What does ecosystem-based fisheries management mean

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What Does Ecosystem-Based Fisheries Management Mean?

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There has been considerable recent interest in ecosystem-based fisheries management, as evinced by several reports (e.g., Christensen et al. 1996 (ESA); Jennings and Kaiser 1998; NMFS 1999; NRC 1999), books (e.g., Hall 1999; Kaiser and de Groot 2000; Jennings et al. 2001), and conferences (e.g., NRC Ocean Study Board Meeting in Monterey, 1996 (ESA 1998); Wakefield Symposium in Anchorage, 1998 (Alaska Sea Grant 1999); ICES-SCOR Symposium in Montpelier, France, 1999 (ICES 2000)). Several factors have contributed to the current relevance and awareness of this issue, including conflicting stakeholders and legislation, debate over the most important processes in an ecosystem, limitations of single species management, and use of this perspective as to justify many different positions. Considering factors that impact marine resource populations in a context beyond just the species level has a long and noted history in fisheries science. Spencer Baird, in his seminal report to Congress (1873), noted five areas of research to explore potential causes of decline in southern New England fisheries:

"1. The decrease or disappearance of the food upon which the fish subsist, necessitating their departure to other localities.
2. A change of location, either entirely capricious or induced by the necessity of looking for food elsewhere, as just referred to.
3. Epidemic diseases, or peculiar atmospheric agencies, such as heat, cold, etc.
4. Destruction by other fishes.
5. The agency of man; this being manifested either in the pollution of the water by the discharge into it of the refuse of manufactories, etc. or by excessive overfishing, or the use of improper apparatus."

Certainly these are resonant of contemporary terms such as trophic cascades, regime shifts, essential fish habitat, top-down/bottom-up controls, or overfishing. There has been notable advancement of technologies, methodologies, and theory over the past 130 years to address these topics. Yet despite the attention given to this problem during the past century and a half, many basic questions remain unanswered.

Among the many possible factors, there are two major reasons why these questions have not been fully addressed. First is the inherent difficulty of ever fully elucidating, particularly to the point of predictability, the multiple and complex dynamics of ecosystems. Second (and often overlooked) is the lack of unambiguous terminology when expressing these issues in an inter-disciplinary context, especially given the ecological, oceanographic, ichthyological, social, and economic mosaic within which fisheries management operates. Used as a buzzword, which it often is, the term "ecosystem management" does little to further elucidatae these broader qustions.

So what does the term "ecosystem" mean? This term likely evokes thoughts of multi-species approaches or the entire fish community or habitat for many fishery scientists, but is much broader than these components, including the entire food web and all abiotic factors that act upon a system. An ecosystem is defined as "an ecological community together with its environment, considered as a unit" (adapted from Tansley 1935). Ecosystems are complex, and cover many processes at many levels of the biological hierarchy. Once one takes a complex system and attempts to assess it in an even more complex socio-political arena, many ambiguous terms become associated with the topic of ecosystem management. It is valuable to attempt to clarify these terms.

Are we as fisheries scientists and managers really attempting ecosystem management in a fisheries context or fisheries management in an ecosystem context? I submit the latter. We technically can not manage an ecosystem. Ecosystem-based fishery management is effectively shorthand for more holistic approaches to resource allocation and management (Larkin 1996). The question then becomes, what is the objective of ecosystem-based fishery management? Is the objective to simultaneously optimize total fish yield in a system, optimize yield of a particular species, provide long-term economic viability, conserve biodiversity, maintain a particular ecosystem state, protect certain species, protect certain ecosystem services, etc.? It is clear from this list of objectives that there will be conflicting goals. The Ecosystems Principles Advisory Panel (EPAP; NMFS 1999) report to Congress simply states that the goal of ecosystem-based fisheries management is to maintain ecosystem health and sustainability.

Ecosystem health is ill-defined and a misnomer. The human analogy of medical homeostasis or toxicological resistance does not apply (Wicklum and Davies 1995). If you or I have a blood pressure, pulse rate, temperature, and brain wave activity within a certain range, we are healthy. If these and related metrics are outside of a specified range, one is termed unhealthy and if one persists outside of this range one will ultimately cease to function. Alternatively, ecosystems can exhibit multiple states that are just as functional as any other. Some states are certainly more desirable than others, but all are viable. I propose using the term "ecosystem status" instead of ecosystem health to describe the condition of an ecosystem in a less subjective and value-laden manner.

