Available online at www.sciencedirect.com
ScienceDirect
Estuarine, Coastal and Shelf Science 78 (2008) 89–106
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

Evaluating the NOAA Coastal and Marine Ecological Classification Standard in estuarine systems: A Columbia River Estuary case study

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Received 17 January 2007; accepted 19 November 2007
Available online 26 December 2007

Abstract

A common first step in conservation planning and resource management is to identify and classify habitat types, and this has led to a proliferation of habitat classification systems. Ideally, classifications should be scientifically and conceptually rigorous, with broad applicability across spatial and temporal scales. Successful systems will also be flexible and adaptable, with a framework and supporting lexicon accessible to users from a variety of disciplines and locations. A new, continental-scale classification system for coastal and marine habitats—the Coastal and Marine Ecological Classification Standard (CMECS)—is currently being developed for North America by NatureServe and the National Oceanic and Atmospheric Administration (NOAA). CMECS is a nested, hierarchical framework that applies a uniform set of rules and terminology across multiple habitat scales using a combination of oceanographic (e.g. salinity, temperature), physiographic (e.g. depth, substratum), and biological (e.g. community type) criteria. Estuaries are arguably the most difficult marine environments to classify due to large spatio-temporal variability resulting in rapidly shifting benthic and water column conditions. We simultaneously collected data at eleven subtidal sites in the Columbia River Estuary (CRE) in fall 2004 to evaluate whether the estuarine component of CMECS could adequately classify habitats across several scales for representative sites within the estuary spanning a range of conditions. Using outputs from an acoustic Doppler current profiler (ADCP), CTD (conductivity, temperature, depth) sensor, and PONAR (benthic dredge) we concluded that the CMECS hierarchy provided a spatially explicit framework in which to integrate multiple parameters to define macro-habitats at the 100 m^2 to >1000 m^2 scales, or across several tiers of the CMECS system. The classification's strengths lie in its nested, hierarchical structure and in the development of a standardized, yet flexible classification lexicon. The application of the CMECS to other estuaries in North America should therefore identify similar habitat types at similar scales as we identified in the CRE. We also suggest that the CMECS could be improved by refining classification thresholds to better reflect ecological processes, by direct integration of temporal variability, and by more explicitly linking physical and biological processes with habitat patterns.

Keywords: classification systems; current measurement; acoustic Doppler current profiler (ADCP); estuaries; United States; Columbia River Estuary

1. Introduction

Estuaries are spatially and temporally dynamic transition zones spanning multiple spatial and temporal scales. The boundaries of estuarine habitats are structured over time and space primarily as a result of daily tidal cycles, seasonal and inter-annual variations in river discharge and temperature,

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0272-7714/$ - see front matter
doi:10.1016/j.ecss.2007.11.020

and long-term shifts in bedform and sediment distribution (Sherwood and Creager, 1990; Dyer, 1997; Reed et al., 2004). Classification of estuarine habitats is therefore both scale dependent (Attrill and Rundle, 2002) and strongly context driven (Elliott and McLusky, 2002), meaning the scale of habitat partitions must appropriately correspond with the physical or biological processes being investigated *and* the partitions may vary depending on scale. For example, ecological boundaries in estuaries may be much more spatially restricted for benthic plants and animals than are those for more mobile organisms that can migrate as physical habitats change (Bottom and Jones, 1990; Colloty et al., 2002). For the most motile and euryhaline species, estuaries might be considered relatively uniform mixed freshwater-seawater habitats, versus a complex continuum of interconnected habitats or physical gradients for more sedentary, stenohaline, or otherwise ecologically-restricted organisms (Neira et al., 1992; Harris et al., 2001). Importantly, the complex interactions over time and space between abiotic and biotic processes often result in ecological boundaries that do not necessarily correspond with boundaries derived using physical or chemical surrogates.

