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How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems

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ABSTRACT

As pressures on coastal zones mount, there is a growing need for frameworks that can be used to conceptualize complex sustainability challenges and help organize research that increases understand about interacting ecological and societal processes, predicts change, and supports the management, persistence, and resilience of coastal systems. The Driver–Pressure–State–Impact–Response (DPSIR) framework is one such approach that has been adopted in some coastal zones around the world. Although the application of the DPSIR framework has considerable potential to bridge the gap between scientific disciplines and link science to coastal policy and management, current applications of DPSIR in coastal environments have been limited and new innovations in the application of the DPSIR model are needed. We conducted a structured review of literature on the DPSIR framework as applied to the function, process and components of complex coastal systems. Our specific focus was on how the DPSIR framework has been used as a tool to organize sophisticated empirical scientific research, support transdisciplinary knowledge at a level appropriate for building understanding about coastal systems, and how adopting a DPSIR approach can help stakeholders to articulate and structure challenges in coastal systems and use the framework to support policy and management outcomes. The review revealed that DPSIR models of coastal systems have been largely used to support and develop conceptual understanding of coastal social–ecological systems and to identify drivers and pressures in the coastal realm. A limited number of studies have used DPSIR as a starting point for semi-quantitative or quantitative analyses, although our review highlights the continued need for, and potential of, transformative quantitative analyses and transdisciplinary applications of the DPSIR framework. The DPSIR models we reviewed were predominantly single sector, encompassing ecological or biophysical factors or focusing primarily on socio-cultural dimensions rather than full integration of both types of information. Only in eight of 24 shortlisted articles did researchers actively engage decision-makers or citizens in their research: given the potential opportunity for using DPSIR as a tool to successfully engage policy-makers and stakeholders, it appears that the DPSIR framework has been under-utilized in this regard.

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1. Introduction

Coastal ecosystems play essential roles in supporting human populations and biodiversity. As of 2005, 40% of the world's population lived within 100 km of the coast (Agardy and Alder, 2005), in areas that support some of the most productive and biodiverse natural communities on the planet. Human populations and development in coastal areas are projected to increase throughout the twenty-first century (Weinstein et al., 2007). Mounting pressures on coastal ecosystems, largely arising from anthropogenic drivers of environmental change (Harley et al., 2006; Syvitski et al., 2009; Mee, 2012; Cazenave and Cozannet, 2014), have prompted considerable scrutiny of the roles that conjoined ecological, social, and governance factors play in coastal management (Adger et al., 2005; Martínez et al., 2007; Duarte et al., 2008; Barbier, 2014; Nursey-Bray et al., 2014). Those pressures have intensified the need to understand how integrated upland-coastal management can ameliorate multiple stressors from both upland and marine environments and how global environmental change will affect ecological and human well-being in diverse coastal zones and across scales (Swaney et al., 2011; Rudd and Lawton, 2013; Rudd, 2014).

Coastal zone management, like a number of other large and emerging societal issues, is often described as a messy or 'wicked' (Balint et al., 2011) environmental problem. The challenges in coastal zones include defining and understanding interacting ecological and societal processes, predicting change, and managing the system toward enhanced persistence and resilience. Addressing these challenges requires a process of problem structuring, to transform unstructured problems into ones that can be effectively addressed with sound evidence about ecological and social system structure and function. This 'containment' process (Hisschemöller and Hoppe, 1995; Shaxson, 2009; Hughes, 2013) also requires information about how decision-makers, scientists, and citizens perceive and define the issues (Rudd, 2011, 2015; Wise et al., 2014). Problem structuring necessarily involves simplification of structure and function in complex coastal socio-ecological systems in exchange for increased policy salience. Predictive knowledge about environmental and human behavior must be balanced through sustained engagement between scientists, policy-makers and citizens in order to define and delineate problems, and facilitate coastal problem solving.

