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Practical application of the Ecosystem Service Approach (ESA): lessons learned and recommendations for the future

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ABSTRACT

An Ecosystem Service Approach (ESA) is increasingly advocated for use in both environmental management and academic applications. However, despite extensive conceptual development, there are still very few examples of the effective use of the ESA for operational management. This contribution reports on the field application of the ESA at six marine and coastal case study sites. Each case study demonstrates a variation on an interdisciplinary approach to translate complex natural science data into ecosystem service terminology, and then explores the usefulness of this information in a management context. From these experiences 6 key recommendations are made to aid the future application of the ESA: (1) Invest resources in collective planning of ESA; (2) apply dynamic and connected approaches including multiple ES; (3) undertake ESA at a local scale; (4) employ interdisciplinary research; (5) work proactively and transparently with data gaps and uncertainty; (6) record ESA and resultant impact. For each recommendation an accompanying discussion of state of the art tools and methods is provided to promote their attainment.

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1. Introduction

Since the Millennium Ecosystem Assessment was published in 2005 (MA 2005) interest in ecosystem services has dramatically increased (Beaumont et al. 2007, Wallace 2007; Daily et al. 2009; Balmford et al. 2011; Fisher et al. 2011; Liquete et al. 2013; Ruckelshaus et al. 2015) and an Ecosystem Services Approach (ESA) has been increasingly recommended to inform environmental management and planning (Daily et al. 2009, Cognetti and Maltagliati 2010; Börger et al. 2014). The ecosystem approach is a well-established strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (CBD 2000). The ESA takes this strategy one step further, and through the inclusion of ecosystem services ensures that the complex relationships between nature and humans are more clearly understood and explicitly included. An ESA can take various forms and include numerous methods, but Martin-Ortega et al. (2015) defined the ESA as having four common characteristics: (1) ecosystem services are valued on the basis of their benefits to humans; (2) ecosystem services are underpinned by ecosystem processes and this relationship is made explicit; (3) the approach requires interdisciplinary collaboration and stakeholder engagement at multiple scales; (4) the outcomes of the approach can be incorporated into environmental policy and management decisions.

Efforts to apply ESA in environmental management and policy contexts are becoming progressively more apparent at scales from local (Naidoo et al. 2011, Polasky et al. 2011) to national (NEA 2011; TEEB 2013) to international, notably with the instigation of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (www.ipbes.net) which has been established specifically to enable and improve the international use of the ESA in policymaking, primarily by providing an interface between the scientific community and policymakers.

In a management context the expectations of the ESA are twofold. First, the ESA can be applied to raise awareness of the importance of the environment in sustaining human social needs and in maintaining human health and wellbeing through the provision of ecosystem services. During the past century, in line with the industrial revolution, there has been an increasing estrangement of Western Society from the natural environment. A primary aim of the ESA is thus to remind society of the intrinsic coupling between human development and the ecosystems. Numerous publications have been produced to improve recognition of this coupling, often using monetary valuation to elucidate the human–nature linkages (Westman 1977, Costanza et al. 1997; Beaumont et al. 2008; de Groot et al. 2010). The ESA has proved effective in this regard, as demonstrated by its endorsement by a wide variety of

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governments, the United Nations, the Global Environment Facility and many non-governmental organizations (Ruckelshaus et al. 2015). Ecosystem service terminology is now present in many high-level policy and management documents, for example including the Aichi targets of the Convention on Biological Diversity and the EU Marine Strategy Framework Directive. This commitment to the ESA is further evidenced by the application of the The Economics of Ecosystems and Biodiversity (TEEB) initiative, across the world, including most recently in Bhutan, Ecuador, Liberia, Philippines and Tanzania, with an aim of identifying and valuing ecosystem services and making recommendations on how these services can be integrated into policies.

A second, more extensive, expectation of the ESA is that it can be used as a transparent and objective framework for understanding the trade-offs between human development and the conservation of natural systems. Applied in this context, the ESA can improve our mechanistic understanding of the two-directional relationships between the environment and human society, and in turn support the sustainable management of natural resources. However, despite extensive conceptual development (Fisher et al. 2009; Liquete et al. 2013), examples of the effective use of the ESA for operational management are still limited to confined areas and issues considering only a small sub-set of ecosystem services. Reasons for this failure in the ESA implementation include: overly complex terminology and insufficient training of users; high uncertainty and accompanying lack of confidence in results; excessive time and costs of implementation; poor fit to current regulatory frameworks and management needs (Egoh et al. 2007; Laurans et al. 2013; Marcone and Mongruel 2013; Ruckelshaus et al. 2015).

