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Biogeographic assessments: A framework for information synthesis in marine spatial planning

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ABSTRACT

This paper presents the Biogeographic Assessment Framework (BAF), a decision support process for marine spatial planning (MSP), developed through two decades of close collaborations between scientists and marine managers. Spatial planning is a considerable challenge for marine stewardship agencies because of the need to synthesize information on complex socio-ecological patterns across geographically broad spatial scales. This challenge is compounded by relatively short time-frames for implementation and limited financial and technological resources. To address this pragmatically, BAF provides a rapid, flexible and multi-disciplinary approach to integrate geospatial information into formats and visualization tools readily useable for spatial planning. Central to BAF is four sequential components: (1) Planning; (2) Data Evaluation; (3) Ecosystem Characterization; and (4) Management Applications. The framework has been applied to support the development of several marine spatial plans in the United States and Territories. This paper describes the structure of the BAF framework and the associated analytical techniques. Two management applications are provided to demonstrate the utility of BAF in supporting decision making in MSP.

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1. Introduction

Marine spatial planning (MSP) is rapidly emerging as a viable approach for comprehensive and efficient management of coastal and marine environments around the world [14,23,16]. If built on a foundation of reliable and objective ecological and sociological information, this evolution of marine planning is expected to maintain essential ecosystem services, encourage compatible uses, minimize resource use conflicts, evaluate tradeoffs in an open and transparent manner, and include significant and meaningful stakeholder involvement [32]. Implementing MSP, however, is a considerable challenge for marine stewardship agencies, in large part because gaps exist in available data and syntheses of data on spatially heterogeneous and dynamic socio-ecological systems are extremely complex [14,20,29,79].

While it may be judicious to embrace the enormous complexity of ecosystems and work toward complete descriptions of ecological systems, pragmatism of management systems will likely necessitate a more limited focus on special areas, vulnerable resources and a subset of critical patterns and processes such as key drivers in the structure and function of the system. With this pragmatic approach, the U.S. National Ocean Policy (NOP), adopted by Executive Order 13547, advises regional planning bodies to analyze, assess and forecast information on key characteristics of coupled social–ecological systems (Box 1). These Regional Assessments are considered one of the essential elements of the spatial plan.

Even with this narrowed scope, historically, limited data coverage for both spatial and temporal dimensions, combined with issues of limited data access, has made effective information-based strategic planning in the marine environment a major technical challenge. In the past decade, however, there have been rapid technological advances in environmental sensors, considerable investments in long-term monitoring and a proliferation in remote sensing systems for acquisition of marine environmental data at a range of spatial and temporal scales [11,24,34]. In addition, advances in the spatial modeling of ecological patterns and processes, such as ocean hydrodynamics, watershed hydrology,

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Box 1–Suggested data needs for the Regional Assessment component of the U.S. Government Framework for Effective Coastal and Marine Spatial Planning (Interagency Ocean Policy Task Force, 2009).

1. Important physical and ecological patterns and processes (e.g., basic habitat distributions and critical habitat functions) that occur in the planning area, including their response to changing conditions;
2. Ecological condition and relative ecological importance or values of areas within the planning area, using regionally-developed evaluation and prioritization schemes;
3. Economic and environmental benefits and impacts of ocean, coastal, and Great Lakes uses in the region;
4. Relationships and linkages within and among regional ecosystems, including neighboring regions both within and outside the planning area and the impacts of anticipated human uses on those connections;
5. Spatial distribution of, and conflicts and compatibilities among, current and emerging ocean uses in the area;
6. Important ecosystem services in the area, and their vulnerability or resilience to the effects of human uses, natural hazards, and global climate change;
7. Contributions of existing placed-based management measures and authorities; and
8. Future requirements of existing and emerging ocean, coastal, and Great Lakes uses

biological distributions and larval connectivity, allow us to predict, visualize and better explain complex ecosystems [68,75,93,46]. Simultaneously, the diversity and geographical scope of mapped socio-economic data has also increased [6,13]. The development of reliable and cost-effective spatial models has been aided by identification of useful surrogates or proxies for complex spatial patterns that are difficult to map directly, such as species distributions, ecological function, and ecosystem service values [51,76,87]. Significant progress has also been made in data sharing through institutional contributions to open access data portals and the broadening of public participation in data collection (i.e., citizen science and crowd sourcing) [11,86,30].

