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Contribution to the Themed Section: 'Integrated assessments'

Introduction

Integrating what? Levels of marine ecosystem-based assessment and management

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Integrated assessment requires examination of factors across biological hierarchies, taxonomic groups, ocean-use sectors, management objectives, and scientific disciplines. The articles in this theme set represent attempts to clarify and elaborate upon what integrated assessments are, with a particular emphasis on how they are being implemented. The aim of this themed article set is to clarify the use of integratedassessment terminology and demonstrate, by presenting case studies, examples in which integrated ecosystem assessments serve as useful tools to implement ecosystem-based management (EBM) while also identifying challenges that must be overcome for this to succeed.

In theory, EBM seeks to address the various natural and anthropogenic pressures faced by the key components of marine systems simultaneously. EBM also attempts to account for "cumulative impacts" that might otherwise be overlooked. Nascent attempts to implement EBM highlight the need—in practice—to address trade-offs across multiple objectives for a given system, in a coordinated and comprehensive manner. During the past decade, the discussion over EBM has shifted from "what is it and why should we do it" (Link, 2002; Browman and Stergiou, 2004, 2005) to "how can we do it and when can we operationalize it" (Arkema *et al*., 2006; Link, 2010; Berkes, 2012). Marine EBM (e.g. Levin and Lubchenco, 2008; McLeod and Leslie, 2009) and similar ecosystem-based efforts for more specific ocean-use sectors, such as ecosystem-based fisheries management (EBFM; e.g. Pikitch *et al*., 2004; Link, 2010) or integrated coastal-zone management (e.g. Cicin-Sain and Knecht, 1998; Moksness *et al*., 2013), have become the mandated approach to managing ocean resources. EBM is a major policy objective of many marine-oriented organizations—as is clear from a perusal of the strategic plans of organizations such as ICES, PICES, FAO, UNEP, and NOAA. The need for integrated assessments frequently arises in the context of discussions over implementing EBM.

The term "integrated assessments" is perceived as mysterious and ultimately unhelpful because it suffers from a plurality of definitions and it is used in a multitude of contexts—i.e. it has high linguistic uncertainty. That is why we pose the question in the title of this introduction: what are we integrating and, hence, what are we assessing?

Returning to the EBM context for sustainably managing marine resources, we note that there are, in fact, multiple levels at which an "ecosystem approach" can be adopted in practice. To illustrate, we focus on the fisheries sector. There are levels of application for EBM that focus solely on fish stocks, levels that focus on fish stocks but with ecosystem considerations incorporated, ecosystem levels that focus solely on the fisheries sector but for the full system of fisheries and stocks, and the full set of ocean-use sectors impacted by and impacting the fisheries sector (Table 1). For example, consider forage stocks such as small pelagic fish. For an ecosystem approach to fisheries (EAF) that takes a stock focus, one would need to consider the effects of environmental factors (e.g. temperature changes or NAO events) and ecological factors (e.g. predator removals or models of multispecies interactions) in addition to targeted fisheries removals to truly grasp what is driving the population dynamics of such stocks. Using the same type of focal species as an example, for EBFM that takes a system focus in the fisheries sector, one would

Table 1. Levels of application for EBM for the fisheries sector, with notes on particular features of each level

	Level of EBM in fisheries sector			
Feature	**EBM**	**EBFM**	**EAF**	**Classical FM**
Sectoral focus	All	Fisheries	Fisheries	Fisheries
Focus of the biological hierarchy	All	Community/whole system	Stock/population	Stock/population
		Aggregate	Maybe multispecies	
Evaluation processes used to do it	Integrated ecosystem assessments	Integrated ecosystem assessments, fisheries sector focus	Integrated stock assessments	Stock assessments
Primary objective of the analysis	Address cross-sector trade-offs	Address fishery sector, living marine resource trade-offs	Delineate status of stock/s	Delineate status of stock
	Ascertain ecosystem goods and services	Ascertain ecosystem productivity	Ascertain stock productivity	Ascertain stock productivity
	Identify best mix of services across goods and services	Identify best mix of goods across fisheries and stocks	Identify levels of optimal stock production cognizant of ecosystem factors	Identify levels of optimal stock production
	Evaluate cross-sector cumulative effects	Evaluate within-sector cumulative effects	Evaluate within-stock effects of multiple drivers	Evaluate within-stock effects of fishing
Primary outputs for decision criteria	Provide systemic reference points	Provide systemic reference points	Provide fishery stock reference points	Provide fishery stock reference points
Analytical tools available to do it	EMs RA MSE	EMs MSMs RA MSE	ESAMs MSMs MSE	SAMs