Whilst reasons for failure in the ESA application have been documented, little attention has been given to providing solutions and recommendations to address these. This contribution aims to fill this gap, drawing on direct ESA experience from the field to propose key recommendations for the future. This paper details a three-step method for determining such recommendations: first, selecting varied case study sites to enable generalizable recommendations to be determined; second, applying an ESA at these varied sites using a common framework to enable comparison; and finally, holding a structured workshop to draw out the key lessons learned and recommendations for future use of the ESA.

2. Methods

2.1. Case study site selection

In discussion with local environmental managers, six case study sites were selected across South West England and North West France (Figure 1), with the generic aim of implementing an ESA for the operational management of marine ecosystems, and to provide variance from which generalizable conclusions could be drawn. A structured selection process was undertaken which included the assessment of criteria including: habitat type, socio-economic aspects, scale, key issues, governance, data availability and stakeholder engagement opportunities. An overview of the attributes of the case study sites is provided in Table 1.

2.2. Application of the ESA

To ensure comparability of the ESA, all sites used the same ecosystem service classification as defined by Liquete et al. (2013), and a common methodological

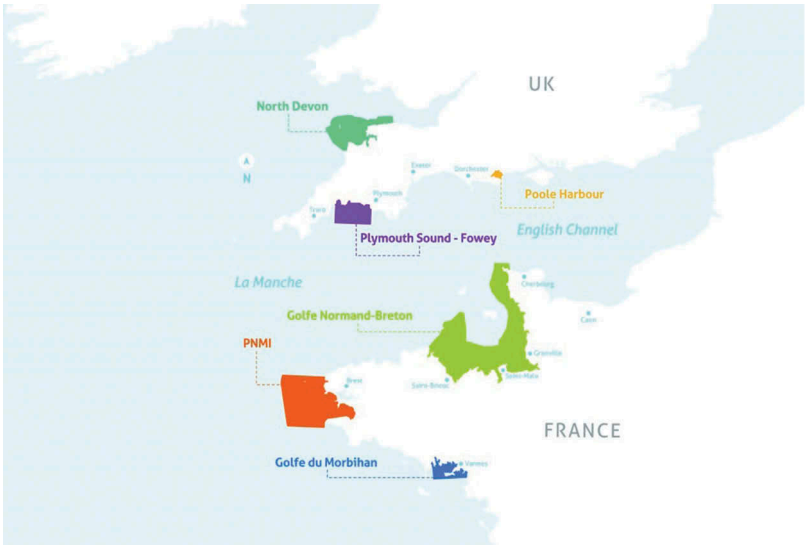

Figure 1. Map of six case study sites.

Table 1. Overview of case studies.

	North Devon Marine Reserve	Poole Harbour	Sound – Fowey	Golfe Normand-Breton	PNMI	Golfe du Morbihan
Aim	Design management options	Improve knowledge	Initial diagnosis	Initial diagnosis; exploratory scenarios	Compare management options	Raising awareness
Habitat	Benthic offshore	Mixed (Harbour)	Mixed (coastal and offshore)	Intertidal zone; fish habitats	Kelp forests	Seagrass beds
Issue	Impact on benthic habitats	Recreational use	Mixed	Increasing demand of all uses	Increasing demand for kelps	Improve seagrass preservation
Services	Fisheries, nutrient cycling, carbon cycling	Recreation	Varied	Recreation and provisioning	Food, remarkable species, ecotourism	Maintenance and regulation services
Methods	Bayesian belief networks	Travel cost method, survey	Varied	INVEST ecosystem accounting	Indicators dynamic modelling	Choice experiment

framework was applied, namely the Triage Process (Pendleton et al. 2015). The principle of the Triage Process is to provide a procedure for delimiting the scope of a potential ESA using a step-wise process to refine the initial broad-scale analysis and to consider, as objectively as possible, the relevance of the ESA in a particular situation. The Triage Process aims to identify the policy issues for which an ESA is expected to provide new insights, the parts of the system to be considered in relation to these policy issues, the sensitivity of the considered marine ES to natural or social factors of changes, the appropriate methods for valuation and finally the feasibility of an ESA in practice. The Triage Process consists of three transparent successive sequences, each consisting of three sub-questions (Figure 2) (Pendleton et al. 2015):

(1) Defining the aims and scope of the ESA.

First, it is important to identify the stakeholders, activities and pressures at a given site, and the possible drivers for wanting to undertake an ESA. Following this, developing an understanding of the policy issues, from a number of stakeholder perspectives, is crucial. Finally, it is necessary to understand the natural system ecosystem components, functions and services that relate to the defined policy issues, as well as the identification of the stakeholders and institutions whose actions are concerned by these policy issues.

