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# Ten myths concerning ecosystem approaches to marine resource management

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**Abstract**

Ecosystem approaches to marine resource management (EAM) offer comprehensive decision making based on rationalization of currently fragmented ocean policies and their implementation. However, despite the apparent utility in addressing these problems, EAM has also been criticized as being nonspecific, immature, invalid as a basis for decision making, and not fully supported by science. While it is commonly perceived that a paradigm shift in governance and science institutions awaits implementation to address these criticisms, in fact, ecosystem considerations *are* being incorporated more frequently, employing existing authorities as the basis for mitigation of sectoral impacts and for resource allocation. Management 'best practices' for EAM are emerging based on these experiences. Ten common criticisms of EAM, which I believe to be myths propagated primarily to maintain the *status quo* among sectoral interests, are discussed. Accelerated evolution of EAM will occur as science better articulates feedbacks, cumulative ecological effects and economic consequences framing policy choices, and more formal "rules of engagement" among sectors (e.g., fishing, coastal development, water quality, and energy) are negotiated. These operating procedures would be established under informal arrangements, in national law, and by international agreement. The management paradigm for marine resources *is* shifting and EAM will eventually be considered redundant with established practice.
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## 1. Introduction

Virtually every contemporary review of ocean and living marine resource management now includes a paean to ecosystem approaches (EAM) or ecosystem-based management (EBM[1]). However, while the concept has become pervasive in the lexicon of ocean science and management, the general perception is that it remains largely a promise unfulfilled. Likewise, it is viewed in many circles as revolutionary—requiring wholesale reassembly of policy-implementing institutions [1], and in fact reinvention of science itself [2]. Given the rhetoric of revolution, and thus the prospects for institutional upheaval, it is not surprising that counter-revolutionaries exist (e.g. [3]) questioning the necessity for shifting approaches from a more traditional issue-by-issue focus. In many instances this resistance to change comes from entrenched sectoral interests (a sector defined as an interest group or activity that impacts or is affected by management decisions). Additionally, governance institutions managing these individual sectors may oppose the power sharing that would occur implicit with broader stakeholder participation in decision making, which is a hallmark of EAM. In the agency/authority context there are issues of jurisdictional scale (local, regional, national) which may lead to real or perceived usurpation of control by progressively higher levels under EAM. Even at the national level, some agencies may fear loss of control of unique mandates as conflicts among mandates would be addressed under any concept of an ecosystem approach.

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[1]EAM is generally defined as extending existing management foci (e.g., fisheries) to include additional considerations consistent with ecosystem management characteristics, while EBM implies a management scheme primarily designed to address overall ecosystem considerations.

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Generally, opposition to EAM/EBM is manifest not necessarily as people or agencies directly expressing their self-interests opposing the approach, but by raising tangential questions such as the specificity, maturity and validity of the concept, and lack of scientific readiness to support EAM. Thus, a series of common misconceptions or "myths" have surfaced as arguments to delay, constrain or oppose implementation. Here I review 10 such common arguments and provide some thoughts on their origins and reasons why I believe they should be largely considered as "myths".

> Myth #1: Ecosystem approaches to ocean resource management are not well defined and we do not know how to implement them.

Most current ocean governance regimes (e.g., national fisheries laws, pollution abatement, and coastal development management) are based on issue-specific management objectives and, in the case of international fisheries agreements, elaborate sharing agreements [4]. Virtually all existing institutions are based on specific management targets and quantifiable objectives. Adding complexity ensuing from inclusion of ecosystem considerations into existing arrangements means that traditional indicators of management progress and allocation of benefits and resulting imposition of control measures may be insufficient to accommodate expanding scope of management. Resultantly, the unknown and potentially allocative nature of measures necessary to meet an expanded ecosystem portfolio can result in resistance to the adoption of more expanded bases for management. Often, resistance to EAM/EBM is based on the perception that, unlike sectoral management, the benefits, objectives, and systems for measuring progress in ecosystem management are not as well defined as for individual sectors. If it can be argued that EAM is vague, qualitative, and immature as a science and a management paradigm, then, some advocate, its tenets should not replace well established institutional arrangements.

*Reality*: EAM have been extensively defined both in terms of purpose and characteristics [5,6]. While there are many definitions of ecosystems, EAM and EBM (see [7] for a review), they invariably share a number of common characteristics involving broadening stakeholder involvement, evaluation of multiple simultaneous drivers or "pressures" on ecosystems, and specifying that EAM/EBM is geographically based vs. being primarily species or singl-issue driven.

