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Short communication

What are the research priorities for marine ecosystem services?

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ABSTRACT

Despite the growing consensus in the applicability of the ecosystem services (ES) approach to marine resource management, its incorporation into real life decision-making remains insufficient. This paper provides the first bottom up consultation about research priorities of marine ES. This paper surveyed 404 marine ES practitioners globally with the aim of identifying the key research priorities for marine ES to determine crucial knowledge gaps that need to be addressed. The results of this study show that topics related to *Linking ES and wellbeing*, and *Integrating economics, natural and social sciences into ecosystem services assessments* are the most important research issues. The research done also indicate that questions concerning the interplay between ecosystems and people were found to be more important than instrumental questions. By identifying and prioritizing research questions this study will help to inform research-funding agencies, governments, and research units seeking to concentrate their financial and human resources on the challenges that require urgent attention, and to enhance the complementarity and minimize duplication of research efforts in the marine ES research community. This study provides the basis for developing a practice-oriented marine ES research agenda.

1. Introduction

Coastal and marine ecosystems play a crucial role in supporting economic prosperity and social welfare in the adjacent human communities [1]. However, coastal areas and their ecosystems are subject to an increasing number of competing activities and pressures as the world's population continues to grow [2]. The impacts of human activities are altering the structure and functioning of ecosystems [3], thus reducing ecosystems' capacity to generate ecosystem services (ES) [4] and crossing planetary boundaries which can put at risk the welfare of the human being [5].

There are multiple human impacts that threaten the functioning of coastal ecosystems: intensive fishing, runoff from land, oil spills, climate change, marine pollution, marine habitat destruction, and marine invasive species, among others [6]. Economic activities such as fishing, aquaculture, tourism, energy production, or shipping are highly dependent on the functioning of coastal marine ecosystems [7]. The maintenance and enhancement of these activities as well as of the multiple benefits available from marine ecosystems depend on how societies and governments find ways to balance the demand and the supply of marine ES [8].

In the field of marine ES the global marine catch has been stagnant for at least the last two decades have triggered a worldwide demand for change in the way coastal and ocean resources are managed [9,10]. At a time when social attitudes and values are changing rapidly due to complex and interconnected drivers [11], there is a need for a shift towards integrative approaches drawing together research across natural and human systems.

An ES approach to resource management moves beyond how people affect ecosystems to include how people depend on, benefit from and are affected by ecosystems [2,12]. The scientific community advocates for its use as a management tool [13–18]. The framework of ES enables the explicit examination of trade-offs between ES and it provides a quantitative approach for assessing the value of marine spatial planning versus sectorial or uncoordinated planning [19,20].

Policy makers are also starting to include the concept of ES in their guidelines and strategies. One relevant example of this is the EU's new post-2010 biodiversity strategy, announced in May 2011, in which ES are directly linked to specific targets [21]. In particular, Target 2 and 4 of the EU Biodiversity Strategy explicitly set priorities to maintain and restore ecosystem and their services, the sustainable use of fisheries resources by improving the management of fish stocks and eliminate adverse impacts on fish stocks and marine ecosystems [21].

Despite the recent attention given to ES, there are numerous challenges that hamper the integration of the ES concept in

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marine spatial planning and decision-making. A fundamental hurdle in using ES in decision-making is the inconsistency with which scientists have conceptualized supply of ES to society [17] and ES demand [22]. Many unresolved problems persist over how ES relate to each other, how ecosystems produce services, how to consistently quantify ES flows, and how changes in land(sea) scapes are likely to affect future supply of ES [23,24]. There is still little research done and empirical understanding of the characteristics and variability of ES demand, its driving forces, and the impacts on human wellbeing. Thus, in order to enhance our ability to quantify, map and ultimately make ES information more accessible to decision-makers, the scientific community acknowledges the inherent differences among ES types, the dynamic process by which ES are produced, the diversity of stakeholders and their preferences for different ES, and furthermore, understand how governance systems are likely to affect the flow of ES to society [25].

Although recent advances have been made [22,26–28], the quantitative relationship between ecosystem structure, processes, functions and services is still poorly understood. This is particularly true for marine and coastal ES, where there is a lack of spatially explicit information added to the difficulty of quantifying ecosystem functions and processes, and the high-levels of multifunctionality, connectivity, and interactions that occur in marine coastal systems [29].

