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Review

Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: A review of knowledge and research needs

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ABSTRACT

The science-based management of natural resources requires knowledge exchange between scientists and environmental decision-makers, however, this exchange remains a significant challenge. Rather, evidence suggests that decision-makers rely on individual experience or other secondary sources of knowledge in isolation from scientific evidence when formulating decisions, potentially compromising the effectiveness of their decisions. As a result a new field of research broadly characterised as 'knowledge exchange' has emerged, focused largely on identifying and overcoming the barriers to knowledge exchange among scientists and decision-makers. More recently knowledge exchange research has also begun to explore the relationship between science and decision-making specifically in relation to marine ecosystems and resources. The aim of this paper is to review the literature in relation to knowledge exchange for natural resource management, with a focus on recent evidence in relation to the management of marine resources. This review identifies critical barriers inhibiting knowledge exchange among marine scientists and decisions-makers, such as the inaccessibility of science to decision-makers as well as institutional barriers that limit the extent to which scientists and decision-makers can prioritise knowledge exchange activities. Options for overcoming these barriers, such as novel approaches to knowledge exchange (e.g. – knowledge co-production, knowledge brokers and boundary organisations) and the enabling environments and institutional reforms needed to complement efforts to improve knowledge exchange, are also identified. This review concludes by articulating the gaps in our understanding of knowledge exchange, to help guide future research in this field and improve the sustainable management of marine resources.

1. Introduction

Ecological goods and services provided by marine systems are critical for human welfare, however, the sustainable management of these resources has been a topic of continued concern in part due to the complex and dynamic socio-ecological systems in which they are imbedded (e.g. – Berkes et al., 2003; Mahon et al., 2008; de Jonge et al., 2012). As a result scholars and resource managers alike have called for new flexible, integrated, holistic forms of management and governance that can deal with the complexity of social-ecological systems and their associated services (Berkes and Folke, 1998; Gunderson and Holling, 2002; Hughes et al., 2005). Calls for more effective approaches to resource management have also been fuelled by burgeoning factors such as population growth, coastal development and climate change, which render the

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conditions under which management must operate increasingly uncertain and unpredictable (e.g. – Millar et al., 2007; Hallegatte, 2009).

One framework that has been proposed to be capable of dealing with the uncertainty associated with complex socio-ecological systems is that of adaptive governance (Österblom and Folke, 2013; Chaffin et al., 2014). Adaptive governance is a concept derived from institutional theory that focuses on the evolution of formal and informal institutional arrangements for the management of shared assets, such as a set of environmental assets that provide ecosystems services (reviewed Nelson et al., 2008). Specifically, adaptive governance refers to society's capacity to understand and respond to environmental and social feedback in the context of change and uncertainty, to sustain and enhance the resistance and resilience of desirable ecosystems (Berkes and Folke, 1998). As such, adaptive governance involves the capacity to 1) understand environmental change, 2) use this information to inform decision making, 3) act on decisions in a manner that sustains the resistance and resilience of desirable ecosystem states and 4) review and adapt decisions as new information becomes available (Evans et al., 2011). Governing resources adaptively, therefore, is a knowledge intensive endeavour (e.g. – MEA, 2005) requiring an understanding of social-ecological systems in their full complexity so as to respond to feedback from the system across both spatial and temporal scales (Berkes et al., 2003; Berkes, 2009).