(2) Refinement of the scope of the ESA in support of scenarios building and policy design.

This refinement stage involves exploring three questions simultaneously to ensure that the ESA will have outputs which are useful and relevant from a management perspective. First, it is a key inclusion criteria that there is potential for change within the given ecosystem services, as if no change is likely to happen there is little point continuing with the ESA. Second, the potential for management to influence this change should be considered, as again if management has no influence over the given ecosystem service or function then the usefulness of the ESA should be called into question. Finally, the influence of wider social, economic, environmental and political issues on the ecosystem service or function should be considered, particularly those beyond the control of local management structures (such as climate change or national policies). Where these wider issues have a more significant impact on the value than the proposed local change, any expected change in value

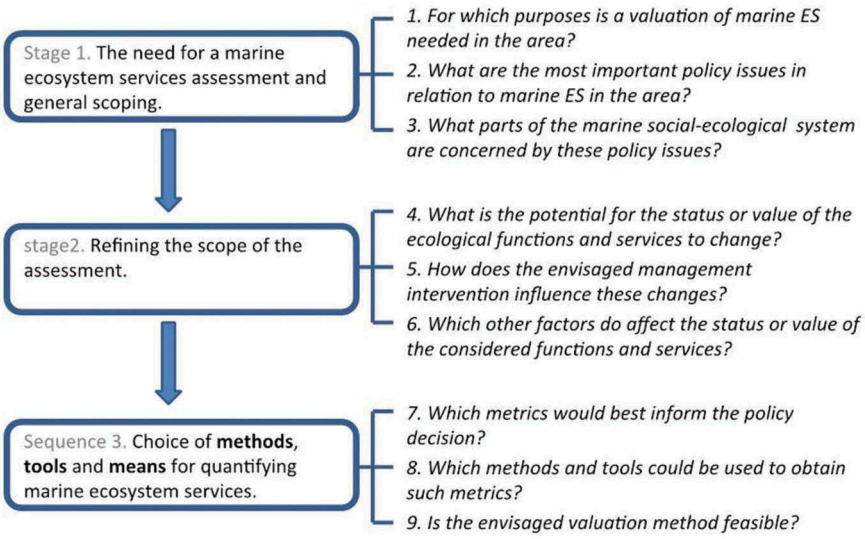

Figure 2. A schematic representation of the Triage process (Pendleton et al. 2015).

from local management action is unlikely to be realized.

(3) The choice of methods, tools and means for the ESA in response to management needs.

The first step is the choice of methods and determining the metrics to be assessed. The metrics assessed will depend on the factors of change, for example: changes related to ecological status should require biophysical metrics, changes affecting human activities may be expressed in terms of monetary values or jobs and changes related to trade-offs may require the assessment of social perception. The second step is to assess which methods and tools could be used, based upon the metrics, the aim of the assessment and the stage of the management process and needs. Finally, it is important to consider how feasible a method is; for example, the manpower and cost requirements for evaluating different services can vary considerably depending on the methods proposed and must be explicitly considered. Where resources for primary data collection are limited, the availability of supporting data (both ecological and socio-economic) will also have a strong influence on the scope of an ESA. In each of the case study sites, the ESA was applied using the Triage Process as a framework. A full description of the case study sites, methods and results is provided in Mongruel and Beaumont (2015), but the key aspects of the six sites are outlined hereafter, each structured to reflect the three sequences of the Triage and a final paragraph of results.

2.2.1. Poole Harbour (PH)

Poole Harbour is one of the largest natural harbours in the world. Its ecological value is recognized by its designation as a Ramsar site, Special Protection Area (SPA) and Site of Special Scientific Interest. It is also part of an Area of Outstanding Natural Beauty and surrounded by a Special Area of Conservation (for Heathland). Poole Harbour supports commercial fisheries (particularly for shellfish), port operations (including for international passenger ferries) and is also an important recreation and tourism destination. Despite the sector's importance, detailed assessments of recreation and tourism are lacking.

This study focused on generating new data for birdwatching, kitesurfing, windsurfing, kayak/canoeing and jet/waterskiing. The objective was to provide information to support recreation management, particularly in terms of ensuring continued use and dealing with conflicts (between groups and to address bird disturbance affecting the status of the SPA).

