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Review

Using ecologically or biologically significant marine areas (EBSAs) to implement marine spatial planning

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ABSTRACT

The Convention on Biological Diversity (CBD) agreed in 2008 on the need to identify Ecologically or Biologically Significant Marine Areas (EBSAs) in the world's oceans to focus future conservation and management efforts. From 2010 to 2014, 9 workshops had described 204 areas meeting the EBSA criteria in approximately 68% of the world's oceans. The workshops comprised experts nominated by more than 100 governments and a similar number of regional and global non government and intergovernmental organizations, supported by a technical team that collated data and provided mapping expertise. Despite this progress, there is uncertainty about how to use EBSA in Marine Spatial Planning (MSP). We review a suite of the existing MSP, Ecosystem Based Management, fisheries and conservation frameworks to determine their common elements and suggest how they can be synthesized. We propose an adaptive hierarchical approach that takes key elements from existing frameworks and show how EBSA can be used to support this approach within national jurisdictions and in areas beyond national jurisdiction. The adaptive hierarchical process encourages early implementation of MSP/EBM using available scientific knowledge and governance and supports the gradual progress to more complex and information rich structures as needed and appropriate. The EBSA process provides a sound basis for developing the scientific advice to support national and international management of the world's oceans by identifying marine systems and the criteria for which they are valued by regional experts.
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Contents

1. Introduction . . . 116
2. Marine spatial planning and ecosystem based management . . . 117
3. Application of framework to areas described as meeting the EBSA criteria by the regional workshops . . . 122
4. Conclusion . . . 124
References . . . 125

1. Introduction

Since the beginning of the current century, concepts of ecosystem based management, marine spatial planning, adaptive management and the precautionary principle have become established in the scientific literature. However, practical examples of implementation are less common. These ideas have two separate

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beginnings, coming independently from fisheries and conservation sciences. The development of an ecosystem approach to fisheries can be traced back hundreds of years (Caddy and Cochrane, 2001), but only in recent decades has the necessity of an ecosystem approach that balances ecological, social, economic and political imperatives been acknowledged (Smith et al. 2007). Despite some successes, many stocks remain overexploited (Caddy and Cochrane, 2001; Worm et al. 2009; FAO, 2011). Similar ideas have been evolving in conservation science, starting with the World Conference on Human Environment (1972), and progressing through the United Nations Conference on Environment and Development (the Rio "Earth Summit", 1992) and the World Summit on Sustainable Development (2002). These conferences led to the establishment of the Convention on Biological Diversity, leading to the Aichi targets and the current Aichi target 11 of 10% of marine areas in effectively managed marine protected areas or other forms of effective spatial management by 2020.

To this point, there has been little consideration of how progress on Target 11 could be linked with Target 6 (sustainably managed fisheries using ecosystem based approaches by 2020). A recent global analysis of the effectiveness of MPAs found that, unless certain criteria are met (i.e. MPAs that are no-take, old, large, isolated and well enforced), MPAs will have little effect on biodiversity outcomes (Edgar et al. 2014). This leads to two possible courses of action, either more effort needs to be taken to develop MPAs that meet the identified criteria for success (including retrofitting existing ones found to be inadequate), or recognizing that MPAs will be ineffective in some circumstances and fail to protect broader ecosystem services, to develop alternative area-based tools. It seems prudent to progress both strategies and recognizing that in many instances the circumstances needed to make MPAs effective will not be met, accept that MPAs alone will not achieve good ecosystem health and biodiversity outcomes (eg Ma et al., 2013). A strategy of integrated management actions that mix input and output-based approaches and temporary and permanent closures may be more successful in achieving conservation goals as well as sustainable fisheries management (Fulton et al. 2014). Marine Spatial Planning (MSP) and Ecosystem Based Management (EBM) are two of the key unifying ideas of many of these frameworks. Describing effective management objectives, estimating cumulative impacts and monitoring are difficult for "single sector" MPAs or fisheries (beyond single species management); they are significantly more difficult for multi-sector EBM or MSP.

Within this context, in November 2011, the Convention on Biological Diversity (CBD) embarked on a series of workshops to facilitate the description of areas meeting the criteria for Ecologically or Biologically Significant Marine Areas (EBSAs) in the world's oceans. The original motivation for the CBDs work on EBSAs was to identify areas in need of protection in open ocean and deep-sea areas (Dunn et al. 2014). This was an important contribution towards achieving Aichi Target 11 (10% of the world's oceans conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures by 2020). CBD workshops in 2005 and 2007 developed seven "scientific criteria for identifying ecologically or biologically significant marine areas in need of protection": (1) Uniqueness or rarity; (2) Special importance for life history of species; (3) Importance for threatened, endangered or declining species and/or habitats; (4) Vulnerability, fragility, sensitivity, slow recovery; (5) Biological productivity; (6) Biological diversity; (7) Naturalness. These criteria were adopted by the 9th meeting of the CBD Conference of Parties (COP) (Dunn et al. 2014). EBSAs have been described for an enormous diversity of areas, from large scale oceanographic features (e.g. the area of high productivity in the equatorial Pacific and the highly productive Bengula current), individual seamounts (e.g. Atlantis seamount in the southern Indian Ocean), spawning areas (e.g. spawning grounds for southern bluefin tuna off Indonesia), areas of high diversity (e.g. Archipel des Bijagos, Guinée-Bissau), or foraging ground for significant fractions of a seabird species (e.g., Clipperton Fracture Zone Petrel Foraging Area). A complete summary of the first six workshops can be found in Bax et al. (in press).

Here, we review existing MSP, EBM, fisheries and conservation frameworks to identify common elements. We then propose an adaptive hierarchical approach that uses the EBSAs identified by the CBD, unifies the common elements of the existing frameworks, builds on the growing body of scientific knowledge and management experience, and supports the gradual progress to an appropriate level of information rich processes as needed to achieve management goals and reduce uncertainty to a desired level.

