



## Boundary work for implementing adaptive management: A water sector application



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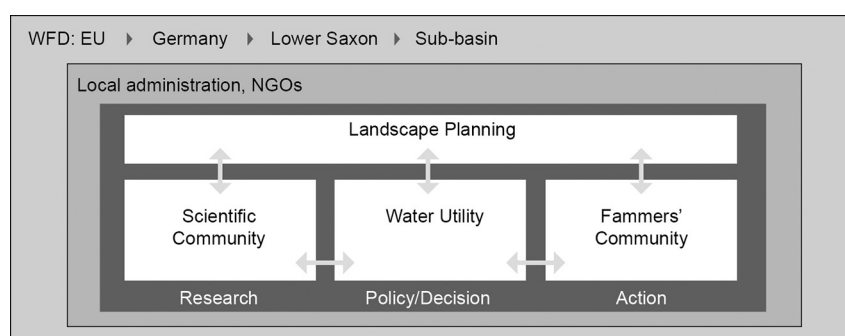
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### HIGHLIGHTS

- We assess boundary work as conceptual framework to support adaptive management.
- Case study is knowledge cogeneration and application in watershed management.
- Evidence found of boundary work for enlightenment, decision, and negotiation support.
- Guidance provided for identifying barriers and implementing adaptive management.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Boundary work, defined as effort to mediate between knowledge and action, is a promising approach for facilitating knowledge co-production for sustainable development. Here, we investigate a case study of knowledge co-production, to assess the applicability of boundary work as a conceptual framework to support implementing adaptive management in the water sector. We refer to a boundary work classification recently proposed by Clark et al., (2016), based on three types of knowledge uses, i.e. enlightenment, decision-, and negotiation-support, and three types of sources, i.e. personal expertise, single, and multiple communities of expertise. Our empirical results confirm boundary work has been crucial for the three types of knowledge use. For enlightenment and decision-support, effective interaction among knowledge producers and users was achieved through diverse boundary work practices, including joint agenda setting, and sharing of data and expertise. This initial boundary work eased subsequent knowledge co-production for decision-support and negotiations, in combination with stepping up of cooperation between relevant actors, suitable legislation and pressure for problem solving. Our analysis highlighted the temporal dimension matters - building trust around enlightenment first, and then using this as a basis for managing knowledge co-production for decision-, and negotiation support. We reconfirmed that boundary work is not a single time achievement, rather is a dynamic process, and we emphasized the importance of key actors driving the process, such as water utilities. Our results provide a rich case study of how strategic boundary work can facilitate knowledge co-production for adaptive management in the water sector. The boundary work practices employed here could also be transferred to other cases. Water utilities, as intermediaries between providers and beneficiaries of the important water-related ecosystem service of clean water provision, can indeed serve as key actors for initiating such boundary work practices.

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## 1. Introduction

Boundary work is a useful concept increasingly proposed to facilitate production and use of knowledge for sustainable development that meets human needs while protecting life-supporting ecosystems (Clark et al., 2016; Mollinga, 2010; van Kerkhoff and Lebel, 2006). Defined by Cash et al. (2003) as any effort put in place by any organization that seeks to mediate between knowledge and action, boundary work entails an active management of the tension that arises at the interface between producers and users of knowledge (Clark et al., 2016). Ultimately, it aims at forming boundaries that allow meaningful communication between producers and users of knowledge, while “avoiding mixing facts with opinions, and science with politics” (Clark et al., 2016).

Recently, Clark et al. (2016) advanced a generalized framework of boundary work to provide guidance on how diverse stakeholders may collaboratively produce knowledge and establish good working relations to promote cooperative implementation (henceforth, we will refer to this in short as “knowledge co-production”). The framework classifies boundary work with respect to two dimensions: use and source of knowledge. It considers three types of knowledge use (enlightenment, decision-support, and negotiation-support) and three types of knowledge source (personal expertise, single community of expertise, and multiple communities of expertise), and thus defines nine different contexts of knowledge co-production. For each of these contexts, it illustrates potential barriers to knowledge co-production as well as defines the related boundary work strategy, by specifying the criteria, attributes, and functions that most contribute to the likelihood of its success (see description in Section 2).