The challenges of scale and context in estuaries have long been recognized and highlight the need for spatially and temporally explicit classification systems (Hansen and Rattray, 1966; Cowardin et al., 1979; Jay et al., 2000; Elliott and McLusky, 2002). Many estuarine, coastal and marine classifications have been developed in recent decades, using a variety of conceptual and methodological approaches (e.g., Boyd et al., 1992; Ibañez et al., 1997; Buzzelli et al., 1999; Whitfield, 1999; Edgar et al., 2000; Bricker et al., 2003; Kenny et al., 2003; Roff et al., 2003). These systems have been generated to address an assortment of management and conservation objectives, and as such have arisen from multiple disciplines and were developed mostly at local or regional scales. A number of these efforts have demonstrated both recurring and persistent associations of marine biological communities with oceanographic and physiographic structures to a degree that the spatial locations of communities can be mapped with measures of certainty (e.g. Doyle et al., 1993; Auster et al., 2001). However, few have attempted to comprehensively reflect underlying ecological pattern and process at multiple scales, which would be broadly useful for facilitating local, regional and global comparisons. One attempt, the Coastal and Marine Ecological Classification Standard (CMECS), is being developed as a potential single classification standard for North America (Madden et al., 2005). The intent of CMECS is to provide a framework for systematically inventorying, describing, characterizing, and predicting habitats and, where applicable, their constituent species and communities. The framework consists of six, nested levels linking broad marine environment types (e.g. intertidal, oceanic) downward to biotopes, which are discrete habitat units that support a unique and recognizable community type. The overall objective is that CMECS will be a flexible and evolving classification framework, designed to be widely applicable across all coastal and marine habitat types from freshwater-marine and marine-terrestrial interfaces to the open ocean (Madden et al., 2005).

While the conceptual framework has been defined and successfully applied (mapped) at the higher levels, it is as yet unknown whether many components of the classification correspond with real-world habitats that can be spatially mapped using existing inventory methods. In this paper, we attempted to apply the CMECS estuarine definitions at various levels using several commonly-collected data types acquired at representative sites spanning a range of ecotypes occurring in the Columbia River Estuary (CRE, Washington-Oregon). We focused on parameters describing energy inputs (e.g., current velocity), physicochemical characteristics of the water column, and benthic substrate rather than biotic distributions because the CMECS approach is structured by physicochemical processes at larger spatial scales and because many management uses of classifications aim to identify suitable habitat for species currently depressed or absent. Specific study objectives included: (1) testing whether existing available sampling approaches (e.g., acoustic Doppler current profilers [ADCP] and benthic and water column sampling devices) can provide the underlying physical and chemical data necessary to classify estuarine habitats at one or more scales; (2) evaluating the sensitivity of CMECS to spatial and temporal variability in both vertical (e.g., water column) and horizontal gradients in environmental conditions (e.g., across zones of freshwater influence); (3) examining the relationship between CMECS classification levels and the processes underlying habitat development and persistence; and (4) evaluating the potential for CRE habitat mapping at the various CMECS classification levels for hypothetical mobile (e.g., salmon) and sessile (e.g., benthic infauna) organisms. Our primary aim was to evaluate CMECS as a classification tool and it was beyond the scope of the study to produce a definitive classification of the CRE.

2. Materials and methods

2.1. Columbia River Estuary: Background

The Columbia River drains approximately 660,000 km^2 of the U.S. Pacific Northwest and British Columbia, and has among the highest annual discharge of all North American rivers (mean annual flow $\sim$7000 $m^3\ s^{-1}$) (Simenstad et al., 1990; Naik and Jay, 2005). The estuary is characterized by strong tidal currents and highly variable freshwater inputs (Hamilton, 1990; Jay and Smith, 1990; Baptista et al., 2005). Within-year river discharge near the mouth can vary by an order of magnitude, from low flows near 2000 $m^3\ s^{-1}$ in fall to levels exceeding 20,000 $m^3\ s^{-1}$ during summer runoff peaks (Bottom et al., 2005).

The upstream extent of the salt-fresh mixing zone and the presence or absence of a salt wedge in the CRE is strongly linked to hydrologic conditions and spring-neap tidal cycles (Hamilton, 1990; Jay and Smith, 1990). In contrast to many large estuaries, high river discharge through the CRE results in generally low salinity and rapid flushing times, and the