to Ecosystem Services: NE Atlantic Road show

Eco-component	Ecosystem Services																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Littoral Rock *(including benthic flora & fauna)*	x		x			x		x	x		x	x	x		x	x	x	x	x	x	x
Littoral Sediment *(including benthic flora & fauna)*	x					x	x	x	x		x	x	x		x	x	x	x	x	x	x
Infralittoral Rock *(including benthic flora & fauna)*	x		x			x		x	x		x	x	x		x	x	x	x		x	x
Circalittoral Rock *(including benthic flora & fauna)*	x					x			x		x	x	x		x	x	x	x		x	x
Sublittoral Sediment *(including benthic flora & fauna)*	x					x		x			x		x		x	x	x	x		x	x
Deep Sea Sediment *(including benthic flora & fauna)*	x			*Data Gap*	*Data Gap*			x		*Data Gap*			x	*No provision of this service at the regional scale*	x			x		x	
Water column (including plankton)		x						x			x		x		x	x	x	x	x	x	x
Demersal Fish	x		x										x			x	x	x		x	x
Pelagic Fish	x		x										x			x	x	x		x	x
Deep Sea Fish	x												x				x	x		x	x
Marine mammals & Reptiles	x		x										x			x	x	x		x	x
Seabirds						x							x			x	x	x		x	x

Low relative contribution to supply of this ecosystem service
Moderate relative contribution to supply of this ecosystem service
High relative contribution to supply of this ecosystem service
Equal relative contribution across all components (or data gap)

1 Sea Food
2 Sea Water
3 Raw Materials
4 Genetic Resources
5 Medicinal Resources
6 Ornamental Resources
7 Air Purification
8 Climate Regulation
9 Disturbance Prevention & Moderation
10 Regulation of Water Flows
11 Waste Treatment
12 Coastal Erosion Prevention
13 Biological Controls
14 Lifecycle Maintenance
15 Gene Pool Protection
16 Aesthetic Information
17 Recreation & Leisure
18 Inspiration for Culture, Art & Design
19 Spiritual Experience
20 Information for Cognitive Development
21 Cultural Heritage & Identity

Table 4 Overall assessment of changes in Ecosystem Service provision arising from Management Options: NE Atlantic Road show

MANAGEMENT OPTIONS	PROVISIONING SERVICES						REGULATING SERVICES							HABITAT		CULTURAL & AMENITY					
	Sea Food	Sea Water	Raw Materials	Genetic Resources	Medicinal Resources	Ornamental Resources	Air Purification	Climate Regulation	Disturbance Prevention or Moderation	Regulation of Water Flows	Waste Treatment	Coastal Erosion Prevention	Biological Control	Lifecycle Maintenance	Gene Pool Protection	Recreation and Leisure	Aesthetic Information	Inspiration for Culture, Art and Design	Spiritual Experience	Information for Cognitive Development	Cultural Heritage and Identity
A. Reduce any activity that contributes physical damage or loss (e.g. abrasion, sealing, smothering) to the North East Atlantic seafloor by 10%	1.79	0.49	0.87	Data Gap	Data Gap	2.77	3.31	2.61	2.58	Data Gap	2.34	2.58	1.63	N/A	2.60	1.46	1.12	1.53	1.89	1.63	1.18
B. Reduce catch (using suitable controls, e.g. Quotas, mesh size) of demersal fishing by 10%	1.50	0.00	0.52	Data Gap	Data Gap	0.40	0.00	0.85	0.00	Data Gap	0.26	0.00	1.07	N/A	0.73	0.18	0.92	0.61	0.00	1.07	0.88
C. Reduce the input of Marine Litter by 10% from any human activity that is amajor contributor to this pressure in the North East Atlantic sea	1.87	2.38	1.76	Data Gap	Data Gap	2.16	1.47	1.80	2.46	Data Gap	2.52	2.46	2.29	N/A	2.39	2.53	2.19	2.40	2.01	2.29	2.21

4 Valuation of changes in Ecosystem Service supply

Although the steps in the ODEMM approach outlined above provide an indication of the degree to which a particular MO influences the supply of different ESs, there remains the issue of how important stakeholders perceive these changes in ES supply relative to each other. For instance, in Table 4 MO A scores highest for change in ‘Sea Food’ (1.87) but this is only around 25% higher than the MO with the lowest impact in this ES category (i.e. option B, scoring 1.50). By contrast, comparing these two options again for ‘Recreation and Leisure’ C is highest (2.58) whereas A scores 1.46 (i.e. around 77% higher). The economic assessment of the management options thus necessitates an appraisal of the relative importance in ES supply change.

One way of making such an appraisal is through attempting to value ESs in a common unit of account, (i.e. in monetary terms). There is some argument as to whether we ought to value ecosystems in monetary terms. Child (2009) cited in Fletcher (2012) argues that we should create a “culture of care*”* rather than using economic efficiency as a yardstick to determine the extinction (through anthropogenic pressures) of a ‘non economically-useful’ species, trading this loss for the protection of a ‘useful’ habitat, with ‘usefulness’ being measured in utilitarian anthropocentric terms coined around ES provisioning. It is difficult to argue against this moral position (that follows the eco-centric views of Aldo Leopold), but in pragmatic terms, species and habitats are being lost, and the question remains as to whether economics (in terms of valuation) helps or hinders human responses to these losses. The Arrow report (Arrow et al., 1993) is highly influential in this field: “[it is] hard to imagine that the establishment of property rights or improved pricing of natural resources could worsen the prospects of future generations.” This is an expression of the opposing (or perhaps contrarian) position, and highlights that there may well be scope for economics to contribute to the solutions facing key environmental problems.

The ODEMM project has contributed to the discourse and evidence base on the valuation of marine ESs in two significant ways: (i) conducting primary valuation studies using a methodology termed ‘choice experiments’ to assess marine cultural ESs; and (ii) the development of a database of marine ES valuations, structured so as to facilitate the process of ‘benefits transfer’ wherein the cost of conducting a site-specific primary valuation study is avoided by relying instead on transferring a value estimate from a previously published study (or studies).

Notwithstanding the shift towards management at a regional (and therefore trans-national) scale in marine management internationally, the vast majority of marine and coastal ecosystem valuation literature refers to study sites at a much smaller spatial scale (e.g. individual strips of coastline and adjacent marine ecosystems). The most frequently applied methodologies in such primary valuation studies fall under the category of ‘stated preference techniques,’ wherein the respondents’ willingness-to-pay (WTP) for a defined change in the natural environment (quality, access or both) is elicited through a structured, survey-based approach.[4] The WTP is hypothetical in the sense that the respondent does not actually pay, and there is therefore a significant *potential* for bias in survey results. As Fletcher (2012) notes, one of the earliest publications in this field referred to the potential for respondents to be “purchasing moral satisfaction” (Kahneman and Knetsch, 1992), with individuals being potentially motivated to over-represent their WTP owing to the ‘warm glow’ they receive from the act of (theoretically) giving without actually doing so (Andreoni, 1989). However, there is a long history of applications in applying stated preference methods, at least for terrestrial biomes.

