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Transdisciplinary research on environmental governance: A view from the inside☆

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ABSTRACT

Working effectively across boundaries is a critical skill for researchers focused on environmental governance in complex social–ecological systems, but challenges remain in the acquisition of such skills given the current structure of traditional disciplinary training. In an effort to contribute to improved coordination of research across disciplinary boundaries, we provide an insiders' view based on our experience participating in a two-year transdisciplinary research initiative designed to address the changing nature of environmental governance in the Intermountain West region of the United States. We discuss transdisciplinary research as a promising approach for addressing complex, real-world problems and identify several challenges. We analyze our transdisciplinary research process using the ideas of boundary setting, boundary concepts, and boundary objects. We conclude with reflections and lessons learned, emphasizing the importance of our external boundary setting, the role of funding, and the inexorable link between individual commitment and project success.

1. Introduction

In the past decade, scholars and practitioners have come to recognize that the quest for global environmental sustainability requires innovative research approaches to address the complexity of social–ecological systems and better connect academic studies to decision-making. Transdisciplinary research is a way of organizing academic inquiry to address complex, real-world problems (Hadorn et al., 2008; Pohl et al., 2008). In this article, we reflect upon our experience participating in a two-year research initiative to develop a transdisciplinary framework for analyzing the changing nature of environmental governance in the intermountain west (IMW) region of the United States. We situate our approach as transdisciplinary, as it required a common articulation of the research problem and the joint development of a research framework across multiple disciplines to create a new analytical approach for addressing complex social–ecological problems. Each of us joined the initiative while engaged in individual research studying different cases of emerging environmental governance efforts across the IMW region, varying in geographic scope and scale, drivers, and stakeholder constituencies. Although rewarding, we found working across disciplines and integrating knowledge to be far more challenging than anticipated. Our goal is to contribute to a small but growing body of literature on how to organize and carry out transdisciplinary research to address these challenges and to provide helpful insights for others interested in using this approach.

We begin with a discussion of transdisciplinary research and its challenges before moving to a brief introduction to the IMW Initiative. In the remainder of the article, the boundaries literature is used to reflect on our transdisciplinary research experience. We discuss the importance of our *boundary setting*, which provided a neutral and enabling environment for our work as well as logistical support for our day-to-day activities. Our *boundary concepts* gave us a common language for discussing the challenge of environmental governance in the IMW region. Finally, in developing a shared research framework, we created a *boundary object* that allowed us to conceptualize the dynamics of environmental governance in the IMW region and guided our individual research projects. Through our insiders' view, we contribute to a better understanding of conducting transdisciplinary research, which has been widely acknowledged to be time-intensive and frustrating (Wiesmann et al., 2008; Winowiecki et al., 2011). We also illustrate its benefits through reflections on how this approach enhanced our analysis of environmental governance, a research area that demands the incorporation of diverse perspectives and knowledge domains. We conclude with a discussion of lessons learned.

2. Transdisciplinary research

There is variation in the definition of "transdisciplinary research" within the current literature (Hochtl et al., 2006; Wesselink, 2009). For this paper we apply the definition used by Jakobsen et al. (2004), who define transdisciplinary research

as "coordinated interaction and integration across multiple disciplines resulting in the restructuring of disciplinary knowledge and the creation of new shared knowledge" (Jakobsen et al., 2004, p. 17). This definition broadly encompasses three defining features emphasized in current discussions of transdisciplinary research. First, transdisciplinary research spans disciplinary boundaries in order to overcome the problem of compartmentalization in academia and develop more holistic comprehension of complex societal problems (Pohl et al., 2008; Max-Neef, 2005). While interdisciplinary work retains disciplinary boundaries (Harris et al., 2008; Petts et al., 2008), transdisciplinary work "literally transcends traditional disciplinary boundaries, challenging and renegotiating them" (Petts et al., 2008, p. 597). Lang et al. (2012) and Hadorn et al. (2008) highlight the importance of a collaborative, reflexive, and integrative research process where participants move past disciplinary boundaries by jointly defining the problem, establishing and implementing a research design, and creating collective products through transdisciplinary research.

