Options for Delivering Ecosystem-Based Marine Management

Reporting

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ODEMM

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Final Report Summary - ODEMM (Options for Delivering Ecosystem-Based Marine Management)

Executive Summary:
It is widely accepted that ecosystem-based management (EBM) is required to deal with the increasing human use of the marine environment. However, consideration of the whole system, including the links between human use, ecological state and ecosystem services, leads to an immensely complex array of factors that need to be accounted for; as such, fully operationalising a holistic approach like EBM is not straightforward.
ODEMM has developed an approach including a series of resources (available to download from www.odemm.com) that can help support decision-makers to implement operational Ecosystem-Based Management (EBM). The approach is illustrated using Europe's Marine Strategy Framework Directive (MSFD) as the context. ODEMM's resources are designed to allow consideration of the state of relevant policy objectives (e.g. the 11 MSFD Descriptors of Good Environmental Status), building on this to elaborate an operational process of creating, appraising and choosing management options, where full consideration of trade-offs across ecological, economic and social issues, and evaluation of the

governance complexity surrounding this, are all considered.
The main series of resources are:
- a method to undertake a rapid assessment of the state of policy objectives using available information on the specific ecosystem components that are relevant to those objectives;
- a linkage framework that identifies all relevant interactions between key ecosystem components – human activities or sectors, their pressures, ecological components and ecosystem services, and the relevant policy objectives;
- a pressure assessment that can be used to weight and rationalise the key threats to ecological components and policy objectives;
- an ecological risk assessment that summarises information from the pressure assessment into overall risk that can be grouped by different elements (e.g. sectors, pressures, ecological components) and related to management options;
- an integrated management strategy evaluation (iMSE) tool that can be used to create management options (MOs) that can target different areas of risk to policy objectives and then evaluate the effectiveness of those MOs;

- a series of methods for analysing the costs and benefits of different MOs based on an ecosystem services approach; and
- a series of methods for appraising the governance complexity associated with EBM, relevant policies and specific MOs.
The role of the ODEMM approach is to provide a solid evidence base to inform decision makers and allow them to make trade-offs with the necessary information available. The tools and approaches do not give the 'right' answer but allow decision-makers to consider trade-offs and likelihood of management success. Despite any inherent subjectivity in the approach, the ODEMM framework captures ecosystem complexity and translates this into simple metrics (i.e. single figures in each cell of a matrix) that allow comparison across management options (see resources at www.odemm.com). We consider this to be a starting point for EBM implementation and a flexible approach which can adapt to changing needs.
The approaches we have developed to date are what we consider to be best practice with the available knowledge and techniques that we currently have at our disposal, but naturally, these can be improved and built on. We believe that moving forward with implementation of EBM requires both advances in research and in the practical organisation of how management of the marine environment takes place. We have thus proposed 10 steps towards successful implementation of EBM.

Project Context and Objectives:
In Europe, the Marine Strategy Framework Directive deals with the implementation of an ecosystem approach to marine environmental management, and the Habitats Directive contributes to the protection of representative habitats. Human activities may have a severe impact on marine ecosystems. Therefore it is important that conduct and management of such activities (including fisheries, transport, dredging, energy generation etc.) are carried out in a way that supports the objectives of the Marine Strategy and the Habitat Directive. The challenge here is to investigate and quantitatively evaluate, specify and propose options and actions for a gradual transition from the current fragmented management of these activities (e.g. fish stock based regime for fisheries management) to a mature integrated management, including strategies for the implementation of the ecosystem approach at regional level, reconciling short-term economic objectives with long-term ecosystem sustainability objectives.
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The overall aim of the ODEMM project was to develop a set of fully-costed ecosystem management options that would deliver the objectives of the Marine Strategy Framework Directive, the Habitats Directive, the European Commission Blue Book and the Guidelines for the Integrated Approach to Maritime Policy, thereby moving forward in making Ecosystem-Based Management (EBM) operational. The project set out to achieve this by (i) providing a comprehensive knowledge base to support policy for the development of sustainable and integrated management of European marine ecosystems; (ii) developing Operational Objectives to achieve the High-Level Policy Objectives set by the MSFD and the HD, and with reference to the proposed Maritime Policy; (iii) identifying Management Options (individual management tools and combinations of tools) to meet the Operational Objectives; (iv) providing a risk assessment framework for the evaluation of Management Options and to assess the risk associated with the different options; (v) conducting a cost-benefit analysis of a range of Management Options using appropriate techniques; (vi) identifying stakeholder opinions on the creation of governance structures directed towards implementation of the ecosystem approach, and to elaborate different scenarios for changing governance structures and legislation to facilitate a gradual transition from the current fragmented management approach towards fully integrated ecosystem management; (vii) documenting the steps necessary for the transition from the current fragmented management scheme to a mature and

integrated approach, and providing a toolkit that could be used to evaluate options for delivering ecosystem-based management; and (viii) communicating and consulting on the outcomes of the project effectively with policy makers and other relevant user groups.

These objectives were framed within some key bounding presumptions:

“(i) the setting of high level objectives is a societal decision, (ii) science (natural and social) should provide data and interpretations so that society makes informed decisions, (iii) science (natural and social) should advise on the selection of management tools to deliver the objectives, and monitor the effectiveness of the management regime in delivering them, and (iv) it is through an informed democratic process that decisions on management regimes should be developed.” (ODEMM Description of work).

While the overall aim of the project was to provide managers and decision-makers with procedures that could help to integrate management and move away from the current fragmented system, it was recognised that environmental objectives and management decisions are ultimately societal and that the role of science is to provide data and advice to the decision making process.

The project had clear objectives of developing approaches that could fulfil this provision of data, advice and options for management. ODEMM considered there to be five key principles to an approach that would make EBM operational. It must:

1. Have clear objectives that are determined by society and set in relevant policy, and then link these objectives to specific components of the ecosystem (i.e. work within a fully integrated ecosystem assessment framework);
2. Account for all possible interactions that are relevant to the policy objectives no matter how insignificant they may at first seem (be holistic), and then be able to weight and rationalise what is important and what management and/or monitoring and research should focus on;
3. Be based on structured, transparent and repeatable analyses that can work in data-poor situations (as well as those that are data-rich), because EBM should be holistic in evaluation of objectives and thus needs to account for issues even if there is little data available on them;
4. Include evaluation of management options that considers the implications in terms of ecological, social and economic outcomes (be able to consider trade-offs);
5. Have clear consideration of the relevant governance settings and how these might influence performance in achieving the EBM goals, at both a broad and specific (e.g. Management Option

performance in achieving the EBM goals, at both a broad and specific (e.g. Management Option Evaluation) level.

Project Results:
We consider that the tools and approaches developed in ODEMM can meet key needs in implementing EBM. In utilising the suite of tools developed during the ODEMM project it is possible to identify (environmental) priorities and relevant potential management options to address these priorities and to then explore their effectiveness (ecological), the wider effects of the management options on ecosystem services and the complexity of their implementation. In a nutshell, the ODEMM approach offers the means to:
1) Formalise and structure information gathered as part of initial assessments or other monitoring and assessment programmes
2) Prioritise the sectors and pressures for management
3) Prioritise the ecological components where threats to them pose the greatest risks to failing to achieve high-level policy objectives (such as the MSFD's Descriptors of Good Environmental Status)
4) Generate management options (based on 2 and 3 above)

5) Evaluate management options in terms of:
a) Evidence of effectiveness
b) Evidence of costs and benefits
c) Governance complexity
6) Provide frameworks for better governance models for effective EBM implementation in different regional contexts
These outputs were achieved through the completion of each of the objectives set out at the beginning of the project and each is expanded on below.
In the work undertaken to date, the ODEMM approach has been applied using Europe's Marine Strategy Framework Directive (MSFD) as the context. This policy is the environmental pillar of the Integrated Maritime Policy and thus the objectives are related to the state of ecological components and the human pressures acting on those components. The applications have achievement of these policy objectives as the key aim and thus the ODEMM approach has a pragmatic grounding for practical implementation by those currently working in decision making and providing advice to decision makers in European regional seas. However, the resources developed and described herein can be adapted to any geographic area or policy context where EBM is key.
Objective 1: To provide a comprehensive knowledge base to support policy for the development of sustainable and integrated management of European marine ecosystems.

The major developments of the knowledge base carried out in the ODEMM project were through an extensive review of the status, trends, pressures and impacts of the marine regions of Europe (Knights et al., 2011) and comprehensive reviews of the legal (Long 2011, Long 2012) and institutional aspects of the governance situation in Europe (Ounanian et al. 2012, van Leeuwen et al. 2012).
These compilations of current knowledge allowed the development of a linkage framework that identifies all relevant interactions between key ecosystem components – human activities or sectors, their pressures, ecological components and ecosystem services, and the relevant policy objectives; and a pressure assessment that can be used to weight and rationalise the key threats to ecological components and policy objectives, both within the context of the relevant governance setting and for the achievement of specific policy objectives.

specific policy objectives.

The ODEMM linkage framework is a systematic structure that firstly lists all relevant components of the ecosystem for the policy in question, and then describes all the causal-chain links between those individual components in a system of linkage tables (matrices) to give a fully connected ecosystem. Thus, the linkage framework provides the structure within which management options can be explored. In the application of this to Europe's MSFD, the policy objectives (i.e. achieving Good Environmental Status (GES) for the Descriptors) are linked to ecological components (e.g. seabirds or intertidal rock habitats) and pressures acting on these (e.g. marine litter), which in turn are linked to each-other and then back to sectors and human activities (e.g. shipping) through the pressures, and to ecosystem services (e.g. provision of raw materials) through change in state of ecological components.

