Integrating Biological, Physical, and Social Coral Reef Monitoring Data: Challenges and Solutions

Integración de Datos de Monitoreo de Arrecifes de Coral Biológicos, Físicos y Sociales: Desafíos y Soluciones

Intégration des Données de Surveillance des Récifs Coralliens Biologiques, Physiques et Sociaux: Défis et Solutions

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ABSTRACT

Most drivers of coastal ecosystem change are linked to a range of anthropogenic influences. Greater connections and inferences between observed changes in coastal ecosystem quality, and human and social parameters could be achieved if biophysical and social science disciplines work together at the inception of any monitoring program for effective coastal resource management.

Progress towards integrated monitoring is improving globally via initiatives and programs. The Global Coral Reef Monitoring Network (GCRMN) developed a Socioeconomic Manual for Coral Reef Management designed to improve understanding of the social and economic conditions, contexts and motivations associated with coral reef use. GCRMN Global Socioeconomic Monitoring Initiative (SocMon and SEM Pasifika) partners use it to guide regional data collection efforts. GCRMN-Caribbean partners recently developed recommended coral reef monitoring guidelines for integrated, standardized ecological and socioeconomic data collection.

The National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program has implemented a National Coral Reef Monitoring Program (NCRMP) for conducting sustained observations of biological, climatic, and socioeconomic indicators in U.S. states and territories. The social science component of NCRMP monitors a set of socioeconomic variables, including knowledge, attitudes, and perceptions of coral reefs and their management. Development of a suite of indicators to track trends in population and socioeconomic structure, impacts of society on coral reefs, and impacts of coral health on communities is the aim. In this paper, we discuss current progress, challenges, and next steps of these different monitoring efforts. We suggest potential ways to improve integrated monitoring and research that benefits coastal resource management.

KEYWORDS: NOAA, Coral Reef Conservation Program, SocMon, GCRMN, Caribbean, integrated monitoring, socioeconomic, indicators

INTRODUCTION

Integrated monitoring is a relatively new phenomenon that is steadily gaining global momentum. One of the major strategic objectives for the Global Socioeconomic Monitoring Initiative for Coastal Management (SocMon) is to ensure that coastal ecosystem resource management decisions are informed through integrated social and biophysical monitoring. Effective coastal resource management is only possible if biophysical and social science disciplines work together at the inception of any monitoring program. The Caribbean and Pacific Islands SocMon have begun exploring the integration of SocMon/SEM-Pasifika with ecological monitoring and its application to decision-making.

Similarly, the U.S. Government's National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Coral Reef Conservation Program has also embarked on a long term monitoring effort that explicitly includes a socioeconomic component. However, the gaps between biophysical and socioeconomic information and their combined use in decision-making remain. This has been in part due to a lack of adequate research that examines the interrelationship of social-ecological systems and the complex two-way relationships between people and coastal and marine resources. Most site or location specific coral reef monitoring shows few examples of any social science monitoring where it exists, the efforts are typically, separate with research teams operating in silos. As a result, these disconnected data streams (social and biophysical) makes it difficult to detect complex patterns, relationships and interacting processes of the two interconnected systems. There continues to be a gap between research and monitoring that examines how changes in biophysical conditions impact ecosystem services, and what, if any, are the human well-being outcomes of management activities centered on ecological health. This paper presents two examples were researchers are attempting to bridge the gap between the biophysical and social science monitoring that occurs in coral reef ecosystems and locales.

BACKGROUND

Traditionally, monitoring objectives for coral reef and fisheries resource management have primarily focused on biological and physical outcomes. Examples include collecting data to assess habitat condition, biodiversity, water quality, and species protection. Coral reef ecosystem monitoring from a biophysical perspective typically includes long-term

tracking of parameters such as; fish biomass, coral cover, diversity of marine organisms. Other typical examples include physical conditions such as water quality, acidification, and water temperature. Recognizing that people are an integral part of the coral reef ecosystem is required for a holistic approach to management of these resources. As a result, a more comprehensive conceptual framework is needed that links social and biophysical sub-systems within the wider coastal ecosystem. Combining multidisciplinary monitoring data on the biophysical and socioeconomic aspects of the system can yield information that improves adaptive management of these important resources (Wongbusarakum and Heenan 2018).