Second, transdisciplinary research integrates knowledge through mutual learning to create new analytical frameworks and approaches for conducting research and improving society's ability to address complex problems (Hadorn et al., 2008; Lang et al., 2012). This differs from an interdisciplinary approach which is less collaborative in that it does not necessarily involve group-based problem identification, working through a process of shared goal setting, methodological selection, or agreed-upon modes of analyzing data along the way (Harris et al., 2008). In contrast, transdisciplinary research participants jointly develop approaches that develop mutual understanding and respect for diverse theories, epistemologies, and methods (Morse et al., 2007; Pohl et al., 2008; Tacconi, 2011; Wickson et al., 2006). Transdisciplinary research focuses on temporality, with integration as an ongoing endeavor, and emphasizes the importance of creating a process that stimulates mutual learning from diverse values, goals, and resources that individuals contribute (Lang et al., 2012; Pohl et al., 2008; Wiesmann et al., 2008).

Finally, transdisciplinary research is problem-focused (Hadorn et al., 2008; Lang et al., 2012; Max-Neef, 2005; Pohl, 2005; Wesselink, 2009; Wickson et al., 2006). The goal is to identify "science-based solutions for problems in the life-world with a high degree of complexity in terms of factual uncertainties, value loads, and societal stakes" (Wiesmann et al., 2008, p. 435). In contrast to interdisciplinary efforts, transdisciplinary research is centrally focused on addressing societal issues (Hochtl et al., 2006; Wesselink, 2009; Wiesmann et al., 2008). It presents an opportunity to address the governance of complex social–ecological problems by integrating an array of theoretical and methodological approaches across the ecological and social sciences (Evely et al., 2010; Folke, 2007; Hadorn et al., 2008; Lang et al., 2012; Ostrom, 2009; Tacconi, 2011; Wickson et al., 2006). Transdisciplinary research stitches together a panorama through negotiations across disciplinary boundaries. It therefore catalyzes the development of innovative strategies to amend human–environment interactions and increase the resilience of social-ecological systems (ACERE, 2009; Chapin et al., 2009;

Folke, 2006; Van Hartesveldt and Giordan, 2008; Pohl et al., 2008; Walker and Salt, 2006).

Our work can be characterized as transdisciplinary in the sense that it was problem-focused and involved mutual learning across disciplinary boundaries through a collaborative, reflexive, and integrative research process resulting in a jointly produced analytical framework that transcends disciplinary paradigms in the social and natural sciences. We developed the IMW framework (outlined below) for a broad spectrum of practitioners, stakeholders, and researchers to apply. Therefore we believe our experience offers insights and lessons on the potential for and the obstacles of transdisciplinary research.

The nature of transdisciplinary research gives rise to a number of challenges, such as communication across disciplinary and professional boundaries (Pohl et al., 2008; Winowiecki et al., 2011). Disciplines and professions often possess unique concepts and jargon not easily translated, making it difficult for transdisciplinary team members to understand one another. Such teams must develop strategies for clarifying and sharing vocabulary, meaning, and context (Winowiecki et al., 2011). Overcoming the communication barrier in transdisciplinary research takes considerable time, effort, patience, and interpersonal skills.

While the problem orientation of transdisciplinary research provides a common reference point for discussions and facilitates cross-boundary dialog (Morse et al., 2007; Winowiecki et al., 2011), it can also create challenges as scholars find themselves pulled between competing desires of addressing societal problems and advancing professionally through the production of peer-reviewed disciplinary publications (Morse et al., 2007; Lele and Norgaard, 2005; Pohl et al., 2008). Wiesmann et al. (2008, p. 438) contend that disciplinary expectations often win out because "the social reference and control systems of participating researchers and stakeholders is anchored within their home institution and not within the transdisciplinary team." A lack of institutional or peer support can make it difficult for individual scholars to commit to transdisciplinary research activities, which may affect the legitimacy of the project. Other challenges widely cited in the literature include a lack of funding and/or training to work across disciplinary boundaries, individuals' fear of failure, insufficient problem framing, long-term participation, and even competing disciplinary policy cultures (Lang et al., 2012; Morse et al., 2007; Pohl, 2008).