A highly influential example of its use is in the Exxon Valdez disaster, one of the first applications to estimate non-use values (Liu et al., 2010) as an input to litigation (Carston et al., 2003) The National Oceanic and Atmospheric Administration (NOAA) formed a panel chaired by Nobel laureate Kenneth Arrow to comment and provide guidance on the valuation methodologies applied. Recommendations included conducting survey pre-tests, survey design so as to minimise non-responses and a preference for face-to-face interviews (Arrow et al., 1993).

[4]See Hanley and Barbier (2009) for an introduction.

A more recent methodological development in the environmental economics literature has been the use of choice experiments (Hanley et al., 2001). Choice experiments (CEs) originate from market research applications (Bateman, 2002) but have been adopted in non-market valuation of ecosystems since the mid-1990s. The CE approach has recently been applied to estimate the loss in recreational benefits associated with algal bloom in the Black Sea (Taylor and Longo, 2010), fisheries management policies (Groeneveld, 2011), and changes in marine biodiversity (Ressurreição et al., 2012).

The ODEMM project team carried out three CE surveys, with one in each of the following countries: Poland, Romania, and Turkey. The methodology employed across these case studies was novel in that it focused on the monetary valuation of cultural ESs other than 'Recreation and Leisure.'

One of the main contrasts between valuation studies for terrestrial versus coastal and marine ecosystems is that respondents are inherently more likely to understand the nature of a change to the former as compared to the latter. One of the novel aspects of the ODEMM valuation studies was therefore the *integration* of the marine ecology with the social science in survey design, wherein an *ecological narrative* was developed by the marine ecology partners. Whereas most CEs are carried out without the opportunity for the participant to pose questions so as to understand the nature of the bio-physical change being valued, in the ODEMM studies there were interactive workshops with marine scientists informing the sample of the general public as regards changes in the marine ecology that were being valued. The conceptual framework – integrating marine ecology, socio-cultural perspectives and the ODEMM ES typology – is presented in Figure 7.

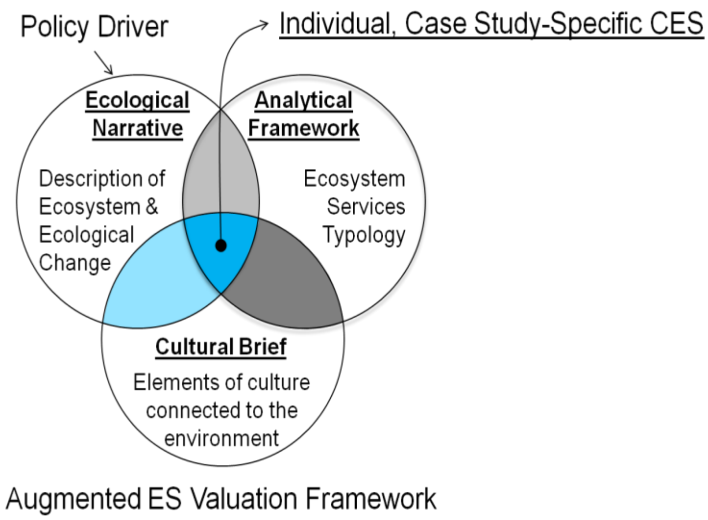

Figure 7 The Approach adopted for ODEMM Choice Experiments to value cultural ecosystem services

In each CE study, a cultural scoping study was carried out prior to the workshops that allowed for the finalisation of the attributes included in the survey design. As it turned out, there were attribute categories that were common across sites (though their cultural relevance differed between sites), and one attribute unique to each site. In Turkey for instance this attribute was the availability and quality of locally-sourced anchovy for traditional meals, and in Poland it was the protection of local artisanal fishing communities. Figure 8 presents a selection of initial results for prevalence of blooms ('Bloom'), population size of key species ('Pop'), and the visibility of key species ('Vis') under both a moderate ('Mod') and a substantial amount of new marine management interventions ('Sub').

As well as conducting primary valuation studies, ODEMM also developed a database of valuation studies. In total 590 studies were reviewed and a synopsis of results is provided in Table 5[5]. What is perhaps the most interesting outcome from this comprehensive review is the extent to which data gaps apply in the valuation of marine and coastal ESs, with the exception of 'Recreation and Leisure'.

[5] The numbers in brackets in Table 5 are those studies that fit a particular ES but have only been short-hand processed as opposed to assessed and categorised in full. Thus for 'Recreation and Leisure' there are 87 full entries as well as an additional 109 studies that contain values for this ES but which have not been fully processed.

Figure 8 Annual mean valuation of common attributes across ODEMM choice experiments

