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Review

Ecological research and environmental management: We need different interfaces based on different knowledge types

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ABSTRACT

The role of ecological science in environmental management has been discussed by many authors who recognize that there is a persistent gap between ecological science and environmental management. Here we develop theory through different perspectives based on knowledge types, research categories and research–management interface types, which we combine into a common framework. To draw out insights for bridging this gap, we build our case by:

(i) explicitizing the link between three categories of ecological research and the type of research–management interface they are associated with. We first evaluate three types of unidirectional interfaces and recommend a new kind of interface – called the Research-Within-Management interface (RWM).
(ii) suggesting that adaptive management and structured decision-making can integrate all these different angles and serve as meta-interfaces in their relation to research.
(iii) distinguishing explanatory knowledge from empirical knowledge, and contending that explanatory knowledge is not necessarily the most important output for the research-management interface today.
(iv) highlighting that experiential ecological knowledge—including the expertise and experience of managers, citizens and scientists—is another primary knowledge input in environmental decision-making that should not be systematically downplayed.

We point out the complementarities as well as the specificities and limitations of the different types of ecological research, ecological knowledge and research–management interfaces, which is of major importance for environmental management and research policies.

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1. Introduction

The role of ecological science in environmental management*[1]—hereafter also referred to as 'management'— has been discussed by many authors who recognize that there is a persistent gap between the two (Hart and Calhoun, 2010; Hulme, 2014; Underwood, 1995, 1998; Van Kerkhoff and Lebel, 2006). These authors stress that ecological scientific knowledge* is not sufficiently taken into account in environmental management (Bestelmeyer et al., 2003; Murphy and Noon, 1991; Sutherland et al., 2004; Underwood, 1995). This gap leads to situations where despite scientific advances, we still often fail to manage natural ecosystems in a sustainable way (Bunnell and Huggard, 1999; Howes et al., 2017; Ludwig, 2001; Ludwig et al., 1993; Prendergast et al., 1999). The gap is also manifest when environmental managers*—also referred to hereafter as 'managers'—from around the world call for more useful information (Cash et al., 2003; McNie, 2007).

Several reasons may explain this situation. First, scientific knowledge is not the only factor in environmental decision-making. Many decisions are affected by values, belief systems or political issues unrelated to scientific knowledge (Gregory et al., 2012; Hart and Calhoun, 2010; Ludwig, 2001; Ludwig et al., 1993; Walters, 2007). Furthermore, environmental management is not usually based on ecology-first decisions (Ludwig et al., 1993; Young et al., 2014): the economic and social aspects of sustainability often outweigh the ecological ones (Dovers et al., 1996). Lastly, the ecological basis for sustainable management remains weak due to the fact that interactions between ecological research and environmental managers are not as effective as they might be (Bunnell and Huggard, 1999; Dovers et al., 1996).

The literature has advanced four proposals—from contrasting points of view—to provide a better account of ecological science in management:

(P1) Some authors stress that the *a priori* (or explanatory) credibility* of a scientific result, judged on the coherence and appeal of its concepts* and mechanisms*, is not sufficient for environmental management and would be better supplemented by empirical knowledge* (see Graham et al., 2006; Hulme, 2014; Roux et al., 2006), which is knowledge based on observation or analysis of real data, i.e. data observed in the field or in field-or-lab experiments (cf. Fig. 1). Empirical knowledge includes both evidential (or evidence-based) knowledge*, generated by empirical scientific research, and experiential knowledge*, resulting from ordinary experience or "isolated" random observations without any relation to any predetermined hypothesis or theory*. In what follows, we define a theory as a system of conceptual constructs that organizes and explains the observable phenomena in a stated domain of interest (Pickett et al., 2007) and puts forward potentially falsifiable predictions (Driscoll and Lindenmayer, 2011). A theory therefore incorporates not only an explanatory part but also an empirical part that has two components: (i) the observable phenomena that helped frame the theory through induction and (ii) unsuccessful attempts to refute the theory, which constitutes its evidential base. The credibility of a scientific result or theory (Watanabe, 1975) can be broken down into *a priori* explanatory credibility, based on "extra-evidential", "a-rational" factors (aesthetics, theoretical coherence …) and *a posteriori* evidential credibility. Although Watanabe (1975) developed the notion of credibility within a probabilistic and academic framework, it remains valuable outside these frameworks, in particular regarding the application of scientific knowledge.

(P2) Other authors consider that not all types of interfaces between research and management (see Table 1) provide efficient links between ecological results and management practices. In what follows, we define an interface as both "the place at which independent and often unrelated systems meet and act on or communicate with each other", which is close to the notion of boundary, and "the means by which interaction or communication is achieved at an interface" (Merriam-Webster's Collegiate Dictionary, 10th Edition), which is related to the notion of boundary work. The notions of interface and boundary naturally emerge as soon as we recognize that research and management are very different in many regards (e.g. evaluation systems, risks involved, temporal horizon, public scrutiny and opinion) (Cash et al., 2003). Cash et al. (2003) insisted that conscientious work needs to be done at the boundary between research and decision making, while Roux et al. (2006), Van Kerkhoff and Lebel (2006), and Hart and Calhoun (2010) stressed that classical unidirectional interfaces from research to management are not sufficient to appropriately integrate scientific knowledge into environmental management.

(P3) Focusing on the research side of the interface, Underwood (1995) believes that recognizing four different categories of ecological research would enhance interactions between ecological research and management decisions (see Table 1 and Fig. 2). Category 1 research (R1) is either "directed to the needs of management" or refers to existing results from ecological research that managers may find useful to "evaluate problems, validate the questions and formulate models of the system being managed"

[1] A star *flags the first occurrence of words that we define in the Glossary found in Supplementary Material Appendix A.