Ecosystem Management, Marine Reserves, and the Art of Airplane Maintenance

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ABSTRACT

The need to move fisheries management from a single-species to an ecosystem approach is widely recognized. Although both approaches have similar goals, they have fundamentally different scope and philosophy. Traditional *single-species management* deals with individual species under a "fix it when it breaks" philosophy. *Ecosystem management* deals with multiple species under a philosophy of preventing fisheries failures by maintaining natural ecosystem structure and function. An essential element of ecosystem management is the establishment of "no-take" marine reserves, areas where extractive activities are prohibited. These areas are needed to better understand ecosystem structure and function and to serve as reference areas for evaluating ecosystem performance and the impacts of fishing and other extractive human activities on the marine ecosystem. Expanded monitoring of populations, habitat, physical factors, and the human dimension is necessary to assess the dynamics, interactions, and performance of key ecosystem components.

KEY WORDS: Conservation, exploitation, fisheries

INTRODUCTION

"If ecosystem management is to be more than another buzzword, then there is no substitute for understanding the structure and dynamics of natural ecosystem over spatial and temporal scales covering several orders of magnitude." (Holling and Meffe, 1996)

Frequent fishery failures have led to widespread calls for moving from single-species to ecosystem management (Murawski, 1991; National Research Council, 1994; Apollonio, 1994; Angermeier and Schlosser, 1995; Christensen *et al.*, 1996). Ecosystem management, however, is a new and evolving science in the early phases of being established (Grumbine, 1994; Wrona and Cash, 1996). The purpose of this paper is to further define and develop the concept of ecosystem management and to note the critical importance of establishing `no-take' marine reserves (Bohnsack, 1993) as part of that effort.

SINGLE SPECIES MANAGEMENT

Fisheries have traditionally dealt with single-species, classified according to type of fishing gear used (e.g. hook-and-line, trap, trawl fisheries) or economic category (i.e. recreational, commercial, artisanal). Models used were developed for large scale temperate fisheries and often have failed to sustain fisheries productivity and protect biodiversity, especially in complex tropical ecosystems (Boehlert, 1996). Protecting marine biodiversity has rarely been an implicit priority in single species models, despite the fact that fisheries productivity depends directly on biodiversity at the genetic, species, community and landscape levels.

Failure of single-species fishery models are due to a variety of social, economic, and biological factors (Ludwig *et al*., 1993; Bohnsack and Ault, 1996) including limited data for many species; excessive value given to short term economic considerations; inadequate consideration of scientific advice in political processes; and a failure to effectively incorporate a risk-adverse precautionary approach to management (Dayton *et al.*, 1995). Most fishery models fail to adequately consider environmental variability and interactions between species, habitat, and the human dimension. Groundfish trawls, for example, alter the physical structure of benthic habitats, an effect that has been largely ignored (Auster *et al*., 1996). Reduced habitat complexity may lead to increased predation on juveniles of harvested species and ultimately recruitment to the harvestable stock. Also, discard mortality from one fishery may greatly impact species in other fisheries. Shrimp trawl bycatch, for example, impacts a variety of ecologically or economically important species (Goodyear and Phares, 1990; Murray *et al*., 1992).

With single-species management, corrective actions are usually taken only after a problem has become acute and clearly demonstrated. Fisheries often undergo significant declines or collapse before corrective actions are taken due to time lags in data collection, review, and other factors (Bohnsack and Ault, 1996). Often, no historical data exist to demonstrate adverse changes. Even with data, there is no agreement about what defines a fishery "collapse". Fisheries often continue to operate when a stock is only a tiny percentage of its original size. Major declines in stock abundance and fishery landings are often dismissed as "natural cycles" or attributed to factors without supporting scientific evidence (Hutchings and Myers, 1994).

Even with good historical data, significant ecosystem changes often are not recognized because the changes are outside the direct experience of living individuals. Few people in North America, for example, notice the absence of passenger pigeons, despite the fact that they once accounted for a fifth of all birds in North America. Pauly (1995) called this the "creeping baseline syndrome" where each generation accepts current conditions as the baseline for monitoring "natural" change and discounts, as anecdotal, historical accounts of past conditions. Often historical accounts are relegated away as grossly distorted, ludicrous, or outlandish.

ECOSYSTEM MANAGEMENT

Christensen (1996) defined ecosystem management as "management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based in our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function." Ecosystem management does not alleviate the need for single-species analyses which must still be done as a starting point (Murawski, 1991). However as a practical matter, full stock assessment can only be done on a very few species that managers must consider. Ecosystem management requires expanded use of comprehensive fishery independent data , increased information from the human dimension, and integration of biological, physical, and other environmental data into the management process.

Ecosystem Management and Airplane Maintenance

Traditional single-species fisheries management is usually practiced under a "fix it when it breaks" philosophy. Action is taken only when a problem occurs and is analogous to how automobiles are often maintained. Parts such as a water pumps, batteries, radiators, and alternators, for example, are repaired or replaced usually after they fail. This approach works fairly well for automobiles because failure of most components, although inconvenient, usually is not life threatening: either the engine never starts or a car can be safely pulled off the road for repair or until help arrives. Only a few of the most critical safety systems are engineered to make failure extremely unlikely. Redundant systems are provided for only the most important systems (e.g. emergency brakes, rear view mirrors, headlights, brake lights, and backup lights). System monitoring may be limited to a few basic items such as fuel, speed, and engine temperature.

