SCIENCE REQUIREMENTS FOR MARINE SPATIAL PLANNING

CONSORTIUM FOR Ocean Leadership

The Consortium for Ocean Leadership is a Washington, D.C.-based nonprofit organization that represents 94 of the leading public and private ocean research and education institutions, aquaria and industry. Ocean Leadership's mission is to advance research, education and sound ocean policy.

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Introduction

On June 12, 2009, President Obama issued a memorandum to the Heads of the Executive Departments and Agencies establishing an Interagency Ocean Policy Task Force and charged the Task Force with recommending a framework for effective coastal and marine spatial planning. The memorandum further states that this framework should be a comprehensive, integrated and ecosystem-based approach that addresses conservation, economic activity, user conflict, and sustainability of ocean, coastal, and Great Lakes resources. This is a critical step forward in addressing fragmented and overlapping jurisdictions in state and federal waters that are currently being managed independently and without coordination by over 20 federal agencies and 35 state governments.

Marine spatial planning (MSP) has been defined by the Intergovernmental Oceanographic Commission (IOC) as "a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process." To facilitate sustainable use of the marine environment, this process addresses multiple, cumulative and potentially conflicting uses of the sea.

MSP is a future-oriented, adaptive, science-based tool that requires fundamental understanding of physical, biogeochemical and ecological patterns and processes and human interactions in the ocean; the ability to observe and measure these characteristics; and finally the capability to forecast these conditions. These tasks are essential to wisely plan for sustainable resource use into the future. MSP must proceed in the face of uncertainty by gathering the best available data and science.

Consequently, plans must be flexible to accommodate new information.

The Presidential memorandum does not specify whether or how the framework applies to state or federal waters, which has significant governance ramifications. This paper does not address the controversial jurisdictional issues associated with setting management boundaries, but instead focuses on the science needed to support the marine spatial planning process that will likely occur throughout state coastal waters and the U.S. exclusive economic zone.

MSP includes the following steps:

- Setting goals and objectives
- Defining and analyzing existing conditions – scoping and data collection
- Understanding interactions and forecasting future conditions
- Generating spatial scenarios and adopting an MSP
- Implementing, monitoring, evaluating, and adapting a plan

Setting Goals and Objectives

A marine spatial plan should be guided by a policy with overarching goals that can be translated into more specific objectives and targets. Depending on the area under consideration, goals may include conservation of marine resources, protection of cultural heritage, promotion of renewable energy development, etc. Quantifiable objectives can be established, such as reducing marine mammal ship strikes by 90% over a defined time period. MSP can combine objectives and maximize benefits to promote efficient and sustainable use of the area. Sometimes, competing uses are incompatible, and thus priorities must be established.

Defining and Analyzing Existing Conditions

The marine environment is much more dynamic than terrestrial systems. It is a three-dimensional, opaque, fluid system with physical, geological, chemical and biological characteristics that fluctuate temporally and spatially. Consequently, one of the first steps in defining and analyzing existing marine conditions is an ecosystem assessment. This should go beyond a static snapshot to consider ecological spatial and temporal variations. It requires long-term research and monitoring that should extend beyond the borders of the management zone to take into consideration human activities that occur elsewhere (e.g. pollution and overfishing) and ecological factors that influence the management zone. Environmental parameters must then be overlaid with the legal, economic and societal uses of the area to provide a baseline for decision makers.

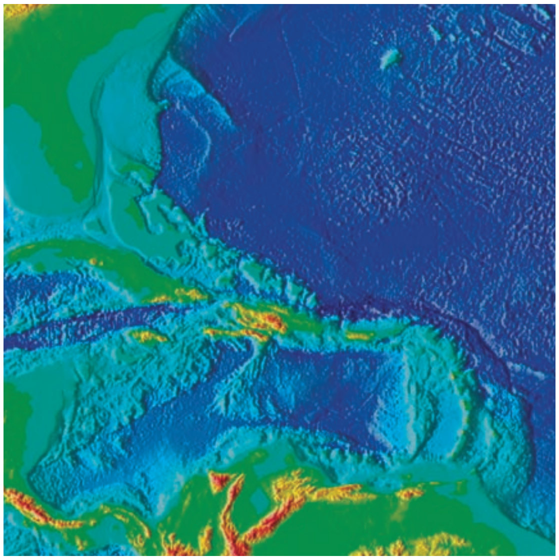
The availability of information to support MSP varies in quantity and quality by location as the United States government has failed to adequately invest in a comprehensive ocean and coastal observing system. While the information needs for MSP will vary by region, specific baseline data should be measured and tracked for MSP in all U.S. waters including: water temperature, ocean currents, salinity and pH; concentrations of nitrogen, phosphorous and dissolved oxygen; biological productivity, species assemblages and relative abundances of native and aquatic invasive species.