The importance of including economic and socio-cultural components within integrated ecosystem assessments has been recognised within the MSFD as fundamental to the sustainable use of marine resources. The ODEMM approach integrates these interactions within a single linkage framework that allows for feedback and complexity. Thus, the ODEMM linkage framework and specifically, the underlying tables, can be used to identify those management options that minimise the impact of human activities on ecological components, whilst juxtaposing these against the demand for ecosystem services and the benefits arising from them. This will allow a thorough appraisal of any measures proposed to help achieve high-level objectives such as those of the MSFD for GES. The resultant matrices for each interaction are represented in an excel linkage table and these are available to download with an accompanying guidance document (available at White et al. 2013a, www.odemm.com/content/linkage-framework). For every numbered interaction, the guidance document describes how the individual components were categorised and the nature of the interactions shown in the accompanying linkage table.

By simply taking the linkage matrices, it is possible to examine the complexity and connectivity in the ecosystem. This helps to highlight aspects such as: which sectors interact with most ecological components, which pressures are most pervasive in the system in terms of connectivity between sectors and ecological components, and where there are similarities between sectors and/or pressures in terms of how they interact with the ecological components of the ecosystem.

Using the linkages between ecological components and ecosystem services, it is possible to weight the contribution of each ecological component to the supply in individual ecosystem services. For example, certain habitat types will contribute more to coastal erosion protection than others will. ODEMM took this one step further to relate how change in risk in the ecological system through application of management options then translates into a change in the potential supply of ecosystem services. This is described below under Objective 5 and in Hussain et al. (2013).

The linkage matrices set the structure for examining the ecosystem, but a weighting is required to help focus on which of the >6000 interactions should be prioritised for management or monitoring purposes. ODEMM thus developed a pressure assessment (PA) methodology (Robinson et al., 2013) that weights the interactions between sectors, pressures and ecological components based on the exposure, severity and recovery lag associated each interaction. This recognises that not all activities undertaken by broad sectors are necessarily as harmful as each other. By centring the approach on pressures, where these are defined as "the mechanism through which an activity has an effect on any part of the ecosystem", we are able to focus on the most damaging aspects of human activities and to thus target management with a higher level of precision.

The Pressure Assessment was developed acknowledging two key principles of operational EBM that any approach must: "Account for all possible interactions that are relevant to the policy objectives no matter how insignificant they may at first seem (be holistic), and then be able to weight and rationalise what is

how insignificant they may at first seem (be holistic), and then be able to weight and rationalise what is important and what management and/or monitoring and research should focus on"; and that the approach should "be based on structured, transparent and repeatable analyses that can work in data-poor situations (as well as those that are data-rich), because EBM should be holistic in evaluation of objectives and thus needs to account for issues even if there is little data available on them."

Pressures can be physical (e.g. abrasion), chemical (e.g. introduction of synthetic components) or biological (e.g. introduction of microbial pathogens) and the same pressure can be caused by a number of different activities. For example, both aggregate extraction and navigational dredging cause abrasion, a physical pressure that can affect a number of different ecological components. By including pressures as the key link between sectors and ecological components, we are thus also able to group activities by their pressure types (see Knights et al., 2013a) and again this can help with prioritisation of management and monitoring, as well as highlighting issues such as potential for cumulative and combined effects of multiple activities.

The initial step for carrying out the PA is the identification and linking up of all of the sectors, pressures and ecological components of the system. Any one sector-pressure-ecological component combination can be described as an impact chain and the pressure assessment gives a relative weighting to each impact chain. The weightings allow for comparison of the relative threat of different sectors and pressures to the range of components in any ecosystem, and for comparison between ecosystems. The ODEMM Pressure Assessment (PA) approach weights each impact chain in terms of five criteria Full details on the categorisation of impact chains across five criteria are given in the latest ODEMM Pressure Assessment guidance document (Robinson et al. 2013; available to download from www.odemm.com/content/pressure-assessment). The confidence assessment undertaken to accompany this is also described therein.

The PA has been applied to each of Europe's four regional seas and any impact chains identified as having the potential to exist from the 18 sectors, 24 pressures and 11 ecological components noted in the ODEMM linkage matrices assessed (methodology is described in Robinson et al. (2013) and full results will be presented in Robinson et al. (in prep)). Of a total of 5515 possible interactions, 3459 were found to have actual overlap (in space and time). A summary of some key findings is given below:

The majority of interactions between European sectors, their pressures and ecological components occurred at a site or local scale; only 15% of interactions were widespread in overlap with ecological components at the regional sea scale. Most interactions were rare or occasional, with only 18% of interactions classed as common and 3% as persistent i.e. where ecological components were thought to be exposed to the sector/pressure at all times where interactions occurred in space.

Where interactions occurred, the vast majority were classified as having a chronic severity, with only around 20% of interactions being either acute, or of low severity. The majority of pressures were categorised to persist for 0-2 years following cessation of activities causing them, but a core group of pressures were found to have the potential to persist in the ecosystem for more than 100 years. These pressures included radionuclides, non-indigenous species and also a number of pressures that would only ever be associated with activities that are unlikely to be removed (e.g. permanent coastal defences causing the pressure 'emergence regime change').

Beyond simply analysing broad patterns in pressure distributions in regional sea ecosystems, the PA database provides a valuable resource for prioritising monitoring and management of human activities and their pressures. High threat issues can be extracted using criteria specified to represent issues of greatest concern. In Robinson et al (in prep) we extracted high threat issues across Europe's regional seas using a number of criteria (Robinson et al. In prep; Robinson et al. 2014)

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Based on the criteria, 109 high threat interactions were identified within Europe's regional seas; the majority of these occured commonly throughout the year and had a long recovery lag due to low resilience of the component affected and/or high pressure persistence. Littoral rock and sublittoral sediment habitats were exposed to the highest number of high threat interactions; by contrast, the deep sea bed was the only component not involved with any high threat interactions. High threat interactions were constrained to a limited number of pressures (11 of the 24 pressures) and a limited number of sectors (9 of 18) and most were concentrated in the Mediterranean – with more interactions found there than in the other three regions combined. Marine litter introduced by Shipping or Tourism and Recreation accounted for almost half of all high threat interactions, with high numbers also associated with Selective Extraction of Species from Fishing and Sealing caused by Coastal Infrastructure.
Confidence assessments were also undertaken by the regional experts on the different criteria evaluated (see approach used in Robinson et al., 2013 and results in Robinson et al., in prep). These revealed the following broad issues: in terms of issues to do with overlap of sectors/pressures and ecological components, coverage and/or resolution of ecological components and sector activities is patchy, but best in the Northeast Atlantic; generally the understanding of how pressures are distributed around sectoral

activities is good, as is the understanding of how these pressures persist in the environment once any activities causing them cease; there is also good understanding of whether pressures have acute, chronic or severe interactions with ecological components overall. Knowledge of the current status of ecological components was variable, but generally good enough to assign each broad ecological component a resilience score with high confidence. The confidence assessment results can be used to highlight research gaps for prioritisation, particularly where low confidence is associated with a potentially high threat interaction.
The project intends to make the database freely accessible following publication of the main outcomes (Robinson et al., in prep). The PA database can be used to highlight priorities for monitoring and management in terms of high threat issues using combinations of criteria, or to examine issues to do with individual criteria, such as the number of high severity sector/pressure components currently affecting a particular ecological component in a given area. It can be adapted to different areas, or the same areas over different spatial scales or time frames or with different management criteria specified, although the time taken to complete a new assessment across all ecosystem components (even at the very coarse resolution described in Robinson et al., 2013) should not be underestimated and it is essential that expert teams have relevant experience and enough breadth in knowledge between them that they can confidently undertake all steps.

Objective 2: To develop Operational Objectives to achieve the High-Level Policy Objectives set by the Marine Strategy Framework Directive and the Habitats Directive, and with reference to the proposed Maritime Policy

A key aspect of any policy-relevant EBM work must be the periodic assessment of the status of key policy objectives. Early in the project we reviewed policy objectives relevant to EBM in Europe's regional seas. At that stage we decided to focus on the high-level objectives of the MSFD going forward as this would be where our work could have greatest impact.
The over-arching objective of Europe's MSFD is to provide ecologically diverse and dynamic oceans that are clean, healthy and productive, and exploited in a sustainable manner. Assessment of this objective is measured in terms of good environmental status (GES) against 11 qualitative descriptors. Progress to

measured in terms of good environmental status (GES) against 11 qualitative descriptors. Progress to date has seen all EU member states submit in 2012, an initial assessment of the state of their seas, with reference to national expectations for GES. However, there is great variation in terms of the interpretation of GES even within the regional seas. ODEMM therefore developed an approach to undertake an assessment at the regional sea scale so that it would be possible to relate national priorities to regional issues in a coherent manner.

Relevant information from existing assessments, from both national and regional sources, was found for most descriptors in most regional seas (See Annexes 1-4, Knights et al., 2011). However, whilst existing assessments are useful in the context for which they were developed, the specific criteria and methodology used to determine status and trends do not allow for easy inter-comparison. This is due to the differing motivations, spatial scales and objectives for which existing assessments have been carried out, which may or may not align with the issues highlighted by the MSFD's descriptors of GES.

Thus the background information collected cannot, on its own, tell us the current performance against the policy objective (e.g. the likelihood of achieving GES for Biodiversity by 2020). As a solution, ODEMM developed a method to undertake a rapid assessment of the current state of the GES Descriptors, using the information available from disparate sources/assessments. The degree of departure from GES is

categorised for each descriptor, based on the current situation and best evidence in the region, giving a measure of the level of effort required to achieve GES for each descriptor.

This approach has been applied in all four regional seas using a combination of existing assessments and/or expert judgement (Breen et al., 2012; also covered in Knights et al., 2011 where background information is also summarised). The outcomes provide insights to facilitate the identification of regional management priorities to support achievement of GES by 2020. ODEMM's approach is thus complementary to the work undertaken by individual Member States on the initial assessment of the state of their individual waters that was completed in 2012.