In contrast, ecosystem management is more analogous to airplane maintenance: the ultimate goal is to maintain the total system by preventing failure of all important systems and components (e.g. wings, landing gear, navigational and electrical systems, etc.). Both fisheries and airplane maintenance share a common goal of avoiding 'crashes.' Success requires: (1) understanding of how various systems operate; (2) building margins of safety into all operational systems; and (3) continuous monitoring of all critical elements. Specific objectives of monitoring are to assess all essential components to detect and correct unacceptable changes before they become major problems. Airplanes are designed with numerous, often redundant systems to monitor operational performance. Instrument displays, for example, provide status information about fuel storage, fuel consumption, engine temperature, altitude, air speed, ground speed, direction, attitude, pitch, and multiple other essential parameters. Redundant systems, sometimes with two backups, compensate for unanticipated failures. Modern aircraft, for example, routinely have three navigational computers, dual steering consoles, multiple engines, and manual backups for certain hydraulic or electrical systems.

Airplane operation and maintenance procedures have been carefully developed after detailed, costly, and painstaking efforts to determine performance criteria. Very precise instructions are provided on when to change the oil, how fast to run the engine, and how many hours between overhauls. Most operating systems even have automatic or computer aided monitoring and performance checks to detect and correct problems. Warnings are automatically given if the engines are running too hot or if the glide path is too steep. Similar models are needed for ecosystem management. Performance criteria must be identified, described, and monitored, often with multiple and redundant systems. When performance is outside of acceptable tolerance levels, real-time response systems must be in place to take necessary corrective actions. This can only be accomplished by having a good understanding of the working components of the system, both human and natural.

Marine Ecological Reserves

Unlike airplanes, ecosystems do not come with operation manuals. For this reason it is absolutely essential to establish "no-take" marine ecological reserves, areas protected from all extractive activities. Such protected areas are needed to serve as a reference guide by showing how natural systems operate and perform. Marine reserves can provide critical baseline information to measure change and allow a better understanding of ecosystem structure, function, and performance. They also serve as "controls" for evaluating impacts of fishing and other extractive human activities on surrounding areas. If management is going to be scientifically based, it is absolutely necessary to have minimally disturbed "reference" areas available for comparison (Ballantine, 1994 and 1997).

Most marine communities probably have been highly altered. This conclusion is supported by changes demonstrated in studies of areas placed under protection from fishing, including intertidal (Duran and Castilla, 1989; Castilla, *et al.*, 1994) and subtidal communities (Towns and Ballantine, 1993; Polunin and Roberts, 1993; Bohnsack, 1996). Robles (1996) provided a recent illustrative example where rocky intertidal areas at Southern California Channel Islands were dominated by seaweed mats while similar habitats on or closer to the mainland were dominated by mussels. Previous explanations for the difference centered on environmental factors killing the mussels: drying Santa Anas winds, hot sun, and low tides. It turns out that spiny lobster destroy mussels at night during high tides, allowing algae to dominate at offshore areas. Due to intense fishing, spiny lobster have been largely eliminated from the inshore coastal habitats, suggesting that inshore mussel dominated communities may be an artifact of fishing activity. Even at larger scales, current conditions probably rarely reflect historical conditions. MacIntyre *et al.* (1995) estimated that biomass in the Atlantic western Boundary current fisheries is only 3 to 10% of what it was when fishing started based on accounts for 60 marine species. Jackson (1997) concluded that similar human-caused changes had occurred in the Caribbean. Changes often occur slowly, insidiously, and persistently until what is "natural" can no longer be recognized.

Few marine areas exist that are protected from all extractive activities. Despite common sense and the fact that large land areas are protected from exploitation, marine reserves remain controversial and are only beginning to be incorporated into policy for most countries. In the Florida Keys National Marine Sanctuary, for example, the establishment of 19 no-take zones in 1997 included less than 1% of Sanctuary waters (U.S. Department of Commerce, 1996). Likewise, California, despite having 104 marine protected areas, currently has only a few hectares under no-take protection (McArdle, 1997).

The lack of marine reserves is an historical accident based on mistaken beliefs. Classically, scientists and managers have assumed that human activities were inconsequential in the marine environment (Knauss, 1992; Hutchings and Myers, 1994). We now know that this assumption was mistaken although denial is still a problem. With the growing importance of human activities, we must question the assumption that ecosystems can be self-maintaining without managing human activities.

Fisheries have classically operated in a command and control framework that assumes fisheries will respond in a precise, deterministic manner with predictable outcomes. Holling and Meffe (1996), noting the increasing failures of "command and control" management in conservation, recommended a golden rule of conservation:

—*"Natural resource management should strive to retain critical types and ranges of natural variation in ecosystems."* —

No-take marine reserves offer perhaps the only way to achieve this goal.

Human Dimension

The human dimension is poorly understood and rarely considered in single-species fishery models. Human activities interact with natural resources in complex ways. Attempts to limit fishing effort, predictably result in human behavior to circumvent their effectiveness. Also, management actions in one fishery can detrimentally impact other species and fisheries by redirecting fishing effort toward other species. The consequences of such behavior may not be easily predicted and are rarely anticipated in fishery models.

A goal of ecosystem management should be to incorporate humans as part of the ecosystem and anticipate changes in the human dimension. Achieving this goal will require a much better understand the human dimension, better monitoring of human activities, and the development of predictive models of human behavior. Instead of reacting to changes in human behavior, ecosystem management can anticipate and incorporate changes into management models. Likewise, it will also be necessary for people to have realistic expectations and to operate within ecosystem limitations (Bohnsack and Ault, 1996).

CONCLUSIONS

A shift from single-species to ecosystem management represents a significant change in philosophy and management. No-take marine ecological reserves are an essential component of ecosystem management and are not a luxury. Marine reserves are necessary for understanding ecosystem structure, function and processes; for measuring changes; and for assessing management performance. More fishery-independent monitoring is needed to supplement fishery data. Successful ecosystem management must routinely include more biological, physical, and environmental information and better integrate the human dimension into management practices.

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