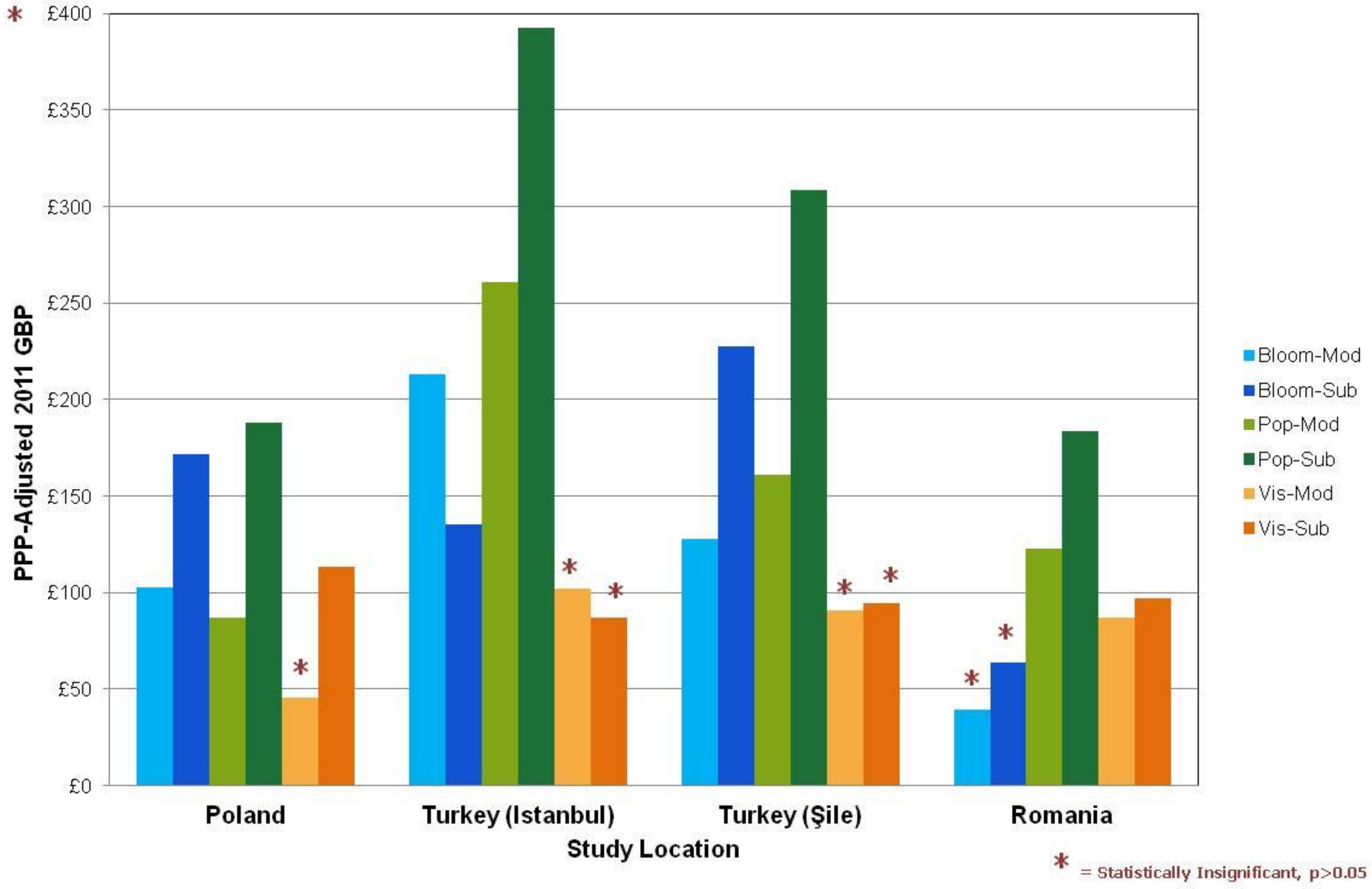

Table 5 Summary of ODEMM benefits transfer database

Ecosystem Service - Study Breakdown

Provisioning	**ES #**	**1**	**2**	**3**	**4**	**5**	**6**		
	ES Name	**Sea Food**	**Sea Water**	**Raw Materials**	**Genetic Resources**	**Medicinal Resources**	**Ornamental Resources**		
	# Studies	28 (+4)	1	4	0	1	0		
Regulating	**ES #**	**7**	**8a**	**8b**	**9**	**10**	**11**	**12**	**13**
	ES Name	**Air Purification**	**Climate Regulation**	**Weather Regulation**	**Disturbance Prevention**	**Regulation of Water Flows**	**Waste Treatment**	**Coastal Erosion Prevention**	**Biological Control**
	# Studies	0	3	0	1	0	2	4	0
Habitat	**ES #**	**14**	**15**						
	ES Name	**Lifecycle Maintenance**	**Gene Pool Protection**						
	# Studies	1	8						
Cultural & Amenity	**ES #**	**16**	**17**	**18**	**19**	**20**	**21**		
	ES Name	**Recreation**	**Aesthetic Information**	**Inspiration for CAD**	**Spiritual Experience**	**Information for Cognitive Development**	**Cultural Heritage & Identity**		
	# Studies	87 (+109)	1	0	0	0	2		
Other	**ES #** / **ES Name**	Bundled	Other						
	# Studies	23	6						

Although the ODEMM economics work on valuation was novel and contributed to the literature, in the regional seas case studies themselves relatively few ESs were assessed as being affected by the BAU+ MO (or the effect could not be quantified). As such, the extent to which valuation could be applied to the case studies was limited. However, the primary valuations are linked in that there is a link between nutrient loading (in the Black Sea and Baltic Sea) and the occurrence/severity of blooms.

5 The assessment of costs

ODEMM has developed a typology of costs associated with the implementation of MOs. Unlike the ODEMM approach to assessing benefits from enhanced ES supply it is not novel per se, but rather adapts from extant cost typologies. In general it is possible to split the assessment of costs across two domains: (i) the affected agents incurring the costs; and (ii) when the costs are incurred – before, during or after the application of the management option, referred to as *ex ante*, *ex nunc* and *ex post* costs, respectively, in economic terms.

Figure 9 sets out a cost framework for the *ex ante* and *ex nunc* governmental costs. It is noteworthy that these cost categories are incurred not only by the regulator (as shown in Figure 9), but also the affected industries (as well as other stakeholders such as the Third Sector and civil society). For instance, the regulator is likely to have to set up the platform for communication but NGOs may need to carry out Planning Activities in preparation for a consultation phase and Communication Activities once the consultation phase is on-going. ODEMM carried out a review of costs for MPA designation and found that only a sub-set of these cost categories have been estimated, and even then the range of value estimates is large, and dependent on a wide number of key variables.

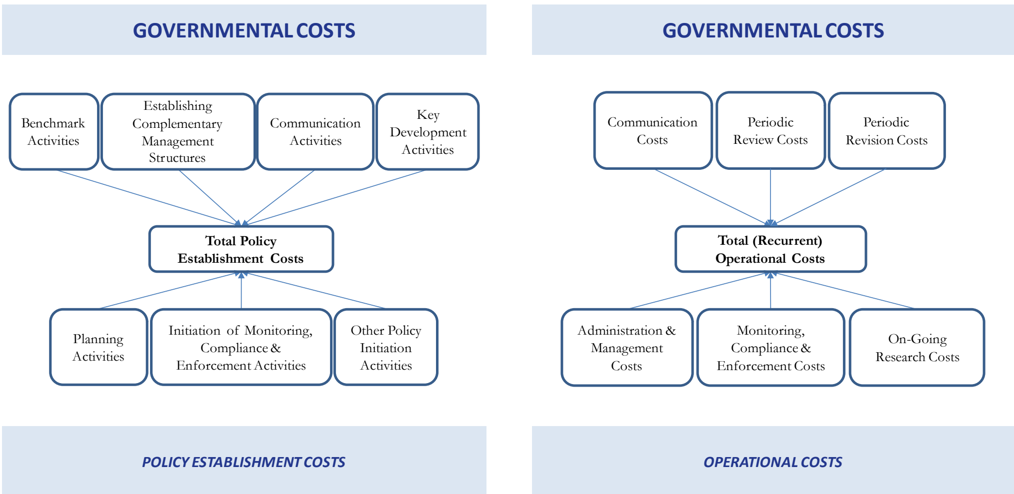

Figure 9 Typology of governmental costs incurred before and during implementation of the Management Option

There are some substantive issues in terms of assessing costs, particularly when appraising MOs that are linked to a regional initiative such as the MSFD. Costs to the regulator are typically borne at Member State (MS) level, but the designation of one particular MS's share of this regulatory burden can be unclear in regional management. This issue of cost-sharing across MSs applies to costs incurred by industry sectors as well, e.g. the costs borne by one MS's trawling fleet versus another MS's.

