

Ecosystem Approach to Marine Fisheries Management

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Background

Sustainable use of living marine resources must consider both the impacts of the ecosystem on the living marine resources, and the impacts of fishery on the ecosystem. This holistic approach to fisheries management has been termed as “ecosystem based fisheries management” (EBFM). Similar holistic management approach in fisheries management have been differently termed as Ecosystem considerations (EC), Ecosystem approach to fisheries (EAF), Ecosystem based management (EBM), Ecosystem Management (EM) etc by various authors. While these are not synonyms, the basic approach stems from the adoption of a perspective encompassing the entire ecosystem. Christie et al. (2007) has recently reviewed about the subtle differences in the meaning of these acronyms.

A lot of attention has recently been directed at assessing the impacts of fisheries on whole marine ecosystems (Pikitch et al., 2004). This has in part been driven by the need to ensure conservation of biological diversity and sustainable use of the biosphere, key provisions of the convention agreed at the UN Rio summit (Tasker et al., 2000). The utilization of sound ecological models and indicators as tools in the exploration and evaluation of ecosystem health and state has been encouraged and endorsed by the leading bodies in ecosystem-based fisheries research and management (ICES, 2000). The potential of the available dynamic ecosystem models to make measurable and meaningful predictions about the effects of fishing on ecosystems has not however been fully assessed. Let us first look at some of the science behind the need for EBFM.

Impacts on Fished Taxa

Harvesting alters ecosystem structure in ways that are only beginning to be understood. It is argued that long-term heavy commercial harvesting is likely to shift the ecosystem to high-turnover species with low trophic levels (Pitcher and Pauly, 1998). The biological mechanism underlying species shifts is that the relatively large, long-lived fishes

which have low mortality rates are more strongly affected by a given fishing mortality rate than are smaller fishes which are part of the same community. A second shift-inducing biological mechanism is habitat degradation caused by various fishing gears, especially bottom trawls. Here, the effect is through destruction of bottom structure, depriving benthic fishes of habitats and prey.

Thirdly, the above and the fishery induced reduction of predatory pressure by benthic fish, may then lead to an increase of small pelagic fish and squids which becomes available for exploitation. This may mask the decline in catches of the demersal groups. In the Gulf of Thailand, in Hong Kong Bay and other areas of the South China Sea, extremely heavy trawl pressure has resulted in a shift from valuable demersal table fish such as croakers, groupers and snappers to a fishery dominated by small pelagics used for animal feed and invertebrates such as jellyfish and squids.

These mechanisms almost often lead, through a positive feedback loop, to a fourth biological mechanism: harvesting small pelagic fish species at lower trophic levels reduces the availability of food for higher trophic levels, which then decline further, releasing more prey for capture by a fishery that finds its targets even lower down the food web, a process now occurring throughout the world (Pitcher and Pauly, 1998). The growing abundance of arrowtooth flounder (*Atheresthes stomias*) in Alaska has been a concern for a decade, while the recent explosion of Humboldt squid (*Dosidicus gigas*) off the U.S. west coast and the high densities of spiny dogfish (*Squalus acanthias*) in New England and the U.S. Atlantic states have led to calls for “ecosystem”-based predator control (Hilborn, 2011). Punt and Butterworth (1995) used trophic models to evaluate the potential to improve fish yields by culling seals. Some examples of such documented species shifts in exploited multispecies fish communities are shown in Table 1.

Table 1: Examples of documented shifts towards smaller, high-turnover species in exploited multispecies communities (modified from Pitcher and Pauly, 1998)

Fishing grounds/ Stocks (period)	Documented species shift
Gulf of Thailand Demersal stocks (1960-1980)	Overall biomass reduced by 90%; residual biomass dominated by trash fish
Philippine shelf Small pelagics (1950-1980)	Gradual replacement of sardine-like fishes by anchovies
Carigara Bay, Philippines All fish (1970-1990)	Fish replaced by jellyfish, now an export item
Black Sea	Small pelagics and jellyfish replace large table fish
North Sea	Halibut and small sharks extinct; cod and haddock threatened; demersal omnivores and small pelagics favoured

Humboldt Current, Chile	Large hake depleted, small pelagics favoured
North Pacific	First marine mammal depletions, followed by huge trawl fisheries: Pollock favoured
South China Sea, Hong Kong	Croakers and groupers almost extinct; small pelagics bulk of fishery
Northwest Coast and Southeast Coast of India	Decline in large predators such as sciaenids, perches and Bombay duck and increase in abundance of oil sardine

Single Species Assessments

The tools developed for single species population dynamics are an essential part of any new methodology. Detailed information on growth, mortality and recruitment schedules and their associated errors and uncertainties are essential for the implementation of the ecosystem approach advocated in the Rio summit.

When considering the management of single components of the ecosystem, such as the target fish stocks, it is possible to set target and limit reference points for particular measurable properties of the species. For example, the implementation of precautionary fisheries management in the North Atlantic has progressed through the setting of reference points for various measures of the status of the exploited species, e.g. the spawning stock biomass (SSB). Two types of reference point are considered - a limit reference point and a target reference point. Management measures are aimed at achieving the target reference point in the medium term and ensuring that the limit reference point is never exceeded.