The approach provides risk criteria, in conjunction with a working definition of GES, for each of the GES Descriptors (all risk criteria and GES definitions developed are listed in Breen et al., (2012) and Annex V of Knights et al. (2011)). Confidence assessment criteria are also given based on the quality of information available, interpretability of information and level of agreement between experts carrying out the assessment.

Each MSFD Descriptor of GES was defined in the Directive (Annex I, EC, 2008), but in many cases the definitions failed to provide sufficient detail to determine if GES is likely to be achieved. For example, Descriptor 2 is defined as "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems" but it is not clear what would constitute adverse effects on the ecosystem, or how these might be linked to the distribution or number of non-indigenous species. For each of the descriptors assessed under ODEMM's risk of departure approach (Breen et al., 2012), a more detailed definition of each high-level objective is given, against which to assess the likelihood of departure (i.e. the risk of failing to achieve the objective).

For each clarified definition associated with achievement of each descriptor, criteria describing high, moderate and low levels of departure from GES are provided, corresponding with different levels of risk of failing to achieve the objective. In some cases, several different criteria for each level of risk are given, largely corresponding with the indicators outlined in the Commission Decision document (EC, 2010), in order to allow the assessment to be applied broadly (in this case across the four European regional seas).

Another feature of the approach is how to address the integration of potentially opposing evidence when there is information available on many different indicators relevant to the assessment of any one Descriptor. Cardoso et al. (2010) provided information about integrating several different pieces of

Descriptor. Cardoso et al. (2010) provided information about integrating several different pieces of evidence i.e. whether this should use an integrated or worst case scenario approach. An integrated approach meant that information should be combined before a final assessment was given, whilst a worst case approach followed a ‘one-out all-out’ principle, whereby if one piece of evidence suggested that the risk was ‘high’ then ‘high’ was automatically indicated for the entire descriptor. In order to reflect this, this approach uses an ‘and’ or an ‘or’ between criteria to indicate which method to use.

Application of the approach allowed a cross-regional comparison of the current level of departure from GES. Experts from all four regional seas completed the assessments in a series of workshops and later work was carried out to ensure consistency and rationalisation of the approach between regional teams (see full details in Breen et al., 2012 as well as results for the confidence assessment). The level of risk in the achievement of GES varied across descriptors and between regions, however when summarized across descriptors, there was little difference in the overall level of risk between regions. For the North East Atlantic, six of the 14 descriptor categories were assessed to be at high risk, whilst seven were assessed as high for the other three regions. In general, those objectives that are described by pressures (i.e. underwater noise, marine litter) or those that are related directly to impacts from pressures (e.g. commercial fish and shellfish and seafloor integrity) exhibited higher risk than state objectives. Five

common descriptors were assessed as having high risk across all four regions, namely Non-indigenous species, commercial fish and shellfish, food webs, sea floor integrity and marine litter. Several others were identified as high risk within particular regions.

This approach combines information on status and human impacts within a regionally consistent framework to assess the level of risk to GES. The need for such a methodology was highlighted in the process of conducting regional assessments from existing information, when specific national or sub-regional status reports were inconsistent with overall regional views. For example, UK predominant habitats (DEFRA, 2010) are reported as being in poor status, but when assessing risk to GES based on Biodiversity of predominant habitats for the whole regional sea (in this case the NE Atlantic), the level of risk was classified as ‘moderate’ indicating the importance of considering spatial scale of assessments when evaluating status at a regional sea level.

The assessment of risk of failing to achieve these GES definitions identified issues for regional prioritisation in addition to those identified in existing status reports. For example, the Baltic Sea and Black Sea Action Plans (BSC, 2009) (HELCOM, 2007) focus on issues relating to the descriptors (1) Biodiversity, (5) Eutrophication, (6) Seafloor Integrity and (8&9) Contaminants and Contaminants in Fish and Shellfish. However, the risk assessment undertaken here suggests that Non-Indigenous Species, Food Webs, Marine Litter and Underwater Noise are also potential areas of concern. This shows that translation of the outcomes of even spatially comparable assessments and their placement in the context of the MSFD may be precluded by differences in assessment objectives.

Our experience of applying this approach across Europe’s regional seas supports the need for a common tool if the results from the initial assessments are to be in any way comparable.

Risk outcomes are closely linked to the level of ambition of the descriptor and these differed between the descriptors. There were few high risk Biodiversity components, although other descriptors that we might expect to have consequences for Biodiversity such as Non-Indigenous Species (NIS) were classified as at high risk. In this example, the crucial difference in GES ambition is in the definition of acceptable ‘loss’. High risk under Biodiversity requires the likelihood of “loss of biodiversity or maintained change in dominance/assemblage structure”, whereas for NIS, significant adverse effects of an invasive species do not have to be as severe as elimination of a population and can include effects such as increased seasonal dominance of algal blooms in the region (See further discussion on this and the importance of the timeline

dominance of algal blooms in the region (See further discussion on this and the importance of the timeline set for risk criteria in the Discussion of Breen et al. (2012)).

Risk scores may also depend on the ability to assess the criteria with the available information. Confidence in assessment can be interpreted in terms of prioritization of action to help achieve GES for particular descriptors where there are few data or a lack of understanding of the limitations of the data. As such, when confidence is low or low-moderate, recommended actions might include: (i) implementing monitoring programmes to improve data knowledge, (ii) re-analysing data to make our current data more useful for the MSFD, (iii) further development and research to improve understanding and use of the descriptors. Where improving data provision is not possible, it may be more sensible to use a precautionary approach, whereby high risk in one descriptor (e.g. Seafloor Integrity) automatically triggers high risk categorisation of a related descriptor i.e. Biodiversity of predominant habitats. This would ensure that at a minimum, monitoring and evaluation of biodiversity aspects would occur. There are clear inter-relationships between some of the descriptors of Europe's MSFD (Borja et al., 2010) and our results suggest that it will be important to recognise the links between descriptors such that high risk issues identified for one descriptor can trigger a similarly high level of priority in others.

The framework allows the state of policy objectives to be assessed at any regional scale and the

methodology can be easily adapted to other policy drivers and their targets/objectives. In combination with other tools, the high risk outcomes presented in this work can be used to help prioritise management measures.

Objective 3: To identify Management Options (individual management tools and combinations of tools) to meet the Operational Objectives, and

Objective 4: To provide a risk assessment framework for the evaluation of Management Options and to assess the risk associated with the different options

As part of the objectives (3 and 4) to identify management options and provide a risk assessment, ODEMM developed a risk assessment to prioritise management and which could subsequently be carried through to select and assess management options. The work undertaken under Objectives 1 and 2 helped to highlight areas of concern in each regional sea, and the PA methodology developed originally under Objective 1 was built on to take forward full risk assessment.

In its assessment, the ODEMM project described a complex network of interactions, with over 3,000 impact chains in some regional sea areas (Knights et al. 2013a; White et al., 2013). The ODEMM pressure assessment (PA) methodology made significant strides towards assessing the threat from those impact chains and a valuable step in determining the importance of each impact chain. However, it is also possible to assign numerical scores to the categories of the PA such that impacts can be grouped across pressures, sectors and/or ecological components, allowing for further exploration of the information at a more aggregated level.

The ODEMM risk assessment methodology is based on an exposure-effect analysis, but also bringing in recovery lag, which adds to the overall level of risk. The pressure assessment (PA) methodology was designed with the concept of risk assessment in mind. As such, the PA criteria can be directly related to the different aspects of risk, and the categorical assessments of the five criteria in the PA (see Robinson et al., 2013) each assigned a numerical score for the risk assessment (for details of how each of the pressure assessment categories was numerically scored see Table 1 in ODEMM Deliverable 9, Knights et al., (2013b)). These scores were then combined to give:

- Impact Risk, which is the combination of scores from the spatial extent, frequency and severity criteria

- Impact Risk, which is the combination of scores from the spatial extent, frequency and severity criteria, and where the greater the Impact Risk score, the greater the threat to that component or combination of components, and
- Recovery Lag, described using a combination of the persistence of the pressure and the generic resilience (recovery time) of the ecological component. This aggregate criterion gives an indication of the time required for potential improvement in ecosystem state to be seen following the management of a specific impact chain, where the greater the recovery lag value, the longer time period required for an ecological component to recover back to its pre-impacted state.

Impact risk and recovery lag can be calculated as the average or summation of all impact chains aggregated by sector, pressure or ecological component (See Piet et al (in prep) for an exploration of how scoring and summation method affects outcomes in the risk assessment approach). The assessment allows the 'worst' impact chain or chains to be identified (either in terms of impact risk and/or recovery lag) in isolation or grouped in combinations e.g. by sector or pressure.

Using the PA described above under objective 1, impact risk and recovery lag were scored for all impact chains found in each of the four regional seas of Europe. Full details of the application and results are described in Knights et al. (2013b) and here we summarise findings for Impact risk only.

The ranking of sectors by impact risk varied between regional seas, but the sectors posing the greatest impact risk were largely common across regions. Fishing was identified as the greatest risk sector in all regions; the risk at least two times greater than from any other sector and consistent with common perceptions of which are the greatest risk sectors. This risk score is the result of a relatively large number of impact chains being attributed to this sector, coupled with a high average risk score per impact chain driven by widespread, frequent and severe pressure assessment outcomes. We can contrast this sector with the relatively high average risk score of sectors such as aggregates and agriculture, but where the number of impact chains they generate has limited their total risk score. Notably, comparison of the maximum risk score associated with any one chain introduced by a particular sector indicates that the majority of sectors, despite often demonstrating relatively low total impact and average impact risk scores, introduce at least one chain of relatively high risk to the ecosystem.

Regionally specific risks were also identified by the assessment. For example, agriculture and aquaculture were identified as high-risk sectors in the Baltic and Black Sea respectively, reflecting the challenges those regions face from Nitrogen and Phosphorus enrichment (N&P) and its contribution to eutrophication. In the Mediterranean Sea, tourism and recreation was identified as a higher risk sector.