A second issue is that any *ex ante* cost assessment is likely to be applied under conditions where the MO is not fully specified. For instance, knowing that the MO is the designation of MPAs in the NE Atlantic is insufficient to facilitate an accurate cost assessment. Rather, it is also necessary to know where exactly the MPAs would be located, and what restrictions on activities and pressures would be applied. It is rarely the case that such a complete specification is available, but in its absence, cost estimate ranges are so large as to be near useless in terms of informing policy. For instance, a network of MPAs of a given size will have very low costs if the MPAs are located away commercial industrial activity, but very high costs if sectors must significantly modify production.

Associated with this final point is the link between costs and benefits that applies especially to the fisheries sector. In the ODEMM case studies, a significant cost was the *foregone benefits stream* to the fishing industry. The various MOs shifted fishing activities in different ways – temporally, spatially and in terms of the species targeted – and this shift from BAU to BAU+ generates an associated cost in some cases – in terms of foregone revenue streams to the sector. These reductions in revenue were in some cases mitigated by increased catches (and producer benefit) once stocks recovered.

As mentioned previously, ODEMM developed a detailed typology of costs for the assessment of MOs to implement marine protected areas. This is presented by way of example in Boxes 1 and 2, focusing on governmental costs (though there are equivalent or complementary cost categories for sectors and other stakeholders). Data on these cost categories is often difficult to obtain and/or confidential. For a review of what information is publicly available, see the associated report on MPA costs that was created for ODEMM (Baulcomb, 2013). Although care must be taken in applying the typology so as to avoid the conflation of different cost categories (to avoid double-counting), it does highlight the range of cost categories that should be considered when pursuing a full cost assessment of marine policy.

Box 1 MPA Establishment Costs - Government

1. The '*Benchmark Activities & Costs'* category includes activities such as collecting spatial ecological data, non-spatial ecological data from researchers, ecological data from assessments of local ecological knowledge, as well as undertaking stakeholder analysis and baseline economic assessments of both market and non-market commodities. This information must be also be synthesised so that it can support the design of various options for the MPA network.
2. The '*Key Development Activities & Costs'* category includes those activities required to build key partnerships within and across countries, with affected communities, and with affected stakeholders. This category also includes those costs associated with developing a communication strategy and developing the key messages and content of outreach material.
3. The '*Communication Activities & Costs'* category includes all of those activities related to dissemination through a range of types of media, including websites, printed material, broadcast material, social media, workshops, and road shows. It also includes the cost of language translations and the cost of conducting awareness campaigns.
4. The '*Planning Activities & Costs'* category contains government staff resourcing (time, training, and overheads), attendance at meetings, the organisation of MPA designation leadership, the development of institutional arrangements, the creation of supporting legislative frameworks/infrastructure, the identification of conservation targets, the evaluation of network proposals, the design of industry compensation schemes, the creation of a draft management plan, the conducting of consultations and appraisals (including, as necessary, strategic environmental assessments, regulatory impact assessments, examinations in public, and public consultations), the drafting of responses to consultations, inter- and intra-national negotiations, and the defence of MPA network designations in the court system.
5. The '*Pre-MPA Network Initiation Activities & Costs'* category includes the creation of the MPA network management entity, the development data and record management systems, the purchase of necessary equipment and infrastructure, staff relocation, staff induction into MPA management procedures, the installation of appropriate IT systems, and the establishment of shared services (i.e. human resources, finance, and facilities management).
6. The '*Monitoring, Compliance & Enforcement Initiation Activities & Costs'* category includes the development of ecological, economic, and stakeholder indicators, the development of licensing and enforcement infrastructure, the development plans for enforcement and monitoring, and staff training.
7. The '*MPA Network Initiation Activities & Costs'* category includes the demarcation of the network boundary, the arrangement of management structures, the arrangement of advisory roles, the initiation of compensation schemes, the official designation of the network, and the arrangement of official network review procedures.
8. The '*Establishing Complementary and Necessary Off-Reserve Management Structures & Costs*' category includes the activities associated with the creation of any complementary and supplementary legislation or management systems that target the marine environment out with the MPA network, but that are actually key to the success of the MPA network. These can include the modernisation of fisheries management, the initiation of wide-scale marine planning systems, and the initiation of wide-scale marine licensing systems.

Box 2 MPA Operation Costs – Government

1. The '*Administration & Management Costs*' category includes costs associated with staff time, staff training, equipment rental, office space rental, meeting attendance, fuel for boats and other vehicles, vehicle maintenance, industry compensation payments, data management systems, and record management systems.
2. The '*Monitoring, Compliance & Enforcement Costs*' category includes costs associated with the operation of marine licensing schemes, the monitoring of ecological, economic, and stakeholder-based data, desk-based case work, conflict resolution, the implementation of management plans and by-laws, legal fees, and surveillance activities generally in the form of a mix of aerial and at-sea patrols, as well as remote boundary surveillance.
3. The '*Communication Costs*' category includes those costs that are associated with education and outreach activities, publicity, guidance document creation and dissemination, management plan information dissemination, the dissemination of management plan evaluations, the dissemination of MPA network performance metrics, the conducting of awareness campaigns, and website maintenance.
4. The '*On-Going Research Costs*' category includes those costs associated with conducting ecological and economic surveys, as well as surveys targeting the more qualitative aspects of stakeholder welfare. This category also includes non-survey research costs focused on relevant ecological, economic, and stakeholder-focused analyses, as well as the costs associated with conducting periodic literature reviews, and the costs associated with specially-focused data collection efforts for the population of a marine GIS system. In turn, this last cost item may be broken down into hardware costs, software costs, and other costs.
5. The '*Periodic Review Costs*' category includes those costs associated with the re-training of staff, the production of new communication materials, the adjustment of statutory instruments, and the adjustment of management systems.
6. The '*Periodic Network Revision Costs'* category includes those costs associated with the consideration of new socio-economic data, and new scientific data, as well as those costs associated with the review of leadership arrangements, management objectives, management strategies, institutional arrangements, management entity structuring, and management plan details. The costs associated with new designations to the MPA network also fall into this category of costs, as do the costs associated with the solicitation of recommendations for MPA network revisions, the costs associated with reviewing the network monitoring systems, the compliance rules, the complaints procedures, the enforcement procedures, and the stakeholder feedback procedures. The costs involved in assessing MPA network performance are also counted in this category of costs, as are the costs of negotiations, consultations, and appraisals related to the review process. Although these costs will be incurred only periodically, they can be substantial.
7. The '*Complementary Off-Reserve Costs*' category includes those costs associated with implementing modern fisheries management, marine spatial planning systems, marine licensing systems, and other marine-related legislation.