In theory, it should be possible to apply reference points to any or all taxa in the ecosystem. ICES (2000) have contended that even if this was practical for a significant number of taxa, it may not ensure adequate protection of all the ecosystem components at risk. There is a need, therefore, to develop reference points for system level emergent properties as a measure of ecosystem health (Hall, 1999; Gislason et al., 2000).

ECOSYSTEM MODELLING USING TROPHIC INTERACTIONS

There are many recent developments in building of trophic models of aquatic ecosystems. Such modelling can now be performed more rapidly and rigorously than ever before, providing a basis for viable and practical simulation models that have real predictive power (Christensen and Pauly, 1993; Walters et al., 1997). This was made possible by the development of Ecopath (Polovina, 1984; Christensen and Pauly, 1992), for construction of mass-balance models of ecosystems, based mainly on diet composition, food consumption rates, biomass and mortality estimates.

Ecopath applications to ecosystems, ranging from low latitude areas to the tropics, and from ponds, rivers, and lakes to estuaries, coral reefs, shelves, and the open sea, but all using the same metrics, allowed identification of several general features of aquatic ecosystems:

Multivariate comparisons demonstrated the basic soundness of E. P. Odum’s (1969) theory of eco-system maturation (Christensen, 1995), including a confirmation of his detailed predictions regarding ecosystems near carrying capacity (Christensen and Pauly, 1998). Conversely, this theory can now be used to predict the effect of fisheries on ecosystems, which tend to reduce their maturity, as illustrated by the comparison of Ecopath models for the Eastern Bering Sea in the 1950s and early 1990s (Trites *et al.*, 1999), and to guide ecosystem rebuilding strategies implied in “Back to the Future” approaches (Pitcher, 1998; Pitcher *et al.*, 2000).

PERFORMANCE MEASURES

It is generally agreed that reductions in single species fishing mortality levels is perhaps the most significant step one could take towards ensuring the persistence of marine ecosystems (Hall and Mainprize, 2004). It is also clear that ecosystem based fisheries management is still in its formative years, although substantial developments have been seen in some countries and regions. Among these, North America, Antarctica, Europe, Australia and New Zealand are the most notable. Probably the most advanced implementation of EBFM in the US context is the North Pacific Fisheries Management Council approach.

Table 2. The six principles for an ecosystem based fisheries management approach (adapted from Inter-agency Marine Fisheries Working Group, 2002)

Principle	Description
Ecosystem identification	The ecosystem that fisheries will be managed within need to be defined on the basis of the main physical, biological and human dependency relationships
Clear objectives	Objectives for fisheries management shall have regard to local and national needs, and management should be decentralized to the maximum extent possible
Long term benefits	EBFM should aim for long term benefits - management should look to restore stocks to levels that are capable of delivering optimal yields over the long term; and achieving such yields should not compromise other marine species and habitats. Management should also aim to support biological biodiversity
Incentives aligned with and ecosystem based approach	Incentives should be realigned to support aims of the ecosystem based approach - incentives and financial support needs to be redirected from fisheries that aim at increasing

fishing efficiency to those that make concerted efforts to those that promote the restoration of fish stocks to optimal yield levels and which support responsible fishing practices in sensitive marine areas

Easily assessed information and alternate management options

Information necessary to implement the ecosystem based approach should be made available to all. Where information is insufficient, adaptive management and the precautionary approach should be followed. If the outcome falls short of what was intended the management decisions should be suitably altered – proactive management

Unfortunately, despite the legislative imperative and clearly articulated principles (Table 2), arriving at an operational framework for an ecosystem based approach to fisheries management is fraught with difficulties. This difficulty is due, not only to the inherent challenge in establishing and quantifying the effects of fishing at an ecosystem level, but also due to the social and political dimensions associated with harvesting fisheries at an environmentally sustainable level.

THE TWO ASPECTS OF EBFM

Very recently, (Hilborn, 2011), classified EBFM as consisting of a core and extended EBFM. The “core” consists of three primary features: (a) doing single species management right, i.e., keeping fishing mortality at or below f_{MSY} , and keeping fleet capacity in line with the potential of the resources, (b) preventing by-catch of non-target species, which can be achieved by gear modification, providing incentives for by-catch avoidance, or by area and seasonal closures, and (c) the avoidance of habitat modifying fishing practices primarily by closing areas or banning of specific fishing methods or gears in sensitive areas. Consideration of trophic interactions and area-based management characterize “extended” EBFM. There are two elements of “extended” EBFM that are underway. One is founded in detailed studies, as exemplified by wide-scale multi-species data collection on food habits and trophic connections sometimes combined with ecosystem models. There are now ecosystem models for many ecosystems. It is possible that ecosystem models will be used to identify “problem” species and potentially direct fisheries to deliberately reduce their abundance.