The ODEMM ecological risk assessment methodology allows users to identify risks at a broad level, such as that illustrated above for whole sectors. This allows high level prioritisation across and within regional sea ecosystems.

In further work, we developed an integrated management strategy evaluation (iMSE) approach that allows users to select management options to target different aspects of risk in the ecosystem.

Improving the state of the environment requires focussing on management of human activities. A key aspect of EBM is, therefore, the choice of management options (MOs) that can target the major threats to the different aspects of the ecosystem. The ODEMM pressure and risk assessments allow the main threats to be identified and indicate the links between components and human activities. The ODEMM integrated Management Strategy Evaluation (iMSE) tool can be used to link types of MOs with the categories of the PA, allowing different manageable aspects of human activities to be targeted to address the main threats in the system. Management options can focus on drivers, pressures, ecological components or combinations of these.

There are different types of MO that can be applied to control human activities; these include spatial and

There are different types of MO that can be applied to control human activities, these include spatial and temporal distribution controls, input and output controls, remediation and restoration. This allows several options to be produced which can achieve the same goal. For example, a management option could target how widespread an activity is through a spatial control; or how often the activity occurs through an input or output control.

The ODEMM iMSE tool is a comprehensive framework that aims to provide guidance for the identification and selection of consistently defined management options and allows an evaluation of these options in terms of their effectiveness to achieve policy objectives through their reduction of risk. Effectiveness is defined as the reduction in ecological risk associated with a specific MO. Management may target a sector or pressure directly and either remove the risk entirely or in part. We can also explore reduction in risk to Descriptors by understanding the links between ecological components, pressures and MSFD Descriptors.

The iMSE tool is based on the most extensive risk assessment framework to date (Knights et al. 2013b), consisting of Driver-Pressure-State combinations (impact chains) that each contribute to the risk of not achieving policy objectives. The tool takes the different aspects of risk (based on the PA criteria) and uses two distinct aspects of a measure, i.e. the “Focus” and the “Type” of measure, to select MOs that can reduce risk.

The “Focus” is determined by the part of the impact chain (Driver-Pressure-State) the measure is supposed to mitigate. A management measure may therefore involve only one single element in the impact chain (i.e. Driver, Pressure or State), the combination of two (i.e. Driver-Pressure or Pressure-State) or three which effectively implies it aims on one specific impact chain (i.e. Driver-Pressure-State) making the measure more specific as more elements are combined.

The “Type” represents the physical measure which affects the impact chain directly. We distinguish six types of measure loosely based on the MSFD (EC, 2008) that each link differently to the risk criteria. The options “Spatial distribution controls”, “Temporal distribution controls”, “Input control” and “Output control” each (or in combination) mitigate the Impact Risk, while “Remediation”, and “Restoration” mitigate the Recovery Lag.

The iMSE tool can analyse how risk is reduced when individual or combinations of MOs are applied, either in terms of a reduction in Impact Risk (IR), Recovery Lag (RL) or Total Risk (which is the product of RL and IR). Reduction in risk can be evaluated for single ecological components, the whole ecosystem or a GES Descriptor.

Using the risk assessment database, the iMSE tool was applied to explore effectiveness of a range of measures that varied in both ‘Type’ and ‘Focus’ (see full details in Piet et al., In prep (a), Deliverable 7 of ODEMM). A total of 20 management measures were selected for comparison, ranging from those that had a specific Focus on one set of impact chains (e.g. applying TACs (total allowable catch) to limit the pressure ‘selective extraction of species’ caused by the sector ‘fisheries’, acting on ‘fish’ specifically), through to those that had a broad Focus (e.g. Banning littering from any sector; i.e. a measure aimed to target the pressure ‘Marine Litter’ regardless of sector or impacts associated).

In the application of the iMSE tool here, the performance of a management option, in terms of its reduction of risk, depended on (a) the number of impact chain(s) and (b) the risk criteria associated with that option. The performance was assessed based on an explicit consideration of three time horizons for management:

- Past: management aimed at reducing existing adverse impacts from past activities
- Present: management aimed at current activities based on preventing/reducing the likelihood they will cause an adverse impact

cause an adverse impact
- Future: management aimed at current activities but considering both the likelihood of an adverse impact as well as the time it takes to return to pre-impacted condition after the implementation management
Outcomes were explored in terms of change in risk for the three time horizons as follows: “Past” was based on the Recovery Lag (RL), “Present” on the Impact Risk (IR), while “Future” was based on the Total Risk (TR). These “Time Horizon” perspectives are explicitly considered in our evaluation of the management options. For the evaluation of the options we assumed a full implementation of the measure (i.e. a 100% reduction of the risk criteria linked to the Type of measure).
From a “Present” perspective we only considered options that affect the likelihood of current activities to cause an adverse impact (where RL is not affected) and do not consider the remaining management options (where IR is not affected) which are specifically intended to reduce existing adverse impacts and hence only relevant for the “Past” perspective. All management options are relevant for the “Future” perspective for which TR applies.
The “Past” perspective shows that the best Recovery option targeting the most impacted ecosystem component (i.e. fish, a combination of pelagic-, demersal- and deep sea fish) performs better in terms of a reduction of the RL than the best Remediation option targeting the second most important pressure (i.e.

Marine litter after Sealing for which management is unlikely).
The “Present” perspective shows that options targeting what is currently the main driver causing adverse impacts (i.e. fisheries), either through a Spatio-temporal closure or through an Input control, cause the largest reductions in IR and that the performance of the options increased as more impact chains are targeted by the measure.
The “Future” perspective shows that the one Output control option performs best because it is preventing a pressure (i.e. marine litter) that has a high likelihood of causing an adverse impact as it is caused by many different drivers together with a long RL due to its persistence.
The iMSE tool provides a powerful means for exploring the effectiveness in MOs, which can then be used as one aspect in the consideration of tradeoffs between different MOs when choosing programmes of measures to help reduce threats to the different aspects of the ecosystem, and in particular here, to reduce risk to the Descriptors of GES. However, whilst the iMSE tool assesses the performance of the potential management options quantitatively in terms of their relative reduction of the risk of an adverse impact, we caution that the results should be used qualitatively (i.e. providing a ranked order of the management options).
Moreover, the final choice of the actual options requires an interpretation of the feasibility of the guidance coming from this tool in a real-world context. The instruments to initiate the MOs, i.e. regulatory, economic and social (van Vliet, 1999), should be based on the outcome of this process considered in the appropriate governance and socio-economic context.

Objective 5: To conduct a cost-benefit analysis of a range of Management Options using appropriate techniques

In ODEMM, a number of approaches were explored that can be used in trade-off analysis of management options (MOs), in terms of cost-benefit analysis (Hussain et al., 2013). On the benefits side, an ecosystem services approach was assumed, where ecosystem services 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). ODEMM set out to use ecosystem services as a unit-of-account for assessing the incremental changes that arise when the state of the ecosystem changes. The approach considers each ecosystem service in

that arise when the state of the ecosystem changes. The approach considers each ecosystem service in turn and assesses, where possible, whether the supply of a particular ecosystem service will be higher or lower (and the extent of change) when comparing one management option with another.

Early in the project it was noted that there were many gaps in terms of the tools and understanding required to complete assessments for benefits arising from application of MOs, in particular when these are based on an ecosystem services approach. There were also gaps in terms of guiding comprehensive cost assessment of any MOs. Effort was therefore placed in furthering these two areas of research independently, rather than on carrying out cost-benefit analysis per se. Emphasis was placed on development of typologies of ecosystem services and costs, to ensure that an appropriate structure is in place for full evaluation of trade-offs in terms of social and economic outcomes of MOs. On the benefits side, work was also undertaken to explore what is possible in terms of estimating change in supply of ecosystem services where data (and knowledge) is lacking, as well as furthering data available for monetary valuation of those services.

The need for a typology of ecosystem services arises so as to ensure that all 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 ODEMM ecosystem service typology built on and adapted extant terrestrial typologies (TEEB, 2010; MA 2005) which have 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 scientific rationale for the categorisation of ecosystem services in the ODEMM typology is set out in Böhnke-Henrichs et al. (2013) and a set of ecosystem service cards which summarise and illustrate the full typology is freely available to download at www.odemm.com. Using these cards (and Böhnke-Henrichs et al., 2013) allows decision-makers to begin to identify those ecosystem services that are likely to be priorities in their particular decision-making context.

The ODEMM approach links up MOs with Sectors, Pressures, Ecological Components and Ecosystem Services. 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 ecosystem services presented in the Böhnke-Henrichs et al. (2013) typology. This means that it is possible to extract the relevant links for any scenario and to see which ecosystem services have the potential to be affected by that scenario.

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 below.

In a series of regional sea case studies, the effects of applying a range of MOs were compared in ODEMM

In a series of regional sea case studies, the effects of applying a range of MOs were compared in ODEMM with the do nothing scenario 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 ecosystem services supply could arise either as a direct effect of a change in ecosystem state and/or as a direct consequence of the management applied (Full details of these assessments are given in individual regional case study reports available on www.liv.ac.uk/odemm/data/ and a tabulated cross-regional overview of the findings, in terms of the ability to quantify change in ecosystem services supply under each scenario, can be found in Annex I of Hussain et al 2013).

The main findings (a full discussion is given in Hussain et al 2013) from the ecosystem services case study work in ODEMM showed that there are many data and/or knowledge gaps in terms of the ability to undertake quantitative analysis of the likely change in ecosystem service supply resulting from application

of management options. There is generally poor understanding of how the change in state of specific ecological components would result in a change of supply of specific ecosystem services. However, there are cases where experts are confident that there would be no effect of the management option applied on the supply of particular ecosystem services. This helps to narrow down the scope of assessments still required to conduct a full ecosystem services trade off analysis.