6 Summary & future research needs

Marine environments provide significant benefits to man, for example through the provision of seafood and other resources worth trillions of Dollars per annum, regulation of the earth's climate and the modulation of global biogeochemical cycles (Holmlund and Hammer 1999), water quality maintenance (Worm et al. 2006) and also cultural and aesthetic benefits (Lewis, 2012). Despite its clear importance, the marine environment is subject to huge pressure from anthropogenic sources. These pressures arise from *inter alia* the overexploitation of marine species, nutrient loading from land-based agriculture, under-water noise, the introduction of invasive species, increasing oceanic acidification and habitat degradation. The threats are frequently interlinked. Further, in terms of biodiversity loss, Lotze et al. (2006) estimate that the human exploitation of marine species is responsible for 96% of species extinctions.

The ODEMM approach attempts to systematically and coherently link MOs that attempt to address one or more of these anthropogenic pressures with end points expressed in terms of changes in the supply of ESs, which are the benefits that humanity derive from (marine) ecosystems. The linkage referred to is using an assessment of risk as an entry point to the determination of the impact of MOs vis-à-vis ecological state (measured in terms of ECs), which in turn affect ESs. Any reduction in ES supply is an implicit cost of the MO, and there are likely to be trade-offs for any MO in terms of the supply of some ESs going up, and the supply of others going down.

There are various key lessons learnt from the economic analysis in ODEMM:

- Outcome 1: <u>A failure to apply the ecosystem-approach (with its focus on the supply of ESs) will mean that policy choices may not be economically efficient, and can easily miss key trade-offs</u>

  Although a MO is likely to be specified with a particular target in mind - for instance one High Level Descriptor (HLD) - in terms of meeting GES for MSFD), the MO is likely to have impacts on *other HLOs* and also impact on specific ESs. These impacts may be significant to the extent that the *co-benefits* in terms of enhanced ES supply, or indeed the *inadvertent losses* in ES supply, mean that the BAU+ that is best in terms of reducing the risk of failing to meet GES for that particular HLD may not be the best choice in economic terms.

  In essence we are saying that a cost-benefit analysis must be based on a specific MO, and in so far as is possible, that MO should be assessed using the ODEMM approach focused on ESs.

  There is a link here to the on-going discussion on *cost-effectiveness analysis* (CEA). CEA differs from CBA in that benefits are not measured. The premise of CEA is that a state change is required irrespective of the benefits accruing, and thus an assessment of benefits is superfluous. The rationale for applying CEA to MSFD is that since it is mandatory for a MS to apply the Directive then CEA might be the preferred assessment tool.

  We would argue caution here owing to the issue of co-benefits. Even if MO1 reduces the risk of meeting a HLD as much as MO2 and is cheaper to implement, it may be the case that MO1 increases the risk of meeting other HLDs and/or that MO2 provides co-benefits in terms of ES provision that as missed when a cost effectiveness approach is taken.

- Outcome 2: <u>The economic analysis of MOs at regional scale requires the attribution of costs and benefits across different nation states, and the constituency of winners and losers may differ</u>

  Although the appropriate spatial scale for the specification of MOs (and the ecological modelling that tests the impacts of such interventions) may well be at the regional scale, it is challenging for economic valuation to be applied at such a large scale when considering some ESs. For instance, the regulating service of 'Disturbance Prevention and Moderation' has been estimated as being extremely valuable (see de Groot et al., 2012; Barbier et al., 2008) but the supply of the ES depends on highly localised conditions such as the typography of marine habitats and the proximity (and value) of developed land near the shoreline. Consequently, there can be a divergence between the appropriate spatial scale for economic analysis versus ecological analysis. There is also a significant research cost associated with up-scaling high-resolution economic analyses to a regional scale in order to be scale-matched with regional-scale ecological analyses. The scale at which actual marine management occurs also depends on governance regimes which can add a third layer to the mapping problem.

- Outcome 3: There are very few re-usable data points for the valuation of marine ESs, and primary valuation is both possible and should be prioritised

  In the review of 590 extant studies for the ODEMM database, there are very few studies that can be used for benefits transfer (i.e. to transfer value estimates from one or more study site(s) to a policy site). Only three studies on cultural ESs were found (if we exclude 'Recreation and Leisure'). The total for most individual ESs was <5. ODEMM has carried out primary valuation and generated usable values[6]. Such work should be prioritised, notwithstanding policy-makers reluctance to fund such studies.

[6] Note that the primary valuation studies were not actually specified in the original consortium proposal; this was additional work so as to improve project outcomes.

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Annex I. Summary - Regional case study work on the potential to quantify change in ES supply following application of Management Options

The four regional case studies that were considered in the ecosystem service assessment focussed on changes of state in ecosystem components most relevant to achieving Good Environmental Status (GES) for one of two MSFD Descriptors, food webs or seafloor integrity, as a result of the potential application of management scenarios. Management scenarios were referred to as Business as usual + (BAU+) (see details in Table A1.1). The resultant change in state due to the application of these scenarios was compared to the state under Business as usual (BAU) where no additional management would be applied in the case study apart from already existing management.

Table A1.1 Outline of case studies with management scenarios considered in the Ecosystem Service assessment (for further details see case study reports at www.odemm.com/content/cost-and-benefits-analyses)

Region	**Baltic**	**Black Sea**	**Mediterranean**	**North East Atlantic**
MSFD descriptor	Food webs	Foodwebs	Seafloor Integrity	Seafloor integrity
Relevant sectors	Fishing benthic trawling, Fishing pelagic trawling, Agriculture	Fishing benthic trawling, Fishing pelagic trawling, Agriculture	Aquaculture, Fishing, Coastal Infrastructure	Agriculture, Fishing, Non-renewable energy (oil & gas), Shipping, Telecommunications
Management options (BAU+)	For eutrophication - a reduction in nutrients as required by the Baltic Sea Action Plan. For fishing, fishing mortality (F) is maintained with a change in gear selectivity (L50% = 40cm) (BAU+1); Maximum sustainable yield (Fmsy) is applied with a change in gear selectivity (L50% = 38cm) (BAU+2); or, Fmsy is applied and there is a change in gear selectivity (L50% = 40cm) (BAU+3)	Fmsy is applied for fishing mortalities and for eutrophication the current primary production is maintained (BAU+1), a 50% decrease in primary production is used (BAU+2) or a 50% increase in primary production is used (BAU+3).	All states reduce in spatial extent of aquaculture so no overlap of aquaculture with Posidonia. All states reduce in spatial extent of fishing (trawling) so no overlap with Posidonia. No change in coastal infrastructure in EU countries while non-EU countries increase from current spatial extent to EU equivalent levels	Extents of sectors when 10% (BAU+1), 30% (BAU+2) or 70% (BAU+3) of the sublittoral sediment habitat in the North Sea case study area is protected with closure of those protected areas to any of the impacting sectors.