The method selected was an online travel cost survey (advertised primarily through social and print media) due to a need to access a broad geographic range of participants and limited resources, with additional multi-criteria analysis and supporting questions to allow wider consideration of respondent preferences. A separate study was commissioned to determine participant numbers through field counts using trail monitors in bird hides (deployed for 80 days) and 55 boat-based transects across the harbour.

A total of 546 responses were received to the online survey. Results suggest an annual spend (on travel and local expenses) of £3.1million across the six activities considered. Birdwatching contributed over 60% of this, due to the high number of participants. Other elements of the survey showed that a decrease in water quality was likely to most significantly affect users' continued participation, in contrast to multi-criteria analysis which suggested that wildlife was most important to users' enjoyment of the harbour.

2.2.2. North Devon Biosphere Reserve (NDBR)

The marine area of the NDBR extends over 1500 km^2 of primarily sedimentary habitats and includes the Lundy Island Marine Nature Reserve, an Area of Outstanding Natural Beauty and Sites of Special Scientific Interest. Tourism is a very important source of income for the local community, and fishing contributes to both the economy and the cultural heritage of the area.

The objective of the study in the NDBR was to raise awareness of the importance of coastal sedimentary habitats in carbon sequestration, waste remediation and the provision of nursery habitats for important commercial species, and to explore whether it was possible to generate information that would support the NDBR management partnership's input into local and national initiatives including the designation of Marine Conservation Zones and the proposed development of an offshore wind farm.

The method selected was a spatial modelling approach utilizing a Bayesian Belief network. A qualitative assessment of the potential level of service provision by each habitat was made using existing literature, and mapped across the NDBR. The effect of known fishing pressure (as the key local impact) was then taken into account and the expected actual service delivery was mapped. A Bayesian Belief Network was used to model changes in the delivery of the services resulting from three hypothetical management scenarios involving marine conservation zones, aggregate extraction and mussel aquaculture. Stakeholder preferences for particular services were accounted for in producing aggregated outputs.

In terms of results, the site provides negligible levels of carbon sequestration, and waste remediation is also low across most of the area, but nursery habitat is provided at higher levels. The north coast and northwest of Lundy are key areas for service provision. Even with fisheries displacement having a negative effect on

nursery habitats, establishing marine conservation zones and mussel aquaculture could provide a net benefit across the NDBR (in terms of percentage change in delivery of the three services), while aggregate extraction would cause a small net loss.

2.2.3. Plymouth Sound to Fowey (PSF)

The PSF site is not an existing management area, but was defined for the purposes of the study to be representative of a typical stretch of open coast with varied habitats (including rocky reefs, seagrass and kelp beds as well as sand and coarse sediments) and a range of issues and activities. It is a large site, extending to 12 miles offshore. The area contains a recently designated Marine Conservation Zone and an offshore Special Area of Conservation. Fisheries, recreation and tourism are important economic activities; there is a commercial port at Fowey and the military makes extensive use of the area.

The study sought to explore ecosystem service assessments at the marine planning scale incorporating a combination of data-rich and data-poor areas, and to generate information that could help inform delivery of the Cornwall Maritime Strategy (2012). Multiple ecosystem services were considered, including nursery habitats for commercial species, carbon sequestration, sea defence and bioremediation of waste (considering supply of clean water, immobilization of pollutants and nutrient cycling), with a separate focus on cultural services.

The study took a spatial approach, mapping the delivery of the services based on information within the literature concerning linkages between habitats and services. A primarily qualitative assessment was made of how services might change under management scenarios concerning dredge spoil disposal, converting protected areas to no-take zones and replace swing moorings with eco-buoys. Some quantification and monetary valuation was undertaken for carbon sequestration. The assessment of cultural services used an online and face-to-face survey with local residents, containing a spatial component in which each respondent was asked to indicate three locations that were considered special, significant or valuable and three that were unpleasant, neglected or challenged.

The baseline maps of ecosystem service delivery illustrated the importance of Plymouth Sound, with its varied habitats, as a nursery for a range of commercial species, nutrient cycling and the provision of clean water. The value of the site for carbon storage amounts to £1.4million per year. The value of the increased carbon sequestration through the recovery of seagrass following the replacement of swing moorings was found to be unlikely to offset the costs of installing the new eco-buoys.

2.2.4. Golfe du Morbihan (GM)

The GM case study area is delimited by the boundaries of the Regional Natural Park (RNP) of the GM. The area includes 30 municipalities and an associated marine area of 125 km. The GM is famous for its high level of biodiversity, natural and cultural heritage, various habitats (mudflats, rocky foreshores, seagrass beds, etc.) and landscapes.