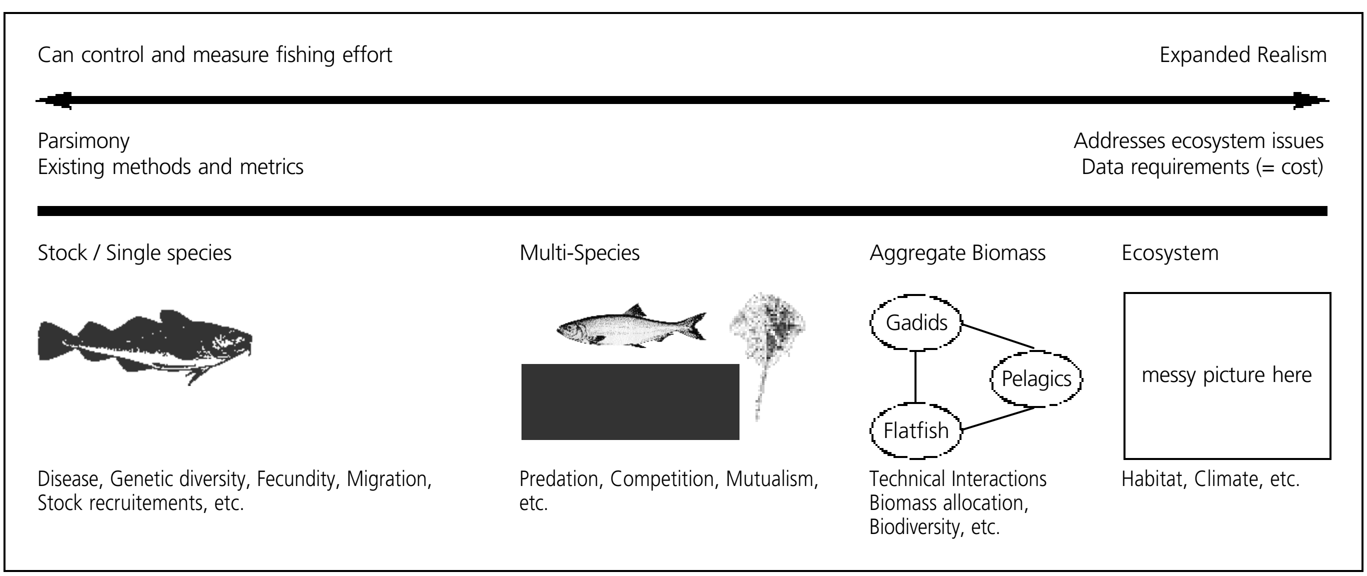
Ecosystem integrity is also an ill-defined term often used in the context of ecosystem sustainability. How does one measure, reproduce, or evaluate integrity? This term implies that unless something is done, whatever that may be, the critical processes in an ecosystem will break and cease to function. As discussed earlier, ecosystems will continue to function, albeit at different configurations. I propose using the term "ecosystem state sustainability" instead of ecosystem integrity to refer to the maintenance of specified processes desirable for persistence in a system. More mathematically specific, we are talking about the persistence (and Lyapunov stability) of a particular state of an ecosystem. For example, we could have an ecosystem with limited blue crabs, numerous menhaden, lots of striped bass, moderate nutrient loading, and minimal hypoxia. And we could manage that system to generally sustain such a set of conditions (i.e., state). One can measure and evaluate processes and component biomass in a system over time to ascertain how sustainable a particular ecosystem state might be. However, the question then becomes what is the desired ecosystem state we would like to sustain?

Ecosystem products (or services) is a term that connotes the measurement and evaluation of specified outputs produced by a system. Although an useful term, it is wise to remember that there are services provided by an ecosystem beyond the scope of fisheries management. For example, marine and freshwater ecosystems alike provide the basis for tourism, eco-tourism, navigation, diving, climate regulation, CO_2 scrubbing, mineral extraction (oil and otherwise), discovery of new materials, and development of new medicines, in addition to commercial and recreational fishing. Collectively prioritizing these products, maintaining the ability of a system to continue to produce these services, and recognizing the impacts of fishing on these other aspects of the ecosystem remains a key challenge for national and international resource management.

There is an apparent duality when considering ecosystem approaches to fisheries management. The argument has polarized at two extremes: either one can approach management from the perspective of the entire ecosystem, or from a single species approach that is cognizant of broader ecosystem considerations. Single species approaches generally do not consider species interactions, allocation of biomass, changes in ecosystem structure or function, biodiversity, non-fishing ecosystem services, protected or rare species, non-target species, ecosystem effects of discarding unwanted bycatch, or gear impacts on habitat. Conversely, ecosystem approaches generally do not consider demographic parameters, density-dependent effects, stock-recruitment relationships, genetic diversity, economic tradeoffs, or standards, reference points, and performance statistics. This duality is really a false dichotomy, and actually represents two extremes along a gradient (Figure 1). The optimal protocol can and should incorporate some of the best aspects of all approaches on this gradient.

This gradient of approaches implies several opportunities and tradeoffs. One can maintain a single species approach and forget ecosystem issues, conduct multiple single species assessments in "harmony," conduct single species assessments with explicit predation mortality or habitat or climate considerations, conduct multi-species assessments, construct aggregate biomass models, or drop population dynamics entirely and focus on whole system models. Certainly more methodology is available at the single species end of the spectrum and this is usually much cheaper (in terms of dollars, time, and

Figure 1. A gradient of possibilities from single species to whole system approaches for fisheries management, noting key processes and pros or cons at each level.



data) than the systemic end of possible approaches. Conversely, the higher end of hierarchy incorporates a wider range of biological processes more explicitly and captures many critical factors that are omitted from the single species approaches. Regardless of position along this gradient, it is clear that there needs to be a broader, more inter-disciplinary approach to fisheries science (Link 2002, this issue).