Data need to inform management decisions based on the established MSP goals and the ecological dynamics of the region. For example, a primary goal of safe shipping routes may prioritize bathymetric, current and marine mammal migration data, whereas a goal of sustainable harvest may prioritize upwelling, productivity and biodiversity information. Compiling and mapping data is expensive and can take extensive amounts of time and resources. In some instances, targeted observations with models might provide sufficient information to support MSP.

Remote sensing technologies provide global coverage, yet data from space provide information only for the surface ocean. Within the ocean *in situ* assets are necessary to both validate satellite data and obtain information through the water column, on the ocean bottom and into the sediments. These biophysical parameters must then be overlaid with the legal, economic, and societal uses of the area to provide a baseline for decision makers.

Physical Parameters

Temperature, salinity, ice cover, current velocities and freshwater fluxes in an area need to be clearly defined and mapped to develop physical models that can be used for navigation and other offshore activities as well as to track pollutants and predict harmful algal bloom outbreaks. Currently, many remote and *in situ* assets are deployed to measure these physical parameters, but measurements need to be sustained, enhanced and integrated including:



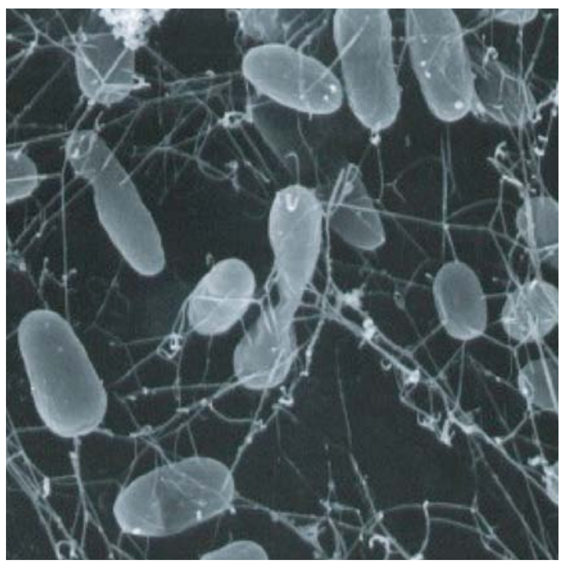
- Circulation and wave spectra from aircraft and satellite altimeters, HF radar, and *in situ* sensors (e.g., buoys, floats, gliders);
- Sea-surface winds from scatterometers and *in situ* sensors; and
- Sea-surface and subsurface temperature and ice cover from infrared and microwave radiometers and *in situ* sensors.

Geological Parameters

High-resolution bathymetric surveys must be conducted to develop seamless digital elevation models of the solid Earth's surface, both above and below sea level. These data are critical for safety of navigation as well as for improving models of coastal inundation related to storm surge and sea-level rise, and for predicting sediment and contaminant transport. The morphology and composition of the seafloor is also a critical component of fisheries habitat. Subsurface structure can reveal potential energy sources (e.g. oil and gas), potential resources like sand or gravel, and be critical in determining the feasibility of siting fixed platforms (oil and gas, wind turbines, etc). Composition of the substrate may also help identify potential sources and sinks of carbon.

Chemical Parameters

Carbonate concentrations, dissolved oxygen, nutrients and other water-quality indicators need to be defined and measured to provide understanding of the chemical environment. Technologies exist to measure most of these chemical characteristics, but deployment and implementation are neither uniform nor widespread. Currently, there are no operational chemical remote sensors, although prototypes for salinity, pH and dissolved carbon dioxide are being developed. Thus, chemical measurements currently require deployment of chemical sensors on a suite of fixed and portable platforms. Given the enormous impact that acidification may have on the entire marine food web, pH/carbonate observations and ecological impact research must be significantly advanced to understand and adapt to a rapidly changing chemical marine environment.



Biological Parameters

As might be expected, the greatest ecosystem uncertainties lie in understanding the complex biology of the marine environment. A wide array of biological parameters need to be observed and measured, ranging from microbial populations, chlorophyll concentrations, and fish distribution patterns to large marine mammal population abundances. Biological sensors and

instruments lag far behind those for physical and chemical parameters. It should be noted that not all organisms have the same ecological value in the marine environment. Research is needed to determine, for example, how the loss of top predators or species that provide physical structure will impact the resiliency of ecosystems. This information will facilitate rational management decisions by helping to identify the most sensitive and productive habitats.