One such definition of EAM is that employed by the United States' National Oceanic and Atmospheric Administration (NOAA). It is by no means unique:

> An ecosystem[2] approach to management (EAM) is one that provides a comprehensive framework for marine and coastal resource decision making. In contrast to individual species or single issue management, EAM considers a wider range of relevant ecological, environmental, and human factors bearing on societal choices regarding resource use.
>
> EAM is differentiated from more narrowly focused management approaches by a number of defining characteristics. EAM is: (1) geographically specified, (2) adaptive in its development over time as new information becomes available or as circumstances change, (3) takes into account ecosystem knowledge and uncertainties, (4) recognizes that multiple simultaneous factors may influence the outcomes of management (particularly those external to the ecosystem), and (5) strives to balance diverse societal objectives that result from resource decision making and allocation. Additionally, because of its complexity and emphasis on stakeholder involvement, the process of implementing EAM needs to be (6) incremental and (7) collaborative [8].

Similarly, the definition provided by FAO [9] of ecosystem approaches to fisheries (EAF) emphasizes societal objectives, the broad range of ecosystem goods and services, and the integration of environment, ecology and human uses:

> An ecosystem[3] approach to fisheries strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries.

EAM has already been implemented in both formal (explicit) and informal (implicit) ways in a variety of institutional settings at local, national, and international levels. Implementation strategies include development of the policy, scientific and managerial resources and expertise necessary to manage using EAM. Increasingly EAM has been adopted in large-scale policy reviews, such as the US Ocean Commission Report [10], the EU Marine Strategy, and the Canadian Oceans Act (see [11,12]). As well, there is a growing body of experience among regional governance institutions moving towards more integrative approaches within the perceived scope of sectoral mandates (e.g., fisheries, energy production, and coastal protection). While it is clear that EAM has been recognized at the highest policy setting levels, impediments remain including the asymmetrical benefits and perceived costs among various user sectors for participating in EAM-related activities. For example, while living marine resource management decisions clearly benefit from decisions regarding coastal water quality, water quality is (arguably) independent of decisions in, for example, fisheries management. Thus, taking

[2]An ecosystem is a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics. These definitions of EAM and ecosystems have been adopted by the US National Oceanic and Atmospheric Administration.

[3]The environment is the biological, chemical, physical, and social conditions that surround organisms. When appropriate, the term environment should be qualified as biological, chemical, and/or social.

controversial decisions across institutions primarily for the benefit of one sector requires a high degree of institutional altruism or shared agendas for progress among them. As well, mismatches in the ability of science and policy to implement and support each other lead to differing perceptions about the readiness of each to undertake decision-making under this concept, and to support decisions with meaningful scientific analysis subject to acceptable levels of uncertainty [11].

While there are significant impediments to implementation of EAM on the governance [14] and science sides [11], the lack of full implementation should not be construed as our inability to define the concept or its attributes, nor that we do not know how the concept could be implemented in theory or in practice [14,15]. An evolutionary approach to EAM would continue primary sectoral management responsibilities in existing institutions, but with greater coordination of those issues that impinge or are dependent upon other sectors.

Myth #2: EAM implementation awaits a "paradigm shift" in management institutions and science support.

Often, EBM and EAM are portrayed as antithetical to current practices particularly as they relate to management targets, the scientific basis supporting management, and the governance system required for effective implementation. For example, is a management objective to conserve biodiversity (however defined and measured) consistent with yield maximization in fisheries [16]? Arguably, since there is not yet a societal consensus for how such diverse objectives should be weighted in a management regime, addressing broader ecosystem objectives should await this coalescence and the subsequent development of new governance institutions and supporting scientific machinery.

*Reality*: Ironically, many (if not all) marine resource management institutions have already adopted some of the EAM principles and characteristics as outlined in the answer to #1; thus this paradigm shift (if in fact one can characterize the end state of EAM/EBM as such) is largely already occurring, e.g. [16]. For example, increased interest in the effects of bycatch and habitat interactions with fishing methods have necessitated greater explicit consideration of these issues in fisheries management, reflecting increased emphasis on more diverse stakeholder interests and a broader understanding of factors ultimately affecting fisheries. Likewise, impacts of energy exploration and extraction in marine environments are increasingly being viewed in the larger context of zoning to reduce impacts on biota and to minimize intersector interactions. These mechanisms for incorporating broader perspectives in decision making have occurred both by expansion of mandates within existing sectoral management, and by the adoption of new management instruments.