2. Marine spatial planning and ecosystem based management

Both ecosystem based management and marine spatial planning are encompassed with the ecosystem approach to management described jointly by the Secretariat of the Convention on Biological Diversity (SCBD, 2004) and the FAO (Garcia et al. 2004). An ecosystem based approach to management that uses EBSAs should therefore also encompass the central concepts of MSP and EBM. Ehler and Douvere (2009) describe MSP as the spatial component of EBM. EBM encompasses a broad range of tools that are not traditionally labelled as "spatial" (eg Individually Transferable Quotas (ITQ), gear controls, conditional permitting of activities, discharge controls), but ultimately the application of every "non-spatial" tool will spatial boundaries dictated by the limits of maritime jurisdictions. Thus, in our view, there is little distinction between spatial and non-spatial tools (eg Day, 2002; Olsen et al. 2007).

In order to understand how MSP and EBM are organised and implemented between different jurisdictions, we reviewed the more commonly cited MSP and EBM implementation guidelines or frameworks (Table 1), and described below.

Integrated Ecosystem Assessment (IEA) has been proposed as a "framework for organizing science in order to inform decisions in marine EBM at multiple scales and across sectors" (Levin et al. 2009). The framework described by Levin et al. (2009) has 5 steps; Scoping, Indicator Development, Risk Analysis, Management Strategy Evaluation and Monitoring and Evaluation (Table 1).

Systematic conservation planning (SCP) takes a conservation-based approach and identifies an 11 stage framework for conservation planning (Pressey and Bottrill, 2009). This framework was itself derived from various other attempts to synthesise a variety of other conservation approaches (Gordon et al. 2005; Bottrill et al. 2006; Redford et al. 2003, Table 1).

Marine Spatial Planning (Douvere et al. 2007; Douvere, 2008; Ehler and Douvere, 2009) is designed to offer countries an operational framework to balance the needs of biodiversity conservation with the needs of sustainable development. Ehler and Douvere (2009) suggest that achieving this balance is one of the key components of any EBM approach. Originally derived from ideas originating from experience in zoning the Great Barrier Reef Marine Park (Day, 2002), it has been extended to encompass a more diverse suite of sectors (Table 1).

The FAO Ecosystem Approach to Fisheries (EAF) outlines a number of key steps, with key activities identified within each step (Fletcher and Bianchi, 2014; Garcia et al. 2004, Table 1). The FAO EAF approach was adapted for use with community based fisheries in the Pacific (Community Based Ecosystem Approach to Fisheries; SPC, 2010). Of direct relevance to the framework developed in this paper are the fisheries adaptive management cycle and hierarchical

Table 1
Comparison of EBM & MSP guidelines. IEA is Integrated Ecosystem Assessment (Levin et al., 2009), MSP is Marine Spatial Planning (Ehler and Douvere, 2009). AFMA ERAEAF is the Australian Fisheries Management Authority Ecosystem Approach (Smith et al., 2014; Hobday et al. 2011). SCP is Systematic Conservation Planning (Pressey and Bottrill, 2009). FAO EAF is the FAO Ecosystem Approach to Fisheries (Fletcher and Bainchi, 2014), CEAFM is Community-based ecosystem approach to fisheries management (SPC, 2010).

Concepts linking each framework	IEA	MSP	AFMA harvest strategy	SCP	FAO EAF	CEAFM
1. The need for scoping and stakeholder engagement	Scoping	Identifying need and establishing authority Obtaining financial support Organizing the process through pre-planning Organizing stakeholder participation	Scoping, Stakeholder engagement and RAGs	Scoping & costing the planning process Identifying & involving stakeholders Describing the context for conservation area Identifying conservation goals	1.1 Initial process planning and stakeholder support 1.2 Defining the fishery, societal values and high level objectives 1.3 Finalise a scoping (EAF baseline) report	Set-up tasks for the promoting agency –broad goals, public awareness, review, stakeholders, legal basis, The community involvement process. Assess requests, define scope,
2. Scientific information on the status of the system	Indicator development	Defining and analysing existing conditions	Stock Assessment	Collecting data on socio-economic variables & threats Collecting data on biodiversity& other natural features	2.1 Asset and Issue identification	Identify and prioritize key issues
3. Scientific inputs to address interactions between pressures and ecosystems,	Risk Analysis	Defining and analysing future conditions	ERAEAF		2.2 Issue prioritisation and risk assessment	Identify and prioritize key issues
4. Clear management objectives and processes	Management strategy development	Preparing and approving the spatial management plan Implementing and enforcing the spatial management plan	Harvest Strategy Control Rules Policy and management response	Setting conservation objectives Reviewing current achievement of objectives Selecting additional conservation areas Applying conservation actions to selected areas	3.1 Determine operational objectives 3.2 Indicator and Performance Measure selection 3.3 Management option evaluation and selection	Develop community goals and objectives Determine management actions and responsibilities Define indicators and performance measures Produce a community-owned management plan Formalising and implementing a community management plan
5. A formalised process for monitoring and evaluation	Monitoring and evaluation	Monitoring and evaluating performance Adapting the spatial management process	Monitoring	Maintaining & monitoring conservation areas	4.1 Develop an Operational Plan and monitor its progress 4.2 Formalization of the management 'plan' 4.3 Review performance of the Management system 4.4 Reporting, communication and auditing of performance	Monitoring performance; reviewing and adapting the plan

or tier-based risk assessments.

Australia has implemented a harvest strategy policy for commonwealth (federal) fisheries that follows a typical adaptive management cycle (Smith et al. 2007, 2008, 2014, Table 1). A harvest strategy specifies the monitoring program, the indicators to be calculated from monitoring data (via an assessment) and use of those indicators in management decisions (through decision rules) to achieve the fishery management objectives. The Ecological Risk Assessment for the Effects of Fishing (ERAEF) is a hierarchical risk assessment framework that allows for the prioritisation of monitoring, assessment and management intervention for species that are at risk to the effects of fishing (Hobday et al. 2011). The framework has several tiers or levels from qualitative (Level 1) to fully quantitative (Level 3). Level 1 allows low risk species to be identified relatively easily and cost effectively, allowing time and resources to be directed to higher risk species at higher levels in the framework. The approach has been adopted by the Marine Stewardship Council and is one of the tools identified by the FAO-EAF toolbox.