Further investment in this area of research is clearly required, but given the current absence of understanding and/or data, ODEMM went on to develop a more qualitative approach to predict the relative change in ecosystem service supply following application of MOs, to facilitate exploring consequences across all ecosystem services (see below). This was deemed important because otherwise decisions made about the selection of management options are based on assessments of the few relatively well studied ecosystem services (Seafood, Tourism and Recreation) which leaves the likelihood that full trade-off analysis of benefits cannot be achieved.

The ecological consequences of marine management were explored with the concept of ecological risk. 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. As the linkages between state of ecological components and supply of ecosystem services have been established in ODEMM using the linkage framework, it was thus possible to then examine how change in risk to the ecosystem would lead to change in supply of ecosystem services.

In order to translate risk reduction to change in supply of ecosystem services, it was necessary to categorise the relative contribution made by each identified ecological component to the supply of each identified ecosystem service. The analysis of the relative contributions of ecological components to ecosystem services is conducted using expert judgment, scoring the contributions on a categorical scale from none, low, moderate or high (Hussain et al. 2013). This then allows a formal link to be assigned between changes in ecosystem services supply to changes in marine management. This is achieved by multiplying the reductions in the ecological risk associated with each ecological component (the output of the ecological risk assessment) by the relative contribution linking each ecological component to each

the ecological risk assessment) by the relative contribution linking each ecological component to each ecosystem service (the categorical score). As the results are based on the best available information, when better information becomes available scores should be reviewed and updated where necessary (as part of an adaptive management process). Thus, 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 management options.

The ODEMM project has contributed to the evidence base on the valuation of marine ecosystem services in two significant ways: (i) conducting primary valuation studies using a methodology termed 'choice experiments' to assess marine cultural ecosystem services; and (ii) the development of a database of marine ecosystem service 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 for a defined change in the natural environment (quality, access or both) is elicited through a structured, survey-based approach. ODEMM investigated willingness-to-pay through choice experiment surveys, with one in each of Poland, Romania, and Turkey. The methodology employed across these case studies was novel in that it focused on the monetary valuation of cultural ecosystem services other than 'Recreation and Leisure.'

In each choice experiment 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.

As well as conducting primary valuation studies, ODEMM also developed a database of valuation studies. In total 590 studies were reviewed (see Hussain et al. 2013 for a synopsis). 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 ecosystem services, with the exception of 'Recreation and Leisure'.

ODEMM has developed a typology of costs, adapted from existing typologies, associated with the implementation of management options. This highlights the range of cost categories that should be considered when pursuing a full cost assessment of marine policy. 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. It is noteworthy that these cost categories are incurred not only by the regulator, 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 non-governmental organisations (NGOs) may need to carry

to set up the platform for communication but non-governmental organisations (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 Marine Protected Area (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 (Baulcomb, 2013).

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

A second issue is that any before application cost assessment is likely to be applied under conditions where the management option is not fully specified. For instance, knowing that the management option 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.

A failure to apply EBM (with its focus on the supply of ecosystem services) will mean that policy choices may not be economically efficient, and can easily miss key trade-offs. Although a management option is likely to be specified with a particular target in mind - for instance achieving GES for one MSFD descriptor, the management option is likely to have impacts on other descriptors and also impact on specific ecosystem services. The management option that is best in terms of reducing the risk of failing to meet GES for that particular descriptor may not be the best choice in economic terms. This could result from co-benefits in terms of enhanced ecosystem service supply, or indeed inadvertent losses in ecosystem service supply.

This links to the cost-effectiveness analysis (CEA) approach. CEA differs from cost-benefit analysis 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. We would argue caution here owing to the issue of co-benefits. Even if management option A reduces the risk of failing to achieve GES for one descriptor as much as management option B and is cheaper to implement, it may be the case that option A increases the risk of failing to achieve GES for other descriptors and/or that option B provides co-benefits in terms of ecosystem service provision that are missed when a cost effectiveness approach is taken.

A cost-benefit analysis must be based on a specific management option, and in so far as is possible, that management option should be assessed using an approach which focusses on ecosystem services. Approaches developed within ODEMM help to facilitate this need.

The economic analysis of management options at a regional scale requires the attribution of costs and benefits across different nation states, and the constituency of winners and losers may differ. Although the appropriate spatial scale for the specification of management options (and the ecological modelling that

appropriate spatial scale for the specification of management options (and the ecological modelling that tests the impacts of such interventions) may be at the regional scale, it is challenging for economic valuation to be applied at such a large scale when considering some ecosystem services. 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 ecosystem services 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.

There are very few re-usable data points for the valuation of marine ecosystem services, 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 ecosystem services were

found (if we exclude 'Recreation and Leisure'). The total for most individual ecosystem services was <5. ODEMM has carried out primary valuation and generated usable values. Such work should be prioritised if we are required to place monetary values across the full range of ecosystem services. At the same time, it may not be appropriate to assign monetary values to all services, and even if it were, there is still a need to link change in state of the ecosystem arising from management interventions to change in supply of the full range of ecosystem services. ODEMM has developed a qualitative method to complete such an assessment (See Hussain et al., (2013) and http://odemm.com/content/cost-and-benefits-analyses).

Objective 6: To identify stakeholder opinions on the creation of governance structures directed towards implementation of the ecosystem approach and to elaborate different scenarios for changing governance structures and legislation to facilitate a gradual transition from the current fragmented management approach towards fully integrated ecosystem management

In ODEMM, another focus of the research was on the exploration of the governance complexity around implementation of policies such as the MSFD. Governance complexity can be defined as the likelihood of adoption and implementation of a management option, given the complexity of the governance system (legislation, institutions and stakeholders) and (lack of) institutional interaction.
The focus of the MSFD is on marine regions. Member States (MSs) sharing a regional sea are supposed to cooperate and coordinate their activities. To achieve this coordination it is suggested they make use of existing regional institutional cooperation structures, such as the Regional Sea Conventions (RSCs). Despite this recognition for the need to organise regional cooperation and coordination between MSs and with efforts undertaken by the RSCs, the MSFD itself does not provide any specific legal framework nor specify governing structures to ensure cooperation and coordination at the regional sea level between MSs (Long, 2012; van Leeuwen et al., 2012).
Early work in ODEMM identified high levels of ambiguity in terms of understanding of the MSFD and how it would be implemented at all levels of governance around Europe (van Leeuwen et al., 2012; Ounanian et al., 2012). Novel work going forward in ODEMM was thus focused on addressing two key challenges in implementation of the MSFD: the development of (1) governance models that would help facilitate thinking about the options and possibilities of stakeholder involvement and regional cooperation and collaboration

about the options and possibilities of stakeholder involvement and regional cooperation and collaboration; and (2) a nested hierarchical structure for linking emerging regional governance requirements with existing sectoral governance arrangements.

Based on the building blocks participation/stakeholder involvement and decision-making power (binding or non-binding decisions) we developed four governance models for regional cooperation: (1) Cross-border platforms; (2) Regional Sea Convention-PLUS; (3) Advisory Alliance and (4) Regional Sea Assembly (van Tatenhove et al., in press; Robinson et al. 2014). These are described below:

Cross border platforms consist of neighbouring MSs working together on an ad hoc basis and coordinating their initiatives in implementing the MSFD through information sharing. Typically cooperation takes place between two or three MSs at the sub-regional level. Participation of representatives of marine sectors and NGOs is mostly through consultation (asked for comments) at the national level. This mode of governance emulates the present way of involving stakeholders in the MSFD process and will not provide stakeholders with formal influence on the outcome of decision-making processes (although they can still exercise informal influence). Furthermore, the cross-border platforms will not have binding decision-making power. Each individual member state remains responsible for the implementation of the MSFD and use of shared information. Cross-border platforms are temporary, because no formal cross-border institutional

arrangements are developed. Participating MSs themselves take the initiative to organise bilateral or trilateral meetings on an ad-hoc basis or will agree on more formal procedures for coordination and collaboration.

The Regional Sea Convention-PLUS governance model takes the existing structures between the EU, RSC and MSs a step further by providing the Regional Sea Convention with a stronger role and mandate in implementing and coordinating the regional aspects of the MSFD. This model replaces the nationally-oriented implementation process with a regional implementation process coordinated by the RSC+. At the level of the marine region or sub-region, MSs negotiate assessment work to define GES, programmes of measures, implementation procedures and policies that shall direct the implementation of MSFD and monitoring programmes at the regional rather than at the national level. In this model, MSs still play a key role, but the difference with the existing situation is that binding decisions to which the MSs adhere, are taken in the RSC+. MSs have to implement these decisions and follow implementation guidelines as formulated by the RSC+. Stakeholder involvement will remain to be implemented at the national level in accordance with MS procedures for stakeholder consultation.

The governance model of the Advisory Alliance is comparable to the Regional Advisory Councils (RACs) known from fisheries under the Common Fisheries Policy (CFP). The RACs are bodies providing advice to the EU Directorate-General for Maritime Affairs and Fisheries (DG MARE) and to national authorities of involved MSs on request. The Advisory Alliance proposed here would consist of representatives of all maritime stakeholders; industry (fisheries, oil and gas industry, shipping, off shore wind energy, coastal tourism), societal groups (eNGOs), and relevant national administrations. An Advisory Alliance would be installed for each marine region or sub-region. The Advisory Alliance formulates non-binding advice to the EU and the MSs and leave the implementation of decisions to the individual MSs. However, and in contrast to how RACs operate at present, it is envisaged that MSs would take on the role of coordination and facilitate collaboration both between MSs and between MSs and stakeholders at the regional sea level. Although this governance model is advisory in nature, and hence has no formal implementing authority in MSFD measures, the platform is intended to stimulate coordination and collaboration through soft modes of governance e.g. best practises and peer pressure.