The notion that there must be a *revolution* in management institutions largely stems from the perceived failures of existing institutions to address degradation of the marine environment, declines in stocks, and conflicts among user groups [1]. Others argue that past failures, and in fact more recent progress, relates mostly to the effectiveness of these institutions in implementing mandates they already have [16]. While this debate is largely one of semantics, the more important point is that institutions (be they existing or yet to be created) need to have operational, achievable objectives that can be accomplished on appropriate time scales in ways that are considered legitimate, transparent and fair by the sectors being regulated [17,18].

With respect to science support for ecosystem approaches, a point that requires repeated emphasis is that ecosystem perspectives require information about the interrelationships among ecosystem components as a basis for informing policy choices [19]. This does not necessarily imply that existing science and monitoring programs should be abandoned, re-focused or even changed. In fact, many of the basic data on ecosystem components (resource surveys, water quality monitoring, and habitat characterization) need to be expanded. The important new focus for science supporting EAM is in data integration across traditional disciplines at appropriate geographic scales, and in understanding feedbacks and interactions among abiotic, biotic and human parts of the ecosystem.

The adoption of EAM/EBM is thus more accurately described as evolutionary (albeit with clear revolutionary tendencies).

Myth #3: There are no good examples of EAM in practice anywhere in the world's ocean and coastal areas.

Is there sufficient practical experience demonstrating the utility and feasibility of EAM/EBM? The fact that very few existing resource management regimes were originally created to address issues from an ecosystem perspective has naturally raised the question of how effective these institutions have been in doing so and whether "best practices" employing EAM/EBM can be derived based on these experiences. Put another way, are there any successful case studies implementing EAM that can serve as a basis from which other existing institutions can evolve or new ones be created?

*Reality*: There are *many* compelling examples at the local, regional, and international levels where some or all of the EAM principles outlined in #1 have successfully been implemented as a basis for living resource management. For example, internationally, the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) specifically has institutionalized EAM principles for the protection of key ecological relationships among predators and prey species, such as krill [20]. At the national level, Australia, Canada, the USA, the EU and other nations and groups have articulated ecosystem principles in their policies and laws. The USA has incorporated protection of ecosystems in diverse statutes including its Endangered Species Act, Coral Conservation Act, Marine

Sanctuaries Act, Marine Mammal Protection Act, and other statutes appropriate to the management of living marine resources. The recently re-authorized Magnuson Stevens Fishery Conservation and Management Act (2007) contains expanded authorities to consider ecosystem impacts, for example explicitly to manage deep coral ecosystems so as to minimize impacts of trawling and other threats. More comprehensive approaches to management of multiple activities occur through implementation of the USA National Environmental Policy Act (NEPA), which requires evaluations of proposed management activities, including cumulative ecological and social impacts in ecosystems. Regional and local examples are plentiful as well.

While most of these examples have not implemented EAM comprehensively, and in fact may not even identify themselves as using ecosystem approaches, there nevertheless is a growing body of experiences of how to implement multi-stakeholder decision making to affect ecosystem objectives of importance at these scales. Importantly, while there is some information on EAM implementation in various settings, there has not been a comprehensive, systematic assessment of EAM implementation, and such a review would be timely and helpful in developing future institutional and science approaches. In particular, the focus of such a review should be on criteria for critical comparisons of case studies (e.g., their success in implementing a broad set of characteristics associated with EAM), a focus on outcomes rather than process, and how existing institutions have adapted to increasing concerns regarding cross-sectoral interactions.

> Myth #4: There is insufficient information for any area currently available to answer all the ecosystem questions necessary to support EAM.

One objection to EAM/EBM often expressed is that the scientific information necessary to undertake comprehensive management is insufficient for any ecosystem never mind for those that remain poorly documented, and therefore an objective basis supporting the concept does not exist in practice.