A full description of case studies and scenarios can be found in the regional case study reports, which can be downloaded from http://www.liv.ac.uk/odemm/data/. In this Annex a summary of the findings is presented, in terms of a categorisation (Table A1.2) of what was found regarding the potential to quantify change in supply of each of the ESs in each case study. Examples are given of each category used for this assessment following Table A1.2, and the results presented in Table A1.3. For a discussion of the outcomes, see Section 3.1 in Chapter 3 of this report.

Table A1.2 Categories used to summarise what was found in terms of any expected change in supply of Ecosystem Services under each management scenario for each case study (see outcomes in Table A1.3).

Yes - modeling results, secondary data or knowledge on specific case study conditions provide justification for this change and this change can be quantified	(dark green)
Possible - secondary data or knowledge on specific case study conditions suggest that this change potentially occurs; further justification or quantification not possible due to lack of knowledge	(light green)
Unlikely - secondary data or knowledge on specific case study conditions suggest that this change is unlikely to occur; further justification or quantification not possible due to lack of knowledge	(yellow)
Unknown - management effects and side-effects on the ecosystem and related ES are not sufficiently understood; ES change may or may not occur (both options equally likely)	(orange)
No - modeling results, secondary data or knowledge on specific case study conditions reject this change	(grey)
A = Change in ES supply due to change in ecosystem state	
B = Change in ES supply as a direct consequence of management action	

Examples of each category:

- **Yes:** An example of where an Ecosystem Service is expected to change (i.e. Yes in Table A1.3) is for the sub-service carbon sequestration (under the service climate regulation) in the Black Sea. Biosequestration of CO2 from the environment is related to growth of organisms such as coccolithophorids. Modelling results suggested that the management scenarios in the Black Sea case study which control the input of nutrients would affect the sequestration of carbon, decreasing the capacity to sequester carbon under BAU+2 when primary production is reduced by 50%, whilst increasing it under BAU+3 when primary production is increased by 50%.

- **Possible:** An example where provision of a service could possibly be changed, would be for the supply of the sub-service fish meal and fish oil (under Raw Materials) in the North East Atlantic (Table A1.3). Changes in fish meal and fish oil are considered possible due to different levels of un-impacted sea floor habitat and due to restrictions for different fishing sectors (see sea food section) under BAU+ scenarios. For this sub-ES there is the risk of double counting catch changes under sea food and raw materials. For the sea food valuation North Sea catches of the respective countries are used. However, only a part of these catches is actually used as sea food while another portion is used as raw material. Where catches are used for sea food valuation, possible changes in this raw material are (at least partly) captured in the changes of sea food. Therefore, changes in fish meal/oil are considered possible but are assessed as part of the sea food ES.

- **Unlikely:** In some cases it was deemed ‘unlikely’ that a service provision would be changed due to management measures. In the Black Sea it was considered unlikely that provisioning of the service Algae under Raw Materials would change (Table A1.3). The management scenarios considered different levels of primary production which could have the potential to increase macroalgae availability under higher nutrient loads or decrease under lower loads. However, this relationship was not clear as algae can also decrease under higher nutrient loads when the habitat is reduced due to increasing anoxic and hypoxic areas. These opposing effects and the lack of more detailed data do not allow us to estimate a change in this ES. Furthermore, in general the change in raw material depends on the relation between sustainable supply and demand of algae as raw material and so far no demand has been identified. Thus, this service is considered unlikely to be affected by eutrophication management scenarios.

- **Unknown:** In many cases it was unknown whether a service would be affected by management or not, for example, for the supply of lifecycle maintenance in the North East Atlantic (Table A1.3). Where the closure of offshore benthic habitats occurs in locations relevant as spawning grounds or nursery areas for commercial species, the involved change in physical disturbance can affect the suitability and quality of these areas as spawning/nursery habitat. Any effect might be positive or negative dependent on how the state of benthic habitats affects habitat requirements of relevant species, which will vary between species. This ES could possibly be affected; especially for BAU+2 and 3 (the increase in area of un-impacted habitat under BAU+1 is negligible). However, due to the regional scale of this assessment, the location of closures is not determined. Thus, on this scale it remains unknown which spawning/nursery areas and which species are affected. Therefore, the direction of change (positive or negative) and the expected magnitude cannot be estimated.

- **No:** Where no change was expected in the supply of the ecosystem service, this may have been due simply to impact of the management measure not overlapping with the ecological components important for the supply of the service. For example, in the Baltic Sea case study, leafy coastal vegetation like reed beds and salt marshes provide Air Purification. Changes in fishery management as considered under the BAU+ scenario are not expected to affect the extent or quality of these habitats. Thus, the supply of this ES is not expected to change under this scenario (Table A1.3). In other cases, no effect is considered when the change in the service would not have direct implications for humans. For example, in the Black Sea, no change is given for the service Biological Control even though changes in fisheries management and nutrient levels could improve the status of the marine food web, thus, contributing to the control of jelly fish. However, the major benefit related to the control of undesired events like species outbreaks, blooms or invasion is health. Both types of undesirable events observed in the Black Sea (algal bloom, Mnemiopsis occurrence) do not have direct health effects. This suggests that Biological Control is to be considered an intermediate or supporting service in the Black Sea case study, affecting indirectly recreation and aesthetic information, sea food and sea water (see for instance, Taylor and Longo (2010) and Knowler (2005)). To avoid double counting, changes in this ES are not valued here. Additionally, the eutrophication events will be partly reduced as a direct result of the management measures (reduction of eutrophication) and not primarily by an improvement of the ecosystem service Biological Control.

Table A1.3 Summary of what was found across the four regional case studies in terms of the potential to predict changes in supply of Ecosystem Services following application of Management Options as described in Table A1.1. Colour coding and letters used are detailed in Table A1.2 above. Where cells blank, assessment was not carried out for this service.