3. The IMW Initiative

Over a two year period, we participated in a transdisciplinary research effort to analyze the changing nature of environmental governance in the IMW region, bounded by the Rocky Mountain Range to the east and the Cascade and Sierra Nevada Mountain Ranges to the west and including the states of Colorado, New Mexico, Arizona, Utah, Wyoming, Montana, and Idaho (Fig. 1). The IMW is a complex social–ecological system containing natural resources that are simultaneously characterized by abundance and scarcity. Rapid population growth and economic development pressures, coupled with changing climatic conditions, create an uncertain future and

raise questions about the region's long-term resilience or ability to absorb and respond to these changes (Folke, 2006; Theobald et al., 2013).

These dynamics raise important questions for environmental governance, the process of steering human–environment interactions through formal and informal institutions, policies, rules, and practices (Evans, 2012; Young, 2012). Historically, the federal government has dominated the region's environmental governance system, but as federal funds decline, new approaches to environmental governance have emerged, including incentive-based watershed programs, roundtables, collaborative conservation initiatives, and water banks. These new mechanisms differ from the traditional governance system in that they emphasize local-level decision-making processes, include citizen science or practice-based judgments, and/or incorporate cross-jurisdictional networks and partnerships. The IMW Initiative seeks to better understand this changing nature of environmental governance in the IMW region.

The IMW Initiative was launched in 2011 as a project of the Environmental Governance Working Group[1] (EGWG), a multi-disciplinary community of scholars interested in the study of environmental governance at Colorado State University (CSU). EGWG was established in 2008 with funding from CSU's School of Global Environmental Sustainability[2] (SoGES) and today includes approximately 30 faculty and graduate students primarily from the College of Liberal Arts and the Warner College of Natural Resources. EGWG facilitates cross-disciplinary dialog through seminars and study groups, which have produced annotated bibliographies, collaborative grant proposals, and co-authored review papers (e.g. Sternlieb et al., 2013).

EGWG's IMW Initiative was intended to coordinate ongoing but disparate research activities at CSU on the many pressing governance challenges in the region. EGWG began by hiring a coordinator who organized three workshops to explore interest in collaboration. The final IMW study group consisted of fourteen graduate students and faculty from the Departments of Political Science and Sociology in the College of Liberal Arts; the Departments of Forest and Rangeland Stewardship, and Geosciences in the Warner College of Natural Resources; and the Graduate Degree Program in Ecology. Study group members met at least once a month and focused on the development of a conceptual framework that could be applied to individual case studies of environmental governance initiatives in the areas of land-use and water across the region (Fig. 2).

We recorded notes for each meeting in order to document the evolution of our transdisciplinary process and to provide a basis to evaluate the resulting coordinated efforts. Our meetings involved rich discussions of the interactive relationship between the co-creation of the analytic framework and the development of individual case studies. Exit surveys were administered to group members in the form of post-project, short answer questions about members' experiences with the transdisciplinary process. These surveys spurred additional joint reflection by the group. Although our collaborative work

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[1] http://egwg.colostate.edu.

[2] http://sustainability.colostate.edu.

Fig. 1 – Map of the intermountain west region of the United States.

involved a great deal of learning by doing, retrospectively we find that the body of literature surrounding boundaries captures our approach to transdisciplinary research and allows us to discuss how it shaped our collective and individual thinking about environmental governance changes in the IMW region.

4.   Boundaries and the IMW Initiative

The original notion of boundary work was introduced by Gieryn (1983), describing a rhetorical process through which scientists construct boundaries distinguishing scientific intellectual activity from non-science. Subsequent boundary scholarship has developed several related concepts which we found helpful for reflecting on our transdisciplinary approach. *Boundary concepts* foster thinking about the complexity and multidimensionality of an issue and provoke constructive discussions (Löwy, 1992; Mollinga, 2010). *Bound-*

ary objects serve as shared structures and ''common objects that form the boundaries between groups'' through their flexibility (Star, 2010, p. 603) (see also: Star and Griesemer, 1989; Bowker and Star, 1999). *Boundary settings* provide a context in which scholars can develop and use these concepts and objects to carry out transdisciplinary work (Mollinga, 2010). Importantly, these ideas are not components of the IMW framework we eventually developed; rather, they provide an analytical structure to assess our transdisciplinary research process. We begin by discussing our boundary setting; without an enabling environment in which to cultivate our ideas, the IMW Initiative would never have broken ground.