The Regional Sea Assembly (RSA) governance model proposes the establishment of a new institution

The Regional Sea Assembly (RSA) governance model proposes the establishment of a new institution. The RSA is given the exclusive competence of management of marine regions (regional sea), its natural resources, habitats and its uses. Hence an important responsibility of the RSA is to implement the MSFD, yet also to decide about other marine policies for a specific regional sea. The assembly is an entirely new governance arrangement at the level of the regional sea, with sovereign decision-making power and an elected representative body. Through elections all citizens and hence all stakeholders of the regional sea can be involved. The Members of the RSA are elected by a voting system and represent the Member States, ideally including neighbouring states (but likely impossible in practise) and the maritime sectors. The RSA has decision-making power on both operationalising and implementing maritime policies. There is a clear demarcation of the RSA from its bureaucracy responsible for the implementation processes. Decisions are taken by all the members of the RSA. The RSA will adopt binding policies for all Member States, industry and other users of the marine environment in a particular regional sea. Because the RSA is responsible for the implementation, it will also have enforcement mechanisms at hand, such as sanctioning in case of non-implementation. Consultation and advice procedures will be set up for those stakeholders who do not participate in the RSA directly.
For each of the models we assessed the governance performance. Governance performance of a model is

the effective and legitimate implementation of the MSFD, given the costs (in setting up and running the model and the capacity to cooperate of public and private actors) needed and the benefits achieved (in terms of cooperation, institutional ambiguity and implementation drift). The models were also evaluated by stakeholders in four regional Round Table Discussions (RTDs) (in the Baltic, the Mediterranean, the Black Sea and the Greater North Sea).
When we compare the different governance models, the Advisory Alliance scores the lowest on performance. The high costs to organise participation are not rewarded by the outcome of the decision-making structure. While increased participation is strived for by many stakeholder groups, the associated governance performance is low as costs of running a model on high stakeholder involvement are high and these costs are not offset by a reduction in other governance performance criteria. The role of stakeholders is only advisory. This makes this model effective in giving insight into stakeholder preferences, but the legitimacy of implementation is low. Furthermore, the participants of the RTDs came to the same conclusion: the effectiveness of the Advisory Alliance is not guaranteed and this model could only function successfully in combination with (elements of) other governance models.
The performance of the other governance models is medium to high, with the highest governance performance for the Cross Border Platforms. An important reason for this is that the way stakeholders are involved in these models is clearly coupled to institutionalized decision-making settings. Yet even though the overall performance is comparable across the three models, the ratio between costs and benefits differs. For example, the Regional Sea Assemblies have the highest score on the benefits (high policy coordination and low degrees of ambiguity and implementation drift), but at the same time, score worst on the costs involved in creating a new decision making structure. Although there is low stakeholder involvement in the Cross Border Platforms and RSC+, these models score high on governance performance because the costs (for setting up and running the model and the capacity to cooperate) are low to medium, while the overall benefits are also medium.
Despite differences for the regional seas, the stakeholders in the RTDs perceived the Cross Border Platforms as a useful starting point for regional cooperation and the Regional Sea Assembly as the most unrealistic governance model. Stakeholders liked the general structure of the RSC+ model, because of its possibilities to contribute to integrated management of the European seas but criticised the lack of stakeholder involvement and the lack of precision of the enforcement of decisions made of this model. The

stakeholder involvement and the lack of precision of the enforcement of decisions made of this model. The preference of the RTDs was therefore to combine the Advisory Alliance with the RSC+ to ensure both stakeholder involvement and binding decision making.

Based on the research undertaken by ODEMM in this area, we draw two important conclusions. First, stakeholder involvement at the regional level is costly and does not necessarily bring many benefits, unless it is combined with decision making power. A second conclusion is that an effective and legitimate implementation of the MSFD can only be realised by a combination of the suggested models. In addition, we have to bear in mind that because of the institutional differences of the four regional seas there is no "one size fits all" solution. Depending on the regional sea as well as the phase of implementation (e.g. defining GES, formulating programmes of measures) different hybrid models are desired.

The implementation of ecosystem-based management (EBM) requires the development of governance structures and coordination mechanisms at the level of the regional seas. The governance challenges to implement EBM are on the one hand to create platform(s) and hybrid governance models, which facilitate regional collaboration and coordination in relation to implementation of EBM, and on the other hand, to allow for coordination and to create synergies between the various sector policies and any relevant institutional setting at the broad policy level.

The process of regionalisation of governance arrangements requires the nesting of individual sectoral governance arrangements. This nested (polycentric) governance system has to deal with the existing multi-level governance arrangements that have emerged and evolved over the last decades to govern activities such as shipping and fisheries or that focus on marine environmental protection more generally. By developing institutional linkages with these governance arrangements it could be possible to ensure a common discourse, policy objectives and decision making and implementation of sectoral measures supporting EBM objectives at the regional sea level. ODEMM developed a nested governance structure that can be used to explore how the institutional setting of the EU (as laid down in the Treaties) at the regional level, can/should be connected with existing sectoral governance arrangements for any policy or management issue (Raakjaer et al., in press; Robinson et al. 2014).

To create constitutional rules and principles within this nested governance system, soft modes of governance are of vital importance. Soft modes of governance (such as the Open Method of Coordination (OMC), peer pressure voluntary agreements, etc.) in the nested governance system at the regional sea levels can prove to be a useful tool for steering policy implementation, because the non-binding nature leaves room for innovative practices, the capacity for policy learning, deliberation, as well as policy coordination.

For the four European regional seas (Baltic, Black, Mediterranean and the North East Atlantic Ocean) we analysed the fragmented governance situation and the challenges to realise institutional interaction and linkages. A corresponding lack of collaborative institutional interaction, between the coordinating parts and the relevant sectoral governance arrangements, was found across seas and sectors. For example, the RSCs which exist in each region have variable levels of interaction with certain sectors such as fishing, shipping or agriculture, limiting their influence on decision making and the potential for coordination in EBM.

Our main concern is that the present governance structures (European, regional, international or national) cannot fully deal with the foreseen challenges of EBM implementation, in particular that of ensuring coordination and collaboration in a multi-governance setting with a dynamic policy environment and various stakeholder groups and interests (national authorities, economic sectors and NGOs).

Clearly EBM calls for regionalisation of the governance system to match the (sub) ecosystem (e.g. regional sea). In this process, institutional ambiguity should be eliminated where possible and regionalisation, in the

sea). In this process, institutional ambiguity should be eliminated where possible and regionalisation, in the sense of developing institutional interactions in a nested governance system at the level of the regional sea, should occur knowing that (in an EU context) such an approach lacks legal support from EU treaties. The reformed CFP might show a way forward for regionalisation in European marine governance drawing on soft modes of governance. We emphasise the importance of understanding the nested governance system. This could be implemented through RSCs or similar institutions (different alternative governance models explained above) serving as a coordination body. Through this, institutional interactions could be encouraged, thus avoiding duplication of activities and benefitting from institutional coexistence, while applying Open Methods of Coordination.

Another important conclusion is that governance structures need to be context dependent (as they to some degree already are) and should avoid a “one size fits all” approach, which tries to create an embroiling umbrella without taking sectoral and regional, national and sub national policy dynamics into account. Because the implementation of EBM takes place in a policy environment of nested institutions, the way forward is to mobilise and allow specific forms of institutional networking and interaction for each of the regional seas to secure collaboration and policy coordination.

To secure tailor-made regional cooperation, policy coordination and collaboration between private and public actors at the level of the regional sea, research is needed to understand a regionalised nested governance system. ODEMM has made a first step to develop governance models, and a first understanding of hybrid models for the different seas and the policy and stakeholder dynamics within the sectors in a nested governance structure.

The next research step should be the development of nested governance systems, based on in depth studies of institutional interactions and inter-linkages and a thorough investigation of how institutional interaction and soft modes of governance are emerging between the Regional Sea Conventions and sectoral governance arrangements in the implementation of the MSFD in the four regional seas. To what extent is institutional interaction facilitating the translation of the objectives of GES into management options for individual sectors? This research can focus on each individual European sea to support policy development, but can also have a comparative element in which lessons across the European seas and even across continents are investigated. The research can focus on successful examples of institutional interaction and soft modes of governance, but also on existing gaps that hamper the translation of the objectives of GES into management options for specific sectors. In addition, research can focus on how institutional interaction and soft modes of governance enhance or constrain stakeholder involvement of different sectors, industry groups and other interest groups in the different European seas. Or on how decision making authority is dispersed across European Institutions, Parties to the Regional Sea Conventions, EU member States, industry groups and other interest groups, and how institutional interaction and soft modes of governance reinforce or change decision making authority of these actors.

Objective 7: To document the steps necessary for the transition from the current fragmented management scheme to a mature and integrated approach, and to provide a toolkit that could be used to evaluate options for delivering ecosystem-based management.

User-friendly guides to the approaches ODEMM has developed to date are at www.odemm.com. These are what we consider to be best practice with the available knowledge and techniques that we currently have at our disposal, but naturally, these can be improved and built on. The following section is a reflection on how we can move forward with improving EBM, based on feedback from participants in roadshows held on the ODEMM tools and approach, as well as feedback from our Advisory Committee and lessons

held on the ODEMM tools and approach, as well as feedback from our Advisory Committee and lessons learnt by the project team. We believe that moving forward with implementation of EBM requires both advances in research and in the practical organisation of how management of the marine environment takes place. The following describes ten steps to moving forward with successful implementation of EBM (where numbers do not indicate any order of importance).

1. Making use of what we have now in practice

Successful trialling of the ODEMM approach through the series of regional roadshows revealed that the resources available (www.odemm.com) can already be of use to those working in practice. There is a particular relevance to implementation of the next stage of the MSFD process in Europe in terms of selection of suitable programmes of (management) measures. However, it is clear that the level of expertise required to make use of the tools should not be underestimated, and at this stage, ODEMM experts would still be needed to guide users through any applications. It is important that the analyses undertaken are not oversimplified, nor applied to objectives for which they have no suitable purpose. ODEMM experts will work with those interested in application of the approaches directly and initiatives are underway to work with agencies and government departments in a number of countries, as well as with regional sea conventions and through collaborations with ongoing research projects.