While multiple sources of knowledge can, and should, inform the management of environmental resources (Raymond et al., 2010), the importance of incorporating primary science into decision-making processes is widely recognised. In this regard, primary science is defined as knowledge that is generated through formalised processes such as through research and/or the application of scientific methodology (Turnbull, 1997; Raymond et al., 2010) and contrasts with constructivist knowledge (Dessler, 1999; Kukla, 2000). Primary science is advocated for its ability to determine environmental baselines, improve our understanding of the likelihood and potential impacts of natural and anthropogenic disturbance to the system and predict the implications of these changes to society (e.g. – Meinke et al., 2009; Cook et al., 2010). For example, biophysical science is important for predicting the likely consequences of disturbances to environmental assets, and testing the effectiveness of possible management responses, thus allowing proactive rather than reactive management actions to be taken (Evans et al., 2011). Primary biophysical science alone, however, cannot establish the societally acceptable thresholds, which is an important element of decision making. Thus, there is a growing recognition that the social and economic sciences are critical for informing the sustainable management of ecological goods and services (Endter-Wada et al., 1998; Mascia, 2003). For example, the social sciences are important for elucidating the cultural beliefs, values, norms and rules of local communities to serve as the foundation of formal laws and regulations that will govern protected areas, thus increasing their likely success (Mascia, 2003). Accordingly, incorporating social and economic science, in combination with biophysical science, into the decision-making processes for natural resource management is now widely advocated (e.g. – Aswani and Hamilton, 2004; Salick and Ross, 2009; de Jonge et al., 2012; Naess, 2013; Glass et al., 2015).

Despite widespread recognition regarding the importance of integrating primary science into the decision-making process for natural resource governance and an increase in the number of applied scientific publications (Ormerod et al., 2002), an implementation gap between science and natural resource management remains (Sutherland et al., 2004; Knight et al., 2008; Kirchhoff, 2013). Specifically in relation to marine systems it was recently shown that although marine resource managers and scientists have similar research interests and identify similar future research priorities, decision-makers may be unaware of the full breadth of existing scientific information that they could use to inform their decision-making processes (Cvitanovic et al., 2013). Subsequently, marine resource decision-makers from a range of agencies and locations were found to rely on individual experiences or other secondary sources of information when developing and implementing conservation actions in isolation from scientific evidence (Cvitanovic et al., 2014a; Addison et al., 2015). This pattern potentially compromises the effectiveness of their decision with adverse flow-on effects to the people and communities who depend on the goods and services provided by marine systems. Accordingly, improving knowledge-exchange among marine scientists and decision-makers is fundamental for supporting the adaptive governance of marine resources and to ensure their sustainable management for future generations (de Jonge and Giebels, 2015). To advance that goal, we provide a narrative review based on published literature describing knowledge exchange among environmental scientists and decision-makers, drawing heavily on an emergent and growing body of literature specifically focused on understanding this relationship in the marine resource management sector. Doing so we identify ongoing barriers to knowledge exchange, the options and enabling environments required to overcome these barriers, and key gaps in our understanding that must be addressed if we are to improve knowledge exchange among marine scientists and decision-makers.

2. An introduction to knowledge exchange

In undertaking this review it is first instructive to provide a brief introduction to the concept of knowledge exchange. Indeed, understanding the relationship between knowledge and decision-making is not new, but rather a long-standing question of academic interest with deep roots in philosophy (Rich, 1979; Majone, 1989). In the past 15 years, however, this relationship has become increasingly prominent in the scientific literature in recognition of the need to converge diverse but complementary disciplinary approaches and views in response to complex problems across a wide range of sectors such as health, education, business and environmental management (Fig. 1). Specifically in the conservation and resource management sectors, knowledge exchange is increasingly recognised as a key factor facilitating the social, environmental and economic impacts of research (Fazey et al., 2013), thus improving the sustainable management of natural systems and the goods and services they provide, and in turn ensuring the safety and well-being of the people that depend on them.

Throughout the literature there are multiple definitions of knowledge exchange and multiple terms used to describe knowledge exchange processes (reviewed by Fazey et al., 2013). A common recognition, however, is that knowledge exchange describes the interchange of knowledge between research users and "scientific" producers (Mitton et al., 2007). The concept of knowledge exchange, therefore, encompasses all facets of knowledge production, sharing, storage, mobilization, translation and use (Best and Holmes, 2010). As such, when done successfully it is believed that knowledge exchange increases the likelihood that knowledge and evidence will be used in policy and practice decisions, thus increasing the success of those decisions in meeting their objectives.

In a recent systematic review of the knowledge exchange literature relevant to the health sector, Contandriopoulos et al. (2010) identify how knowledge exchange processes primarily occur at two complementary levels. The first, termed *autonomy*, refers to the fact that the potential users of knowledge are typically sovereign in their capacity to mobilise knowledge and subsequently, modify