Seagrass beds are sensitive to pressures impacting environmental quality (e.g. lack of light, herbicides, trampling, grubbing, etc.) and are an important habitat within the RNP of the GM. To reconcile conservation and development objectives, RNP managers used an ESA, to: (1) raise awareness of seagrass issues; (2) improve the management of seagrass through an integrated approach and (3) identify management options to facilitate trade-offs.

A wide range of techniques were used to assess how stakeholders perceived and valued the ecosystem services provided by seagrass, including interviews, workshops, focus groups, conceptual modelling and a choice experiment. Knowledge exchange and communication were key factors in the assessment, which included the development of a platform for knowledge integration and sharing.

The results obtained in the GM are gathered in a knowledge platform on seagrass beds called ZOSTERA, and includes: a seagrass beds atlas with 30 maps; a scientific report on ecology, biology of seagrass beds and their interactions with human activities; five leaflets that summarize the results obtained during the project; a comic strip on seagrass beds, the ecosystem services they offer and the natural and human pressures they face; a conceptual model of interactions between seagrass beds and human activities. Unfortunately, the Zostera platform is not available on the internet as it was developed with a private software (ExtendSim). However, there is a lot of information, products and training support regarding Zostera on the PNRGM website (http://www.parc-golfe-morbihan.bzh/les-herbiers-de-zosteres/)

2.2.5. Parc naturel marin d'Iroise (PNMI)

The Molène archipelago is a shallow area of almost 300 km^2 which is home to the most diversified algae Laminaria fields in Europe and the most extensive in France, containing dozens of species of algae, marine mammals and birds of national and European significance. The archipelago is included in the PNMI boundaries, a Marine Protected Area (MPA) and a large part of its perimeter is listed under the European Habitats and Birds directives (Natura 2000 network), and also recognized as a UNESCO Man and Biosphere Reserve.

The focus within the PNMI was the ecosystem services provided by kelp forests. Demand for kelp

products is increasing, and so the objective of the ESA was to assess the current provision of services provided by the Iroise kelp ecosystem and provide new insights into the current management debate to support management initiatives that would ensure sustainable yields, secure employment for harvesters, mitigate impacts on other users and protect key species that depend on the kelp.

A dynamic numeric simulation model of the kelp socio-ecosystem was developed using expert participation to simulate the impacts of different management strategies on key ecosystem services. The metrics used in the model were appropriately sensitive to drivers of change, and provided indicators that were subsequently used in multi-criteria analysis to assess the impacts of different scenarios.

This tool provided new highlights regarding the harvestable biomass with respect of plants size and kelp population dynamics, and the impacts of permanent or temporary no-take zones. Knowledge gaps in some areas and existing data accessibility issues prevented us from producing a complete quantitative and dynamic ESA.

2.2.6. The Golfe Normand-Breton (GNB)

The GNB case study site is a vast marine area of over 11,700 km^2 and is sandy-mud sediment for the most part, dotted with areas of rocky reefs and biogenic habitats. The area includes a multitude of coastal and marine sites of varying protected statuses (e.g. Natura 2000 and Ramsar sites, National Nature Reserves, etc.).

At the time our study was carried out, the GNB was a proposed MPA, and the purpose of the ESA in this case was to establish an initial diagnosis of the ecosystem services provided by this large marine area, and to anticipate future changes particularly in terms of ensuring continued participation and dealing with future conflicts.

A variety of methods were applied including: a map of benthic habitats which was linked to a 'habitats-function' and 'habitat-services' matrix; a model for ascertaining a sustainable level of fishing and describing fishing fleets' socio-economic contribution to, and dependence on, the stocks studied; a cumulative impact risk model (InVEST, Sharp et al. 2016) to determine the level of risk on benthic habitats and the services they deliver (Cabral et al. 2015); and an ecosystem accounting approach highlighting the complex relationship between human activities and ecosystem services of the area.

This large-scale assessment of ecosystem services has enabled an initial diagnosis of the ecosystem services and ecological functions of this area. This wide-ranging, interdisciplinary approach allowed collection of quantitative and qualitative information on all ecosystem services in the area, their benefits and the efforts made by society to conserve them.