EMs, ecosystem models; RA, risk analyses; MSE, management strategy evaluations; ESAMs, extended stock assessment models; MSMs, multispecies models; SAMs, stock assessment models; EBM, ecosystem-based management; EBFM, ecosystem-based fisheries management; EAF, ecosystem approaches to fisheries; FM, fisheries management. For full EBM, this would be consideration of all ocean-use sectors. For EBFM, this would be only the fisheries sector with an ecosystem emphasis. For EAF, this would be fisheries management with inclusion of ecosystem considerations. For FM, there would be no explicit consideration of ecosystem features.

have to consider not only the impacts of other factors on these forage stocks, but also the dynamics of these forage stocks on other parts of the ecosystem. For instance, there are seabirds or marine mammals that have some form of protected or conservation status and that are highly dependent on small pelagic forage fish. There are commercially targeted groundfish that are also major predators of these small pelagic forage fish. There are also multiple fisheries operating on both the groundfish and the small pelagic species. In such a case, clearly a more integrated, "bigger picture" evaluation of the whole system and how it fits together is needed to address the potential trade-offs among the different uses of and impacts to these forage stocks. Further, if these forage stocks represent a key pathway of energy from lower trophic levels to upper trophic levels (which they typically do), then the resilience, structure, and functioning of the system would need to be evaluated. For an EBM that covers all ocean-use sectors, consideration of these small pelagics and their role in the ecosystem is warranted in a broader context for anthropogenic drivers such as power plant discharges (thermal impacts), eutrophication, toxin deposition, hydroelectric energy generation, dredging for navigation safety, and similar uses that might impact the habitats of these species. One can envision similar examples for other ocean-use sectors, but facets of this full range of considerations across different levels of EBM are demonstrated in Möllmann *et al.* (2014). The salient point being that one can do integrated assessments at all these levels of application, but they are called different things.

For EBM that focuses only on single species of fish (Table 1, EAF), integrated stock assessments can/have been used. Certainly, classical stock assessments integrate a wide array of standard data streams (e.g. Fournier and Archibald, 1982; Methot, 1989; Punt and Hilborn, 1997; ICES, 2012). Here, integrated stock assessments, although often termed integrated assessments or integrated analyses, are referring to other factors beyond the typical catch, abundance, and biology data, particularly bringing more statistical techniques and approaches into consideration. These integrated stock assessments have been discussed in many other contexts (e.g. Fournier and Archibald, 1982; Maunder and Punt, 2013; Methot and Wetzel, 2013). In this EAF context, such integrated stock assessments use extended stock assessment models that incorporate other facets of the ecology, oceanography, or environment to explain and predict stock dynamics (e.g. Maunder and Watters, 2003; Methot and Wetzel, 2013). A growing body of multispecies models can also explore some facets of these considerations (e.g. Townsend *et al.*, 2008; ICES, 2011) and, although they could be used in an integrated stock assessment process and their outputs are often used as inputs into extended stock assessment models, they are not typically termed integrated stock assessment models themselves. Möllmann *et al.* (2014) provide an excellent example covering the range of assessment models used to inform the management of living marine resources in the Baltic. Their ensemble approach of using multiple models to inform the decision-making process has strong potential for both integrated stock assessments and advancing EBFM more broadly by providing multiple perspectives on the same problem without being biased from using only a limited set of model assumptions, model structures, or modelling frameworks.