We find that guides share a suite of common elements that can be expanded or collapsed to meet different aspirational and operational objectives. MSP and EBM can cover a wide range of

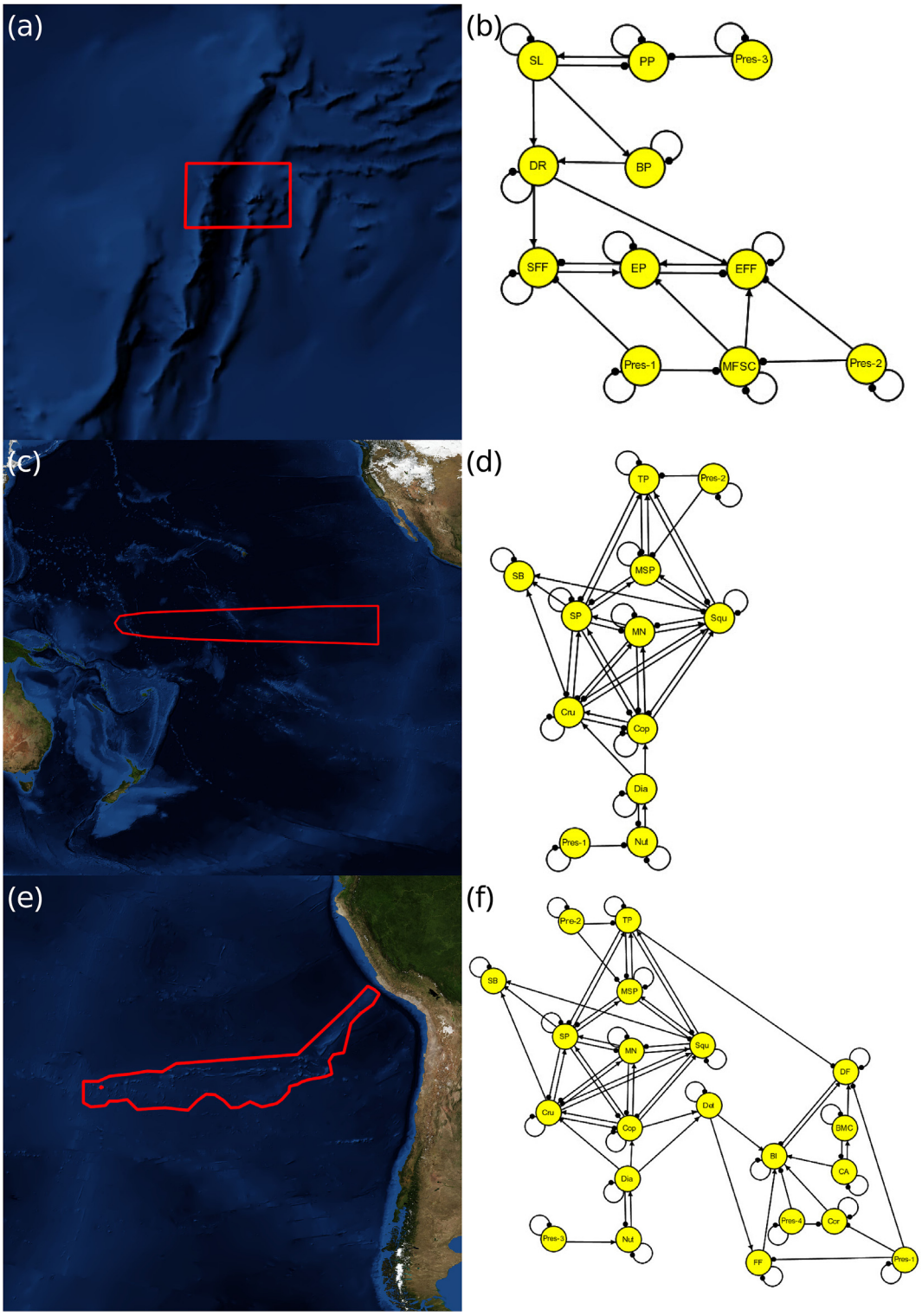

Fig. 1. (a) Map of the Coral Seamount and Fracture Zone Feature area. (b) Illustrative qualitative model of possible relevant (step 3.2) subsystem for Coral Seamount and Fracture zone. The model concentrates on the seamount and not on the adjacent fracture zone. The ecosystem components are: MFSC, matrix forming stony corals; SFF, sessile filter feeders; EP, epizooic predators; EFF, epizoic filter feeders; DR, detrital rain; BP, benthopelagic organisms; SL, scattering layer; PP, primary production; Pres-1, fishing (trawling and longline); Pres-2, ocean acidification; Pres-3, southward shift of the subtropical convergence zone. (c) Map of the Equatorial High-Productivity Zone; (d). Illustrative qualitative model of relevant (step 3.2) subsystem for the Equatorial High-Productivity Zone. The model trophic pathways leading to top predators; Cop, copepods; Cru, crustaceans (pelagic); Dia, diatoms; MN, micronekton; MSP, medium-sized predators; Nut, nutrients; SB, seabirds; SP, small pelagic fish; Squ, squid; TP, top predators; Pres-1, fishing; Pres-2, decreased productivity. (e) Map of the Dorsal De Nazca Y De Salas Y Gómez area. (f) Illustrative qualitative model of possible relevant subsystem (step 3.2) for the Dorsal De Nazca Y De Salas Y Gómez. The model covers all the features identified in the EBSA description, including the seamounts and pelagic zone. The ecosystem components are: BI, Benthic Invertebrates; BMC, Bentho-Pelagic Micro Crustacea; CA, Coraline Algae; Cop, Copeopods; Cru, Planktonic Crustecea; Cor, matrix forming stony corals; Det, Detrital rain; DF Demersal Fish; Dia, Diatoms; MN, Micronekton; MSP Mid-sized Pelagic Fish; NUT, Nutrients; SB, Sea Birds; SFF, sessile filter feeders; SP, Small Pelagic Fish; Squ, Squid; TP, Top Predators; Pres-1, Benthic Trawling; Pres-2 Pelagic Fisheries; Pres-3 Changes in nutrient loads; Pres-4 Ocean Acidification.