Less focus, however, has been directed at the development of conceptual and analytical frameworks for prioritizing, analyzing and communicating complex, spatially explicit and non-linear socio-ecological patterns and processes [81,29,79]. This gap presents a significant challenge for the operationalization of MSP that is made more urgent as ocean uses increase and diversify globally. Typically, the MSP process involves multiple stakeholder groups with different, sometimes competing, goals for the use and management of the same geographical space. Therefore, balancing human uses to minimize conflict between users, ensure long-term environmental sustainability, and maximize the value of ecosystem services delivered is a primary challenge for MSP ([79,90]). Effective decision making in MSP, particularly where there are many stakeholder groups with highly divergent interests, requires a framework for data synthesis that provides a comprehensive, transparent and reliable science-based approach, accounts for uncertainty in the data, and provides sufficient flexibility to enable objective scenario assessment.

The Biogeographic Assessment Framework (BAF), a flexible, multi-disciplinary approach to integrate geospatial information into formats and visualization tools readily useable by coastal managers has been developed. This framework has evolved from two decades of close partnerships with natural resource managers addressing complex problems in both temperate and tropical marine and coastal environments [55]. The BAF incorporates a broad spatial ecology perspective that integrates concepts and techniques from traditional ecology, biogeography, landscape ecology, sociology and economics, remote sensing and the emerging fields of spatial eco-informatics and computational ecology [92,54,15,91]. Although the BAF approach shares some attributes with NOAA's Integrated Ecosystem Assessments (IEA), the two approaches support different, but complementary objectives. BAF provides a comprehensive spatial characterization and user conflict assessment to support spatial planning, whereas IEAs provide a structure to assess ecosystem status, risk to ecosystem indicators and the impact of management decisions within an adaptive management process [45]. The BAF is a rapid and flexible approach for responding to the relatively short time scales that are typical for implementation of management actions, such as the development of marine spatial plans, marine protected area management plans or evaluations of MPA design. The BAF usually relies on existing data sets, not all portions of the ecosystem need to be included, indicators are not required, and when compared with IEA, the BAF focuses more on spatial variation.

This paper presents an overview of the structure of the Biogeographic Assessment Framework and associated analytical techniques to demonstrate the utility of the framework in support of marine spatial planning in the United States of America (USA).

2. Methodology

2.1. Conceptual background for the Biogeographic Assessment Framework (BAF)

To understand how MSP can benefit from implementing the BAF, it is necessary to first define the subject of biogeography which provides concepts and techniques that underpin the framework. In essence, biogeography is the study of the spatial and temporal distributions of organisms, including people, and their habitats, and the historical and biological drivers of distributions [10]. Application of biogeographic concepts and analytical approaches have made major contributions to conservation planning, particularly in classifying regions with distinct characteristics and explaining patterns in species distributions and biodiversity [48,81]. Typical results from ecological biogeography range from distribution maps for species or habitats to more complex ecological analyses that integrate biological, physical and sociological variables to create maps of biodiversity and human activities within a region [59,75,56]. Biogeographic studies are usually perceived as global or continental in spatial extent and often concerned with geological time scales. However, the approach can be applied at finer scales. BAF as described here considers spatial and temporal domains that focus on more recent patterns (typically <30 years from present) than conventional studies in Biogeography and are analyzed at sub-continental spatial extents.

2.2. Operational attributes of the Biogeographic Assessment Framework (BAF)

BAF is designed to display diverse, spatially complex and multi-scale biogeographic information in a readily consumable manner via maps and spatial analyses aimed at supporting the management decision making process. At the core of the BAF analytical process are a suite of interoperable spatial technologies including Geographical Information Systems (GIS), remote sensing image analysis software, statistical data mining algorithms for predictive modeling, web-based mapping tools and database Management Applications. Although representation of ecologically realistic patterns is less problematic in data rich regions, operationally the BAF approach is flexible enough to also efficiently address