4.1.   Boundary setting

Participation in transdisciplinary research requires scholars to integrate knowledge across multiple disciplines often in the face of institutional and logistical obstacles (Morse et al., 2007;
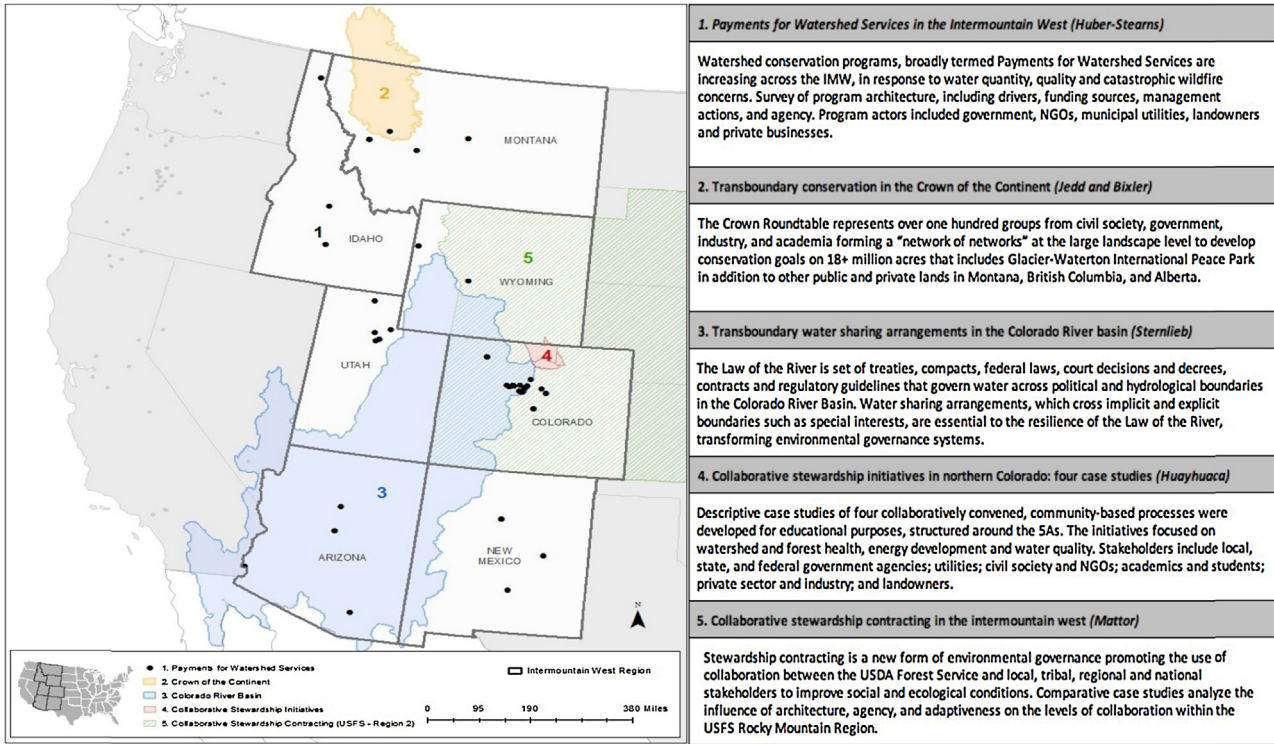
1. Payments for Watershed Services in the Intermountain West *(Huber-Stearns)*
Watershed conservation programs, broadly termed Payments for Watershed Services are increasing across the IMW, in response to water quantity, quality and catastrophic wildfire concerns. Survey of program architecture, including drivers, funding sources, management actions, and agency. Program actors included government, NGOs, municipal utilities, landowners and private businesses.
2. Transboundary conservation in the Crown of the Continent *(Jedd and Bixler)*
The Crown Roundtable represents over one hundred groups from civil society, government, industry, and academia forming a "network of networks" at the large landscape level to develop conservation goals on 18+ million acres that includes Glacier-Waterton International Peace Park in addition to other public and private lands in Montana, British Columbia, and Alberta.
3. Transboundary water sharing arrangements in the Colorado River basin *(Sternlieb)*
The Law of the River is set of treaties, compacts, federal laws, court decisions and decrees, contracts and regulatory guidelines that govern water across political and hydrological boundaries in the Colorado River Basin. Water sharing arrangements, which cross implicit and explicit boundaries such as special interests, are essential to the resilience of the Law of the River, transforming environmental governance systems.
4. Collaborative stewardship initiatives in northern Colorado: four case studies *(Huayhuaca)*
Descriptive case studies of four collaboratively convened, community-based processes were developed for educational purposes, structured around the 5As. The initiatives focused on watershed and forest health, energy development and water quality. Stakeholders include local, state, and federal government agencies; utilities; civil society and NGOs; academics and students; private sector and industry; and landowners.
5. Collaborative stewardship contracting in the intermountain west *(Mattor)*
Stewardship contracting is a new form of environmental governance promoting the use of collaboration between the USDA Forest Service and local, tribal, regional and national stakeholders to improve social and ecological conditions. Comparative case studies analyze the influence of architecture, agency, and adaptiveness on the levels of collaboration within the USFS Rocky Mountain Region.