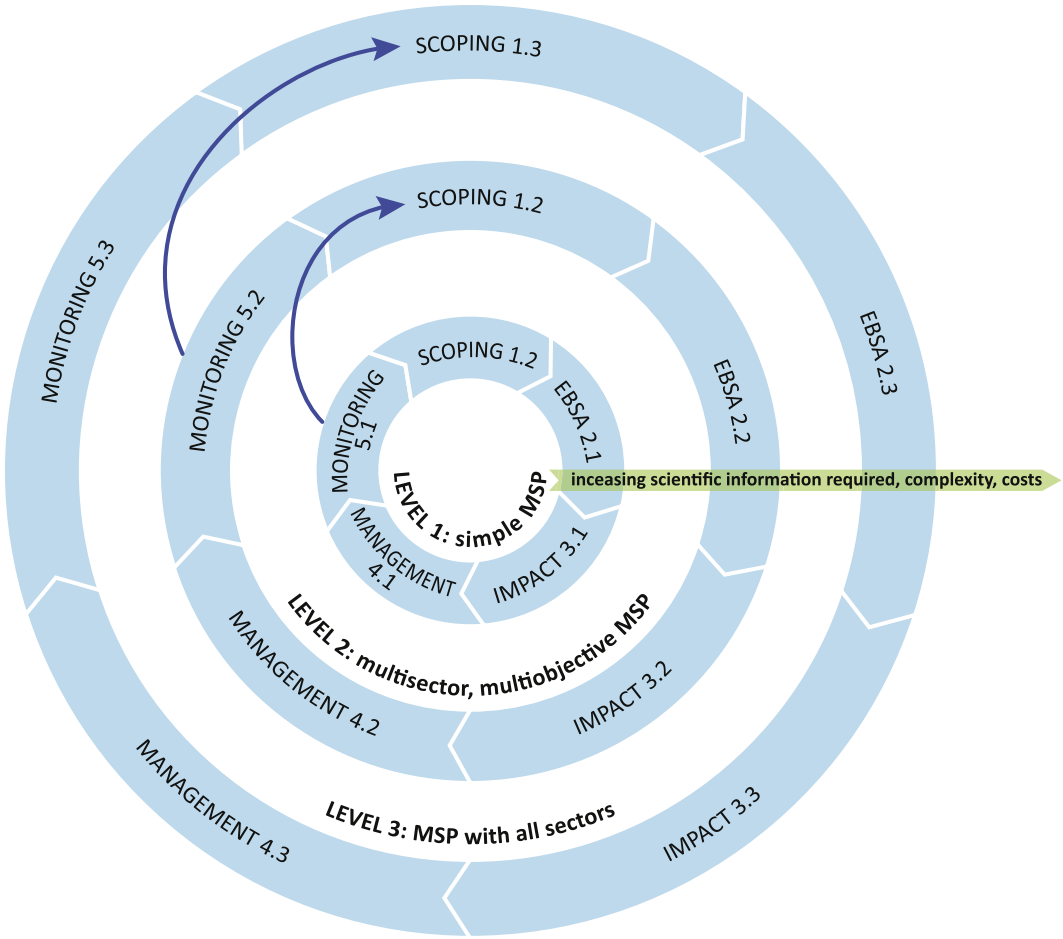

Fig. 2. Schematic diagram of the process to use scientific information related to EBSAs within an MSP/EBM framework. The numbers refer to the levels articulated in the text below. It is similar to many other frameworks, with the exception that it acknowledges that it is MSP/EBM. It can be started with very simple tools and slowly built upon as capacity and scientific understanding increases.

approaches and scenarios. Every framework emphasises the need for adaptive management (Curtin and Prellezo, 2010). Without adaptive management we cannot hope to manage systems where we are uncertain about key ecological and biological processes. They can be modified to meet different needs and different levels of capacity and they also share many concepts with Integrated Coastal Management (Olsen, 2003). The six frameworks we have reviewed come from two distinct approaches to supporting marine management; conservation science, and fisheries science. However, they all show a set of commonalities and aspire to achieve similar goals. The five overarching concepts linking each framework are (1) the need for scoping and stakeholder engagement, (2) scientific information on the status and important assets and values of the system, (3) scientific inputs to address interactions between pressures and ecosystems, (4) clear management objectives and processes, and (5) a formalised process for monitoring and evaluation (Table 1).

These common elements listed above can be used to design a framework that incorporates the internationally ongoing process of describing EBSAs and identifies ways in which the scientific information used to describe EBSAs can also be used to inform MSP and EBM (Table 1). They are; (1) Scoping – Understanding the political/institutional and social domain and motivations for management; (2) EBSA – Understanding the ecological/biological values in the system; (3) Impact – Understanding the interaction between ecological/biological values and pressures; (4) Informing a management response based on the values, pressures and socio-economic values; and (5) Monitoring the effectiveness of management through indicators that can detect changes on the values. The five steps, corresponding to the 5 concepts linking frameworks in Table 1, can be revisited in an iterative and hierarchical fashion (Fig. 2), so that the initial cycle can be completed relatively quickly to inform and support the next cycle. It is important that the early cycles be completed relatively rapidly to maintain the impetus and to avoid the pursuit of perfection or "analysis paralysis".

The first level (the inner circle in Fig. 2) should be based on existing science and used by existing authorities. It is only after at least one round of the adaptive cycle that the development of new science, new legislation or establishing new authorities should be considered. In this way, the limitations and problems of existing science and management can be identified and new programs can be designed and prioritized to specifically target those limits and problems. The second level (the middle circle in Fig. 2) takes the learnings and experience from the first level and applies them to more complex problems, with more stakeholders and potentially more than one sector interacting with the EBSA. The third level (the outer circle in Fig. 2) is national/regional implementation of MSP with all sectors involved, and integrated into other management regimes. It will include dedicated monitoring and surveys to identify the state and trends of EBSA and will require the most resources to implement.

It is also important to recognize that management agencies embarking on this process can enter the inner circles at anyone of its steps. For example, monitoring regimes may already exist, from

which indicators have been identified (step 5), but perhaps without an explicit link to management objectives acting in response to pressures (step 4) that are inferred or predicted to influence these indicators (steps 3). So long as existing monitoring regimes are determined to be located within EBSA's (step 2) there would be no impediment to entering the inner circle at step 5 in this case.