2.3. Deriving key lessons learned and recommendations

This set of case studies provided an ideal opportunity to compare and contrast how the ESA worked in different situations. The study sites chose to use the ESA for a wide range of purposes, from initial diagnosis to raising awareness to enabling management option comparisons, and used also various technical tools, from qualitative analysis to economic valuation and modelling. Throughout the process, academics and stakeholders were requested to keep a record of what worked well, what could be improved and what was unsuccessful, including all aspects of the ESA process from terminology and communication through to methods and final results. When the ESA was completed at all sites, a 'Lessons Learned' workshop was held to gather feedback from the study site teams. This workshop mixed the viewpoint of managers, stakeholders and academics, with six external experts, examining achievements and good practices but also limitations and pitfalls, with an overarching aim of providing an output of a series of lessons learned and recommendations for the future. The workshop was informed primarily by the experiences at the six case study sites with inputs also drawn from the participants' wider knowledge, and was structured around four goals: (1) to explore how useful the methods used in the ESA are in practice; (2) to detail specific advice on how to approach the different ES and which classifications and terminology to use; (3) to provide a description of 'best practice' for communication of ES assessments; (4) to critically assess the success of the Triage Process.

3. Results: recommendations and lessons learned

3.1. Recommendation 1: invest resources in collective planning of ESA

It is recommended that a strategic planning approach is applied at the outset of the ESA process, for example, the 'Triage Process', or similar, to scope the study area and plan the ESA prior to undertaking the approach. The metrics and format of the ESA outputs should be agreed upon by both the academics and the users as the relevant assessment method depends upon the context of use. The aim should be for continuous dialogue between academics undertaking ESA and users of these methods from the outset of the ESA.

The ESA can require significant time, effort and expertise which was found to discourage environmental managers from adopting this approach. It is therefore critical to ensure from inception that ESA are efficient, transparent and provide useful information for the purpose. This includes that the

information provided by the ESA fits within current policy and management regimes. In this case, the Triage Process (Pendleton et al. 2015) was implemented and assisted the selection of the appropriate set of ESs and the most effective methodology for the ESA at all case study sites. It also enabled stakeholder engagement, ensuring the ownership of the ESA and empowerment of the users from the outset.

The selection and adaptation of the method was found to be a critical scoping step, with the appropriate method depending upon the context, including the needs and preferences of the stakeholders, the data availability, the temporal and spatial scale, the wider policy landscape and the academic viability. A pragmatic decision may be informed using quick relatively simple methods while long-term assessment may justify more accurate but also expensive approaches. In the context of long-term purposes, methodological innovation may be seen as a start-up investment for future uses. The objective of the ESA was carefully considered at the start of each case study and the methodologies selected accordingly and in discussion with the user. For example, considering the six case study sites, recreational activities were assessed at two sites, but in different contexts. In Poole Harbour the Travel Cost Method was applied providing tangible, directly useful, quantitative (monetary and non-monetary) results, as requested by the managers of this area. Stakeholders found both the monetary values and additional information on wider preferences useful for management. However, in the GNB, a whole ecosystem accounting framework was developed, and in this case recreational activities assessment used an innovative methodology consisting of strictly separating ecosystem-independent activities, but also in properly valuing the means dedicated to ecosystem-dependant activities by the whole population of users. The ecosystem accounting was comparatively costly and time-consuming but it should be now 'ready-to-use' for regular implementations in the future (Martin et al. 2018). It was also notable from the case studies that some managers had a preference for monetary values, for example Poole Harbour and GNB, but in other case studies areas, such as PSF and PNMI, there was some caution regarding monetary values resulting from a fundamental objection to the monetization of the natural environment. In these cases, other metrics, such as qualitative preferences, were preferred and considered of greater use.

3.2. Recommendation 2: apply dynamic and connected approaches including multiple ES

It is recommended that models and approaches continue to be developed to demonstrate changes in multiple ES provision according to pressures or management scenarios, with improved spatial and temporal resolution. However, in the absence of detailed quantitative modelled scenarios, qualitative stakeholder-led scenarios can be equally beneficial in informing management.

Most ESA are static, focus on one or two ES and provide a snapshot of a specific spatial area. Whilst this approach is useful for raising awareness, management challenges require consideration of interconnected dynamic processes. ESA are generally most effective when dealing with changes in values resulting from a variety of possible scenarios, and for understanding the trade-offs between different ES under such scenarios. At the PNMI site, a complete system dynamic model of kelp ES provision was developed, and found to be very useful by the local managers, but this was only made possible by the large amount of available data concerning this ecosystem and its uses. For most cases, the resources did not allow for quantitative and connective scenario results as this was too time-consuming and expensive to undertake. However, this lack of resources did not prevent a dynamic connected approach being undertaken, as in several of the cases study areas (PSF, NDBR, GNB) stakeholder-led scenario approaches were used to demonstrate qualitatively how ES provision changes under different futures. This scenario-led approach proved valuable in terms of initiating discussions and informing debate regarding future potential management schemes and provided a useful indication of potential future scenarios.