In further development of this work, time will need to be committed to making the resources more accessible and user-friendly, such that it will be possible for suitably qualified individuals to apply the approach without direct use of ODEMM partners. However, it was clear from the experience of the project team, the advisory committee and all stakeholders who experienced the ODEMM approach that for any institution to really engage with EBM, a truly interdisciplinary team needs to be put together. Different departments working separately to advise on different aspects of evidence required to inform EBM will be flawed (e.g. economics teams working separately to those preparing the advice on state of the ecosystem) (see point 9 below).

2. Using ODEMM tools to identify gaps and priorities for research

There is already a substantial amount of information that can be taken from the application of the ODEMM tools to date, on knowledge gaps and data limitations. As one example, the confidence assessments that accompany the ODEMM pressure assessment database reveal that there are particular pressures that are amongst the most widespread in terms of the potential to affect our regional seas, but that are actually still very poorly understood in terms of the thresholds at which they start to really cause noticeable detrimental impacts to the different components of our ecosystems (e.g. marine litter). A useful standalone exercise will be to analyse the various ODEMM resources for gaps to draw up a list of priorities for research.

3. From governance complexity to governance clarity

A significant concern emerging from the research undertaken in ODEMM is that the present governance structures (European, regional, international or national) cannot fully deal with the foreseen challenges of EBM implementation, in particular that of ensuring coordination and collaboration in a multi-governance setting with a dynamic policy environment and various stakeholder groups and interests. This issue clearly requires further attention, as a lack of governance clarity will continue to undermine any implementation of policies such as the MSFD.

ODEMM has made a first step to develop governance models, and a first understanding of hybrid models for the different seas and the policy and stakeholder dynamics within the sectors in a nested governance structure. The understanding of governance complexity needs to be taken further to bind this to systematic decision making and the need for the approaches developed to provide governance clarity has also been emphasized by both the advisory committee and participants of ODEMM's roadshows.

As with all aspects of the ODEMM approach, we believe it is the holistic understanding of complexity that

As with all aspects of the ODEMM approach, we believe it is the holistic understanding of complexity that can ultimately be used to highlight clarity. In this context this may be by indicating governance settings and modes that allow certain policy objectives (e.g. elements of ecosystem integrity and health) to always be retained. We foresee a key part of our ongoing research to be to develop further the understanding of the linkages within the ecosystem, where this ultimately can also highlight governance structures that are most relevant to particular issues in EBM (see point 8 below).

4. Working at multiple spatial and temporal scales

We set out in ODEMM to develop and test methods that could provide evidence for regional-sea scale EBM with a focus on the current situation and future scenarios for comparison of management options. However, all of our approaches can be applied over different spatial scales and time horizons, and there is a clear need to pursue this further. Many of the participants of our roadshows and workshops felt uncomfortable with results presented at the scale of regional seas (even if policies may require such assessments) and there is an obvious need to apply the analyses across multiple scales (regional, sub-regional, national and local) to explore how priorities might change and how they can be related to those that are relevant at different scales (and different policies). Furthermore, we can learn from history in terms of exploring how our ecosystems differed under historic policy commitments, human drivers and environmental conditions. This is an area that can be developed further in the application of the ODEMM approach.

In addition, we found that the interdisciplinary work required by EBM presented its own challenges in terms of selection of the appropriate scales at which to work. For example, there is a significant research cost associated with up-scaling high-resolution economic analyses to match with regional-scale ecological analyses, and the scale at which actual marine management occurs also depends on governance regimes that may operate over various scales. Consideration of the appropriate scales and time horizons of analysis for the various disciplines required to provide the advice for EBM, is an obvious next step in progressing the interdisciplinary research required here (see Point 9).

5. Moving forward with Cost-Benefit Analysis

We had originally set out in ODEMM with the objective of completing full cost-benefit analysis on management options for every case study explored. This would be based on an ecosystem services approach where benefits were described in terms of change in value of ecosystem services following change in state of the ecosystem under management scenarios, and costs of implementation and operation would be weighed up against these. Ultimately this was not possible given the gaps in both understanding and methodology discovered, but advances were made on how to account for changes in ecosystem services and costs in a holistic manner. Work undertaken clearly illustrated that without an overall and complete assessment of change in supply of ecosystem services and costs arising from implementation of different management options, policy choices may not be economically efficient, and will easily miss key trade-offs.

We would therefore argue that CBA based on an ecosystem services approach should still be pursued as the appropriate methodology for incorporating economic and social trade-offs into EBM, and the feedback we received from out roadshow participants and advisory committee was that they were indeed pleased that progress was at least being made in this area. We caution against the use of cost-effectiveness analysis (CEA) on its own, because it is likely to miss co-benefits arising under particular management scenarios, and thus will more likely favour management options where costs are limited regardless of the potential long-term gain in economic and social benefits. We do, however, acknowledge there is a still much progress to be made on an ecosystem service type approach to CBA, but have developed suitable typologies and approaches to move this forward and will continue to work in this area.

typologies and approaches to move this forward and will continue to work in this area.

6. Environmental drivers and indirect effects

Our initial premise in ODEMM was to focus on issues that can be managed (i.e. identifying human drivers and activities whose threats are manageable), and as such less consideration was given to the role of indirect effects, nor was there explicit consideration of environmental drivers (although these were of course reflected in the setting of the context for any scenario covered). In future work, we will explore these aspects further, for example using decision trees or Bayesian networks to identify critical pathways in management response that are limited by the proliferation of indirect effects and/or environmental drivers under particular conditions. We will also consider how the uncertainty associated with stochastic responses in ecosystems (see examples in Knights et al., 2014) can be expressed and clearly communicated in our confidence assessments. As discussed with our roadshow participants, the need for clear communication of confidence in evidence provided is critical, particularly where the approaches used utilise expert judgement for some aspects of the assessment (see Point 7 following).

7. Holistic assessment, expert judgement and confidence

ODEMM tools do not provide concrete answers but good quality and unbiased information to allow managers to reach a decision. There are aspects of expert judgement used with all approaches, but as

has recently been pointed out by Barnard & Boyes (2013), the move from single species/single issue advice to the ecosystem-level advice required by EBM is simply not possible without elements of expert judgement. Yet the use of expert judgement is met with some resistance still in the field of marine ecosystem science, advice and policy despite the fact that it is used widely across disciplines including public health assessment, structural engineering, nuclear safety and air traffic control (see review in Barnard & Boyes, 2013). It is essential that it is recognised that factors which cannot be quantified, may be just as, if not more important, than those that can.

ODEMM had five key principles around which our work was based; two of these describe the need for holistic assessment, where analyses must thus be able to work in both data-poor and data-rich situations, and must thus be structured, transparent and repeatable. These principles will in most situations lead to the need for expert judgement and our advisory committee and roadshow participants commented on the benefits of being presented with approaches that allow the complete picture to be represented when weighing up management options, whilst cautioning the need for transparency, particular in terms of the communication of uncertainty/confidence. We still defend our key principles as being central to EBM implementation, but will look to moving forward and learning from best practice in the use of expert judgement and communication of uncertainty from other disciplines. Barnard & Boyes (2013) provide an excellent introduction to this area.

8. A fully linked-up ecosystem approach in EBM

A key aspect of the ODEMM approach is the linkage framework and detailed linkages described between human drivers (sectors), pressures, ecosystem components, policy objectives and ecosystem services. We also developed other approaches that help to structure the view of the ecosystem; for example, the nested governance model that helps to identify the relevant actors around any management option and the typologies defined to capture the full cost and benefit landscape associated with full trade-off analysis. We argue that classification and visualisation of the landscape within which advice is presented for EBM is absolutely key and the provision of clear definitions for pressures and ecosystem services and the identification of relevant management scales, institutions, stakeholders, laws, and policy objectives has been a major achievement of the project.

There is much more that can be done here, however, including the potential to compare across/examine relatedness and conflict between policies through linkages into the different components already described

relatedness and conflict between policies through linkages into the different components already described in our linkage framework, and the potential to extend linkages through management options into the different levels of governance hierarchy for some clear test examples. An approach is described above (under objectives 3 & 4) whereby the type and focus of management options can be used to link to relevant aspects within the broader linkage framework (e.g. joining up MOs with relevant sectors, pressures and/or ecological components). It is also recognised that future work could expand on this to include linkages between relevant laws, policies, institutes, and stakeholders (the governance setting) and the aspects already included in the ODEMM linkage matrices (e.g. from stakeholder groups or policies to sectors or ecological components).

9. Interdisciplinary working and benefits for EBM

The ODEMM experience highlighted that implementation of EBM will always require teams that are truly interdisciplinary in nature. At the same time, the efforts required to move forward the understanding and methodology within each individual discipline, meant that there was less time available to fully develop the interdisciplinary aspects of the project. The advisory committee and participants of our roadshows were impressed by the level of cohesion in the project across disciplines, and the project team felt a great deal of satisfaction in working together. However, there is much more that could be done in terms of closing the gaps further, and it was recognised that any future work should have designated milestones and deliverables that focus entirely on moving forward interdisciplinary working (e.g. sabbaticals and exchanges for project team members to experience working amongst teams from the different disciplines on core aspects of work). In addition, we have highlighted above a number of aspects of work that would help to build up the interdisciplinary nature of our work (see points 4 and 8).

10. Need for adaptive and responsive management to meet expectations of EBM

Finally, we emphasise the importance of adaptive management in responding to the outcomes from approaches such as those developed under ODEMM; to be holistic in approach (as EBM demands) we are working in a data-poor environment with many uncertainties and as more information becomes available (e.g. better information on the state of our ecosystems, or the value given to particular ecosystem services) results should be reviewed and advice to management updated. If it is not possible for management to respond to this evolving evidence base, then the whole process of EBM will be undermined. Furthermore there must be mechanisms in place whereby management options can be appropriately enforced; without this, efforts to implement EBM are rendered futile; yet a review by Long (2012) highlighted that there are currently many gaps in terms of legal mechanisms to ensure compliance with management implemented under EBM. This suggests a need for change at the level of operational management and legal policy but another important step forward in the research environment will be the consideration of how soft modes of governance might be associated with different response levels to management where legally binding enforcement is perhaps missing.

