Incorporating Human and Ecological Communities in Marine Conservation: an Alternative to Zacharias and Roff

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In a recent essay, Zacharias and Roff (2000) transformed a terrestrially based framework for biodiversity monitoring proposed by Noss (1990) into a conservation program that they suggest can be applied to marine realms. This new framework is intended to address marine conservation issues and provide guidance in the design of conservation strategies. Zacharias and Roff's approach is descriptive and hierarchical, nesting genetic structure within species within community composition within abiotic, oceanographic conditions. They conclude that conservation is often best served by classifying and delineating spatial domains according to the largest, abiotic level of this hierarchy, in large part because physical measurements are relatively easy to obtain. Thus, they urge that increased efforts be spent gathering data on water properties, bottom topography, wave exposure, substrate type, depth, disturbances, entrainment, and desiccation in marine environments (terms selected from their Table 3). We concur with parts of their rationale for this large-scale approach to conservation. In marine systems, biological communities can map onto abiotic conditions, and threats often occur at scales beyond local space-based conservation efforts.

We depart from Zacharias and Roff because we are not confident that an ecological approach to conserving marine biodiversity based on physical and chemical measurements will be effective. Their modifications alter the purpose of Noss's original framework and fail to account for biotic interactions and socioeconomic issues that necessarily influence management options. We propose an alternative framework that emphasizes the reciprocal links between ecological processes, anthropogenic threats, and management options in marine systems.

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Noss (1990) provided a variety of potential variables (mostly biotic) that could serve as indicators of environmental status and trends across four levels of organization (genes, species, communities and ecosystems, and landscapes) and three components of organization (composition, structure, and function). Zacharias and Roff (2000) state that such a hierarchical framework can be "used to assess the various conservation options" (p. 1333) and can inform the selection of variables for monitoring. Their core message, however, is that precise areas for conservation can be identified based on physical and chemical parameters. In their essay, Zacharias and Roff abandon much of the original flavor of Noss's approach, which included hypothesis testing, adaptive management, integration across scales, and practical steps for selecting and using indicators. Our own bias is that effective conservation requires an understanding of how systems work. System processes, particularly species interactions and spatial phenomena, are central to the maintenance of diversity, are often directly affected by anthropogenic change, and can alter the intended consequences of management actions.

The development of conservation and management plans for marine ecosystems requires an understanding of the fundamental mechanisms that maintain and regulate marine biodiversity. Although physical and chemical factors may influence patterns of biological diversity, even a perfect physical and chemical map of the ocean would not be sufficient to indicate how much or where protection should be focused. First, it is clear that species interactions themselves influence patterns of biodiversity. Indeed, the original and classic examples of single species strongly influencing entire local communities were from marine systems (Paine 1969; Estes & Palmisano 1974). Second, environmental managers require biological information, including migratory patterns, optimal breeding sites and seasons, critical life-history stages, growth rates of individuals and populations, specific habitat requirements, dispersal distances, population responses to low numbers, and species interactions (Botsford et al. 1997; Castilla & Fernandez 1998; Kramer & Chapman 1999; Zeller & Russ 1998; Walters 2000). For instance, spatial protection is not the best way to conserve threatened loggerhead turtles: protecting nesting beaches has much less impact on population growth than reducing the bycatch of juvenile and subadult turtles (Crouse et al. 1987). Major climatic and oceanographic shifts can have surprising consequences for biodiversity when translated through complex food webs. For example, the Pacific Decadal Oscillation is thought to alter productivity in entire ocean basins (Mantua et al. 1997), which may be partly responsible for recent dramatic declines in Aleutian sea lions. Consequently, orcas (*Orcinus orca*) have shifted to diets of sea otters (*Enhydra lutris*), causing cascading effects that even include coastal nutrient dynamics (Duggins et al. 1989; Estes et al. 1998).

In addition to contributing to spatial and temporal patterns, species interactions also alter the outcome of conservation actions. Even inside protected areas, for instance, prey species can decline as a result of top-down effects (Cole & Keuskamp 1998; Babcock et al. 1999). The slow recovery of cod in the Northwest Atlantic has been attributed to an increase in pelagic fishes that are predators or competitors of early life-history stages of cod (Swain & Sinclair 2000). Ecosystem-level consequences of exploitation, such as the alteration of food webs, may contribute to the inability of some fish stocks to recover rapidly despite protective measures (Hutchings 2000). In an iconic example of how community dynamics and conservation interact, artesenal fisheries change the relative abundance of exploitable resources both directly and indirectly in Chilean intertidal systems (Castilla & Durán 1985; Castilla & Fernandez 1998). Identifying priority information needs for sustaining marine fisheries, the National Research Council (1999) explicitly states the need to understand mechanisms at lower levels of organization—populations and communities—and the need for multispecies trophic models. Ironically, Zacharias and Roff dropped community dynamics from Noss's original conservation framework, thereby downplaying the levels of organization that are directly influenced by humans. Threats such as introduced species, exploitation, and pollution can affect food webs without obvious consequence for abiotic conditions.

Zacharias and Roff also replaced Noss's landscape considerations (patch structure, patch dynamics, anthropogenic disturbance) with a simplified oceanographic view of marine ecosystems. But coastlines are heterogeneous and subject to substantial habitat modification, while patchiness in the open ocean arises from both biological and physical processes. Population persistence of broadcast spawners likely requires habitats in networks connected by larval dispersal. Furthermore, many species change habitat preferences as they age. Consequently, conservation efforts will be most effective if they acknowledge both habitat diversity and its connection to biological life cycles. Because most current threats to marine environments occur at land-ocean boundaries, including continental shelves, fragmentation of these habitats (e.g., seagrass, kelp beds, mangroves, coral reefs) needs to be addressed.