The development of Global Coral Reef Monitoring Network (GCRMN) Socioeconomic Manual for Coral Reef Management (Bunce et al. 2000) was intended to improve the understanding of the social and economic conditions, contexts and motivations associated with the use of coral reef ecosystems. At the outset, this manual also called for the integration of social science and biophysical information for the purpose of improving coral reef and fisheries management. The region specific guidelines that were subsequently developed for the Caribbean, Central America, Brazil, South Asia, Southeast Asia, Western Indian Ocean, and Pacific Islands also take the approach that coral reef and nearshore resource management works best with integrative approaches to planning, implementing, and monitoring for evidence-based decision- making.

The Millennium Ecosystem Assessment (MEA 2005) provides the basis for fostering integrated approaches to natural resource management. The MEA framework acknowledges that humans are an integral part of all ecosystems. The MEA groups the benefits people obtain from ecosystems into four categories. Provisioning services such as food and water and nature-based materials and resources; regulating services such as flood and disease control; cultural services such as heritage, spiritual, recreational, and cultural benefits and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. Successful conservation of coral reefs results in maintaining ecosystem services, which in turn benefits human well-being. A fully functioning coral reef ecosystem provides; food security by supporting reef-associated fish stocks; cultural, spiritual, and aesthetic values to people and society; human health and safety via storm protection by reducing coastal residents' vulnerability to extreme weather events and economic benefits and livelihoods via fishing and tourism.

INTEGRATED CORAL REEF MONITORING

Integrated monitoring, in this context, can be defined as monitoring that brings together biophysical and socioeconomic monitoring leading to a greater understanding of the ecosystem, including human communities. Similar to interdisciplinary research, integrated monitoring is a process of answering a question or addressing a topic that is too complex to be dealt with adequately by a single discipline or profession (Klein and Newell 1997). An integrated monitoring approach involves plans, designs, and objectives that should include biological, physical, and socioeconomic data collection and analyses. These data can complement one another to produce a holistic view of the social-ecological system and its interactions, and to better understand how management might affect each of the individual sub-systems as well as their interactions. Long-term and integrated monitoring through interdisciplinary research can provide reliable data thus creating a nexus between social, environmental and ecological data . The integrated data outputs can in turn inform timely decision-making exemplifying a holistic approach to management (Chettri et al. 2015).

Removing research silos requires acknowledging that human well-being is a key component that resides within natural resource management policies and objectives. Once this happens the natural progression in terms of research and management objectives should shift activities towards an interdisciplinary context. Often, humans are referred to in a negative context with regard to the environment. Terms such as human stressors, drivers, pressures or threats are commonly used in reference to the relationship between humans and natural resources. While some of these stressors may affect the properties and functions these resources, at the same time it is equally important to understand their *benefit to society* (Boerema et al. 2017).

Understanding interactions of biophysical and social systems is critical for planning and adaptive management decisions. The goal of integrated monitoring is to make explicit linkages among social and biophysical systems and to monitor how changes in one affect the other. Achieving this goal requires the involvement of multiple disciplines in monitoring. Despite the obvious need for integrated monitoring approaches, comprehensive frameworks to guide how biophysical monitoring and socioeconomic monitoring can be brought together, are either lacking or limited in scope.

GCRMN CARIBBEAN – INTEGRATED MONITORING FRAMEWORK

The Caribbean node of the Global Coral Reef Monitoring Network (GCRMN-Caribbean) have implemented a set of baseline scientific monitoring methods providing a basic framework for existing and developing monitoring programs to contribute data that supports a regional understanding of status and trends of Caribbean coral reefs. The purpose of this collaborative effort is to collect, collate and report on reef monitoring data that will be widely available for a variety of purposes including: contributing to the understanding of the processes that shape coral reefs; providing actionable advice to policy makers, stakeholders, and communities at a variety of special scales from local to Caribbean wide. GCRMN-Caribbean have proposed a set of preferred coral reef monitoring guidelines for ecological and socioeconomic data collection. These methods were drafted using the experience and lessons learned from long term and well vetted scientific protocols, and seek to provide a compromise between practical applicability and ease of comparison between existing methods and long-term datasets.

It is important to think about the ways social science information can be linked to drivers of biophysical changes to coral reefs. Integrated and interdisciplinary frameworks can lead to questions that provide management relevant

solutions towards ecosystem improvements. The Caribbean framework is based on the original GCRMN Socioeconomic Monitoring Manual (Bunce et al, 2000) and related regional-specific guidelines. However, based on the goal of the Caribbean node, this framework outlines broad sectors of human activity that can be potentially linked to observed ecological changes (see Table 1). These sectors can be considered to be drivers of coral reef ecosystem change and can be linked to major industries such as; tourism, fisheries, agriculture, other industries, as well as land use and demographic characteristics (UNEP 2017).