Global ocean productivity calculations are derived from ocean color measurements made from space. Unfortunately, the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor that is expected to be launched on the National Polar Orbiting Environmental Satellite (NPOES) will not provide high-quality ocean color data, creating a critical gap in this knowledge for the foreseeable future. Consequently, effective use of non-US data is essential for continuity of the observing record, as is development of a new global-scale mission to measure ocean color. This effort should be accompanied by data on deeper-dwelling plankton that cannot currently be assayed from space.

Looking below the surface waters, good baseline data on migration routes and breeding grounds for many marine mammals and certain fish stocks are in hand. However, grasp on the marine food web between these large animals and microbes is limited. For instance, data on the distributions of small pelagics are incomplete. There is also need for data on the distributions of invasive species, jellyfish and ctenophores, sponges and deep-sea corals. Far more data are in hand for temperate waters than high-latitude or tropical environments, so needed investments in observations and process studies will vary by location.

Understanding of bottom-dwelling species is also limited. For the vast majority of benthic species, ecological function is poorly known. Adult dynamics can depend critically on larval transport, and identification of sensitive habitats for all life stages will require both observations and process studies. For the Northeast coastal zone, benthic invertebrate surveys were more thorough in the last century than they are in this one. The absence of a comprehensive federal, ecosystem-based science program has led to significant gaps in the science required for marine spatial planning.

Human Parameters

Because humans so densely populate the coastal zone, information about existing human activities must be cataloged, including marine transportation routes, military exclusion zones, energy and mining sites, and both commercial and recreational fishing grounds. These data should also include information on shore-side human activities that may affect the marine environment, such as point- and nonpoint-source pollution.

Because the goal of MSP is to manage human use and exposure to the marine environment, better understanding of the relationships between human health and the ocean is paramount. Health of humans can be negatively impacted by the ocean through pathogens (e.g. toxic algal blooms), but can also be protected through marine-derived pharmaceuticals as well as through the lipid contents of marine foods. Federal investment in this area is paltry, with limited involvement by NSF, NIH, NOAA and CDC.

Understanding Interactions and Forecasting Future Conditions

Although collection of high-quality remotely sensed and *in situ* data is an essential requirement of MSP, it is not enough to merely map and catalog ecological and human parameters. We must also develop the scientific capacity needed to understand how these systems interact. This understanding will require development of an appropriate theoretical base and analysis and integration tools that can catalyze the development of forecast models.

As stated previously, the marine environment is exceedingly dynamic with irregular shifts in its physics, chemistry, geology and biology that are being confounded with human perturbations and impacts from climate change (e.g. warming waters, altered currents, acidification, etc.). Because planning is a future-oriented activity, it needs accurate forecasts of future ecological conditions. To make such forecasts requires continuity of time-series data and process studies of the marine environment as well as the ability to estimate future human demands on ocean space. There is growing demand for models of future geophysical conditions of the ocean (e.g., sediment transport and warming waters) and the biogeochemical environment (pollutants and organism abundances). Modelers will need to integrate many, and some very large, data streams from various sources (*in situ* sensors, satellites, fish surveys) that were not designed for marine spatial planning and may be highly contested or otherwise proprietary. Sustained funding for data acquisition, computing, the development of analytic and data-fusion tools, and modeling is required for accurate predictions based on long-time series.

The quality of the plan depends on the quality of the information collected. Data must be reliable, calibrated and validated to meet the needs of MSP. Creation and maintenance of common databases and data sets will facilitate marine spatial planning and thus is an appropriate and critical role for the federal government. Quality control and management of the data are essential for both assessment and prediction. Data collected for MSP should be made public and accessible in as near real time as possible via the web, with searchable queries for marine spatial databases. Consequently, fast and accurate indication of the quality of the data needs to be built into the system. Standardized documentation must include quality descriptors and uncertainties for parameters and projections.

It should be noted that MSP goes beyond layered data entry, as spatial information science and engineering are rapidly evolving fields whose research results will continually revise best practices in MSP, as will new research results in marine and social sciences. For instance, ecosystem conditions may be altered by processes that begin far outside them. Examples include known climate oscillators such as El Niño Southern Oscillation and the North Atlantic Oscillation. Climate change will bring others. Increasing freshwater inputs from high latitudes are changing ecosystem structure in the Gulf of Maine, and some of those changes propagate in coastal currents as far South as Cape Hatteras. Thus, MSP must remain flexible enough to accommodate patterns and rates of change that have not been seen before in human history.