*Reality*: As a comprehensive framework, EAM is supported by relevant biological, oceanographic, economic and social information appropriate to the problem set being managed. While there may be insufficient information to conclusively answer *all* technical questions regarding the impacts of particular policy choices, there usually is information to at least identify qualitatively the likely interactions among species and sectors and the directionality of particular human activities on biota and their social and economic impacts. Adaptive management approaches incorporate new information as it becomes available, and identifies priorities for science to reduce uncertainty and improve understanding of the effects of policy choices. In many areas of the world, there are sophisticated ecosystem monitoring and research programs. An important aspect of science supporting EAM is that it builds upon existing institutions and information collected for a variety of specific purposes, and provides a framework to combine these data in ways that add additional value. While, arguably, there is insufficient information to completely understand the many factors influencing *any* ecosystem, often it is not science that is limiting [21], but the will of political systems to make decisions in controversial and uncertain circumstances [17]. More complete scientific information, models and analysis can help narrow the range of feasible solutions, but uncertainties in ecosystem responses will always remain. The challenge is to view ecosystem approaches as an opportunity to learn and adapt management measures based on the accumulation of knowledge in the face of such uncertainty. Viewed as adaptive experimentation and setup to differentiate between conflicting hypotheses of factors governing poorly understood processes, EAM provides a powerful framework to protect ecosystems and their functions while developing a deeper understanding of their resilience to human activities.

> Myth #5: EAM is too difficult a concept to apply in multinational regional management organizations (RMOs), and EAM can only apply to a few developed countries in the world that have the technical and financial resources to support it.

Multi-sectoral consensus necessary to balance societal goals is difficult at the national level, but may be impossible when perspectives necessary for striking this balance vary among states involved in RMOs. Similarly, can countries in the developing world undertake EAM/EBM, when the concepts have been difficult to implement in the developed world where governance instruments and science support are reasonably well established and supported?

*Reality*: Regional EAM programs are being implemented in a large and diverse set of the world's large marine ecosystems (LMEs; [22]). In particular, many developing nations seem especially open to the EAM/EBM concept. Existing management and control may be poorly organized or substantially underfunded in these regions, and assistance programs supporting both the governance model and scientific support for EAM can fill important gaps for nations endeavouring to increase the protection of ocean ecosystems while achieving sustainable exploitation of resources. While financial and technical assistance associated with more traditional management paradigms doubtlessly are appreciated, the multi-sector approach of EAM is appealing in areas where sectoral interests are not well entrenched and resources are scarce.

The LME approach to implementation of EAM takes advantage of natural boundaries in the world's coastal regions in terms of marine biodiversity, productivity and hydrography. Many of these LME regions overlap the territorial jurisdictions of multiple countries. Thus, the LME concept naturally leads to regional multi-national approaches to resource management. A number of governmental and NGO-supported programs are providing critical LME-scale science and assistance with governance

development, including United Nations Environment Program (UNEP) Regional Seas Program (http://www.unep.org/regionalseas/), the Global Environmental Facility (http://www.thegef.org/), and numerous others. Significantly, many of these cooperative efforts in the developing world are strengthening regional science and management capabilities through the infusion of scientific and technical expertise and support for basic information collection supporting the development of these institutions. Technical expertise provided by many countries has helped envision, develop and implement these programs.

Importantly, EAM, like many multi-national resource focal areas, requires processes for resource allocation, assessment of resource condition, and management deliberation. In principle, these three components are equally applicable to EAM as for individual resource sectors. The balance between conservation and utilization strategies will be a matter of societal choice and negotiation, consistent with the operating principles of any agreement. In fact, the relative success of the LME approach in developing nations is remarkable, and is perhaps indicative of the lack of institutional inertia that comes in situations where existing governance institutions and arrangements may resist change and evolution.

Myth #6: There are no good sets of principles or guidelines for implementing EAM.

It is often argued that since EAM incorporates such broad and often divergent sets of issues, that the principles upon which to assess progress and to inform governance institutions are ambiguous, vague and in some cases contradictory. If this is the case, then, how can governance institutions tasked with implementing EAM effectively make decisions, implement policy choices, and assess progress towards a set of articulated goals?

*Reality*: Principles and guidelines for the development of EAM have been articulated by a diverse set of sectoral interests both in terrestrial settings and for coastal and oceanic environments. For example, the Convention on Biodiversity (CBD) [23] has developed 12 principles supporting EAM:

The objectives of management of land, water and living resources are a matter of societal choices:

- Management should be decentralized to the lowest appropriate level,
- Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems,
- Understand and manage ecosystems in an economic context to reduce market distortions that adversely affect biological diversity, align incentives to promote biodiversity, and internalize costs and benefits in the given ecosystem to the extent feasible,
- Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach,
- Manage the ecosystem in an economic context,
- Ecosystem must be managed within the limits of their functioning,
- The ecosystem approach should be undertaken at the appropriate spatial and temporal scales,
- Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term,
- Management must recognize the change is inevitable,
- The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity,
- The ecosystem approach should consider all forms of relevant information, including scientific, indigenous and local knowledge, innovations and practices,
- The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Similarly, a number of groups have adopted sets of principles applicable to individual sectors, such as in fisheries [24]. FAO [9,25] has articulated not only the principles of EAF, but also a process for operational implementation [14,25]:

- Set high level policy goals
- Identify broad objectives
- Prioritize issues to be addressed in management
- Set operational objectives
- Develop indicators and reference points
- Develop decision rules for application of measures
- Monitor and evaluate performance

Sainsbury et al. [14] provide a comprehensive operational framework for ecosystem-based decision making for fisheries, and sets of comparable goals and performance standards have been proposed for coastal zone management [26]. In principle these implementation steps are generalizable to broader EBM. A particular set of principles applicable to management institutions is a matter of choice and degree of assumed risk for the consequences of particular management outcomes. Importantly, human values and value systems vary regionally, and even within countries and regions there can be vastly different perspectives from economic and ethical perspectives [27,28]. Thus, the selection of the principles upon which conflicts are to be resolved must be informed by the diverse perspectives articulated at the geographic scales consistent with ecosystem definitions. However, given the globalization of marine-based economies, often, value systems of distant consumers can impact on decisions made at local and regional ecosystem scales. An important perspective on principles and guidelines is that while they are contextual, there are quantifiable goals as well as measurable suites of ecosystem commodities and services provided that can be evaluated with respect to the implementation of a specific set of policy choices, and the costs to society of implementing them.

Myth #7: There are no appropriate management benchmarks and associated indicators of "success" in achieving ecosystem objectives.

While management targets for species, water quality, ingestion of toxic agents and other indicators are well developed as a basis for sectoral management, it is often argued that similar unequivocal and measurable quantities do not exist for many of the ecosystem attributes often cited as the objectives of EAM/EMB (e.g., maintenance of ecosystem "health"). If progress cannot be benchmarked against management targets, then how is EAM/EBM possible?

*Reality*: While it is rather straightforward to establish management benchmarks for individual species for conservation and utilization purposes (e.g., population size thresholds and maximum removal rates), indices of ecosystem health and maintenance are more complicated [16,29–31]. This is because marine ecosystems have many more dimensions than do individual sectors (e.g., water quality, productivity at lower trophic levels, ecosystem 'balance" among trophic levels, and production of other goods and services). There are many candidate indicators and suites of indicators that can be employed as operational indicators of maintenance of ecosystem "health". The final selection of appropriate sets of indicators for a particular EAM problem is dictated by the specific negotiated goals of EAM [32], and the feasible subset of those objectives that are consistent with societal priorities (e.g., it may not be feasible to simultaneously achieve biomass objectives for sets of interacting species). As the choice of appropriate ecosystem metrics indicating "success" in EAM is context specific, it is inadvisable to articulate a single set of operational principles or characteristics that apply in all situations. Thus, it is impossible to articulate a single set of indicators applicable in all situations. As Degnbol [32] observes, "*Indicators represent the link between objectives and action in management*". Thus, they represent not only a judgment about what society values from an ecosystem but a report card on the progress of management institutions in achieving strategic objectives. Performance management is a hallmark of political and government systems now, and this trend will continue. One of the important components of selecting appropriate ecosystem indicators of successful achievement of management objectives is to be parsimonious in their selection, and to link the benefits of their achievement and the risks of failure to achieve them. The challenge for EAM/EBM will be to link the incremental changes in selected indicators to a target end state to the societal costs and benefits of achieving the end state.

Myth #8: A complex model of species interactions among all components of an ecosystem is necessary to guide EAM.

Ecosystems are often defined based on the complexity of the interactions between their physical, biotic and human components. Because of the large number of potential interactions, complex nonlinear models have been used to examine tradeoffs and understand the impacts of multiple simultaneous factors that effect particular ecosystem components. Given the complexity and specificity of such models and their "data hungry" appetites, how then can one undertake EAM when most of the world's ecosystems are not understood sufficiently to be able to construct and validate such models? Consequently, are more parsimonious issue-by-issue management solutions to be preferred in the interim?