3.3. Recommendation 3: undertake the ESA at a local scale

It is recommended that ESA are developed at a local scale to ensure their relevance for operational management purposes. They should also have a continuing life and implement as much as possible methods which could be applied to other sites in order to reduce the costs of broad-scale ESA.

To date, most ESA research has been either conceptual or at larger scales (MA 2005; NEA 2011) neglecting local scale. Large ESA do not tend to address specific management issues, and hence rarely go further than raising awareness. ESA provides a clear and extensive vision of the complex issues raised by the use of marine ecosystems which fits well with the complex objectives of local marine governance. The case study sites documented here aimed to address this gap in local ES knowledge and to link ESA with existing local management bodies. Case study areas and methods were specifically designated to be useful to local managers. Initial diagnosis, thinking about trade-offs, providing data for comparing real management options, as well as building on existing and creating good stakeholder relationships

were all carefully undertaken to ensure ESA was effective at a local scale. Although it will not be possible to have high-resolution ESA at every local site, due to limited resources and data, utilizing currently available tools and data means that some degree of ESA should be possible at most sites, even with limited resources available. In the case studies, this local-scale approach was proven to be critical in ensuring the ESA outputs were relevant and applicable.

3.4. Recommendation 4: employ interdisciplinary research

It is recommended that the ESA is applied by interdisciplinary research teams, including academics who are actively interested in the integrative dimension of the ESA rather than solely in the further advances of their own scientific realms. Funding sources for interdisciplinary research are sporadic and vary significantly between countries and topics, thus improved consistency in such funding should be encouraged.

To understand the relationships between human activities and pressures, ecosystem functions, services and benefits, and how these may change under given scenarios, interdisciplinary research is essential. In the case study sites, the interdisciplinary approach was actively pursued and valuable in enabling scientists from different disciplines to exchange ideas through informal day-to-day contact and structured workshops. The case studies successfully built on established relationships and developed a shared vocabulary. The input from natural science was essential in supporting the social science research and vice versa, as the ecologists benefited from the reinforcement of the social importance of their studies, and the ESA encouraged them to work at novel scales. Ecologists who focus traditionally on small scales could see how their work contributed to the 'big picture'; for example, ecologists at the GNB site wanted to see how the wealth of individual studies, which represented years of results, could be combined into a larger picture they had not seen. This holistic approach was driven by stakeholders' priorities and it helped also to prioritize when the issue at stake was a problem of ES supply, for which more ecological science was needed, or a problem of ES demand, to be mainly assessed by social scientists. Whilst there is no pre-requisite of team composition, and this should be decided on a case by case basis, on reflection it was agreed that it would have been additionally valuable to involve a broader range of social scientists at the case study sites, for example environmental psychologists, to provide wider assessment of people's perceptions, health and well-being.

3.5. Recommendation 5: work proactively and transparently with data gaps and uncertainty

It is recommended that the data gaps and uncertainty in the ESA should be communicated clearly to the users, with explicit instruction on how this uncertainty should be interpreted. Extensive smart methods of addressing data gaps should be employed, including citizen science, collaboration with existing monitoring programmes and a strategic focus on the most essential issues.

Decisions in marine management have to be made even if data are imperfect, missing and incomplete. In marine and coastal ESA, there are often extensive data gaps and this was the situation in all the case study sites. Data gaps include lack of knowledge on the extent and status of marine habitats, their contribution to ecological functions and the economic data at a local scale, especially regarding the beneficiaries of ES. The PSF case study was specifically selected as a 'low data' example to explore how to manage this limitation. It was found that simple qualitative information was enough to start structured debate about trade-offs, generating useful outcomes such as consideration of alternative options and a widened appreciation of differing perspectives. In addition, even if no decision was at stake, or just a hypothetical scenario was being explored, ESA was still useful for engaging users in the production of information. In the NDBR, the lack of data restricted options for the ESA, leading to a greater reliance on expert opinion and qualitative assessment, and reduced confidence. However, the stakeholders are used to making decisions where uncertainty is high, and responded well to the outputs despite these limitations. Where specific data for fine scale habitat levels was lacking, amalgamating habitats into broad categories and considering shared characteristics provided useful information on the distribution and delivery of ES. In addition, maps showing 'heat spots' with direction of change of service delivery were better received than attempts to quantify a percentage change. In both these case study sites, the uncertainty and data gaps were communicated to the end users using a mixture of workshops organized around maps, thus empowering the users to understand the extent of uncertainty and apply the outputs accordingly.