A promising field of application of boundary work is adaptive management of natural resources, which requires an adequate understanding of interdependencies between the atmosphere, hydrosphere, biosphere, lithosphere, and the social processes in the anthroposphere. Adaptive management is here understood as an innovative management paradigm that acknowledges an increasing collective awareness of uncertainty and change, and puts emphasis on the importance of social learning (Albert et al., 2012; Pahl-Wostl et al., 2011; Schultz et al., 2015). Ideally, it emerges as a collective effort of stakeholders that engage in iterative learning cycles to pursue an array of long-term societal objectives (Cortner and Moote, 1994; Gleick, 2000; Pahl-Wostl et al., 2011, 2007). In real-life, however, implementing adaptive management is an arduous challenge, primarily because it requires “linking of diverse stakeholders and knowledge systems, across management levels and across institutional boundaries” (Kowalski and Jenkins, 2015). In this respect, the boundary work framework could be of substantial assistance by helping foresee potential barriers to knowledge co-production and identify the related boundary work strategies. Despite increasing research on boundary work - for example, concerning design of multi-purpose watershed investments (Adem Esmail and Geneletti, 2017), participatory scenario processes (Chaudhury et al., 2012), and boundary organizations (Boezeman et al., 2013) - empirical evidence on how boundary work can support knowledge co-production for adaptive management is still limited.

The objective of this research is thus to investigate - in a case study of knowledge co-production for adaptive watershed management - if and how boundary work have been put in place. Hence, basing on the collected evidences of presence or absence of boundary work, assess its applicability as a conceptual framework to support implementing adaptive management in the water sector. We consider the water sector as an example because it offers interesting insight into adaptive management and, more generally, into transitions towards sustainability (e.g. Pahl-Wostl et al., 2011; Lieberherr and Truffer, 2015; Truffer et al., 2013). Specifically, we address the following research questions: (i) what were the main types of knowledge use and source in the case study? (ii) What were the critical barriers for knowledge co-

production? (iii) Which boundary work practices were put in place, and to what extent were they effective in contributing to adaptive management?

The selected case study consists of almost three decades of knowledge co-production for adaptive management in the Fuhrberg watershed, in Germany, whose prime beneficiaries are the 650 thousand inhabitants of the city of Hannover and surroundings. The case study is highly pertinent for the objective of this research because it presents long-term and close interactions in knowledge co-production, involving different groups of stakeholders at both individual and organizational levels. Actors involved include scientists, water managers, farmers, landscape planners, local authorities, and environmental groups (See Section 3).

In the next section, we illustrate the boundary work framework. We then introduce the Fuhrberg case study of knowledge co-production for adaptive management. Section 4 presents the operational steps of our methodology: (i) developing a conceptual understanding, (ii) defining limits, and units of analysis of the case study, (iii) collecting data, and (iv) analyzing data. Section 5 reports the results, which consist of empirical evidences of barriers to knowledge co-production and related boundary work practices in the case study. Finally, in the last two sections, we discuss the results and draw some conclusions for better boundary work practice in adaptive watershed management.

## 2. The boundary work framework

A subset of the bridging organization literature (Folke et al., 2005; Olsson et al., 2007; Berkes, 2009; Crona and Parker 2012), the concept of boundary work was originally introduced to understand efforts to demarcate science from non-science (Gieryn, 1983). Since then, the concept has evolved to provide a better framing of an active management of the tension that arises at the interface between stakeholders involved in knowledge co-production. For the scope of this research, we here present the main elements of the boundary work framework shown in Fig. 1, drawing primarily from Cash et al. (2003) and Clark et al. (2016).

The most innovative aspect of the framework is perhaps the systematic classification into nine different contexts of knowledge co-production, based on “what knowledge is used for” and “how users perceive its source”. This makes the framework highly effective in capturing the potential barriers, hence in identifying the most appropriate boundary work strategies (i.e. bundle of specific actions and measures) that could be deployed to overcome such barriers. The classification considers three types of knowledge uses and three types of knowledge sources. In terms of use, knowledge can contribute to enlightenment, support decision-making by a single user, or support negotiations between multiple users (see columns in Fig. 1). In terms of source, users may perceive knowledge as originating from themselves, from a single community of expertise, or from multiple and potentially conflicting communities of expertise (see rows in Fig. 1).

For each context, based on the analysis of several decades of international agricultural research, Clark et al. (2016) provide examples of barriers to knowledge co-production as well as define the most appropriate boundary work strategy to overcome them. Altogether, they identify nine strategies, which they label as: *Contemplation*, *Decision*, *Politics*, *Demarcation*, *Integrative Research & Development*, *Expert Advice*, *Participatory Research & Development*, *Assessment*, and *Political Bargaining*. These strategies, which are well described in Clark et al. (2016), span from the simplest context in which knowledge is used for enlightenment and stakeholders perceive it as their own (*Contemplation*), to the most challenging context in which stakeholders with divergent interests use knowledge from potentially conflicting sources, for negotiation purposes (*Political bargaining*). Here, it suffices to note that these strategies differ mainly in terms of the effectiveness criteria that have to take into account.

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