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Defining ecologically, geographically, and politically coherent boundaries for the Northern Gulf of Mexico coastal region: Facilitating ecosystem-based management

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ABSTRACT

Ecosystem-based management (EBM) is an integrated approach that recognizes the complex interactions within an ecosystem. Proper facilitation of EBM techniques require explicitly defined spatial boundaries, but biophysical processes, human activities, and the ecosystems that they influence operate at various scales. Careful thought to combine ecological, physical, and regulatory boundaries to define spatial scales of coastal regions can be a tedious yet significant early step towards the meaningful application of ecosystem-based management. We recommend nine coastal regions for the Northern Gulf of Mexico by creating both regulatory and biophysically meaningful spatial boundaries. A basic framework illustrating the utility of publicly available spatial datasets for defining the seaward, landward, and lateral boundaries of coastal regions is provided. These nine coastal regions will be key in creating spatial criteria for the Northern Gulf of Mexico, within which differences in ecosystem services can be measured, and temporal changes in ecosystem services can be tracked. The framework developed here is meant to build capacity for EBM and serve as a starting point for the continued discussion and modification of sensible ecological, geographical and political boundaries.

1. Introduction

Ecosystem-based management (EBM) is an integrated approach to management that recognizes the complex interactions within a place-based system (Toonen et al., 2011). This approach considers the entire ecosystem, including humans, and often employs ecosystem services to measure system health (Samhouri et al., 2012). Ecosystem services are the products and outcomes from which humans can profit and benefit when an ecosystem is healthy, productive, and resilient (such as sustainable fisheries, eco-tourism, coastal flood protection, etc.) (McLeod et al., 2005).

The emphasis on managing places rather than relying on a unidimensional variable or a single species has been widely accepted both nationally and internationally; three examples are the U.S. Commission on Ocean Policy, Pew Ocean Commission and Millennium Ecosystem Assessment, and the United National Environment Programme (Borja et al., 2009; Crowder and Norse, 2008; Douvere, 2008; Dell'Apa et al., 2015). The U.S. Commission on Ocean Policy's An Ocean Blueprint for the 21st Century devotes a chapter to advancing a regional approach to EBM (USCOP, 2004). Although there have been successful EBM approaches in large-scale applications (e.g., Tallis and Polasky, 2009; Ruckelshaus et al., 2015) there are few examples of ecosystem-wide practice at the level of local and regional coastal environments where most management decisions are made (Douvere, 2008; Katsanevakis et al., 2011; but see Leslie et al., 2015). On their own, many regulatory bodies and stakeholders lack the necessary framework, legal authority, and operational tools needed to facilitate an ecosystem approach in the coastal environment (Arkema et al., 2006; Heenan et al., 2016). One such tool is a framework to define spatial boundaries of the focal ecosystem and appropriate spatial scales at which pertinent biophysical processes and human activities operate (Crowder and Norse, 2008). Herein, we define reproducible and meaningful spatial boundaries of coastal regions needed to build capacity for an EBM for the northern Gulf of Mexico.

Defining meaningful boundaries of coastal ecosystems is a crucial initial step towards coastal EBM, but it can be daunting to understand the complexities of such dynamic and open systems (Crowder and Norse, 2008; Stelzenmüller et al., 2013; Leslie et al., 2015). An

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unavoidable consideration is to define the ecosystem services that are critical to the desired functioning of the particular system. Ecosystem services are influenced by a suite of ecological and social factors, often measured using a range of available datasets that have various spatial scales (Halpern et al., 2008). Consequently, EBM initiatives are difficult to implement and their outcomes difficult to quantify, unless the levels of ecosystem services are systematically and periodically evaluated. Therefore, keys to defining the spatial boundaries used in EBM efforts include consideration of the ecosystem services to be measured, and the spatial and temporal scales corresponding to available data.

Government jurisdictional borders are common and logical boundaries that typically correspond with spatial coverage of monitoring efforts of the associated regulatory and natural resource agencies (Dallimer and Strange, 2015). These agencies usually influence and direct management actions within their jurisdiction. Agency monitoring efforts generally represent long-term and consistent datasets for large-scale coastal systems. However, agency-defined jurisdictional borders notably do not always match the ecological scales at which coastal systems function (Cowen et al., 2006). These can range from trans-global in scale, to a specific isolated habitat unit. Alternatively, attempts to define boundaries based solely on the biophysical processes of an ecosystem can be contentious and could result in unmanageably large units (Leslie et al., 2015). Therefore, careful consideration is needed to define appropriate spatial scales which combine ecological, physical, and regulatory boundaries for management of coastal regions. Although tedious, it is a significant early step towards the meaningful application of ecosystem-based management.

