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Integrated ecosystem analysis in Irish waters; Providing the context for ecosystem-based fisheries management

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ABSTRACT

Fishing has long been considered the most impactful human activity on the marine ecosystem. To adopt ecosystem-based fisheries management (EBFM) requires consideration of all human impacts, not just those of fishing. The ODEMM (Options for Delivering Ecosystem-based Marine Management) approach provides an integrated ecosystem assessment that is a flexible, cost-efficient and expert-based. The framework traces the sectors affecting the marine environment, the pressures they create, and the ecological characteristics affected. This research presents the first application of the ODEMM framework outside of the ODEMM project, completed for Ireland's marine waters. The assessment places fishing in the context of other anthropogenic pressures and highlights areas of threat to Marine Strategy Framework Directive (MSFD) descriptors. From 1874 impact chains, just 59 (44 of which were attributed to the fishing sector) account for 64% of the Total Risk score, highlighting areas for management action with a high risk-reduction return. Of the sectors, The analysis showed *Waste Water* to have the highest average risk of all sectors, followed by *Land-based Industry, Fishing* and then *Shipping.* In terms of total risk, *Fishing* was the most important sector, due to its high connectance to many ecosystem components and widespread influence, even though many of the impacts are relatively low and the components impacted show a high degree of recoverability. Litter was identified as the pressure with the highest total risk scores (average and summed) due to its persistence, and widespread reach. Among the ecological characteristics, deep water habitats that have low resilience to pressures showed the highest average total risk, yet the highest impact risks were for ecological characteristics that were closer to land and were impacted more frequently. These conclusions highlight the importance of context and interpretation in the analysis. The impact chains were further linked through to the MSFD environmental status descriptors, indicating *Biological Diversity* and *Food Webs* as the descriptors most at risk, followed by *Sea-floor Integrity*. As the first independent application of the method, issues arose with interpretation of some categories and definitions, and some modifications are discussed.

Overall, this has proven a valuable exercise for helping to identify management priorities. The analysis presented provides useful context for EBFM and a basis for decision making and trade-off analysis for Ireland. The ODEMM framework employed offers a comprehensive, adaptable, globally-applicable tool to guide ecosystem management and the decision-making process, by highlighting risk areas and priorities for management action and research.

1. Introduction

Today's ecosystems are widely recognized as being highly impacted and extensively modified by human activities (Firth et al., 2016; Halpern et al., 2008, 2007; Millennium Ecosystem Assessment, 2005; OSPAR Commission, 2010). We struggle to balance our aspirational goals of sustainable management (e.g. Sustainable Development Goal 14: "Conserve and sustainably use the oceans, seas and marine resources" (United Nations, 2015)) with an increasingly developed world and rising population levels (Meadows et al., 2005). Improved

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knowledge and recognition of the multitude of anthropogenic pressures affecting natural ecosystems has resulted in broad acceptance that ecosystem-based management is essential for the effective conservation and management required to maintain ecosystem services (European Environment Agency, 2006; Halpern et al., 2008; Levin et al., 2009; OSPAR Commission, 2010; Pikitch, 2004). Ecosystem-based management requires consideration of the whole suite of anthropogenic pressures affecting entire ecosystems, rather than focusing on individual components (Borja et al., 2016; Halpern et al., 2007; Harvey et al., 2017; Hilborn, 2011; Levin et al., 2009). In recent years, legislation and policy have also moved in this direction, increasingly requiring scientists and managers to be holistic in their work, advice, and decision-making, rather than looking at single or few elements in isolation (e.g. Marine Strategy Framework Directive (MSFD; European Union, 2008), Common Fisheries Policy (CFP; European Union, 2013), Maritime Spatial Planning Directive (MSPD; European Union, 2014), Magnuson-Stevens Fishery Conservation and Management Act, (MSA: Magnuson-Stevens Fishery Conservation and Management Act., 1996), Australia's Oceans Policy (Environment Australia, 1999), Canadian Oceans Act (Department of Fisheries and Oceans, 1996); Oceans Act of 2000 (US Congress, 2000), South African National Water Act (Government of the Republic of South Africa, 1998), etc.). Within Europe, the MSFD specifically enshrines the ecosystem approach in a legislative framework to manage European seas in a sustainable, holistic manner, through establishing (by 2020) and maintaining 'good environmental status' (GES) of the marine ecosystem (European Union, 2008). The current CFP specifically aims to deliver economically, environmentally and socially sustainable fisheries. The CFP also acknowledges that the impacts of human activities on all components of the ecosystem are not fully understood, and makes specific references to multi-annual ecosystem-based management plans (European Commission, 2018; European Union, 2013). The MSPD requires us to manage our waters more coherently by ensuring cross-sectoral human activities at sea take place in an efficient, safe and sustainable way (European Union, 2014). Taken together, these Directives require us to look at fisheries in the context of the suite of other human induced pressures affecting our marine ecosystems.