One explicit consideration of ecosystem-based fishery management should be biomass tradeoffs. The sum of single species MSY is greater than MSY for the system, and it is energetically impossible to simultaneously maximize yield for multiple species (Brown et al. 1976; May et al. 1979). The objective, as difficult as it may be, should be to specify the species mix desired in the fish assemblage of an ecosystem (Larkin 1996; i.e., what is the desired state of the ecosystem as discussed earlier). This raises the consideration about alternate steady states. Presuming there is agreement on what the desirable ecosystem state should look like in terms of species composition, relative abundance, etc., it is questionable if a system can be manipulated to that end (Beddington 1986). Although it may be desirable to go back to the "glory days" of a fishery associated with a certain ecosystem state, we need to be frank about the probability that a multi-species trajectory may not be reversible, particularly given environmental regime shifts.

This broaches what is doable and what is intractable. I do not mean to imply that the task of ecosystem-based fisheries management is hopeless, when in fact it is possible to manage and bound conditions that may increase the chances of sustaining a certain fish assemblage while concurrently minimizing ecological impacts to a system. Additionally, ecosystem considerations do not substitute for what is already known from a single species approach. Basically, we will still need to reduce fishing capacity and mortality. Invoking ecosystem considerations is not a crutch for failing to implement clear-cut single species fisheries management advice. So how are these ecosystem considerations implemented into fisheries management? In many instances, they already are. There are several Fishery Management Plans (FMPs) that consider groups of fish as assemblages, there are ecological considerations written into many of the same FMPs, there are many single species assessments that incorporate a host of broader considerations, and there are several multi-species or aggregate models that exist and have been used with some success. Let us continue to use and expand upon these approaches.

What needs to be done to improve the implementation of ecosystem considerations into fisheries management? First, the dialogue should continue to clearly define fishery goals in an ecosystem context and develop protocols that resolve competing goals for any given ecosystem. This will be an iterative process and will require that all stakeholders be provided with an opportunity for input. Second, a suite of ecosystem metrics and indicators merit exploration to determine if there are ecosystem analogs to single species reference points, standards, and similar control rules. Table 1 lists examples of indices, parameters, and similar metrics along the gradient that may be useful in determining whether an ecosystem is overfished. These metrics need to be sensitive to change, directional, general enough to be useful, feasible to measure, and able to incorporate uncertainty. Third, more appropriate theory, models, and methods at the aggregate and system level need to be developed and applied. Some of these approaches exist or can be extended from single species approaches, but several other issues have yet to be fully explored. This is a fruitful area for research. Fourth, monitoring should be maintained and expanded. The reason to maintain current monitoring is that many of the system-level emergent properties can be calculated from extant resource survey data. Expansion of monitoring programs to include habitat characterization, environmental variables, food habits, and non-target species will be essential to truly implement an ecosystem approach to fisheries management. This expanded monitoring will augment single species approaches and provide complementary information and insight that can not be obtained from classical methods, but it will also be costly. Yet given the increasing set of stakeholders and associated lawsuits,

Table 1. Examples of ecosystem emergent properties that can be measured and perhaps serve as proxies for decision criteria in fisheries management.

Systems Analysis (Cybernetic) Metrics	Exergy, emergy, total production, total biomass, energy flux, resilience, persistence, resistance, stability, free energy, information content
Aggregate Metrics	Mass flux, ascendancy, redundancy, developmental capacity, guild composition, trophic transfer efficiency, production and biomass in a trophic level or group
Food Web Metrics	Connectivity, trophic links, modal chain length, % omnivory, % cannibalism, linkage density, allocation of species across trophic levels, interaction strength, cycles, predator/prey ratio
Community Metrics	Diversity indices, size spectra, species richness, evenness, dominance, overlap indices, interaction indices
Single Species Metrics	MSY, F_{MAX}, F_{MSY}, $F_{0.1}$, $F_{20\%MSP}$, SSB, MEY, YPR, F=M, Z, etc.

the cost is worth it. Finally, we need to formalize plans for fisheries in the context of ecosystems. As an example from U.S. marine fisheries that is germane for most aquatic resource management agencies , the EPAP (NMFS 1999) has stated the need for Fishery-Ecosystem Plans (FEPs), but what do these types of plans look like? I submit that to develop these plans, we need to incorporate the issues described above (see also, Link 2002, this issue) and develop guidelines similar to, but qualitatively different than, those that exist for national standards of single species Fishery Management Plans (FMPs, NOAA 1996; Restrepo et al. 1998).

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