*Reality*: While complex models are useful for managing species that have predator–prey or habitat interrelationships, even qualitative understanding of these phenomena ("who eats whom", spatial distributions of key species and human use "footprints") can be used to establish cautionary management accounting for these potential interactions. These notional concepts are particularly important when the consequences may be great if the effects are not considered or cannot be quantified. Simple conceptual models of ecosystem function (including basic food webs) are helpful to guide the establishment of plausible subsets of potential outcomes, particularly in an adaptive management scenario, where provisional management policies are considered "experiments" for the purposes of gathering additional information.

While complex models can, at the outset of a management program, be used to quantify risks of policy alternatives, it is not necessary to have this information at the outset, assuming the range of possible system states in relation to proposed management alternatives can be outlined, and unacceptable outcomes and their potential risks considered. Of course, sophisticated modeling of ecosystem interactions and bioeconomic impacts of policy choices can help to identify feasible subsets of management options, and to understand their benefits and costs. In the developed world often legislative or legal instruments require such evaluations. In this case, careful evaluation of options under these principles of benefits and costs can insulate difficult decisions from the accusation that they may be arbitrary or politicized. In particular, elaborate models are important when there is the possibility for nonlinear or abrupt ecosystem change resulting from exceeding critical management thresholds (e.g., loss of a keystone species, invasion by another). However, even sophisticated models will have trouble capturing such behaviors if not documented in the specific ecosystem being managed unless underlying principles of ecosystem function can be better defined. Thus, there is a great and increasing importance of comparative ecosystem analysis to understand the conditions under which such changes can occur.

Myth #9: It is impossible to establish the boundaries necessary to define EAM.

Hard boundaries (that is, sharp contrasts in species distributions and ecological processes) rarely exist in

marine and coastal ecosystems. Rather, ecological processes exist along gradients dictated in part by a number of physical co-variates (e.g., temperature, depth, salinity). Human activities are dictated by, and follow these gradients of productivity. Imposed over these environmental systems are geo-political boundaries which may or may not conform with ecological properties. Given these environmental gradients and the wide-ranging distributions of some species, as well as sharp jurisdictional divisions, how then can one define the unique geographic boundaries necessary to undertake EAM?

*Reality*: As noted in #1 above, an ecosystem is defined as a geographically specific collection of animals, plants, and supporting environmental processes. That being said, the definition of appropriate scales for EAM is hierarchical in nature, and may change given the specific sets of problems to be addressed. For example, some problems may require that a specific bay or harbor be defined as a management unit for some particular purpose. However, because environmental regimes may apply over larger scales, and some animals have wide distributions, small-scale ecosystems defined for one purpose are imbedded in larger scales—up to the global scale. Specific criteria for ecosystem boundary definition have been applied to define LMEs [22], which is a useful compromise scale using patterns of biodiversity, productivity and hydrography to define boundaries. Ironically, many argue that EAM should be applied to the smallest possible (local) scale, to allow co-management at the local level (e.g., see CBD principal #2 above). However, in doing so the number of interactions among adjacent local ecosystems and the necessity to coordinate for large-scale phenomena, mean that more elements of governance need to be included as the focus of EAM becomes more local (Fig. 1). Similarly, the smaller the geographic scale used to define any ecosystem, the greater the likelihood that factors external to the prescribed ecosystem boundaries are important in influencing its productivity and status (e.g., global change, economic policies, migration patterns of animals). Thus there is a paradox of scale that the smaller the spatial resolution, the larger the number of institutional entities that may potentially be involved in decision making. It is important to stress that EAM is generally applied to ecological boundaries, which may or may not be coincident with jurisdictional boundaries. Country, state, or local jurisdictional boundaries may be imbedded within a larger set of ecological boundaries, which then require multi-jurisdictional cooperation in science and management activities to be effective.

Myth #10: Use of Marine Protected Areas (MPAs) is synonymous with EAM.

Many papers, books and popular articles concerned with EAM/EBM often cite MPAs as the appropriate management solution for a multiplicity of management problems related to conservation of exploited stocks, preservation of biodiversity, enhancement of fisheries yields and other societal goals. It is a widely held view, then, that MPAs are a required management tool consistent with EAM/EBM