Generating Spatial Scenarios and Adopting an MSP

Evaluating spatial options is essential for developing robust strategies and alternatives for the planning process. Alternative spatial scenarios must be consistent with the objectives of the plan and should specify criteria for selecting spatial management measures. There are a variety of ways to develop and analyze these scenarios. Choosing among them is ultimately a political decision that hopefully will lead to the most effective, efficient and equitable plan.

The plan itself is a document that consists of a statement of objectives, an explanation of the spatial framework, a set of policies, and a zoning map to identify existing activities and designations. The purpose of the plan is to guide and coordinate proposals for future development, zoning, regulation and permitting.

Plan Implementation, Monitoring, Evaluation and Adaptation

Marine spatial planning is an iterative process that requires robust monitoring and evaluation to enable planners, managers and governments to learn continually from experience and new research findings. Monitoring and evaluating should be compatible with the goals and objectives of the marine spatial plan to set outcome measures that are transparent and establish accountability. This process should include dedicated resources for lab and field research, time-series data collection, quality control, analysis and interpretation. Established baseline data on indicators at the beginning of the MSP process enable determinations of whether the objectives of the plan are being achieved. Review and adaptation are essential. Results of evaluation iteratively feed back into planning and analysis. Finally, a communications strategy must allow stakeholders to independently assess whether the executed actions based on the marine spatial plans have produced desired results.

Recommendations

Ecosystem-Based Science

- Develop a national, ecosystem-based science program that will conduct a combination of experimental approaches and long-term monitoring of marine food webs, their key interactions and their quantitative relationships;
- Increase interdisciplinary research to determine the properties that are most important to preserve marine ecosystem structure and function (including the creation of a habitat classification scheme);
- Initiate a comprehensive program to monitor, understand and predict impacts of climate change and ocean acidification on marine ecosystems; and
- Develop a comprehensive interagency (NIH, NSF, NOAA, CDC & FDA) research initiative to elucidate relationships between the oceans and human health.

Observations

- Develop, deploy and integrate a suite of real-time ocean ecological measurements throughout the water column into ongoing observing systems such as Ocean Observatories Initiative (OOI), Argos, Integrated Ocean Observing System (IOOS), Ocean Biogeographic Information System (OBIS) and Global Ocean Observing System (GOOS);

- Monitor freshwater input, sediment load, nutrient concentration and chemical contaminants from point and nonpoint, onshore sources;
- Conduct high-resolution topographic shoreline and offshore bathymetric surveys to provide bottom and sub-bottom mapping of sediments, bottom structures, and subsurface geology; and
- Make a firm commitment to long time series of high-quality, sea-surface temperature, ocean color, altimetry and sea-surface, wind-vector satellite data.

Data Management

- Create a permanent, national, inter-agency cyber infrastructure system that collects marine data and develops products and services for MSP;
- Integrate real-time ecological measurements into a maritime information system, such as the Department of Interior's marine cadastre;
- Develop or adopt existing standard protocols for data collection with quality assurance;
- Develop or adopt existing standard formats for a data atlas that is updated regularly with ecological and economic information;
- Develop tools for analysis and integration of disparate geospatial data sets; and
- Expand numerical modeling programs that include ecosystem science.

Governance

- Establish regional science advisory committees and monitoring working groups (including academic scientists) to provide scientific expertise and set priorities for research and data collection in marine spatial planning activities; and
- Establish a national ocean reinvestment fund to provide a stable source of revenues for sustained time series of ocean observations needed for MSP.

Summary

The marine environment is in continual flux on multiple time scales. Successful management requires the ability to understand and predict the sea's varying physics, biogeochemistry and ecosystem interactions in space and time. There is need for long-term ocean and coastal observing, monitoring and research programs to collect, integrate, and disseminate real-time physical, biogeochemical, ecosystem, social, and economic data for marine spatial plans and implementation. These programs are vital to understanding and predicting future ocean dynamics and objective evaluation of MSP. There will always be a level of uncertainty or lack of data in a particular area, but it should not be used as an excuse to postpone a marine spatial planning process. Targeted observations and models should be used to fill these knowledge gaps to move the process forward.

Diverse governmental jurisdictions (county, state, federal, international) and overlapping agency management responsibilities have the potential to confound marine spatial planning and demand an overarching ocean policy to establish authority and set national objectives. The existing patchwork of federal monitoring and research programs needs to be integrated across agencies and given a dedicated budget to provide a stable and consistent ecosystem-based science initiative to support marine spatial planning.

Marine spatial planning is a powerful tool to foster coordinated decision making within and between state and federal agencies. Decisions need to be based on the best available science and will require continual information gathering to establish baselines, monitor ecosystems, and evaluate the efficacy of marine spatial plans.

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