Coastal ecosystems in a current state of distress can benefit most from effective ecosystem-based management initiatives (Halpern et al., 2008). The coastal zone of the Northern Gulf of Mexico is subject to numerous ecosystem stressors such as overfishing, nutrient loading and other pollutants, invasive species, habitat loss, and sea-level rise (Halpern et al., 2008). Additionally, major tropical storms and hurricanes are periodic, and one of the world's largest hypoxic areas frequently forms along its coast (NMFS, 2012). The warm sub-tropical water of the Gulf coast supports highly productive fisheries and also attracts rapidly developing human populations, diverse industries, and comprises many of the nation's leading ports in terms of tonnage and commercial fish landings (Karnauskas et al., 2013). We present a framework to define coherent and reproducible spatial boundaries of coastal regions across the Northern Gulf of Mexico, in order to facilitate assessment of large-scale ecosystem health useful to ecosystem-based management in this region. Herein we define and recommend spatially explicit coastal regions for the Northern Gulf of Mexico using both regulatory and biophysically meaningful spatial boundaries.

2. Methods

The Northern Gulf of Mexico includes over 2600 km of coastline located within five states of the USA, from the Texas border with Mexico to the tip of Florida's peninsula, and contains a complex network of bayous, inlets, tidal rivers, bays, and islands. Coastal zone is defined as the transitional area that straddles the open ocean and the continent. Spatial boundaries were chosen based on a classification system that collectively considered political, ecological, and geographical boundaries. This is an important difference from boundaries for ecoregions, which are defined strictly by their distinctive geography and climate, because many data that are essential to characterizing and monitoring ecosystem services are reported at jurisdictionally defined spatial scales.

This framework for defining spatial boundaries of coastal regions focuses on a number of well-known and easily reproducible national spatial datasets (Table 1). The table presents potential options for defining seaward and landward spatial boundaries that can be used to identify and select among well-documented and easily reproducible spatial datasets for coastal regions of the United States. It is meant to be

Table 1
Simplified framework to defining spatial boundaries for coastal regions of the United States. This table is meant to be a simple guide and does not include all potential options for defining spatial boundaries for coastal regions in the U.S.

Steps to defining spatial boundaries		Option	Datasource	Description
1	Define Seaward Boundary	Include only county-linked data	US Census Department, TIGER/Line County Layer (USCB, 2016)	Includes all counties, if coastal includes submerged lands out to 3 miles seaward from the mean high tide line.
		Include all non-federal submerged lands	USGS Digital Offshore Cadastre - Submerged Lands Act Boundary Line (USGS, 2002)	Includes all state coastal submerged lands as determined by the Submerged Lands Act (SLA) which extends from 3 to 9 miles seaward from the mean high tide line depending on the state in question.
		Include all federal submerged lands	NOAA, USEEZ: Boundaries of the Exclusive Economic Zones of the United States and Territories (NOAA, 2016b)	Includes all U.S. federal waters out to 200 nautical miles from the mean high tide line.
		Include all submerged lands to a certain depth contour	Data source varies by spatial extent of study	
2	Define Landward Boundary	Include only submerged lands	NOAA Mean High Water Line (NOAA, 2016a)	Includes all submerged lands at the mean high tide line as determined by NOAAs Office of Coast Survey Shorelines
		Include all Coastal Counties	US Census Department, TIGER/Line County Layer (USCB, 2016)	Includes all counties and equivalent in the U.S., requires hand selection of coastal counties.
		Include Coastal Zone Management Program Counties	USGS Coastal Zone Management Counties (USGS, 2009)	Includes the 492 coastal zone management program counties and county equivalents published by NOAA.
		Include all lands to a certain topographic contour	USGS National Elevation Dataset (USGS, 2015a)	Includes basic bare earth elevation information for the United States
		Include all coastal watersheds	USGS Hydrologic Unit Code (USGS, 2015b)	Includes all coastal watersheds by varying level of classification using the USGS Hydrologic Unit Code Classifications
		Include all coastal land-based ecoregions	EPA Ecoregions of North America (USEPA, 2016)	Includes land-based ecoregions by level
3	Define Lateral Boundaries	Includes numerous options, and should include careful consideration of scale of ecosystem services being measured and data availability.		