To be of use to managers, a conservation framework must include more than physical descriptions of ecosystem parameters and simple organismal biology. Marine resource management is strongly influenced by the opinions and actions of stakeholders, an influence particularly acute in marine systems because of overlapping jurisdictions and disputed access to a pelagic "commons." In Washington state, for example, marine conservation must incorporate private landowners who own half of the tidelands, several state agencies that control the benthos versus fish stocks, tribal nations with usual and accustomed fishing rights, and commercial and recreational users who expect access to resources. Stakeholders can be incorporated throughout the process of establishing new management guidelines, as is currently done in national marine sanctuaries (National Oceanic and Atmospheric Administration 1996). Equally, stakeholders can be presented with several biologically feasible solutions to address conservation problems and asked to choose among them (Ferrier et al. 2000).

Following Noss (1990) and Zacharias and Roff (2000), we propose an alternative conceptual framework for conserving marine systems. Rather than relying on abiotic characteristics to define marine conservation strategies, our approach focuses on the threats to marine systems. Figure 1 illustrates spheres of influence in marine conservation; it is designed to point out key connections rather than to be comprehensive. The inner sphere, representing an ecosystem, includes biological structure (habitat), interactions (food webs), and abiotic conditions, with abiotic conditions and habitat clearly influencing species interactions. The middle sphere includes the five major threats to marine environments (National Research Council 1995) and their primary interrelationships. The outer sphere constitutes corresponding management options. In the United States, threats such as pollution are often addressed through lawsuits because of the power of the Clean Water Act, whereas exploitation is the domain of fisheries management. Consequently, the proximal target for each management option is human behavior (middle sphere in Fig. 1) rather than ecosystems (inner sphere). Socioeconomic tradeoffs embodied at the threat level represent an additional constraint to strategies of marine conservation. Consider a variety of seabirds that are bycatch victims of longline fishing globally (Ryan & Boix-Hinzen 1998). Once this threat is recognized, fishing restrictions can be considered in light of fishers' profits, technological developments, and informa-

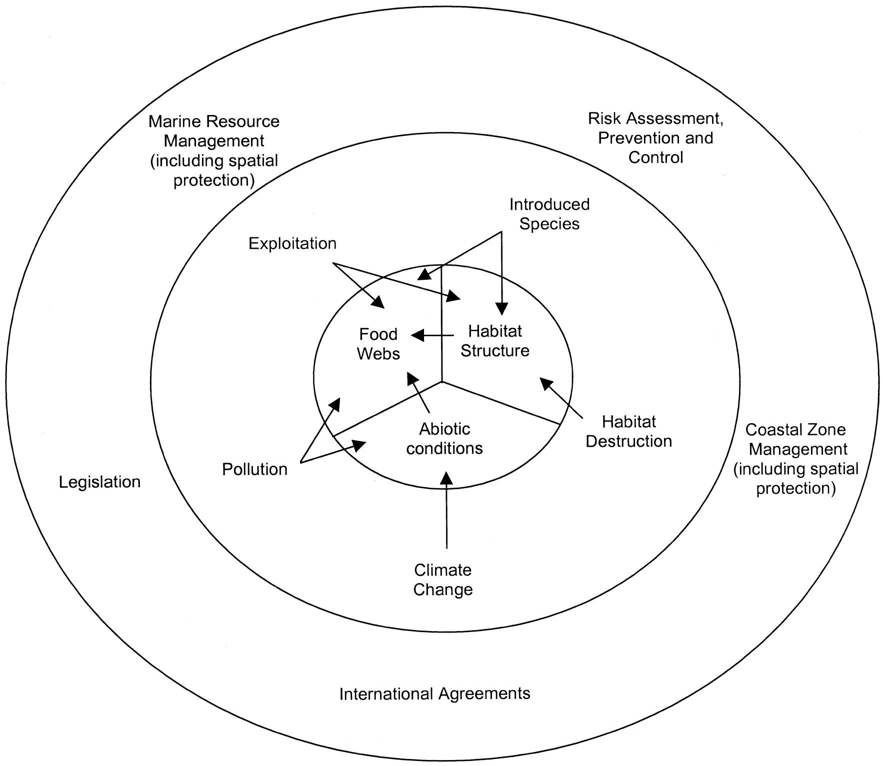

Figure 1. Spheres of influence in marine conservation. The inner sphere includes biological structure, interactions, and abiotic conditions, with arrows showing the influence of environmental conditions on food-web interactions. The middle sphere includes the five major threats to marine environments and their primary pathways of influence. The outer sphere constitutes management options. Others (Pajak 2000) have crafted similar conceptual frameworks in which the spheres are inverted, with the environment as an outer boundary within which societies and institutions exist.

tion on times, places, and prey bases where birds are active. It is difficult to imagine how Zacharias and Roff's flow charts (their figs. 1 & 2) would help determine what new information to gather, because identifying representative or distinct areas is of no consequence. Still, abiotic conditions may be influential if, for instance, birds are attracted to certain abiotic features of the ocean in which their prey are concentrated.

Our conservation framework is broad enough to account for the variety of threats facing marine ecosystems and could be usefully combined with frameworks proposed previously. These frameworks include the use of hierarchical indicators to assess biological status and trends (Noss 1990), identification of management regions based on biotic interactions and abiotic conditions (Zacharias & Roff 2000), and the inclusion of stakeholder concerns in determining whether conservation strategies are effective (Pajak 2000). In short, we believe that our capacity to conserve marine resources and the ecosystems in which they are embedded will be diminished if conservation efforts focus on physical and chemical descriptions and discount the known significance of biological interactions and social constraints. Most emerging marine conservation challenges, along the shore and at sea, are driven by human excesses. Solutions primarily require addressing the biological causes in politically practicable, socially responsible, and ecologically informed ways.

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