We have also considered the development of the EBSA process to date in deciding on the appropriate steps (Table 1). As noted in the previous section, setting objectives in the scoping step can determine the number and form of different steps in each framework. Depending on the objective, different or additional steps can be selected and different processes prioritized. Any framework that is decided upon should have increasing levels of scientific information, complexity and costs, a hierarchical approach consistent with the ideas expressed in the tiered harvest strategies (Smith et al. 2008) and ERAEAF (Hobday et al. 2011). Each increasing level would impose greater requirements in the form of capacity, time, cost and scientific knowledge, but would yield increasing benefits in terms of ecosystem outcomes. It is envisaged that the first level would be easy to implement with low capacity and scientific requirements. The increasing levels of complexity are shown in Fig. 2, illustrating the links between each of the framework steps.

1. Scoping – Understanding the political/institutional and social domain and motivations for management.

   This step identifies the key drivers for management and the stakeholders who have an interest in the area being managed. It identifies the aspirational objectives of the system (e.g. maintain biodiversity, maximum sustainable yield, economic growth) in terms of ecological/biological, social, economic and political needs. All the reviewed frameworks identify detailed stakeholder participation as a key component of this initial step, as it provides legitimacy for future steps. This step will be primarily conducted in conjunction with the agencies responsible for the managing the system.

   Example hierarchical levels would include:

   1.1 Small single sector/use stakeholder engagement with aspirational objectives focused on the needs of that sector and consideration of a limited set of political, economic, social or ecological/biological objectives.
   1.2 Multiple sectors considered with multiple political, economic, social or ecological/biological objectives.
   1.3 Consideration of all sectors, current states and future activities. All political, economic, social or ecological/biological objectives considered.

2. EBSA – Understanding the ecological/biological values in the system.

   This step is where most of the key information related to the EBSA criteria is described and summarised. As ecosystems are large and extremely complicated, there is a need for a suite of tools that can be used to adequately characterize the system. Use of the EBSA criteria facilitates the prioritisation of the "Relevant Subsystem" (Dambacher et al. 2015) or the "abstraction of ecosystems into sub-systems thought to be most influential to the management issues at hand" (Levin et al. 2009). At this point, the setting of operational objectives for the relevant subsystem (i.e. area meeting the EBSA criteria) is critical to the effective management of the system. These objectives should include social, economic, political and ecological/biological components so that the area can be managed sustainably. This should also be done in an environment that does not consider the uses or the management of the systems, thus an area of high fisheries productivity (eg Benguela Current, Area No. 43, UNEP/CBD/RW/EBSA/SEA/1/4) is just as relevant as an area with unique biodiversity that is subject to less development/exploitation (eg Archipelago de Galapagos y Prolongacion Occidental, Area No. 10, UNEP/CBD/RW/EBSA/ETTP/1/4). We use the term "biodiversity values" for the ecosystem components described as meeting the EBSA criteria.

   Example hierarchical levels would include:

   2.1 Developing EBSA descriptions based on traditional knowledge and existing scientific information.
   2.2 Incorporation of information from industry and other sources, combined with targeted surveys and sampling of the ecosystem values and associated components
   2.3 Full ecosystem monitoring with information used to update the biodiversity values articulated in the EBSA descriptions

3. Impact – Understanding the interaction between ecological/biological values (EBSA) and pressures.

   The values identified in the EBSA description and identification process can be overlayed with the current pressures that exist within the area or may exist over the term of the management time cycle. However, to identify which biodiversity values may be impacted and the cumulative impact of multiple sectors over time, models of the relevant subsystem that incorporate understanding of the ecosystem components are needed. In the simplest case, this may be a simple matrix of values and pressures, identifying which values in the relevant subsystem are most likely to be impacted. With increasing understanding of the biodiversity values and ecosystem components, it is possible to construct qualitative ecosystem models that allow for a more formal quantitative analysis of the cumulative impacts of pressures on biodiversity and ecosystem values (Dambacher et al. 2009, 2010; Hosack and Dambacher, 2012). Finally, in areas with a high degree of scientific capacity, statistical models can provide information on key thresholds to trigger management interventions (e.g. Foster et al. 2014) and numerical ecosystem models analysis of future scenarios (e.g. Fulton et al. 2011). With increasing data, understanding of each area meeting the EBSA criteria will improve, supporting a more refined understanding of the ecosystem. Better data will support improved analyses of trends and resilience.

   Example hierarchical levels would include:

   3.1 Development of simple conceptual models of potential interactions between biodiversity values and pressures.
   3.2 Development of qualitative models of cumulative impact that incorporate an understanding of ecosystem structure and impacts of pressures on specific values.
   3.3 Development of statistical models to identify thresholds and trends and numerical ecosystem models to explore future scenarios.

4. Informing a management response based on the values, pressures and socio-economic values.

   The information resulting from the previous three steps provides management agencies an opportunity to focus management interventions on particular pressures that are acting on the identified values in the area meeting the EBSA criteria. The goal is to use the improved understanding of the ecosystem to identify the minimum intervention that will meet the operational objectives and ensure that the aspirational objectives are met. Identifying the minimum intervention that is needed will require a good understanding of how the pressures are likely to interact with the values. The minimum intervention should only target the pressures that interact with the values. Using this approach would emphasise the use of sectoral management arrangements, unless there are cumulative impacts that span multiple sectors. For example, fisheries agencies would be responsible for managing deep-sea benthic fisheries, except in circumstances where other sectors impacted the same biodiversity values in the area. If deep-sea mining were to also be

undertaken in the same area, then the cumulative impact of these activities would have to be assessed, resulting in different interventions. In some circumstances, the number of values and complexity of ecosystems might render single sector approaches inefficient and marine protected areas would be required.

Example hierarchical levels would be.

4.1 Identification of operational objectives with clearly articulated thresholds to trigger actions from conceptual ecosystem models. These thresholds may result from a formal process of expert and stakeholder elicitation (eg Hosack and Dambacher, 2012). The links between pressures and values should be identified and a heuristic understanding of the whole ecosystem should be used to identify which management interventions will have the greatest impact.

4.2 An improved understanding of ecosystem structure should be used to build qualitative models, building on knowledge from monitoring and scientific sampling. These models can be used to identify the direct and indirect impacts of pressures on biodiversity values.

4.3 Management Strategy Evaluation using qualitative, statistical and numerical ecosystem models to identify thresholds and alternative management scenarios to meet operational objectives.