Fig. 2 – Individual case studies developed by IMW study group team members.
We thank the Bureau of Reclamation (Lower Basin Office, Boulder City), Colorado State University Geospatial Centroid, and Crown Roundtable for map production data.

Pohl et al., 2008; Wiesmann et al., 2008). According to Mollinga (2010), the boundary setting provides a space where this knowledge integration can be effectively developed and applied. The external boundary setting includes the disciplinary or programmatic home for the research effort, funding arrangements, and administrative processes, while the internal setting refers to how the group carries out its work. In terms of our external setting (Fig. 3), we are fortunate our university has several initiatives supportive of cross-disciplinary interaction.[3] EGWG, which was the primary institutional home for our work, had already established itself as a neutral space for cross-disciplinary communication and thus increased the legitimacy of the IMW Initiative (contrasted with a more ad hoc arrangement), making it easier for participants to prioritize IMW-related work. In addition, EGWG provided leadership and management for the study group by conceiving the broad contours of the project and hiring a coordinator who provided administrative support. SoGES, an umbrella organization for environmental education and research across campus, was another important part of the IMW Initiative's external setting. Among other functions, it supports innovative research that goes beyond traditional disciplinary boundaries. The IMW Initiative was selected as one of the SoGES "Global Challenge Research Teams," which provided

funding for a coordinator and participation in a professional conference, and contributed physical meeting space.

A third component of the external setting was our link to the Earth System Governance (ESG) network, which was launched in 2009 as a core project of the International Human
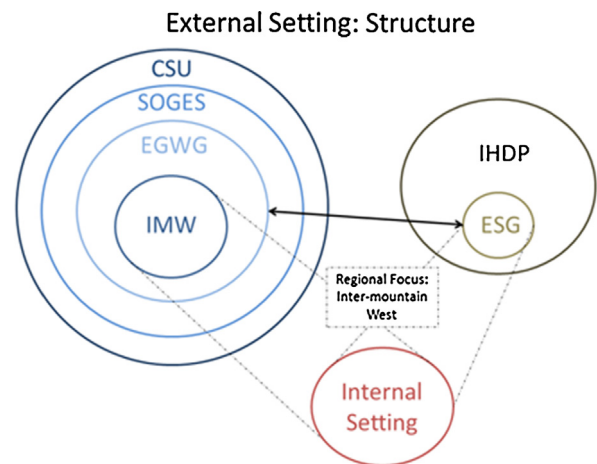

Fig. 3 – The Boundary Settings of the IMW Initiative Study Group. Colorado State University (CSU), School of Global Environmental Sustainability (SoGES), Environmental Governance Working Group (EGWG), Intermountain West Initiative (IMW), International Human Dimensions Programme on Global Environmental Change (IHDP), Earth System Governance network (ESG).

