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# Strategies for Incorporating Ecosystem Considerations in Fisheries Management

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## Abstract

Ecosystem considerations are increasingly being advocated for inclusion in fisheries and other marine and coastal management programs. Ecosystem-level issues most commonly cited as relevant to fisheries management include conservation and management of target and non-target species and biodiversity, consideration of tradeoffs among fisheries and other sectors, accounting for feedback effects (e.g., predator-prey and habitat effects of gear), maintaining ecosystem productivity and balanced trophic structure, and use of adaptive approaches in management. The national standards and essential fish habitat provisions under the Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) provide tools to address many but not all of these issues. Some ecosystem issues may well be addressed as emergent properties of regional ecosystems that are managed with integrated fishery management plans emphasizing conservative single-species or fishery-by-fishery FMPs. Other issues may only be addressed under umbrella ecosystem plans or by additional authorities not currently provided in relevant fisheries or other implementing legislation. Existing provisions of MSFCMA may be more relevant to management of recovering resources but less so for optimizing among multiple conflicting uses of rebuilt ecosystems.

## Introduction

Explicit accounting for the health and productivity of ecosystems as a focus of marine and coastal management is a central recommendation of both the report of the US Commission on Ocean Policy (USCOP 2004) and the Pew Oceans Commission (Pew Oceans Commission 2003). There is considerable parallel international interest in ecosystem issues, with the emphasis on integrated approaches to management (Constable et al. 2000; Sainsbury et al. 2000; Garcia et al. 2003; Aqorau 2003; Sainsbury and Sumaila 2003). The recommendations resulting from high-level US and international policy commissions, and those from other from science, management and stakeholder groups have identified ecosystems perspectives as both an organizing theme for science, and as a basis for balancing societal needs for continuing production of goods and delivery of services resulting from healthy ecosystems. Recently, NOAA has adopted a set of ecosystem principles both as a way to efficiently organize and integrate its internal science activities, and to provide a consistent set of institutional goals in the various

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marine and coastal management activities in which it participates (e.g., fisheries, sanctuaries, coastal management, protected resources, etc.; Sissenwine and Mace 2003; Sissenwine and Murawski 2004).

The purpose of this paper is to explore the extent to which issues commonly identified as being part of an ‘ecosystem approach’ can and are being addressed within existing legislation that bears upon marine and coastal resource management. A view in some fishery science and management circles is that if conservative single species management is applied to all the significant fisheries within a regional ecosystem, many (perhaps most) of the ecosystem issues of interest would be addressed either explicitly in conservation measures or implicitly as a result of the cumulative effects of the management program (ICES 2000; Witherell et al. 2000; Bodal 2003; Mace et al. 2004). Existing provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), including its 10 national standards (NS), and provisions to identify and protect essential fish habitat, provide broad prescriptive guidance for conserving species, minimizing bycatch, protecting habitat, and involving stakeholders in decision making. Additionally, there are institutional arrangements that allow the fishery management Councils and NOAA to comment upon or otherwise participate in the management of activities outside the scope of fisheries, but which bear upon fisheries. For example, management measures developed under the authority of the Marine Mammal Protection Act, Endangered Species Act and other legislation may be codified within fishery management plans (e.g., closed areas, gear restrictions, etc.), which will have impacts on fishery resources and fisheries.

In order to facilitate discussion of the extent to which ecosystem issues are addressed under existing authorities, the MSFCMA national standards and EFH provisions are mapped into a list of ecosystem principles and objectives that are commonly cited as embodying an ecosystem approach to management (Table 1). Based on this analysis, some strategies are explored for emphasizing ecosystem-level issues in current and future governance discussions.

### **Ecosystem Principles, Objectives and Goals**

A number of recent policy and science-related reviews have suggested both high-level and operational principles, and objectives as the goals of ecosystem approaches to management (e.g., Larkin 1996; Done and Reichelt 1998; USDOC 1999; ICES 2000; Murawski 2000; Sainsbury et al. 2000; Dayton et al. 2002; Garcia et al. 2003; Browman and Stergiou 2004; Hall and Mainprize 2004; Sainsbury and Sumaila 2003; Sissenwine and Murawski 2004; Sissenwine and Mace 2003). While there is no commonly agreed set of goals comprising an ecosystem approach, most reviews have focused on some or all of the following elements:

*Conservation and Management of Species* – Fisheries management programs focus on target species of fisheries economic concern. Non-target species are increasingly a concern (Pope et al. 2000; Gislason 2003), particularly if the effects of harvesting result

in the status of a non-target species approaching protected, endangered or threatened (PET) status. Increasingly, ecosystem discussions include the direct and indirect effects of harvesting on measures of biodiversity. There remains an ongoing debate regarding the usefulness of indices of diversity as management indicators, and whether biodiversity is an ‘emergent’ property of ecosystems, as opposed to a direct indicator that would support reference points (ICES 2000, Rice 2000, Link et al. 2002; Rice and Rochet in press; Sainsbury and Sumaila 2003).