			Baltic				Black Sea			Mediterranean	North East Atlantic		
			Eutrophication	Fisheries									
	Ecosystem Service	Sub-ES	BAU+	BAU+1	BAU+2	BAU+3	BAU+1	BAU+2	BAU+3	BAU+	BAU+1	BAU+2	BAU+3
Provisioning Services	Sea Food	Fish	A	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB
		shellfish	A	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB
		other	A	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB
		sea weed	A								AB	AB	AB
	Sea Water	water for desalinization	A							A			
		ballast water	A							A	AB	AB	AB
		water for industrial cooling	A							A			
	Raw Materials	Aggregates									AB	AB	AB
		fish meal; fish oil	A	AB	AB	AB		AB			AB	AB	AB
		salt											
		algae	A								AB	AB	AB
	Genetic Resources									A	AB	AB	AB
	Medicinal Resources		A	A	A	A				A	AB	AB	AB
	Ornamental Resources	Sea shell, aquarium fish	A							A	AB	AB	AB
Regulating Services	Air Purification	Capturing fine dust (PM10), NO_x and SO_2								B	AB	AB	AB
	Climate Regulation	Carbon sequestration	A	A	A	A				AB	A	A	A
		Capturing N20								AB	B	B	B
		DMS release	A	A	A	A				AB	AB	AB	AB
		Methane Emission											
	Disturbance Prevention and Moderation	dampening the intensity of storm floods, tsunamis, hurricanes	**				**	**	**	B	B	B	B
	Coastal Erosion Prevention		**				**	**	**	AB	B	B	B

			Baltic				Black Sea			Mediterranean	North East Atlantic		
			Eutrophication	Fisheries									
			BAU+	BAU+1	BAU+2	BAU+3	BAU+1	BAU+2	BAU+3	BAU+	BAU+1	BAU+2	BAU+3
	Ecosystem Service	Sub-ES											
	Regulation of Water Flows	maintenance of deep channels by coastal currents which are used for shipping	**	A	A	A	**	**	**	B	B	B	B
	Waste Treatment	Removal of nutrients	A*	A	A	A					AB	A	A
	Biological Control	Limit population size of harmful jellyfish	A	A	A	A				AB	AB	AB	AB
		Avoidance or reduction of harmful algae blooms								AB	AB	AB	AB
		Limit population size of other problematic organisms		A	A	A				AB	A	A	A
Habitat	Life Cycle Maintenance	Contribution of a study area to commercial catches elsewhere	A	AB	AB	AB				A	A	A	A
	Gene Pool Protection	maintenance of viable gene pools through natural selection/evolutionary processes	A	A	A	A					A	A	A
Cultural & Amenity	Recreation and Leisure	Recreational fishing		A	A	A					AB	AB	AB
		SCUBA diving		A	A	A					AB	AB	AB
		Beach recreation	A								AB	AB	AB
		Bird/whale/seal watching		A	A	A					AB	A	A
	Aesthetic Information		A	A	A	A					A	A	A
	Inspiration for Culture Art and Design		A	A	A	A					A	A	A
	Spiritual experience		A								A	A	A
	Information for Cognitive Development		A	A	A	A					A^B	A^B	A^B

			Baltic				Black Sea			Mediterranean	North East Atlantic		
			Eutrophication	Fisheries									
			BAU+	BAU+1	BAU+2	BAU+3	BAU+1	BAU+2	BAU+3	BAU+	BAU+1	BAU+2	BAU+3
	Ecosystem Service	**Sub-ES**											
	Cultural Heritage and Indentity		A	A	A	A					AB	AB	AB

** management measures are not specified in sufficient detail; for certain measures (e.g. restoration of coastal wetlands to reduce nutrient input) changes in ES provision are considered possible.

* Removal of nutrients could be further broken down with unknown or no effect depending on the aspect of waste removal

^A is unknown and colour coding refers to B

Annex 2 Management options, Ecological Component weighting and final change in Ecosystem Services for the Mediterranean case study

Table A2.1 Colour Coding & Classification Key: Mediterranean Sea ODEMM Road show

Characteristics	Score = 1 (light blue)	Score = 2 (medium blue)	Score = 3 (dark blue)
Level of Risk Reduction	Low	Medium	High
Original % Risk Reduction Range	< 2%	2% - 4%	> 4%

Table A2.2 Simplified Risk Reduction Scores: Mediterranean Sea ODEMM Road show

Eco-component	MO A	MO B	MO C
Littoral Rock *(including benthic flora & fauna)*	3.00	0.00	1.00
Littoral Sediment *(including benthic flora & fauna)*	3.00	0.00	1.00
Sublittoral Sediment *(including benthic flora & fauna)*	3.00	0.00	2.00
Sublittoral Rock *(including benthic flora & fauna)*	2.00	0.00	2.00
Deep sea bed *(including benthic flora & fauna)*	2.00	0.00	2.00
Water column *(including plankton)*	1.00	0.00	2.00
Deep sea fish	1.00	0.00	3.00
Demersal Fish	1.00	0.00	2.00
Pelagic Fish	1.00	1.00	2.00
Marine mammals & Reptiles	1.00	1.00	3.00
Seabirds	2.00	1.00	3.00

Table A2.3 Assigning contributions of Ecological Components to Ecosystem Services: Mediterranean Sea Road show

	Ecosystem Services																				
Eco-component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Littoral Rock *(including benthic flora & fauna)*	x		x		x	x		x	x		x	x	x		x	x	x	x	x	x	x
Littoral Sediment *(including benthic flora & fauna)*	x		x		?	x	x	x	x		x	x	x		x	x	x	x	x	x	x
Sublittoral Sediment *(including benthic flora & fauna)*	x		x		x	x		x			x		x		x	x	x	x		x	x
Sublittoral Rock *(including benthic flora & fauna)*	x				x	x					x		x		x	x	x	x		x	
Deep sea bed *(including benthic flora & fauna)*	x				?			x					x		x					x	
Water column *(including plankton)*		x		**Data Gap**				x		**Data Gap**	x		x	**No Provision at Regional Scale**	x	x	x	x	x	x	x
Deep sea fish	x												x			x	x			x	
Demersal Fish	x		x										x			x	x	x		x	x
Pelagic Fish	x		x										x			x	x	x		x	x
Marine mammals & Reptiles	x		x										x			x	x	x		x	x
Seabirds													x			x	x	x		x	x

Low relative contribution to supply of this ecosystem service
Moderate relative contribution to supply of this ecosystem service
High relative contribution to supply of this ecosystem service

1 Sea Food
2 Sea Water
3 Raw Materials
4 Genetic Resources
5 Medicinal Resources
6 Ornamental Resources
7 Air Purification
8 Climate Regulation
9 Disturbance Prevention & Moderation
10 Regulation of Water Flows
11 Waste Treatment
12 Coastal Erosion Prevention
13 Biological Controls
14 Lifecycle Maintenance
15 Gene Pool Protection
16 Aesthetic Information
17 Recreation & Leisure
18 Inspiration for Culture, Art & Design
19 Spiritual Experience
20 Information for Cognitive Development
21 Cultural Heritage & Identity