One approach to increase knowledge regarding complex systems has been to adopt a socio-ecological (SES) or coupled human and natural systems (CHANS) approach that aligns dynamic change, adaptation, and transformation with persistence across multiple scales and multiple dimensions (Folke et al., 2010). Coastal systems, in which reciprocal feedbacks from human and natural drivers flow across the land-sea interface, have been recognized as quintessentially coupled systems, exhibiting complex and uncertain dynamics and non-linear relationships (López-Angarita et al., 2014). Despite recent research that has identified linked feedbacks across the many different dimensions of complex coastal systems, understanding of the coupled and reciprocal drivers of coastal systems and their functioning is nascent. A central tenet of the coupled or complex systems approach is that the delineation between social and ecological systems is artificial and arbitrary, and that to study or analyze these systems requires integrated approaches. SES and CHANS approaches are related, with adopters of the different approaches often having different scientific conceptualizations of a study system. A CHANS perspective is often adopted by ecologists who believe that humans are components within an ecosystem, whereas social scientists who posit that human–environmental interactions are subsumed within a larger social system order may adopt an SES construct (Westley et al., 2002). However, this differentiation is not universally accepted (Rozzi et al., 2015). The SES approach has been linked with institutional analysis (e.g., Ostrom, 2007, 2009), governance transformations (e.g., Ayers and Kittinger, 2014) and supporting decision-making in applied coastal management and policy (e.g., Schlüter et al., 2013; Forrester et al., 2014; López-Angarita et al., 2014). While much SES research has, to date, focused on conceptual development and organizing indicator systems, efforts to develop models with real-world empirical research links are also underway (e.g., Cook et al., 2014; Vogt et al., 2015). Recognizing and acknowledging the different orientations of CHANS and SES research, we adopt a single term, SES, to represent a complex, coupled systems approach throughout the paper. However, we do so neither in opposition to the CHANS construct nor to support unnecessarily nuanced terminology distinctions (*sensu* Healy, 2015), but rather for consistent terminology and clarity.

There is a pressing need to better understand how humans benefit from as well as impact coastal environments, how coastal decision-makers perceive coast-related challenges and choose courses of action (e.g., in urban development, shipping, energy development, migration policy), and to design communication strategies for often complex and context-dependent SES science. Repeated calls for transdisciplinary approaches in the study of SESs (e.g., Walker et al., 2002; Weaver et al., 2014) have not yet, however, stimulated the level of support and enthusiasm needed for broad engagement and participation in transformative coastal science (e.g., Campbell, 2005; Lebel, 2012; Glavovic, 2013). That is, research that crosses academic disciplines and also engages scientists, policy-makers, and societal actors in the knowledge creation process are the exception, rather than the rule, in current coastal research efforts globally.

One approach that holds promise to help structure complex environmental problems and unify and connect conceptual exploration across social and natural sciences is the Driver–Pressure–State–Impact–Response (DPSIR) framework (Ness et al., 2009; Bell, 2012; Gregory et al., 2013). Originally developed in the 1970s as a stress-response model, it evolved over time and the Organization for Economic and Cooperation Development (OECD) adapted it as the Pressures–State–Response (PSR) model (OECD, 1994). DPSIR, as it is known today, resulted from the European Environment Agency (EEA, 1995) adding two new components, Driving Forces and Impact, to help policy makers identify cause–effect relationships between human and natural systems, and assist in assessing progress toward sustainable development (Smeets and Weterings, 1999; de Stefano, 2010). The UNEP adopted a version of the framework to help organize their series of Global Environment Outlook reports (Ajero et al., 2012). Because of its ability to integrate knowledge across different disciplines and help formalize different decision alternatives, the application of the DPSIR framework has considerable potential for bridging the gap between scientific disciplines as well as linking science to policy and management (Svarstad et al., 2008; Tscherning et al., 2012). Specifically, DPSIR may offer an approach to articulate problem structure and serve as a template to help organize sophisticated SES research and help identify viable options for managing and protecting coastal systems, and increasing social adaptive capacity and resilience to exogenous drivers.

The aim of this paper is to assess the potential for the DPSIR framework to be used as a tool to simultaneously organize sophisticated scientific research at a level appropriate for building understanding about coastal SESs and, simultaneously, to help stakeholders and policy-makers to articulate and manage coastal sustainability challenges. Other recent DPSIR reviews have examined the role of the framework in supporting environmental decision-making in a mix of terrestrial and aquatic contexts