5. Monitoring the effectiveness of management through indicators that can detect changes on the values.

Understanding if the management interventions are meeting the operational objectives and can achieve the aspirational objectives will be met through evaluating performance by monitoring. Monitoring programs should be linked to the operational objectives, and meet three broad requirements; (1) there are appropriate management actions in place with appropriate governance to respond to monitoring; 2) the management actions will result in changed behaviour of the resource users and 3) these will lead to an improvement in or sufficiently reduced uncertainty in the indicator.

Example hierarchical levels would be:

5.1 Utilising existing programs and capabilities to monitor the pressures and values identified for each area meeting the EBSA criteria if these programs are suitably located. Developing heuristic understanding of how the area has changed, based on, for example, monitoring of analogous systems where existing programs are suitably located, and/or from partial observation of the system's components/processes via global observing systems such as MODIS Indicators are identified from conceptual models (step 3.1) using current ecosystem knowledge.

5.2 Building capacity to target particular biodiversity values and identifying the degree of confidence on the current state of each biodiversity value. Targeting of scientific sampling linked to operational objectives. Indicators identified from qualitative models (step 3.2).

5.3 Full scientific monitoring program with a sampling design to allow identification of threshold and trends from data. Statistical models used to track performance and trends of values relative to operational objectives. Identification of indicators improved with additional data (step 3.3).

Completing a cycle of adaptive management at any level would meet the objectives of an ecosystem approach. It may not be possible or necessary to move beyond comparatively simple approaches in some circumstances. However, as scientific capacity and governance increases, more complex levels can be completed, allowing a move from level 1 to level 2 and then eventually from level 2 to level 3. It is envisaged that level 3 will present significant challenges to most countries, especially once the domains of social, economic, political and ecological/biological are considered.

3. Application of framework to areas described as meeting the EBSA criteria by the regional workshops

Examples of areas meeting the EBSA criteria from the regional workshops (step 2.1)

The EBSA workshops have described 203 areas meeting the EBSA criteria since 2011 (Bax et al. (in press)). The areas were described as part of a purely scientific process that did not consider either the pressures on those areas, nor the management activities that might be occurring in the areas. For each area, the biological and ecological components that meet one or more of the seven EBSA criteria are described in detail in the reports of these EBSA workshops. The ecological and biological components are the biodiversity values of the system. To illustrate these values, we have used three examples from the workshops that describe different systems and different values. The examples cover three distinct ecosystems with significantly different characteristics. The Coral Seamount and Fracture Zone Feature is an example of a deep-sea ecosystem, focusing primarily on the benthic ecology and biology. The Equatorial High Productivity Zone is a large scale pelagic ocean feature. The Dorsal De Nazca Y De Salas Y Gómez area includes a combination of deep-sea features that rise to near the surface, combined with extensive pelagic biodiversity values.

Coral Seamount and Fracture Zone Feature[1*]

The Coral Seamount (Fig. 1a) is located in the south west Indian Ocean, approximately 1500 km south west of South Africa. The seamount is one of the better know areas in the south ocean and has had significant survey effort from the Southern Indian Ocean Deep Sea Fisheries Association (Shotton, 2006), a multi agency collaboration on the RV Nansen (Rogers et al. 2009) and a more recent cruise on the RV James Cook (Rogers and Taylor, 2012). The Coral Seamount is unique in the south west Indian ocean, containing a seamount that summits in ca. 300 m, beside a deep sea trench that extends to over 5200 m below sea level. The area described as meeting the EBSA criteria lies below highly productive sub-Antarctic waters, described as the Agulhas Front (Area No. 11). However, the biodiversity values highlighted in the description of this area are connected to the unique geomorphology of the area (EBSA Criterion 1), the vulnerability of the Scleractinian coral reefs to disturbance (EBSA Criterion 4), and the high biodiversity of the seamount (Rogers and Taylor, 2012). The seamount is occupied by a diversity of benthic invertebrates, including octocorals, sponges, scleractinian corals (Solenosmilia variabilis and Caryophyllia antarctica) and zoanthid anemones (Rogers and Taylor, 2012). The seamount shows clear distribution from depths of 800 m to the summit, with habitats dominated by sediment, hermit crabs and gastropods, followed by polycheate tubes and a summit covered with sponges and small coral thickets (Rogers and Taylor, 2012).

Equatorial High-Productivity Zone[2]

The Central Pacific high productivity zone (Fig. 1c) is a large-scale oceanographic feature, comprising the western extent of flow from the Humbolt current up the west coast of South America

[1] Area No. 23 from the Southern Indian Ocean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs). Workshop report available at: http://www.cbd.int/doc/meetings/mar/ebsa-sio-01/official/ebsa-sio-01-04-en.pdf.

[2] Area 16 from the Western South Pacific Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs). Workshop report available at: http://www.cbd.int/doc/meetings/mar/rwebsa-wspac-01/official/rwebsa-wspac-01-sbstta-16-inf-06-en.pdf.

and across the Pacific as the south equatorial current. It brings cool, nutrient-rich waters to the surface waters of the central Pacific Ocean supporting high primary production over a large area. The Pacific south equatorial current initiates along the coast of South America and flows west along the equator into the central Pacific (Ganachaud et al. 2011). The associated warm pool, responsible for significant fisheries production in the central western Pacific is linked to this area. Primary and secondary productivity between the cool tongue and the warm pool have potential linkages, in part through the Eastern Warm Pool Convergence Zone (Grandperrin, 1978; Lehodey, 2001; Picaut et al. 2001; Lehodey et al. 2011). There is the potential for changes in the eastern pacific linked to climate change to effect fisheries production in the western Pacific, via the linkage through this area. The area is identified as a unique feature in the western south Pacific (EBSA Criterion 1) and as an area of high productivity (EBSA Criterion 5).

Dorsal De Nazca Y De Salas Y Gómez[3*]

The Dorsal De Nzaca Y De Salas Y Gomez area (Fig. 1e) is focused around the Salas y Gomez and Nazca ridges in the south eastern Pacific Ocean. The area we are considering here is only the area in ABNJ. It contains approximately 110 seamounts with summit depths between the surface and 2000 m (Parin et al. 1997). The area is a recognised hotspot for biological endemism, with 41.2% of fishes and 46.3% of invertebrates endemic to the area (Parin et al., 1997). The ridges provide habitat for a number of long-lived species including deep water sharks (Parin and Kotlyar, 2007) and reef building corals. They have been identified as areas for aggregations of thresher sharks and swordfish (Litvinov 1989, Yáñez et al., 2004, 2006, 2009) and are a breeding zone for the Chilean jack mackerel (*Trachurus murphyi*) (Arcos et al., 2001; Anon, 2007). The ridges are also a frequent habitat for blue whales (Hucke-Gaete et al. 2004)) and leatherback turtles (Shillinger et al., 2008). The area meets the criteria for uniqueness (EBSA Criterion 1), life history (EBSA Criterion 2), threatened species (EBSA Criterion 3), vulnerability (EBSA Criterion 4), biological diversity (EBSA Criterion 6) and naturalness (EBSA Criterion 7).