*Minimization of Bycatch* – Bycatch includes both ‘byproduct’ species that are caught in association with target species, and are retained for sale, as well as target and non-target species or sizes of animals that are discarded (Alverson et al. 1994; Cook 2003; Kelleher, in press). While most bycatch concerns relate to the conservation status of target and non-target species, there is an additional concern regarding the magnitude of discards (an issue of waste), irrespective of the mortality rates that may affect conservation status. Additionally, discards may create secondary ecosystem impacts due to scavenging and nutrient recycling.

*Consideration of Tradeoffs* – Tradeoff issues involve reconciling conflicting goals in the management of species due to their interactions, or among fishing sectors that compete for target or non-target species. Optimization of regional ecosystem benefits within the fisheries sectors involves considering the socioeconomic impacts of various alternatives. Characteristics of the management system that evaluate tradeoffs include equity among stakeholders, fairness in dealing with conflicting objectives, and transparency of the deliberative process. The cumulative effects of fishing and non-fishing impacts on ecosystems, and the evaluation of tradeoffs between fishing and non-fishing impacts and benefits are also important aspects of ecosystem-level tradeoffs.

*Accounting for Feedback Effects (interactions among components)* – Feedback effects include several categories of interaction effects among species within an ecosystem and the impacts of fishing on the productive capacity of ecosystems. These effects include harvesting in predator-prey systems (Larkin 1996; Pauly et al. 1998), and the impacts of bottom-tending fishing gears on habitat, which may, in turn negatively influence productivity of target or non-target species (Collie et al. 2000; Kaiser et al. 2004). A critical issue in ecosystem analysis is understanding the potential for creating irreversible effects due to harvesting, and the induction of alternative biological community regimes due to harvesting.

*Establishment of Ecosystem Boundaries* – Ecosystem issues occur over a continuum of spatial scales, from very local to global. Because of the open nature of marine systems, boundaries among regional ecosystems will always be variable, and pertain differently to the species and processes being considered. An important aspect of an ecosystem approach is to allow flexible boundaries depending on issues being considered, and variations in the physical or biological conditions (Pauly et al. 2004).

*Maintenance of Ecosystem productivity* – An important perspective that comes from considering ecosystems is maintenance of the productivity of the biological system,

including primary and secondary production, benthic processes, and effects of human activities on the carrying capacity of ecosystems (Pauly and Christensen 1995).

*Balancing Ecosystem Structure* – Trophic balance (e.g., the production and standing stock at sequential trophic levels from primary and secondary producers to consumers) has been emphasized as a potential indicator of ecosystem-level overfishing. Overharvesting of predators can cause cascading effects down the food chain, as can overharvest of prey species (Pauly et al. 1998).

*Accounting for Climate Variability* – Climate variability can be expressed as low frequency (e.g., decadal) scale trends, high-frequency (e.g. inter-annual) trends or variation without trend. In the extreme, significant low-frequency variability may result in regime changes in biological communities and ecosystems influenced by such variability.

*Use of Adaptive Approaches* – Adaptive approaches are considered a necessary element of ecosystem approaches because of the lack of knowledge regarding critical relationships among biological components and between biological and physical variables. Elements of an adaptive approach include the consideration of multiple causative effects for observed changes in the ecosystem, the incorporation of scientific approaches within an adaptive approach, so as to learn about critical ecosystem processes, and the use of management techniques that reverse the burden of proof in deliberating about the impacts of harvesting effects on ecosystem attributes.

### **Provisions of the Magnuson-Stevens Act**

The Magnuson Stevens Fishery Conservation and Management Act (USDOC 1996) provides guidance on strategic goals as well as a number of specific standards under which proposed management programs must be evaluated. Some or all of these pertain to ecosystem issues, as identified above. The 10 national standards as provided in section 301 of the MSFCMA are:

- (1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.*
- (2) Conservation and management measures shall be based upon the best scientific information available*
- (3) To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination*
- (4) Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and*

- equitable to all such fishermen (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.*
- (5) *Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.*
- (6) *Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fish resources, and catches.*
- (7) *Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.*
- (8) *Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.*
- (9) *Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.*
- (10) *Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.*

In addition to the national standards, the MSFCMA specifies in its *Contents of Fishery Management Plans* that essential fish habitat be described:

*(7) describe and identify essential fish habitat for the fishery based upon the guidelines established by the secretary under section 305(b)(1)(A), minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat.*

In developing its guidelines for defining essential fish habitat (USDOC 2002), it is stipulated that:

*FMPs should identify habitat areas of particular concern within EFH. In determining whether a type, or area of EFH is a habitat area of particular concern, one or more of the following criteria must be met:*

- i. The importance of the ecological function provided by the habitat.*
- ii. The extent to which the habitat is sensitive to human-induced environmental degradation.*

- iii. *Whether, and to what extent, development activities are, or will be, stressing the habitat type.*
- iv. *The rarity of the habitat type.*

*FMPs should analyze how the cumulative impacts of fishing and non-fishing activities influence the function of EFH on an ecosystem or watershed scale. An assessment of the cumulative and synergistic effects of multiple threats, including the effects of natural stresses (such as storm damage or climate-based environmental shifts) and an assessment of the ecological risks resulting from the impact of those threats on EFH, also should be included.*

### **Analysis of Existing MSFCMA Provisions with Respect to Ecosystem Objectives**

Mapping of the various ecosystem-related goals and objectives into the NS and EFH provisions of MSFCMA is done in Table 1. For each ecosystem objective or sub-objective, the relevance of each of the 10 national standards and the EHF provisions are evaluated on a four level scale:

- (a) Direct relevance of the ecosystem objective to the NS or EFH
- (b) Indirect relevance of the ecosystem objective to the NS or EFH
- (c) Some relationship to the NS or EFH
- (d) No relevance to the NS or EFH.

While this classification is highly subjective, it is proposed as a method to evaluate where existing provisions adequately address ecosystem objectives of concern, and where the current provisions may not apply. The purpose of this exercise is primarily to stimulate debate on (1) the appropriateness of the various proposed ecosystem principles and objectives in the context of management, and (2) the necessity or even the ability to address certain ecosystem objectives within the context of a fisheries or more broad-based marine ecosystem management program.

Below, each of the categories of ecosystem-related principles or objectives are evaluated in terms of the relevance of various MSFCMA provisions.

*Conserve and Manage Species:* The MSFCMA pertains primarily to the conservation of fishery target species. Given the precedence of NS-1 (prevent overfishing) and the use of best scientific data, these provisions are directly relevant to the goal of conserving target stocks. The provisions that allow for variations in fisheries, fish resources and catches, for minimizing bycatch and for designation of EFH are also primarily established for target stocks. Under NS-1 guidelines, assemblages of target stocks can also be managed directly, and the proposed revisions on NS-1 will potentially allow more flexibility to manage assemblages of linked stocks. Non-target stocks of fish and invertebrates can also be managed under MSFCMA provisions, but to date the incorporation of non-target species into FMPs has varied widely. For example, groundfish FMPs in Alaska include over 100 species, including many non-target species of little or no commercial value. To the contrary, the groundfish FMP in New England includes 19 stocks and fewer species,

whereas the gear is capable of catching over 200 extant species. PET species are not directly managed under MSFCMA, but many of the measures used to conserve and rebuild these stocks are codified in existing FMPs (e.g., stellar sea lion closures in Alaska, rolling harbor porpoise closures in New England). The use of HAPC to protect rare habitats (including non-target species such as corals) is consistent with goals to conserve biodiversity as an element of an ecosystem approach.

*Minimize Bycatch:* The objective of minimizing bycatch is particularly relevant under MSFCMA in order to address target species management. In particular, strategies to minimize regulatory discards of target species are addressed with gear, time, and area provisions. The minimization of non-target species bycatch is more problematic, particularly where biological communities are productive and diverse. Again, bycatch minimization for PET species is primarily handled outside of MSFCMA, but some regulations serve dual purposes (e.g., harbor porpoise closures in New England are used to reduce mortality on groundfish stocks as well).

*Consider Tradeoffs:* Tradeoffs in ecosystem approaches involve developing alternative management scenarios that may have differential impacts among various fishing sectors, and, when considered, between fishing and non-fishing sectors. MSFCMA provisions allow for consultation in non-fishing management venues, particularly in the context of providing comments on non-fishing related threats to resource species. Within the fisheries sectors, the councils can balance fisheries interests when there are conflicts among FMPs, but these inter-FMP tradeoff analyses are generally not cast as a search for a global optimum of benefits, but rather maintenance of near-status quo allocations, consistent with the need for conservation of the resources. Since overall effort management among FMPs is not generally considered, there have been in the past numerous cases of effort flowing from regulated to non-regulated stocks, with the result being a scenario of sequential depletion. Many of the provisions of MSFCMA provide management processes that are transparent, and that emphasize fairness and equity. Cumulative impacts of multiple fisheries and non-fishing effects are stipulated in the guidelines implementing EFH, but there is no complementary requirement in non-fishing sector management for other marine uses.