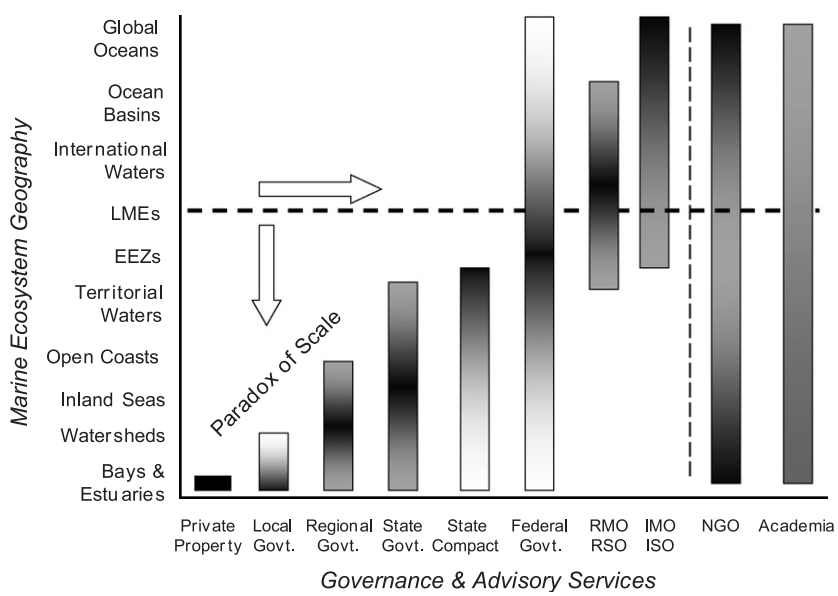


Fig. 1. The intersection between hierarchical scales of marine ecosystem geography and living resource governance and scientific advisory services. At the smallest geographic scale, parcels of land abutting bays, estuaries and watersheds may be held in private ownership, where primary management decisions are made. However, even at this small scale, local, regional, state, and federal management decisions may apply. Shading in each rectangle indicates where primary (darker) management authorities and focus generally reside. Nongovernmental organizations (NGOs) and academia tend to provide input at all scales, although many NGOs tend to be either local or global in scale. The dashed horizontal line shows that for an arbitrary ecosystem geography (e.g., large marine ecosystems, LMEs) governance tends to be by the federal government, regional management organization (RMO), supported by regional science organizations (RSO), or international management organizations (IMO) supported by international science organizations (ISO). The paradox of scale refers to the fact that smaller scales of geographic organization may tend to involve higher numbers of management layers.

and in fact so much so that in many views EAM/EBM is synonymous with MPAs.

*Reality*: This is perhaps the most widely held misperception regarding ecosystem approaches [8]. In fact, an EAM is not synonymous with MPAs, and thus one does not *have* to implement MPAs in order to be successfully managing resources using EAM. MPAs are increasingly being proposed for use as a fishery and ecosystem management tool, particularly given the advent of vessel tracking schemes and other border enforcement techniques that can help assure the integrity of their boundaries. MPAs and other forms of closures are important tools to accomplish certain types of management objectives. However, MPAs are just one of a wide variety of management tools applicable to ocean resources. They are neither necessary in all cases, nor are they sufficient to guarantee the accomplishment management objectives (notwithstanding [33–35]). Additional frequently used tools include prohibitions on specific activities or harvesting methods, the use of closed seasons for particular activities, input controls on the amount of regulated activities (e.g., fishing effort), output controls on natural resources extracted from ecosystem (quotas), and many other measures. Further, there is a continuum of types of MPAs ranging from short-term prohibitions on a limited set of activities, to "no take" reserves, including special management areas where most or all human activities are restricted or prohibited. While MPAs may be the most appropriate tool to accomplish some objectives (e.g., to protect highly sensitive marine habitat types such as deep corals), they often come with considerable costs to one or more affected constituencies. The social and environmental costs and benefits of a portfolio of measures, including MPAs, need to be weighed carefully (as they should be with the implementation of any management tool used to conserve marine resources). The use of MPAs has to be considered carefully so as not to concentrate otherwise diffuse activities which may increase, for example, habitat damage exceeding some critical threshold due to repetitive impacts or in the displacement of activities to other, perhaps more vulnerable areas or species.

Equating MPA and EAM/EBM is perhaps the most challenging of all the "myths". This is because many local groups and sectors oppose the implementation of specific MPAs (e.g., because of their allocative nature), or because one sector may feel particularly disadvantaged by their use (e.g. [36]). By association, then, these groups have opposed EAM.