Efforts to implement ecosystem approaches to fisheries management (EAFM) and ecosystem-based fisheries management (EBFM), as well as the necessary research to underpin them have increased dramatically in recent years (Borja et al., 2016; Korpinen and Andersen, 2016; Pitcher et al., 2009; Trochta et al., 2018), partly in response to legislation. However, actual practical tactical implementation of EBFM in the real world has been much rarer (Borja et al., 2011; Skern-Mauritzen et al., 2016). Efforts have ranged in scale and ambition, from simply incorporating some 'ecosystem knowledge' into single species assessment models at one extreme, to building complex ecosystem models that incorporate the suite of **D**rivers, **A**ctivities, **P**ressures, **S**tate, **I**mpacts (human **W**elfare), management **R**esponses (as **M**easures); (*sensu* DAPSI (W)R(M) after Borja et al., 2016). Ecosystems approaches by definition should include all sectors (Borja et al., 2016; Dickey-Collas, 2014; Fitzpatrick et al., 2010), yet they rarely do (but see Knights et al., 2015). It is perhaps the daunting complexity of what can and/or should be included in EBFM that has led to the rarity of 'real-world' implementation, yet in order to advance EBFM, fisheries (and its pressures) must be placed within the context of the wide range of others sectors and the pressures they create if measures are to be in anyway effective.

Common perception often assumes that fishing is the sector creating the most pressures, affecting the widest range of ecosystem components, and with the greatest impact. However, is this really the case? And if so, does it apply everywhere equally? What pressures beyond 'extraction of species' and 'sea floor degradation' does it create, and which ones should we be most concerned about? And importantly, is focusing on fisheries the most efficient way to reduce risk and pressure on the marine environment? Many questions remain, and thus much is to be gained by placing fisheries within the wider context of the ecosystem.

To deliver holistic ecosystems-based marine management, managers must know the causal drivers of impact if they are to be managed (Knights et al., 2014). Integrated ecosystem assessments (IEA's) have been proposed as a framework to facilitate ecosystem-based management, and to steer management efforts to achieve multiple objectives (Dickey-Collas, 2014; Harvey et al., 2017; Levin et al., 2014, 2009). IEA takes a birds-eye view to assess the suite of pressures that co-exist, identify the sectors that cause them, and the ecosystem components affected by them, thus providing the context in which the sectors and pressures operate. Conceptually, IEA is both simple and sensible, yet implementation is more difficult (Dickey-Collas, 2014; Walther and Möllmann, 2014). The data, monitoring and modelling requirements of full ecosystem based management are many and daunting (Borja et al., 2016; Harvey et al., 2017; Hilborn, 2011; Hobday et al., 2011; McQuatters-Gollop, 2012). Inevitably an extensive list of pressures and threatened ecological components results from such an IEA, and resources are rarely, if ever, sufficient to address them all (Halpern et al., 2007). Therefore tough decisions must be made, and priorities specified. IEA can play a central role in the decision-making process by providing holistic information that is based on best available understanding and knowledge, which then allows comparisons and judgements to be made (i.e. identification of trade-offs) and the most appropriate objectives for management to be determined (Walther and Möllmann, 2014).

There are many tools and stages in the IEA toolbox that are applicable at a range of scales (Harvey et al., 2017; Levin et al., 2014, 2009). One key element, however, is risk assessment (Battista et al., 2017; DePiper et al., 2017; Fletcher, 2015; Hilborn, 2011; Hobday et al., 2011; Holsman et al., 2017; Korpinen and Andersen, 2016; Slater et al., 2017). In broad terms, risk assessment comprises identification (scoping) of relevant pressure elements to include in your assessment (in consultation with stakeholders), an analysis of the 'susceptibility' of ecosystem components, and their ability to recover ('resilience') post-impact (Levin et al., 2009). Assessments may be quantitative (i.e. indicator-based, see review in Borja et al., 2016), qualitative (e.g. ODEMM, Robinson et al., 2014), or a mixture of the two (e.g. Bayesian Network Analysis, Fletcher et al., 2014); indeed a wide range of methodologies for applying such risk assessments exist (see Korpinen and Andersen, 2016). Quantitative and qualitative assessments are not mutually exclusive, in fact they are often complimentary, each filling the gaps left by the other and can be used together in a series of steps.

In 2014, the ODEMM project (Options for Delivering Ecosystem-based Marine Management, FP7, http://odemm.com/; Robinson et al., 2014) developed a flexible, adaptable and relatively quick and cost-efficient tool that can be tailored to requirements in order to allow the identification and assessment of risk. ODEMM grew out of the OSPAR Quality Status Report methodology (OSPAR Commission, 2010; Walther and Möllmann, 2014), building upon it, while refining the process and developing outputs. The framework traces the causal links of impact (i.e. pressure mechanisms or 'impact chains', sensu Knights et al., 2015) between multiple sectors and the marine environment, 'to provide the structure within which management options can be explored' (Robinson et al., 2014). Scores which detail the spatial extent/overlap, frequency of occurrence, degree of impact, persistence and resilience for each pressure pathway, based on pre-determined categorical thresholds are then assigned by an expert panel informed by data and supported by a cross-check methodology. Through the process, all available information can be incorporated, along with tacit knowledge and expert judgement where data gaps exist. From this assessment, products that are easily interpreted and understood can be created that facilitate the communication of complex messages in a relatively simple format to non-scientists such as policy-makers and stakeholders. This simplicity is critical for enabling the entire suite of ecosystem threats to be observed and understood (Borja et al., 2016). It