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Assessing uncertainty associated with the monitoring and evaluation of spatially managed areas

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ABSTRACT

Marine spatial planning (MSP) is advocated to support an ecosystem approach to marine management, as it allows consideration of multiple management objectives including marine conservation. The monitoring and evaluation of both implemented marine plans and the planning process itself is susceptible to various uncertainties. Here, uncertainties related to a stepwise monitoring and evaluation framework for spatially managed areas were characterised and quantified with the help of two modified and developed tools. In particular, Walker-type and pedigree matrices were utilised to assess both the sources and respective relative levels of uncertainty present in the assessment of nine European case studies that conducted a stepwise monitoring and evaluation process applying a common framework. Across the southern and northern European case studies major sources of uncertainty were found in relation to the knowledge base, management scenarios with related objectives and data availability. Although case studies made flexible use of the framework to account for the particularities of the local realms, the revealed pattern of associated uncertainty was highly consistent across the case studies. The scored pedigree matrices showed that the criteria 'stakeholder engagement' and 'cross validation' had greatest influence on the overall robustness of the case study assessments. The observed distribution of median pedigree scores was within acceptable ranges with respect to simulated possible score distributions. In addition, a sensitivity analysis revealed that the scoring of the pedigree criteria by five or more experts would result in less variable interquartile ranges of respective median scores. In conclusion, the developed complementary tools showed great flexibility in characterising and assessing uncertainty despite context-dependent differences among case studies such as geographical area, quality of available data, level of spatial management implementation or management objectives. Moreover, the

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obtained findings allow prioritising efforts and future research to support an iterative monitoring and evaluation of marine spatial plans.

1. Introduction

Worldwide place-based management tools such as marine spatial planning (MSP) are advocated to support an ecosystem approach to marine management, as they enable consideration of multiple management objectives, including those related to marine conservation [1–3]. As a consequence, an increasing number of practical examples of implemented MSP and ongoing marine planning processes are observed [4]. Regardless of the degree of MSP implementation, monitoring and evaluation are crucial components in relation to both the MSP process itself and the performance assessment of already implemented plans. Evaluation is generally accepted as an essential learning and improving step in MSP [5]. Recognising the need for practical evaluation tools, a generic and flexible framework was developed [6] which based on good practice of ecosystem-based management and lessons learned from existing practical applications [2]. The framework provides a practical guidance to assess the effectiveness of spatially managed areas (SMAs). It contains structured tasks and tangible suggestions on how to structure the analysis or to select appropriate methods depending on the quality of the available data (www.mesma.ucc.ie/emanual/; see Appendix A). The framework is regarded as flexible because it can be used for different degrees of analysis ranging from a qualitative and conceptual application to an in depth data driven assessment. In other words, SMAs can be evaluated by comparing the components of an ongoing evaluation process to the one suggested by the framework. Alternatively, the framework provides guidance for performance assessment using spatial and temporal resolved data to develop potential spatial management scenarios.

The framework can also be regarded as an integrated assessment (see [7]), since it uses a multidisciplinary approach to address complex societal questions encompassing a variety of perspectives [8]. A vast array of information from disparate sources is needed in order to scientifically evaluate management effectiveness, to inform decision makers and to deliver feedback with lessons learned from the evaluation. At many levels throughout this integrated assessment uncertainty gets introduced into the process. First of all, uncertainty is inherent to each individual disciplinary scientific field, and surely increases when different scientific disciplines and approaches for integrated environmental management and assessment are combined.

Integrated assessment models often inadequately address uncertainties and claim that multiple diverse approaches are needed to undertake a robust assessment of uncertainty [8]. Uncertainty cannot be eliminated from any integrated assessment or model-based decision support, however it should be recognised and constructively handled [9,10]. Scientific advice can never rule out uncertainty, related to inadequate knowledge, unpredictability of ecosystem behavior or ambiguity in the science-policy interface [11].

Several authors have distinguished between categories of uncertainty. It can be differentiated between substantive uncertainty which refers to lack of knowledge (also known as epistemic uncertainty), strategic uncertainty due to imperfect knowledge about how actors will anticipate and respond to each other's actions, and finally institutional uncertainty which refers to incomplete knowledge about formal competences, procedures and conventions [12]. From the standpoint of the nature of uncertainty, it can be further categorised into epistemic (due to imperfect knowledge, hence reducible) and stochastic or ontological (generated by inherent variability, therefore irreducible) [13]. These types of uncertainty can be dealt with in different ways, either passively or actively. Passive methods include ignorance (no choice is made regarding uncertainty handling), recognised ignorance (the uncertainty is identified and expressed but no decision is taken), and avoidance (uncertainty is avoided by limiting the scope). In contrast, active methods focus on either increasing uncertainty tolerance or reducing uncertainty [14].

In general, three key advantages can be drawn from any uncertainty assessment. First, uncertainty characterisation allows to allocate the available resources to researchers and institutions in order to match the needs of decision makers and to fill critical gaps [15,16]. Second, the analysis of uncertainty highlights the most important issues to focus on, whilst avoiding collation of large quantities of often ambiguous or conflicting information that would make it harder to take the necessary decisions. Third, by communicating the different levels of uncertainty, the participative dialogue is fed, which helps in trust building [14].

As a result, three key questions on uncertainty arise in the context of spatial management performance assessments: (1) how can the various sources of uncertainty be identified throughout the assessment process; (2) to what extent is the detected uncertainty quantifiable; and (3) how do these different uncertainties influence the overall assessment results? While there is an increasing consensus about the importance of communicating uncertainty, there is no such consensus on best communication practices [17]. Therefore, to support the communication of uncertainty associated with a policy or scientific advice, integrated assessments should be accompanied by an uncertainty assessment that clarifies the quality and soundness of the conclusions [18].

The present study addresses the potential and limitations of the practical assessment of uncertainty associated with the step-wise evaluation procedure provided by a conceptual framework [6]. Specifically, the aims were to (i) develop transparent methods to identify, characterise and quantify the uncertainty associated with the process of monitoring and evaluating spatially managed areas; (ii) assess the effects of different types of uncertainty on the assessment results; and (iii) derive some general recommendations regarding the practical assessment of uncertainty.

2. Material and methods

2.1. Monitoring and evaluation of spatially managed areas in practice

The overall aim of this study was to characterise and quantify the uncertainty associated with the monitoring and evaluation of SMAs which reflects an integrated assessment. Therefore, standard tools were adapted and extended to match a standardised assessment process described by a framework for the monitoring and evaluation of SMAs developed within the EU-funded project MESMA [6]. The framework was applied in nine different case study areas in northern and southern Europe, reflecting a large diversity of spatial scales, contexts, ongoing management plans and strategies, level of spatial management implementation and assessed operational objectives (Table 1; www.mesmacentralexchange.eu/help/category/12/examples.html).

The use of the framework ranged from the observation of a process to the development and evaluation of spatially managed