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Paradigms of sustainable ocean management

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ABSTRACT

Covering nearly half of the Earth's surface, the high seas provide a diverse range of ecosystem services crucial to human well-being and the health of both marine and terrestrial ecosystems. At the same time, the vastness of the high seas and the limitations of corresponding governance instruments present a considerable challenge to policy-makers working to promote sustainable management. This report reviews new developments in sustainable management of the oceans, including the high seas, which has often focused primarily on fishing regulations, while lacking broader consideration of marine ecosystem services and material cycles. In addition, an overview is provided of paradigms for assessing and managing marine systems. Enhanced interdisciplinary and cross-sectoral communication based on clear definitions is needed to achieve deeper understanding of marine ecosystems and the services they provide. Experts discussed these and other issues on October 1, 2013 within the context of an international symposium held at the University of Tokyo on the "Future Management of Ocean Ecosystem Services". This manuscript provides a brief overview of these discussions together with supplementary background material.

1. Introduction

The oceans cover over 70% of the Earth's surface area and constitute a complex challenge for policy-makers and researchers alike. Part V of the 1982 United Nations Convention on the Law of the Sea (UNCLOS) formally recognizes exclusive economic zones (EEZ), thereby providing a framework for sovereign states to manage their coastal waters, generally within a 200 nautical mile boundary [1]. A rigorous and detailed paradigm for management of the high seas, which constitute marine areas beyond the EEZ and therefore nearly half of the Earth's surface, has remained elusive.

Ecosystem services arising from the ocean impact the whole human population, and link with effective functioning of many terrestrial ecosystems. In terms of provisioning services alone, an estimated 2.6 billion people rely on the oceans for their primary source of protein [2]. At the same time, regulating services, including the ocean's absorption of roughly 30% of annual carbon dioxide emissions produced by humans, have drawn increasing recognition within the context of climate change discussions [3].

Despite the vastness of the oceans, truly pristine or untouched areas no longer exist, and over 40% of the ocean has been estimated to be heavily affected by human activities [4]. Anthropogenic changes to marine ecosystems are occurring from the micro to the macro level, ranging from alterations to the ocean's biogeochemistry, including rising ocean acidification levels (currently higher than at any point in the last 800,000 years) to the elimination of apex predators due to unsustainable fishing practices [5,6]. Increasing rates of potentially irreversible biodiversity loss have been noted in both terrestrial and marine areas [7]. While these changes are significant in themselves, there are strong synergistic effects among them, further amplifying their overall impact. Furthermore, significant gaps are evident in high seas governance, which often focuses primarily on fishing activities and regulations, while largely disregarding the broad bundle of ecosystem services being provided by the oceans. Likewise, the growing body of knowledge about how strongly marine and terrestrial systems are linked underscores the challenges associated with identifying the whole range of relevant stakeholders for discussing governance issues.

An international symposium held at the University of Tokyo on October 1, 2013 brought together a range of international and domestic experts to discuss issues surrounding the conservation and sustainable use of the oceans, primarily towards identifying further needs and to propose new areas or mechanisms of ocean governance. Points of discussion included existing paradigms of ocean management, methodologies for assessing marine health, and the prevailing marine policy environment. In addition, the scope and objectives of a five-year collaborative project on the "New Ocean Paradigm on its Biogeochemistry, Ecosystem and Sustainable Use" (NEOPS) was introduced and discussed. A summary of salient aspects of these discussions is included here along with considerations for the development of a new paradigm based on the division of the ocean into provinces defined by their material cycling and ecosystem functions.

2. Assessment and sustainable management of ocean ecosystem services

2.1. Paradigms of ocean management

Extraction of marine resources, primarily fish, characterizes the core element of most ocean management activities today. Historical examples exist, however, demonstrating deep understanding of nutrient cycles and land–sea linkages, including the planting and management of upstream forests by fishers in Japan [8]. Likewise, a scattering of marine protected areas (MPAs) with varying levels of monitoring and enforcement mechanisms formally regulate extractive activities in some areas [9]. Eco-tourism

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also represents a substantial incentive to pursue marine conservation activities. With tourism considered to be the largest industry in the world, constituting 10% of global GDP, eco-tourism alone accounts for revenues totaling USD 10–17.5 billion annually [10].

In accordance with UNCLOS Article 56, an area-based management paradigm characterizes the EEZ around the world, specifically recognizing the sovereign rights of coastal states "for the purpose of exploring and exploiting, conserving and managing the natural resources". Furthermore, Article 61 gives coastal states the capacity to determine catch limits for living resources within its EEZ [1].

Highly migratory species pose a challenge for area-based management, as such species are likely to move across multiple sovereign territories as well as the high seas over the course of their life cycles. Article 61 of UNCLOS provides a framework for quota-based management in such conditions, "taking into account the best scientific evidence" and in cooperation "as appropriate" with "competent international organizations, whether subregional, regional or global" [1].