Above we have highlighted a number of clear avenues for furthering the research to underpin advice for successful implementation of ecosystem-based management of marine ecosystems. ODEMM provides some very useful starting points for delivering EBM (with resources at www.odemm.com) and we look forward to moving forward in this area.

Objective 8: To communicate and consult on the outcomes of the project effectively with policy makers and other relevant user groups.

Documentation of the communication and consultation on the outcomes of the project is given under the description of the potential impact (including the socio-economic impact and the wider societal

description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results following.

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Potential Impact:

Overview

Over the duration of the ODEMM project, and continuing into the project's legacy, dissemination and exploitation of results has been a key aim. In addition we are confident that the socio-economic impact and

exploitation of results has been a key aim. In addition we are confident that the socio-economic impact and wider societal implications are strong. The project has utilised expertise from a wide range of disciplines and countries across Europe and has had a good gender balance throughout the work. The project is strongly interdisciplinary, with experts from the natural and social sciences working closely together throughout. We have been complemented by our Advisory Committee on the strength of the integration in the project and on the overall cohesion and coordination adopted to fulfil the work.

We have produced a number of materials that can be used for science education (e.g. ecosystem services cards) which are freely downloadable from our final outputs website, www.odemm.com and have also used a range of media and communication tools to reach a wide audience, ranging from academic publications through to specialist flyers and online webinars.

We have engaged with civil society and policy makers through a number of dedicated project workshops and roadshows, all of which had a strong element of participation enhancing the engagement of those attending. Ultimately, we are confident that the project has had impact due to the number and variety of invitations that have been received in the final year to participate in workshops, conferences and meetings

ranging from national to global in impact.

Direct engagement through ODEMM workshops and roadshows
Civil society and policy makers have contributed directly to the development of our work and final outcomes. For example, participants at a number of dedicated workshops helped to develop and test ideas around regional governance models that would help with implementation of Ecosystem-based management policies such as the Marine Strategy Framework Directive.

Decision makers need to incorporate known information and scientific advice with other pertinent factors which may arise in a given context. In Knights et al. (2014) we presented a stepwise process that can be undertaken in decision-making around environmental policies, but we also described the various uncertainties that can arise within the process of providing advice for the different steps and commented on other factors that might influence the decisions that are ultimately made, such as political will. The broader criteria that influence decision-making on choice of management measures to implement were then explored further in a high-level thematic workshop.

The ODEMM thematic workshop on decision making included stakeholders involved in providing evidence for, or weighing up the evidence around, decision-making for ecosystem-based marine management policies across Europe. In this workshop, a list of broad criteria that may influence decision making was used as a starting point and was further developed with the participants (see Annex I in Culhane et al., 2013).

Building on the experience taken from the thematic decision-making workshop, we designed four regional roadshows to showcase the approaches developed in ODEMM that we felt could be most readily taken up in practice to aid decision-making around choice of management measures to implement. Specifically we asked participants to explore the types of information that would be available to consider trade-offs that might need to be made when selecting and implementing ecosystem-based management options. Participants were presented with evidence on ecological effectiveness, economic benefits and governance complexity associated with a number of management options for comparison

complexity associated with a number of management options for comparison.

On completion of the four regional roadshows, some broad themes emerged in terms of the experience of the participants in trying out the ODEMM approaches:
1. The ODEMM approach has a pragmatic aspect for real-world implementation in the current political and economic climate.
2. The ODEMM approach can facilitate the provision of evidence which can be used to both inform decision makers and present to other stakeholders. Participants at the ODEMM roadshows felt that the approaches laid out by ODEMM achieved a rationale for prioritisation of management options that can be upheld by policy-makers.
3. The holistic perspective incorporated in this approach offered improved understanding of the system and the process of assessing options.
4. It was also noted that the approach provides a practical way of linking management options with potential changes in the ecosystem and ecosystem services and focus on those options which may be the most successful.

Successful trialling of the ODEMM approach through the series of regional roadshows revealed that the resources available (www.odemm.com) can already be of use to those working in practice. There is a particular relevance to implementation of the next stage of the MSFD process in Europe in terms of selection of suitable programmes of (management) measures. ODEMM experts are working directly with those interested in application of the approaches and initiatives are underway to work with agencies and government departments in a number of countries, as well as with regional sea conventions and through collaborations with ongoing research projects.

Impact from Major Outputs
The major outputs from ODEMM include: (1) an accessible set of resources that can be used to evaluate management options utilising the major tools developed in ODEMM and available at www.odemm.com , and (2) guidance towards implementation of Ecosystem-based Management in Europe, through the report “Towards Delivering Ecosystem Based Marine Management: The ODEMM Approach” (downloadable from www.odemm.com) which describes the challenges facing the implementation of the MSFD and EBM in Europe; the ODEMM approach to applying EBM; steps to improve implementation of EBM in European regional seas; and the ODEMM tools and approaches developed which can facilitate implementation of EBM. Each of the individual tools and approaches is also documented more fully in guidance documents and/or academic publications. A summary of the relevant documentation is given for each major output under the resources section at www.odemm.com as well as a relevant contact for each aspect of work.

All of these outputs are now available, in time for use by member states and Europe’s coordinating bodies to utilise them in the latter stages of MSFD implementation and review. In particular, the toolkit will be useful to any individual countries or regional bodies who wish to weigh up the effectiveness, costs and benefits and governance complexity associated with different programmes of management measures for their regional seas, prior to the implementation of these by 2016. Over the final few months of the project there were four regional roadshows aimed at optimising the impact of the timely outputs described above. The results have most impact for those working in Europe on implementation of the MSFD and related policies, but are also of great interest to researchers, stakeholders, regulators and policy advisors working more broadly on development and implementation of policy related to sustainable use of regional seas, in

more broadly on development and implementation of policy related to sustainable use of regional seas, in Europe and beyond.

Individual outputs, such as the ODEMM linkage framework, the pressure assessment methodology, the risk assessment, the integrated Management Strategy Evaluation tool and the alternative regional governance models are already being made available to interested stakeholders such as the European Environment Agency and national MSFD implementation work. In addition, ODEMM is collaborating with a number of other European projects (such as Meece, Mesma, MEDISEH/MAREA, STAGES, DEVOTES, PERSEUS, CSP-LIFE) and there is interest from some of these to utilise methodologies developed in ODEMM.

The main series of resources (understanding and tools) from ODEMM has been developed to support decision makers in an Ecosystem-Based Management context and with particular relevance to implementation of the Marine Strategy Framework Directive in Europe. Specifically we have developed:
- a method to undertake a rapid assessment of the state of policy objectives using available information on the specific ecosystem components that are relevant to those objectives;

- a linkage framework that identifies all relevant interactions between key ecosystem components – human activities or sectors, their pressures, ecological components and ecosystem services, and the relevant policy objectives;
- a pressure assessment that can be used to weight and rationalise the key threats to ecological components and policy objectives;
- an ecological risk assessment that summarises information from the pressure assessment into overall risk that can be grouped by different elements (e.g. sectors, pressures, ecological components) and related to management options;
- an integrated management strategy evaluation (iMSE) tool that can be used to create management options (MOs) that can target different areas of risk to policy objectives and then evaluate the effectiveness of those MOs;
- a series of methods for analysing the costs and benefits of different MOs based on an ecosystem services approach; and
- a series of methods for appraising the governance complexity associated with EBM, relevant policies and specific MOs.
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With these resources, policy driver objectives can then be related to an operational process of creating, appraising and choosing management options to inform decision makers, allowing for full consideration of trade-offs across ecological, economic and social issues and the governance complexity surrounding this. All of these resources are described at www.odemm.com and a summary of the overall approach and its tools can be found in Robinson et al. (2014) also downloadable from www.odemm.com. A full list of deliverables (with downloads available where possible) can be found at www.liv.ac.uk/odemm.

Wider impact through dissemination activities
In addition to the dissemination activities described already, the partners have engaged in many other modes of dissemination such as attendance at relevant conferences (e.g. the ICES Annual Science Conferences in 2012 and 2013); Reporting to national ministries directly on use of tools (eg in the UK, the Netherlands, Finland, Ireland, Denmark, Romania); dedicated conference sessions (e.g. the MARE conference 2013); production of targeted leaflets and showcasing ODEMM achievements and

conference 2013), production of targeted leaflets and showcasing ODEMM achievements and participation in joint meetings with other projects. ODEMM has been disseminated through involvement of partners in working groups of ICES and OSPAR where work has been undertaken specifically on ODEMM tools (e.g. WGECO meetings in 2011, 2012 and 2013; OSPAR EIHA Intersessional Group on Cumulative Effects).

In addition to this, the project Coordinator, Dr Leonie Robinson, was able to accept invitations to speak at a number of meetings in Brussels that relate directly to the Implementation of the Marine Strategy Framework Directive. These included meetings of the MSFD Coordination Group, a joint meeting of the MSFD's GES and ESA working groups, and the HOPE Conference held in March 2014 where Dr Robinson addressed the audience on Gaps in Knowledge related to Implementation of the Marine Strategy Framework Directive and more broadly Ecosystem-based Management. All of these invitations have been off the back of the impact of ODEMM work.

As far as possible, dissemination activities are documented in Section 4.2 of the Final Report. Furthermore, the project has produced a large number of publications, many of which are documented in

Section 4.2 of the Final Report.

List of Websites:
for all relevant project context and information on the consortium etc
for an accessible guide to the project's main resource outputs

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