For EBM in the fisheries sector that includes an ecosystem emphasis (Table 1, EBFM), parts of integrated ecosystem assessments can/have been used. Integrated ecosystem assessments are, by their nature, designed to be multisectoral (Levin *et al*., 2008, 2009) but, clearly, the overall process can be adopted for sector-specific applications. A large part of doing EBFM at this level entails exploring trade-offs among different fishery fleets, targeted species, and non-targeted species. Möllmann *et al*. (2014) describe some facets of integrated ecosystem assessments that have been used in the fishery sector for the Baltic, capitalizing on the other ecosystem factors that so readily and so obviously impact fish in that Sea. Samhouri *et al*. (2014) note how features of integrated ecosystem assessments have, to date, largely been used to advance EBFM in a fisheries context in the USA. They particularly emphasize the important role of contextual information and the use of indicators for ecosystem considerations in the fisheries management process. The contributions to this article theme set present various renditions of an integrated ecosystem assessment process and, following from them, it is not difficult to envision how this approach could be adapted to other ocean-use sectors.

For all ocean-use sectors, integrated ecosystem assessments are the most appropriate tool (Table 1, EBM). Nascent integrated ecosystem assessment efforts have been underway for approximately half a decade, though mostly piecemeal and usually not in a fully implemented manner (Dickey-Collas, 2014). Progress from the few instances where integrated ecosystem assessments are beginning to be more fully utilized is reported in this theme set, with notes on lessons learned (Samhouri *et al*., 2014) and guidelines for implementing integrated ecosystem assessments (Levin *et al*., 2014) highlighted. This is done with the intention of better informing multiple ocean-use sector management and avoiding the clashes that often arise when competing ocean-use sectors do not communicate their objectives. One of the key findings from both the Samhouri *et al*. and Levin *et al*. works is the importance of early and frequent engagement of stakeholders in the process. This observation is reinforced by the frank insights about the development of the ICES approach to integrated ecosystem assessment offered by Dickey-Collas (2014).

The North American examples on integrated ecosystem assessments are complemented by broader European perspectives (Dickey-Collas, 2014; Walther and Möllmann, 2014). These authors note progress to-date on integrated ecosystem assessments in the ICES context, particularly identifying some important challenges facing their implementation. They note that these challenges could in fact impede the ability to fully embrace EBM. The European perspectives bemoan the generally slow implementation of integrated ecosystem assessments. Yet an important point that Samhouri *et al*. (2014) make is that it takes time to develop new processes and protocols, so delays in the use of integrated ecosystem assessments and their products should not necessarily be viewed as a hurdle to overcome but rather a natural part of the research-to-operations developmental process.

One item that Walther and Möllmann note is the need to (re)-consider institutional structures and frameworks for using information generated from integrated ecosystem assessments. This observation is repeated in other contributions to this theme set, especially Samhouri *et al*. (2014). There may, in fact, be no clear, easy, or imminent answers, but that discussion should continue. Dickey-Collas (2014) notes that although the way forward may indeed be messy, the need to consider broader factors when managing marine resources is highly warranted and an adaptable, innovative approach across multiple considerations is very much required—just as has been envisioned for integrated assessments.

We conclude by posing a few questions for readers to ponder.

- Are integrated assessments (integrated stock assessments or integrated ecosystem assessments) an improvement over how we do assessments now and, if so, how?
- Are integrated approaches important to consider as we move towards implementing EBM at all of its various levels?
- Are the strengths and weaknesses of such integrated approaches readily apparent?
- What needs to happen next to better use such integrated approaches? What is impeding the fuller implementation of these approaches?

We trust that this themed set of articles will be as thought-provoking as it is informative. We hope that our start at delineating the levels of EBM and the types of integrated assessments serves as a useful means to minimize some of the linguistic uncertainty that often surrounds EBM. As we move forward with the implementation of EBM at all of its various levels, we hope that the clarifications provided here, the elucidations of the different integrated assessments, identification of key challenges, and the examples demonstrated in the various contributions, serve to move forward the implementation of EBM.

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