Identification of potential pressures on the system (level 3.1)

A preliminary assessment of the EBSA described above indicates the presence of the following potential pressures in these areas: pelagic fisheries, benthic fisheries, ocean acidification and potential changes in nutrient levels due to climate change (Table 2). This is not an exhaustive list of pressures, but is sufficient to demonstrate how an impact assessment might initially occur.

We have constructed illustrative qualitative models of the relevant-subsystems of each of the example areas meeting the EBSA criteria. The key ecosystem components that are, or interact with, the biodiversity values are shown as yellow nodes. Positive (lines terminating in arrows) or negative (lines terminating in round circles) represent ecological processes such as of rates of birth or death that result in changes in the values (biomass, abundance, etc) of the nodes (Dambacher et al. 2002). This model of the relevant subsystem can be used to clearly articulate the links between components and pressures and can be used in mathematical analyses to identify indicator groups and relative/cumulative impacts.

Development and analysis of qualitative mathematical models (step 3.2)

Qualitative mathematical models can provide a formal representation of an ecosystem based on a general description of its biological and environmental processes. Here we are only interested in the sign (+. −, 0) of the direct effects in a network of interactions that accounts for what increases, decreases or otherwise regulates a population variable. This network of interactions can be encoded as a sign-directed graph, or signed digraph, in which a positive effect of one variable on another is shown as a link ending in an arrow, and a negative effect as a link ending in a filled circle (e.g. Puccia and Levins, 1985; Dambacher et al. 2002, Fig. 1).

The qualitative effects of pressures or management interventions can also be depicted in signed digraphs through links to specific input variables in the system. Based on the network of interactions encoded within the signed digraph, the consequences of an input to the system, say through in increase or decrease in the intensity of a pressure or an intervention, can be predicted by assessing the sign of the effects transmitted along interaction pathways leading from the input variable to any given response variable (Puccia and Levins, 1985; Dambacher et al. 2002). By assessing the predicted responses of ecosystem variables, it is possible to identify informative indicators for monitoring programs (Dambacher et al. 2012; Hayes et al. 2015).

Coral Seamount and Fracture Zone Feature

A qualitative model of the Coral Seamount and Fracture Zone, focuses on seamounts with seamount peaks reaching above 1500 m depth. Stony corals comprise the dominant fauna, by biomass, on seamounts and have an associated assemblage of sponges and brittlestars (Rowden et al. 2010; O'Hara et al. 2008). Sessile and epizooic filter feedters are shown as having strong links with the flux of detrital rain, which is derived from bentho-pelagic and scattering layer organisms. And while stony corals also consume detrital rain, they are not portrayed as being sensitive to changes in detrital flux (i.e., no positive link from detrital flux) due to their long life spans and slow growth rates (Clark et al. 2010). We identified three potential pressures of concern in the EBSA documentation and in the references contained therein, namely fishing activity, (Althaus et al. 2009; Williams et al. 2010, Pres-1 in Fig. 1b), ocean acidification (Thresher et al., 2011Pres-2 in Fig. 1b) and a southward shift of the sub-Antarctic convergence zone (Pres-3). The framework outlined above serves to characterize potential interactions between biodiversity values and pressures, as per step 3.1. Fig. 1b illustrates a qualitative model of the relevant sub-system, as per step 3.2.

A qualitative analysis of the signed digraph in Fig. 1b indicates that there is the potential for all pressures to adversely affect the components of the system. However, we only have the ability to directly manage the impacts occurring from fishing activities (Pres-1). Most fishing activity within this area is managed under the auspices of the Southern Indian Ocean Deep Sea Fishing Association (SIODFA) as a benthic protected area, and will soon be managed by the Southern Indian Ocean Fisheries Agreement (SIOFA). To manage the areas effectively on an ecosystem basis, SIOFA needs to be able to access information on the state of the other pressures and understand the state and trend of the biodiversity values. This is currently only possible on an ad hoc basis.

Equatorial High-Productivity Zone

A qualitative model of the Equatorial High-Productivity Zone focuses on the trophic pathways leading to top predators, and includes interactions with medium-sized predators, small pelagic fish, seabirds and squid (Fig. 1d). This system does not have any immediate pressures that are acting on the values identified in the EBSA description. However, climate change has the potential to affect temperature and productivity in the area (Fig. 1d). The other potential pressure is fishing activity on the top predators and medium sized pelagic fish, specifically tuna species. This pressure is currently managed by the Western and Central Pacific Fisheries Commission (WCPFC). The potential interaction between fisheries

[3] Area 18 from the Eastern Tropical and Temperate Pacific Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs). Workshop report available at: http://www.cbd.int/doc/meetings/mar/ebsa-ettp-01/official/ebsa-ettp-01-04-en.pdf.

Table 2
Potential interactions between pressures and values identified in the example areas meeting the EBSA criteria. This preliminary analysis does not include all potential pressures or interactions.

	Pelagic Fisheries	Benthic Fisheries	Ocean Acidification	Change in Nutrients due to Climate Change
Coral Seamount				
Equatorial High-Productivity Zone				
Dorsal De Nazca Y De Salas Y Gómez				

	Highly unlikely interaction
	Possible interaction
	Likely interaction
	Highly likely interaction

and shift in productivity has been noted (Bell et al. 2011). While fisheries production is unlikely to increase over the whole of the Pacific (Bell et al. 2011), there is the potential for shifts in production. The outputs of CMIP5 (http://pcmdi-cmip.llnl.gov/cmip5/availability.html) suggest that temperatures in this area will increase, increasing the probability of reductions in the productivity in the EBSA. The potential for shifts in areas with high fisheries catches due to climate change, which will have implications for the management of the area. The biodiversity value (high productivity) should be monitored, preferably through satellite observation locally calibrated with in-situ sampling and information passed to the relevant fisheries agencies to add to the information base supporting the long-term sustainable management of the tuna stocks in the area.