GCRMN Caribbean recognizes the importance of using this type of integrated approach to coral reef monitoring and in particular stresses the importance of systematic implementation of a monitoring of social science indicators in conjunction with biophysical monitoring. This will improve comparability and enhance the ability to make connections and inferences between observed changes in the coral reef ecosystem quality and human and social parameters across difference sites and countries in the Greater Caribbean area.

INTEGRATION OF NOAA'S CORAL REEF MONITORING

The National Oceanic Atmospheric Administration (NOAA) through its Coral Reef Conservation Program (CRCP) has been implementing a long term National Coral Reef Monitoring Program (NCRMP). This is the first time that systematic collection of biophysical and human dimensions data is being collected across all US Coral Reef Jurisdictions. The three main components are Climate (Sea Surface Temp, Ocean Acidification), Benthic (Fish and Corals), Socioeconomic (household surveys, secondary data). The socioeconomic component is the newest addition to CRCPC's monitoring efforts as the other biophysical components have had a longer history of various types of data collection. Socioeconomic data is collected in all seven (7) US jurisdictions, however even with the addition of this new data stream, NCRMP in its current form cannot truly be described as interdisciplinary. Even so, it may be possible to examine currently collected socioeconomic data alongside key biophysical parameters. One example could be comparing the public's perception of the quantity/quality of coral reefs in a given location, or the public perception of fish abundance (have numbers declined or increased) could be compared with coral health or fish biomass data collected by scientists using benthic monitoring approaches. If there are gaps between public perception of a key coral reef ecological attribute and the actual status then managers can decide how best to reduce the gap between perception and reality.

Beyond long-term coral reef monitoring, NOAA CRCP recently launched its strategic plan that is influenced by an ecosystem services framework. Figure 1 illustrates the ecosystem services framework that underpins the NOAA CRCP strategic planning and implementation process. Social science approaches including socioeconomic monitoring data will be a key component of this type of management framework.

Figure 1 illustrates the underlying assumptions beginning with;

i) Assumption 1: Good/successful management should lead to improved ecological functions (Green Box).
ii) Assumption 2: These improvements in ecosystem function should lead to the generation of coral reef relevant Ecosystem Services (Yellow Boxes).
iii) Assumption 3: improvements in ecosystem services should in turn lead to desirable Human Wellbeing outcomes (Clay Box).

Human well-being includes factors such as adaptation to climate change, social justice, and the ability to find gainful employment. This framework reinforces the connection between human health, well-being and healthy ecosystems of which a socio-ecological approach to monitoring key if the goal is to move towards improved interdisciplinary coordination and planning.