Around 60% of the ocean lies outside of the EEZ, rendering current forms of area-based management a partial solution at best [11]. Quota-based management is also contentious, in part, due to disagreements over the role that maximum sustainable yield (MSY) should play in calculating quotas. Furthermore, the static nature of MSY calculations is poorly adapted to take into account natural fluctuations within the ocean – an inherently dynamic system – as well as limitations in the availability of data for the high seas [12].

In a broader sense, the Convention on Biological Diversity (CBD) has cited the ecosystem approach as the "primary framework for action under the convention" [13]. Accordingly, the 193 Parties are called upon to apply the approach, as appropriate, towards "integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way" [13]. Among other things, the approach recognizes the integral role of people in many of the world's ecosystems as well as the need for adaptive management to address the inherent dynamism of ecosystems and the incomplete information available about their underlying processes.

2.2. Assessing marine ecosystems

Defining ecosystem health can be problematic, and often takes on human-centric proportions. The ubiquity of human influence on marine systems, however, precludes the possibility of assessing these ecosystems independently of human systems. A number of tools have therefore been developed, based in part on the concept of coupled socio-ecological systems.

Efforts are still underway to develop adequate assessment tools to understand terrestrial systems, but assessing marine systems may be considerably more challenging. "On-the-ground" verification of models becomes more complicated – counting fish stocks, for example, has been compared to "counting trees, except that you do not see them and they move" [14]. Not only is the surface area of the oceans vastly larger than the Earth's land mass, but marine systems extend into a third dimension, while terrestrial systems are comparatively two-dimensional. Shifting of populations due to changing ocean and climate conditions may further aggravate this challenge [15].

In addition, primary production is vastly different in terrestrial and marine systems. Annual net primary productivity in terrestrial and marine areas has been estimated at 780 and 147 g/m^2, respectively [16]. Biomass per unit area shows an even more dramatic difference, with densely populated systems like tropical rainforests being estimated to contain 6–80 kg/m^2 of biomass, while the open ocean is estimated at 0–0.005 kg/m^2 [16].

With these and other considerations in mind, four different systems for assessing marine ecosystems are briefly described in the following sections and summarized in Table 1.

2.2.1. The Ocean Health Index

A collaborative effort aimed at providing a comprehensive measurement of ocean health, the Ocean Health Index (OHI) is based on the definition of a healthy ocean as one that "sustainably delivers a range of benefits to people now and in the future" [17]. A broad set of 10 goals encompasses both human-centric (e.g., food provision) and nature-centric (e.g., biodiversity) considerations. Scores from all 10 goals are combined into an overall rating for each of the 221 countries and territorial regions being assessed [17]. These, in turn, are compiled into a global score.

Collaborators on the OHI see its value in bringing together a wide range of indicators that are often considered in isolation, and making them easily comparable. The resulting scores are meant to serve as a neutral, science-based tool to support policy-makers in setting management goals and designing corresponding interventions. Launched in 2012, the OHI released its second set of scores in October 2013, and efforts are currently underway to expand the scope of the assessment to include the high seas. Furthermore, a toolbox is under development to enable application of the OHI at any scale or location, opening up the possibility for sub-regional and local assessments [18].

2.2.2. Fishery Performance Indicators

The triple bottom line of ecological, economic and community sustainability is at the core of the Fishery Performance Indicators (FPIs) developed by several researchers as a rapid assessment instrument for the World Bank and others to provide "a clear picture of the ecological, social and economic situation associated with the fisheries management system" [19]. A cornerstone of the development and application of the FPIs is an understanding that economic issues related to food security, poverty reduction and income generation are all inextricably linked to conservation and sustainable use of biodiversity.

The 117 FPIs are divided into input indicators (50) and output indicators (67) – the former are used to measure inputs that enable the success or failure of the fishery, while the latter capture the performance of the fishery in line with the economic, ecological and social terms of the triple bottom line [20]. The broad range of indicators reflects a view that many different factors can combine in complex ways for a larger cumulative impact, weakening the explanatory potential of piecemeal assessments of individual aspects of a fishery. At the same time, potential problem areas can be identified through comparative analysis of indicator data from different fisheries as well as through classification and weighting of the respective indicators associated with ecological, economic and community sustainability.

2.2.3. Ecologically or Biologically Significant Marine Area criteria

During the Ninth Conference of the Parties to the Convention on Biological Diversity (CBD COP9) held in May 2008, scientific criteria were formally adopted for the identification of Ecologically or Biologically Significant Marine Areas (EBSAs) in need of protection [13]. Seven criteria for identifying such EBSAs were created and the CBD Secretariat has held a series of regional workshops to bring together scientists and experts to describe marine areas according to the criteria. As of October 2013, 92 countries have been involved in the process, and about 75% of the total ocean area has been considered. As a result, 172 areas satisfying the EBSA criteria have been identified both within and outside of areas under national jurisdiction [21].