## 2. Final thoughts

The evolution of EAM is moving at an uneven (punctuated?) pace driven by incremental developments in science and in governance, which are on parallel but nonsimultaneous tracks [11]. Many (if not all) ocean-dependent sectors are now being governed under some principles of EAM, even if they may not be articulated as such. Evolution of governance will continue as long as governed sectors believe that the institutions are legitimate and transparent and there are adequate incentives to participate [37]. The fact that some sectors may feel that specific issues are not legitimate concerns means that the science of the unknown or poorly known will continue to be a central issue in the debate about EAM. Objections to EAM have resulted when sector-specific management authorities feel that broadening governance to resolve mismatches [13] dilutes their advisory or decision-making authority. Ironically, failure to do so may in fact drive the search for alternative governance approaches that are less sector specific. Individual sectors have opposed EAM because of their objections to specific measures (e.g., site-specific MPAs), which they perceive as linked to the concept. Development of the "rules of engagement" among sectors (e.g., what issues should be solved, the principles upon which agreements are reached, the management measures enabling resolution and the mechanisms for dispute resolution), either using existing institutions, or by using new advisory or decision-making bodies, is one of the critical next steps in the evolution of ecosystem governance.

One recurring theme in developing the principles supporting EAM is whether progress can or should be made in incremental vs. transformational steps. Incremental evolution of EAM allows existing institutions to adapt to take on broader multi-sectoral issues as the established constituencies perceive the need to involve the existing institutions in resolving management problems and the institutions themselves become competent to do so. However, the danger in such an approach is that institutions may not be capable of addressing in a timely way management problems whose solution sets vary significantly from the *status quo* or require broadening the identification of stakeholders and thus diluting power of the established sectoral interests. Progress in scientific understanding of ecosystems and pressures on them may provide the impetus for transformational change, and this will weigh against the inevitable institutional inertia. However, if transformational change in management approach is dependent on scientific discovery, this does not provide a predictable time line along which institutional evolution proceeds.

While revised legislation and new international instruments can hasten the evolution of EAM, there is much the resource management and science communities and agencies can do now to increase communication, develop informal working agreements, and enhance coordination (all of which are basic elements of EAM/EBM). Likewise, the science supporting EAM needs to progress quickly by integrating information across disciplines on appropriate regional (ecosystem) scales, and by prioritizing and coordinating data collection, experimentation and exploration activities consistent with issues identified by the management community. The development of integrated ecosystem assessments, in addition to more specific sectoral advice and products will expand the consideration of issues within traditional management fora. As integrated

ecosystem assessments are developed and provided, there will be increased focus on causal relationships, possible thresholds, and cumulative impacts of diverse activities. Science has a critical role to play in developing information necessary to enable more sophisticated approaches to ecosystem governance, and thus is a critical change agent for the advancement for EAM. Likewise, existing management authorities are successful when they are proactive about emerging issues. Understanding that as ecosystem issues emerge they must be addressed is the domain of an adaptive approach emphasized in so many definitions of EAM/EBM [7]. Management of natural resources requires building a broader framework for evaluating competing and conflicting agendas and harmonizing the institutions responsible for advancing them. Within a sector, tunnel vision may have been acceptable in the past as it provided short-term fixes, but society is now taking a broader, longer-term view of decisions affecting the quality of the environment and human life, and no single entity is in charge. Hence, the increasing importance of the broad, cooperative stakeholder engagement aspects of EAM is becoming paramount. What is needed is a formalization of the ways regulatory institutions will address tradeoffs and develop the processes to broaden stakeholder input into decision making.

A more philosophical question lies in what constitutes "doing" EAM/EBM as opposed to the alternative. Clearly science is not supporting EAM/EMB if essential resource status indicators are not periodically updated and interactions among resources, the environment and critical habitats are not evaluated and considered. Management institutions, even ones that are primarily single sector in focus, "do" EAM/EBM if they consider the impacts of the regulated activities on the environment and on other sectors. A more complicated issue lies in what it takes for a regional ecosystem (with its multiple sectoral issues) to be considered managed under EAM/EBM principles (e.g., how many of the EAM principles must be incorporated in order for a management program to be considered an EAM?). Clearly there are no hard and fast rules for this determination, and in fact, the 'best practices', and the fundamental definition of EAM will likely change over time and with management experience. In any regard, the increased focus on multiple perspectives of ecosystem health and the engagement of broad sectoral interests clearly suggests that evolution of the approach is proceeding. Of course, evolution, by definition, has no end point and so too what constitutes practicing EAM/EBM will likewise shift over time. Eventually the concepts of EAM/EBM will simply be subsumed into ocean resource management and will cease to be a point of debate.

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