In addition, it is necessary to deal with the impacts of global change in marine social–ecological systems and the changes that are very likely to occur to marine systems in the near future. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) identified warming temperatures, rising sea levels, declining sea oxygen concentrations, increasing acidification of marine environments, changes in the migration of species and fluctuating precipitation patterns as likely changes that can modify the structure and productivity of marine ecosystems as well as their ability to provide ES for society [30].

Under the dilemma on the lack of standardization of research priorities, a basic but a fundamental question remains unresolved: what are the research priorities in marine ES? To address this question, this paper identifies the most important research priorities for marine ES. By considering questions of overall relevance a list of core marine ES research priorities that require urgent attention is developed, while at the same time identify crucial information gaps to improve practical application of ES knowledge as identified by different stakeholders (e.g., managers, users, and scientists). Disentangling the research questions will help to clarify how the needs of social and natural sciences in ES research can be addressed and integrated, and will hopefully enhance the complementarities of investigated research questions and approaches, and minimize duplication of research efforts in the marine ES research field.

2. Materials and methods

2.1. Research question identification

To get an overview on important issues related to ES research, a list of coastal, marine, and ES-related research questions and priorities among scientific papers and reports is searched that focused on identifying and prioritizing ES research, and the most common recurrent issues were selected as the main topics. Based on this, a literature analysis was undertaken on topics including key research questions and priorities for ES [23,31] such as classifications and frameworks [32,33], climate change [30]; the contribution of biodiversity to ES [9]; cultural ES [12]; ES flows [34]; integrate economic, social and natural sciences [1,4,31]; mapping and indicators of ES [35]; spatial planning, management, and decision making [1,19,36]; understanding of ecosystem production functions [1,3]; and valuation of ES [21,37]. Gaps in current scientific knowledge were also identified as an integral part of this review process.

An initial list of 138 questions of potential relevance for this survey was identified. These questions were synthesized into 85 research ones which were grouped into 10 main topics according to the most common issues found in ES literature. In a second step, a number of selected experts were contacted in the field of ES based on their expertize, years of experience and reputation of their research, who are presently involved in ES projects, networks or research groups to assist us in tailoring the survey. The list of research questions was systematically refined and reduced to 50.

A common conceptual problem of these types of inquiries was to find the optimal balance between high-generality and high-specificity of different questions [38]. This potential bias is minimized by framing the questions so that they were sufficiently general to be applicable to a broad range of ecosystems and socioeconomic contexts and by offering the respondents the additional opportunity to name specific topics or research questions that they considered to be of importance in marine ES research. The resulting set of 50 questions was arranged under 10 main topics/themes (Table 1) and was included in an online survey tool.

2.2. Design of the questionnaire

The objective of the questionnaire was to identify information gaps and the most important research priorities for marine ES according to expert knowledge. The questionnaire was structured in three parts (see the Supplementary material for detailed information of the questionnaire).

In part 1, the 10 main topics were presented in which respondents were asked to rate on a Likert scale ranging from 1 to 4 the importance of each of the main topics to advance knowledge and practice of the ES approach [39]. To address the concerns of Cooke et al. [40] pointed out about what is usually included and excluded from the list and their influence on potential funding for future research, the respondents were also invited to provide additional topics if they felt an important research topic were missing in the questionnaire (hereafter "Supplementary topics", see Table 9). With this we offered respondents the opportunity to narrow the rather general topics down to more specific topics or areas of interest.

In part 2, respondents were asked their opinions on which research questions (set of 50 questions) they believed, if answered, would have the greatest impact on addressing future opportunities and challenges relating to marine ES science. In the first phase of the survey, subsets of five questions were presented under each topic and asked the respondents to choose three out of five from the list. In order to facilitate the raking exercise questions that received less than 50% of response rate in the first phase were eliminated from the list. Thus, in the second phase of the survey the list of questions was reduced to 35 (see Table 1 for details), and was submitted to a wider sample of practitioners who were invited to rate the relevance of each question on a Likert scale ranging from 1 to 4. By following the method proposed by Braunisch et al. [41], the respondents were invited at the end of the thematic sections to nominate questions that were relevant to that section and sufficiently important that they should have been included (hereafter "Supplementary questions", Table 10).

Finally, in part 3, participants were asked to specify their affiliation (e.g., academia, NGOs, representatives of the industrial sectors, etc.), main type of activity (e.g., researcher, survey and monitoring, legislation, etc.) and socioeconomic characteristics (e.g., education, number of years working on ES, etc.).