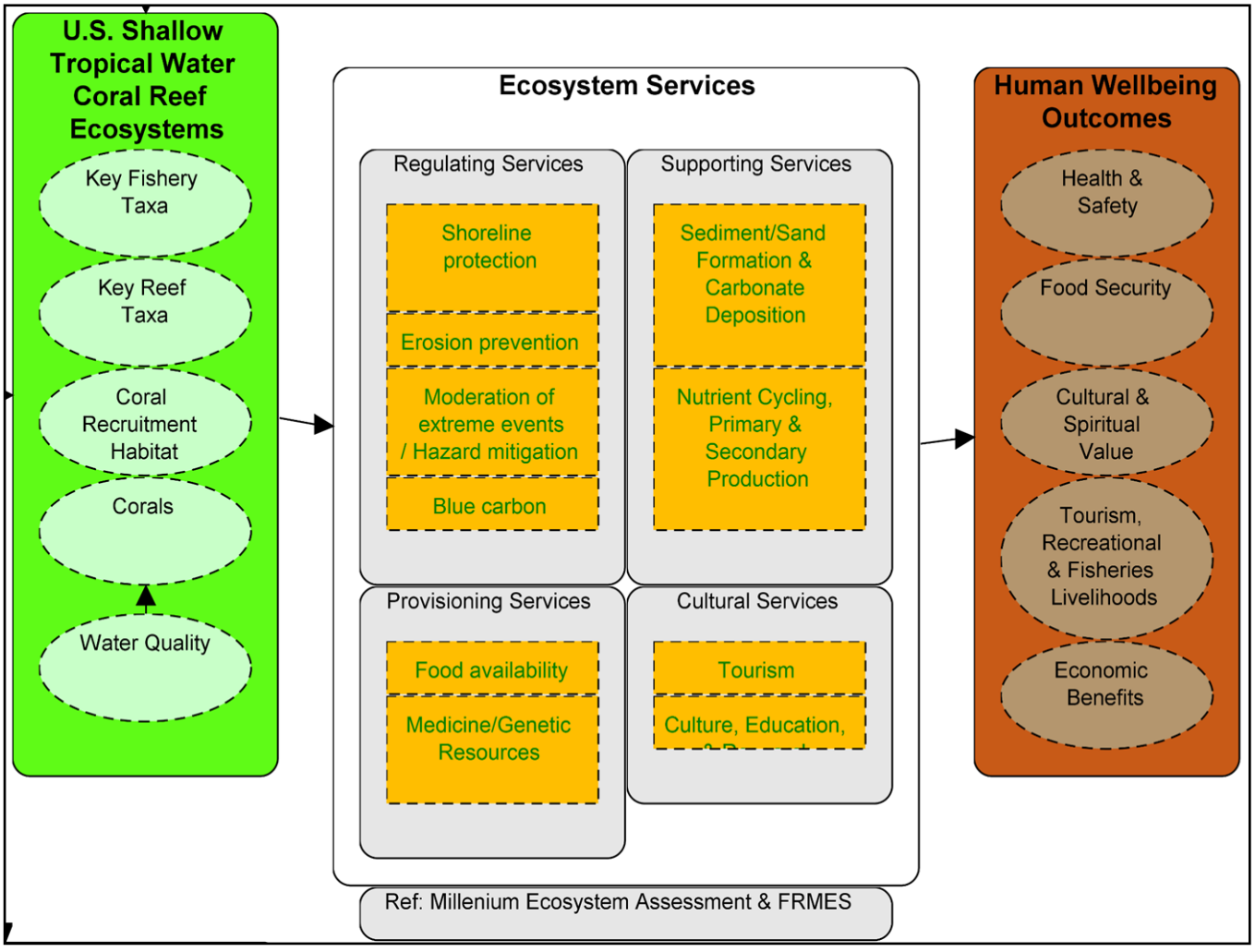
Table 1. Human linkages to potential drivers of change

Drivers	Description
Tourism	Tourist Arrivals, Types of Activities (where, when, frequency, density), Infrastructure, Carrying Capacity
Fishing	Fishing infrastructure, locations, fishing pressure (kgs fish/shellfish landed), gear types, number of fishers
Agriculture*	Large scale point source – coffee, sugarcane, lumber, abattoir
Industry	Mining/Quarries, Power Plants, Sewage Treatment
Population/Demographics	Distribution, point and non-point source
Land Use	Spatial distribution, open spaces, GIS information

DISCUSSION

Effective integrated monitoring is an interdisciplinary process that requires a cohesive and interdisciplinary research team with a strong collaborative work ethic and a commitment to learning about the system as a whole. Building the foundations for an effective team involves identifying a good mix of team members with expertise from socioeconomic monitoring and biophysical monitoring (Wongbusarakum and Heenan 2018). These members should share motivations and values, and understand that integrated monitoring usually focuses on a real-world problems including climate change and impacts to corals and people who depend on them (Tait and Lyall 2007, Cinner et al. 2016). The wider aim of the team is to generate a holistic understanding of, and strategic insights for, addressing complex interlinked issues so that the coastal management will be more effectively plan or adapt their strategies and actions. Coral reef conservation and management is inextricably linked to humans, their behavior and the social and economic systems within which they operate. Taking an integrated approach helps to remind scientists and resource managers that the reason for managing coral reefs is to maintain and improve ecosystem function. The examples presented here represent an attempt at implementing the approach. Full integration has not yet been achieved however in the case of NOAA's Coral Reef Conservation Program who by organizing their new implementation strategy on an ecosystem service and human well-being framework should yield opportunities for more interdisciplinary approaches to coral reef management. By piloting a standardized approach that incorporates contemporaneous collection of biophysical and socioeconomic data, GCRMN- Caribbean are regional leaders in the implementation of this socioecological approach. As data continues to be generated by these two different efforts, it is hoped that future analyses will include interaction of key variables across disciplines. This should lead improved responses to ecological management needs that simultaneously takes into consideration the societal impacts to reef dependent communities and the wider society.

Figure 1. Strategic planning framework NOAA's Coral Reef Conservation Program



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