Table A2.4 Overall assessment of changes in Ecosystem Service provision arising from Management Options: Mediterranean Sea Road show

MANAGEMENT OPTIONS	PROVISIONING SERVICES						REGULATING SERVICES							HABITAT		CULTURAL & AMENITY					
	Sea Food	Sea Water	Raw Materials	Genetic Resources	Medicinal Resources	Ornamental Resources	Air Purification	Climate Regulation	Disturbance Prevention or Moderation	Regulation of Water Flows	Waste Treatment	Coastal Erosion Prevention	Biological Control	Lifecycle Maintenance	Gene Pool Protection	Recreation and Leisure	Aesthetic Information	Inspiration for Culture, Art and Design	Spiritual Experience	Information for Cognitive Development	Cultural Heritage and Identity
A. Reduce any activity that contributes physical damage or loss (e.g. abrasion, sealing, smothering) to the Mediterranean seafloor by 10%	2.42	1.55	2.83	Data Gap	3.87	4.06	4.31	3.08	4.26	Data Gap	3.51	4.26	2.57	0.00	3.56	2.44	2.47	2.42	3.35	2.57	2.21
B. Reduce catch (using suitable controls, e.g. Quotas, mesh size) of pelagic fishing, e.g. targeting Tuna and Swordfish, by 10%	0.10	0.00	0.14	Data Gap	0.00	0.00	0.00	0.00	0.00	Data Gap	0.00	0.00	0.11	0.00	0.00	0.14	0.14	0.16	0.00	0.11	0.18
C. Reduce the input of Marine Litter by 10% from any human activity that is a major contributor to this pressure in the Mediterranean Sea	3.15	2.46	2.75	Data Gap	2.55	2.38	1.90	2.51	1.92	Data Gap	2.33	1.92	3.37	0.00	2.64	3.35	3.29	3.28	2.11	3.37	3.43

Annex 3 Management options, Ecological Component weighting and final change in Ecosystem Services for the Black Sea case study

Table A3.1 Colour Coding & Classification Key: Black Sea ODEMM Road show

Characteristics	Score = 1 (light blue)	Score = 2 (medium blue)	Score = 3 (dark blue)
Level of Risk Reduction	Low	Medium	High
Original % Risk Reduction Range	< 1%	1% - 2%	> 3%

Table A3.2 Simplified Risk Reduction Scores: NE Atlantic ODEMM Road show

Eco-component	MO A	MO B	MO C
Littoral Rock *(including benthic flora & fauna)*	3	0	1
Littoral Sediment *(including benthic flora & fauna)*	3	0	1
Sublittoral Rock *(including benthic flora & fauna)*	3	0	1
Sublittoral Sediment *(including benthic flora & fauna)*	3	0	1
Water column (including plankton)	2	0	2
Demersal Fish	2	0	1
Pelagic Fish	2	1	1
Marine mammals & Reptiles	1	1	0
Seabirds	2	1	0

Table A3.3 Assigning contributions of Ecological Components to Ecosystem Services: Black Sea Road show

	Ecosystem Services																				
Eco-component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Littoral Rock *(including benthic flora & fauna)*	x					x		x	x		x	x	x		x	x	x	x		x	x
Littoral Sediment *(including benthic flora & fauna)*	x						x	x	x		x	x	x		x	x	x	x		x	x
Sublittoral Rock *(including benthic flora & fauna)*	x					x		x	x		x	x	x		x	x	x	x	No Evidence of Linkages to Marine Ecosystem State in Black Sea	x	x
Sublittoral Sediment *(including benthic flora & fauna)*	x		x			x		x	x		x	x	x	No Provision at Regional Scale	x	x	x	x		x	x
Water column (including plankton)		x		Data Gap	Data Gap			x		Data Gap	x		x		x	x	x	x		x	x
Demersal Fish	x												x			x	x	x		x	x
Pelagic Fish	x												x			x	x	x		x	x
Marine mammals & Reptiles													x			x	x	x		x	x
Seabirds													x			x	x	x		x	x

Low relative contribution to supply of this ecosystem service
Moderate relative contribution to supply of this ecosystem service
High relative contribution to supply of this ecosystem service

1 Sea Food
2 Sea Water
3 Raw Materials
4 Genetic Resources
5 Medicinal Resources
6 Ornamental Resources
7 Air Purification
8 Climate Regulation
9 Disturbance Prevention & Moderation
10 Regulation of Water Flows
11 Waste Treatment
12 Coastal Erosion Prevention
13 Biological Controls
14 Lifecycle Maintenance
15 Gene Pool Protection
16 Aesthetic Information
17 Recreation & Leisure
18 Inspiration for Culture, Art & Design
19 Spiritual Experience
20 Information for Cognitive Development
21 Cultural Heritage & Identity

Table A3.4 Overall assessment of changes in Ecosystem Service provision arising from Management Options: Black Sea Road show

MANAGEMENT OPTIONS	PROVISIONING SERVICES						REGULATING SERVICES							HABITAT		CULTURAL & AMENITY					
	Sea Food	Sea Water	Raw Materials	Genetic Resources	Medicinal Resources	Ornamental Resources	Air Purification	Climate Regulation	Disturbance Prevention or Moderation	Regulation of Water Flows	Waste Treatment	Coastal Erosion Prevention	Biological Control	Lifecycle Maintenance	Gene Pool Protection	Recreation and Leisure	Aesthetic Information	Inspiration for Culture, Art and Design	Spiritual Experience	Information for Cognitive Development	Cultural Heritage and Identity
A. Reduce any activity that contributes physical damage or loss (e.g. abrasion, sealing, smothering) to the Black Sea seafloor by 10%	2.16	1.11	3.63	Data Gap	Data Gap	3.08	2.84	2.16	2.82	Data Gap	2.56	2.82	1.93	0.00	2.59	2.03	1.95	2.00	No Evidence	2.12	1.94
B. Reduce catch (using suitable controls, e.g. Quotas, mesh size) of pelagic fishing, e.g. targeting Anchovy, by 10%	0.16	0.00	0.00	Data Gap	Data Gap	0.00	0.00	0.00	0.00	Data Gap	0.00	0.00	0.14	0.00	0.00	0.18	0.20	0.18	No Evidence	0.17	0.20
C. Reduce discharges of any activity that is a major contributor to Nitrogen and Phosphorus enrichment in the Black Sea by 10%	0.46	1.07	0.42	Data Gap	Data Gap	0.51	0.53	0.76	0.55	Data Gap	0.65	0.55	0.56	0.00	0.63	0.45	0.43	0.45	No Evidence	0.45	0.44

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