In some cases, expert knowledge was explicitly used in the absence of alternatives. At the GM site, an expert workshop was held to overcome the lack of knowledge regarding the ecological functions delivered by seagrass beds and this successfully led

managers to re-assess the reason why this habitat should be preserved. At the GNB site, in order to develop a model on risks for the habitats, it was necessary to mix various sources of information, including expert judgement. The expert judgement was widely accepted by the stakeholders throughout the case study sites as the ESA was undertaken in partnership, enabling the development of trust-based relationships. In addition, in many of the case studies it was found that including stakeholders in the data discovery process highlighted sources of information which might otherwise have been overlooked, and thus provided significant benefits to both the academics and the end users.

3.6. Recommendation 6: record ESA and resultant impact

It is recommended that the ESA is clearly recorded, with good accessibility of documentation of the methods, the results and the implementation of the results including mistakes made.

In all of the case studies, a significant amount of knowledge and data was held in a variety of informal settings by the local managers and stakeholders, and it was recognized that a significant amount of local case study research is not fully recorded. To increase the capacity to undertake successful future ESA, and to reduce the future resources required to undertake ESA, the systematic recording of both the ESA and the results is critical. Increasing the body of evidence regarding the ESA will reduce the effort needed to undertake ESA in the future and enhance confidence in this approach. In particular, a record of the impact, including extent of influence, should be made. This record will need to be dynamic as the impact of ESA on management and policy is likely to be at the time of study, but may also extend into the future. New online platforms may provide a valuable method of recording and sharing data and experiences; for example, Oppla (www.oppla.eu) is a new knowledge marketplace and provides a potential place where ESA case study findings can be documented and disseminated.

4. Discussion

The six case studies described here were successful in producing a wealth of results and data of benefit to the individual sites, but also given their variability it has also been possible to draw generalized recommendations for the future application of the ESA. The value of these recommendations can be further verified by considering how useful the ESA was to management at the six sites. In all cases, there was positive feedback from the stakeholders both during and after the ESA was applied.

Generic benefits of the ESA at all sites included an improved understanding of the ESA by academics, managers and stakeholders alike, improved transparency of ES and potential trade-offs, and through enabling discussion and shared learning between stakeholders and with the wider academic community, the long-term interactions of these groups have noticeably improved. More specifically, in the NDBR there was strong consensus among stakeholders that the approach taken was very useful and some stakeholders expected to use the maps of current levels of service delivery. In Poole Harbour, a survey of stakeholders found that 75% thought the results would be useful in raising awareness of the condition and value of the harbour, and 87% thought they would be useful in supporting management decisions and informing policies, with the results already being used in the Bournemouth and Poole Sports Strategy and informing the Poole Harbour Aquatic Management Plan review. The PSF experience proved that even in data-poor areas qualitative outputs are a useful tool for stimulating discussion and considering trade-offs, even if they have limited direct use in policy development. The GNB and the PNMI ESA improved understanding of the ES provided in these areas and through improved transparency regarding trade-offs continue to support collective reflection on the integrated management of these areas. The ecosystem service simulation model developed in the PNMI was used to define new regulations for kelp harvesting. In the GM, the results complete the objectives of the Natura 2000 document and it is intended they will also be used in reviewing the Plan for Sea Development (a maritime planning document).

There is well documented and widespread opinion that the ESA has the potential to significantly improve the development of policy and management strategies but practical success stories of ESA implementation are rare. Given the case study evidence presented here, it is reasonable to propose that in all six case study sites the ESA has proved a valuable mechanism to enable the management of the local areas. The potential benefits of incorporating the ESA into a wide range of management context are clearly significant, from simply providing qualitative information on the ecosystem services present in an area, to engaging and integrating stakeholders, through to providing monetary values which can be applied directly in policy and management decisions. As the marine ecosystems become increasingly populated with competing activities and demands, coupled with escalating environmental pressures, there is an urgent need for transparent and objective frameworks which can be applied to enable sustainable and equitable decision-making. The evidence documented here suggests that the ESA, if successfully implemented, has the potential to provide such a framework.

The case study experience reported here validates the previous reasons for failure of implementation, but more importantly also provides clear lessons for the future. It is proposed that the primary barriers to successful ESA are not data gaps and resource limitations, but instead are organizational and communication-based issues which can be relatively easily overcome following the recommendations made here. In conclusion, we believe the ESA has great potential in ensuring our continued sustainable development, and as such offer the six recommendations as pragmatic guidance to increase the extent to which ESA are operational and useful in a policy and management context in the future.

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