Dorsal De Nazca Y De Salas Y Gómez

This area had the highest number of biodiversity values identified of the examples given here, and it is a system that includes both benthic and pelagic components (Fig. 1f; Anderson et al. 2011; Przeslawski et al. 2011; Zintzen et al., 2010; Williams et al. 2011). The pelagic system is portrayed by the same model in Fig. 1d, with plankton and zooplankton contributing to detrital rain that is consumed by sessile filter feeders and benthic invertebrates. Sessile filter feeders and corals both provide habitat and resources for invertebrates, which subsequently support demersal fishes and their predators. There are potentially four pressures acting on the system, benthic fisheries (Pres-1), pelagic fisheries (Pres-2), ocean acidification (Pres-4) and Changes in nutrients due to climate change (Pres-3). These pressures have the potential to impact throughout the entire system. For example, pelagic fisheries (Pres-2) may have a net negative effect on benthic invertebrates (BI) through the link from top predators (TP) to demersal fish (DF). Conversely, increasing nutrients due to climate change has the potential to generate positive effects throughout the system. The major jack mackerel fishery occurs to the south of this EBSA and is managed by the South Pacific Regional Fisheries Management Organisation (SPRFMO). In this area, there is a significant swordfish fishery, which is managed by the Inter-American Tropical Tuna Commission (IATTC). There does not appear to be a significant benthic fishery in the area.

Given the complexity of the values in the area, the relatively small amount of fisheries in the area, and the potential for the effects of the different pressures to cascade through the system, it might be appropriate to consider the some areas within the EBSA as potential candidates for strong spatial management including marine protected areas. It will be difficult to manage the area within an ecosystem approach when the values are so diverse, while continuing to exploit pelagic species, especially when the effects of climate change are uncertain. Alternatively, careful monitoring of pressures and impacts might allow continued sustainable use. This analysis is only preliminary and more work is needed to fully articulate the system, feedbacks and pressures. This would be the focus of level 2.

4. Conclusion

There are many approaches to marine spatial planning and ecosystem based management that expand on detailed technical ideas that are difficult to implement and require significant scientific input. What we have tried to articulate here is an approach that can be started simply, using a basic understanding of ecosystems, and slowly expanded, as needed, to meet more complex demands. A common theme amongst all of the frameworks reviewed was an adaptive cycle. However, this can be difficult to begin and multiple simple starting points are needed. Once the cycle has begun, hierarchical levels can be used to add extra components, improve descriptions of existing components and allow for prioritisation.

It is also important to note the difference between aspirational objectives (i.e. Aichi Targets) and operational objectives, which have associated thresholds for agreed management action. Both play important but different roles in management. Aspirational targets are set in the first phase of management (i.e. scoping). They set the general tenor of the process and represent broad agreement among consulted stakeholders on a particular outcome. Hilborn (2007) notes that there are four main components to successful fisheries: biological, economic, social and political. Past management has often focused solely on target species to meet economic and social goals and ignored the broader effects of fishing. In addition, the human aspects of the management cycle have been very poorly studied (Fulton et al. 2011), limiting both the sustainability of fisheries and broader agreement on what is an acceptable trade-off between production and environmental impact. Consultation and consideration of the aspirations of all four categories of stakeholders is required in moving towards EBM. Different objectives lead to different outcomes and an emphasis on a single objective can lead to perverse results with regard to EBM (Hilborn, 2007). Likewise, Redford et al. (2003) noted that many of the different conservation approaches varied in terms of aspirational and operational objectives, and differences in aspirational objectives are often most prevalent. While conservation frameworks frequently focus on protection and the identification of areas to be protected with the least cost, fisheries frameworks focus on sustainable fisheries, food security and livelihoods. Nonetheless, both share common management frameworks. And while they may emphasise different steps or include additional steps depending on the aspirational objectives, the underlying sequence of scoping, information, impacts/objectives, management action, monitoring and review remains consistent. The point of origin for most conflicts will be when the aspirational objectives do not include all stakeholders.

Operational objectives are the key to a functioning adaptive management cycle. These objectives, and their associated thresholds, targets and limits, identify the points where actions must be taken if aspirational objectives are to be met. Each operational objective will have one or more indicators that will trigger different management actions (including review). The monitoring and evaluation of the indicators will determine over time if management is working of if changes need to be made.

The key interfaces for science and knowledge are the description and potential identification of an EBSA (step 2), the interaction between pressures and the area meeting the EBSA criteria (step 3) and monitoring and evaluation (step 5). These steps represent the main point of interface between science and policy and are where most scientific information will feed into the adaptive cycle. In contrast, scientists will have a much more limited role to play in the scoping (step 1) and management (step 4) steps. These are the key points where other stakeholders will participate in the framework and where considerations of economic, social and political objectives will be included. It may also be worth considering if a process similar to a harvest management strategy might be worth including in the framework to improve responsiveness and allow better integration of social and economic objectives and the incentivisation of particular activities (Smith et al., 2014).

One of the unanswered questions that has emerged from the EBSA process, at least from a scientific perspective, has been what steps should follow the description and potential identification of an EBSA. This paper attempts to outline potential steps to be taken after the EBSA process, including potential approaches to selecting the appropriate body to manage activities in a given area meeting the EBSA criteria. As identified in the examples, there are already agencies responsible for the management of specific pressures, and each of these has committed to adopting an ecosystem approach. Each of those agencies clearly has primacy in managing specific pressures. However, there is currently no body that is responsible for managing the interactions between the pressures on each system, for identifying new pressures, for identifying cumulative impacts, and the relative contribution of each pressure to the cumulative impact. Information from the EBSA process would provide the technical means to estimate these impacts. This agency would not necessarily have a management focus, leaving the management of each sector to the appropriate agency. However, the absence of any mechanism for aggregating and reporting pressures from each sector so that the full impacts can be understood, limits the ability of each sectoral body to manage activities on an ecosystem basis. Communication between these sectoral bodies will be understandably ad-hoc until such a mechanism is established. The scientific work to describe and identify EBSAs provides the beginning of such a mechanism.

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