The second element of extended EBFM is area-based management. Examples of existing area-based management include closed areas to protect spawning stocks, juvenile fish or sensitive habitats (Worm et al., 2009). There is a growing use of area-based management to reduce by-catch, such as short term closures in the eastern Bering Sea and the North Sea (National Research Council, 2003), or the larger and longer closures to protect cod in New England and rockfish off California. There is also the implementation of large-scale systems of marine protected areas in many parts of the world. Area based management is currently a reality, and it is certainly going to continue to expand. Nevertheless, the cost of ecosystem models and area-based management is very high. Just doing stock assessments for every species instead of the current practice of the economically

important ones will likely require a multi-fold increase in science and management costs. Integrated Ecosystem Assessment (IEA) has emerged (Levin et al., 2009) as one approach to solve the problem, by seeking important indicators of ecosystem condition rather than tracking all species in the ecosystem. Rather than doing single species assessment for each species, simpler ecosystem based indicators could be used in the management control rules.

EBFM IN ASIAN CONTEXT

Application of EBMF implies a balanced approach to addressing ecosystem wellbeing and thus contributes positively to biodiversity, governance and human wellbeing aspects in order to contribute to social development and poverty alleviation and many Asian countries have adopted this principle. EBFM is very useful in situations where conflict resolution is required. All Asian countries have EBFM aligned activities and there are many initiatives that are aimed at implementing the CCRF. For example, India has stated in its Marine fishery Policy of 2004 that marine fisheries management should be placed in the context of EBFM. Many traditional systems have practices that broadly conform to EBFM principles but are not recognized as “Ecosystem-based” approaches and there is a lack of appreciation of what is already being done. EBFM can also be used for addressing adaptation/resilience of fisheries and aquaculture to climate change impact/effects. Each country has its own context for policy development and resource allocation, therefore implementation of EBFM will differ depending on that context. Many countries note that existing legislation and/or policy may not explicitly support the EBFM and will require amendment or updating.

A regional consultative workshop on practical implementation of the Ecosystem Approach to Fisheries and Aquaculture in the APFIC region was held at Jeju, Republic of Korea, 6-8 September 2010 and adopted an action plan and recommendations from APFIC Regional Consultative workshop on “Practical Implementation of the Ecosystem Approach to Fisheries and Aquaculture” held at Colombo, Sri Lanka during 18-22 May 2009. Member countries were of the view that mainstreaming EBFM as a national system for management requires strong commitment of government and other relevant stakeholders.

The Fisheries Improved for Sustainable Harvest (FISH) project in the Philippines is likely the first EBFM project in the tropics and is at early stages of implementation. The FISH project is a seven-year effort focused on strengthening the capability of local and national institutions to manage coastal resources and marine fish stocks (www.oneocean.org). It is funded with an eight million dollar grant from 2003–2010 from the US Agency for International Development (USAID) to the Philippine government with technical assistance provided by Tetra Tech EMI, a private consultant agency, and other institutions (e.g., University of Washington).

India has also taken the initiative to construct models of trophic interactions of food webs of some of the important aquatic ecosystems. For example the Arabian Sea off Karnataka has been modeled (Mohamed et al., 2008) and preliminary ecological simulations have been done to aid fisheries policy (Mohamed and Zacharia, 2009). Similarly an inland reservoir has been modeled and changes in management policy were compared on a

temporal basis (Panikker and Khan, 2008). Similar modeling exercises are also underway in Thailand and Malaysia.

FUTURE OF EBFM

Hilborn (2011) predicts two possible futures for EBFM that are not mutually exclusive. The core elements of EBFM, getting single-species fishing mortalities right, reducing by-catch, and protecting sensitive habitats, are widely accepted, being implemented, and are reasonably inexpensive. This will mean lowering fishing mortality on all species below the levels that produce MSY and probably lowering even more the exploitation rates on forage species. Various agencies are now using various ecosystem indicators to modify their regulations (Fletcher et al., 2010). Essentially, ecosystem impacts of competition and predation are ignored when single-species assessments are used on a stand-alone basis. This aspect of EBFM could significantly modify management since the U.S. and many other countries use estimates of unfished biomass when making harvest decisions.

The second phase of EBFM is true ecosystem-based control rules, supported by ecosystem models and ecosystem indicators. Hilborn (2011) states that this second phase will not occur for many years because of the high cost and lack of ecosystem-based objectives. There is a great deal of science going into using ecosystem indicators (Smith et al., 2007; Fletcher et al., 2010) and there is little sign of implementation and acceptance with ecosystem models replacing current single species models.

Lastly, EBFM does need to take account of the role of people in the ecosystem. Much of the current implementation of EBFM relates primarily to the natural ecosystem and regulation of harvest and gears are the key control variables. Another major element of fisheries management is allocation of access to fishing. There is considerable dispute over this area of fisheries management, and allocation often consumes as much management energy as does harvest regulation. Meanwhile, increasing evidence points to an interrelation between how fish are allocated and the ecosystem consequences of fishing (Costello et al., 2008). These new vistas need to be studied in the Asian and tropical seas context, but it is quite clear that the holistic EBFM is the way forward in fisheries management and conservation.

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