*Accounting for Feedbacks:* predator-prey feedbacks and effects of fishing gear on benthic habitats for target species are anticipated under MSFCMA provisions, but are handled in different ways by the various Councils. In Alaska, harvesting of pelagic prey species (e.g., capelin) is not allowed, which is the most restrictive of potential options. Elsewhere, predator-prey systems are managed using precautionary setting of measures, or by assuming that the links are accounted for in natural mortality rates calculated for prey species. The irreversibility of harvesting impacts is accounted for in the threshold biomass and control rules under NS-1. Harvest-induced regime changes are not addressed directly under these provisions.

*Boundaries of Ecosystems:* The establishment of management units includes both the requirement to manage stocks throughout their ranges and to manage stocks of interrelated species. This, management units for migratory species may involve joint

Council plans. However, these management units are primarily related to target species, and thus non-target species, and ecosystem processes are not directly accounted for in the definitions of management units.

*Ecosystem Productivity and Structure:* Ecosystem productivity and structure are generally not addressed directly in management under MSFCMA. In particular, balanced structure of fish components of the ecosystem may be an emergent property resulting from conservative application of single-species management principles. However, such a “piece-wise” balancing of trophic components may create a sub-optimal series of benefits given predator-prey interactions that may occur. Ecosystem productivity may be influenced by harvesting (e.g., benthos), but climate and non-fishing human effects are likely more important as drivers at low trophic levels.

*Climate Variability:* Climate variability may have important implications for the development of harvest strategies, particularly if recruitment of target species is climate sensitive. The development of harvest control strategies that are robust to such variations (low, high frequency, trended, or non trended) is possible and has been used in some cases in FMPs.

*Adaptive approaches to management:* Adaptive approaches to management are particularly relevant to situations where uncertainty about causal factors may result in highly uncertain management programs (Sainsbury 1991). For example, when stocks have been chronically overfished, it may not be possible to establish Bmsy with much confidence owing to uncertainty in density dependent responses. In these cases, scientifically directed adaptive approaches may be used by management to help clarify management options. Adaptive approaches can be used under some of the existing MSFCMA provisions, and proposals for revisions of NS-1 could potentially allow greater uses of adaptive management.

In addition to the ecosystem considerations above, it is instructive to apply the same analysis to NOAAs stated principles for an ecosystem approach (Table 1; Sissenwine and Murawski 2004). Those principles are that an ecosystem approach is adaptive, regionally directed, uses ecosystem knowledge, accounts for uncertainty, considers multiple influences, and seeks to balance diverse objectives. Many of the current provisions of the MSFCMA are relevant to these principles, as discussed above.

### **Strategies to Address Ecosystem Issues**

As discussed above, a number of the provisions of MSFCMA are directly relevant to the generally recognized objectives of ecosystem approaches to management. In particular, provisions dealing with target species conservation, use of best scientific data, development of open stakeholder-transparent processes, and incorporation of essential fish habitat provisions provide very significant authorities to address issues of ecosystem concern. While the MSFCMA would appear to allow greater consideration of non-target species, the provisions have been applied in very different ways by the Councils, and more consistency in application seems warranted.

Several of the issues relevant to ecosystem objectives appear to be emergent properties of a conservative regional fishery management system based primarily on single species or fishery-by-fishery approaches. These include biodiversity protection, and trophic balance/structure. However, since these are important considerations and it is not a given that these properties will be satisfied by traditional focus on species and fisheries, monitoring of them seems important (Sainsbury and Sumaila 2004). For example, routine calculation of indices such as diversity metrics (Rice 2000), slopes of size spectra (Rice and Rochet, in press), FIB indices (Gislason 2003), etc. may provide insights into how management approaches in aggregate address these considerations. Also, routine reporting on non-target species abundance indices (e.g., from trawl survey catches) would provide detection of potential problems before species reach thresholds for PET status.

Umbrella fishery ecosystem plans (USDOC 1999) appear to have utility in addressing some issues not currently addressed well under MSFCAM. These include developing optimal fishing strategies for competing fisheries within an ecosystem, clarification of cumulative fishing and non-fishing impacts, and incorporating effects of climate change on ecosystem productivity. Some issues are not currently addressed under existing fishery provisions, and would not be so even with an umbrella ecosystem plan. In particular, these involve non-fishing sector tradeoffs.

Last, many of the provisions of MSFCMA were developed to allow rebuilding of depleted stocks, and the mechanics for doing so are specified in the guidelines in detail. With its focus on stock rebuilding, issues of optimality, particularly for rebuilt resources and ecosystems are less well described. For example, while fishing all stocks at their single-species optima may result in no overfishing of target stocks, the resulting stream of cumulative benefits for a regional ecosystem may not be maximized. Maximum benefits may result when interactions among stocks are better considered. Thus, the provisions and mechanisms under MSFCMA should be reviewed with respect to attaining maximum societal benefits consistent with the conservation of target and non-target species.

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