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[3] The Center for Collaborative Conservation at CSU is another catalytic entity that shares overlapping participation with EGWG. All authors on this paper have been affiliated with the Center, primarily through fellowships and project funding.

Dimensions Programme on Global Environmental Change (IHDP) and is today the largest social science research network in the area of environmental governance.[4] As an ESG Research Centre, EGWG is committed to implementing the ESG Science Plan, which is organized around a set of five analytical themes. As discussed below, these themes served as our primary boundary concepts. Tethering the IMW Initiative to the ESG science plan situated our research within an international community founded upon cross-disciplinary scholarship.

While EGWG, SoGES and the ESG network provided an enabling environment for our transdisciplinary collaboration, each member was also situated in a particular discipline within their department, including landscape ecology, geography, forest policy, environmental sociology, and forest science. Being based in distinct departments, each with their own administrative procedures and disciplinary expectations, can conflict with transdisciplinary work. Many of us, especially the graduate students, had difficulty navigating between our transdisciplinary interests and departmental obligations. Fortunately, several of the students' faculty advisors were involved in the IMW Initiative and provided guidance for successfully balancing these obligations in the face of institutional and logistical obstacles.

Our internal setting was very important and evolved over time through trial and error. As suggested by Wiesmann et al. (2008), having a project coordinator was fundamental to maintaining momentum. Reflecting on the process, one participant noted, "I believe that a collaborative group of any kind, especially one that crosses multiple disciplines, needs a leader… to make final decisions, set goals, bring the group together, arrange logistics, and stay on task." We used web-based polls to arrange meetings, trying to accommodate schedules for a majority of participants. As another participant discussed, "Scheduling was always a major hurdle, as we all needed to manage our department obligations. However, the nice thing was that meeting space was always available." In terms of carrying out our work, we developed several strategies (discussed below) and utilized online collaboration tools, including shared cloud storage and a real-time document editing program to share and co-create documents. These platforms allowed us to work independently while providing an opportunity to share discoveries and ideas between meetings. They also facilitated writing sessions where a number of us sat together co-authoring and discussing a document simultaneously. External deadlines (e.g. conference presentations) helped focus our work.

Our study group was held together by a core group of individuals who were committed to the project from the outset, despite few material incentives and formidable institutional barriers. Morse et al. (2007) argue that individual dedication, patience, and willingness to take risks are important to the success of any cross-disciplinary research exercise. Several participants had worked together in other EGWG study groups, which had established familiarity, trust, and affability that helped reduce the transaction costs associated with embarking on this transdisciplinary effort. Both participating graduate students and faculty considered this study group a complement to their ongoing research as it

situated our individual research efforts within the group's broader analysis of environmental governance in the intermountain west. Notably, some acknowledged being predisposed to working across disciplinary boundaries, observing they tend to operate at the fringes of their own disciplines, and/or have moved between disciplines over the course of their careers.

Both the external and internal boundary settings helped create a sense of community, alleviating some of the isolation often experienced in academia. According to one participant, "The IMW group was essentially a forum for me to continue group engagement and co-learning in this time of transition after coursework and exams." Our study group therefore became a valued community for its members and a key site for mutual learning.

4.2. Boundary concepts

As noted above, communication barriers are one of the most significant obstacles in any boundary-crossing activity (Pohl et al., 2008; Winowiecki et al., 2011). Löwy (1992) describes boundary concepts as loose concepts that create alliances across knowledge and professional domains, while still protecting the authority and legitimacy of participants' home domains. These are "fuzzy" terms or phrases that refer to the same object, process, or quality in the construction of shared understanding of a given phenomenon. Effective boundary concepts are inherently multidimensional, and make it possible for researchers to develop a common language and shared understandings despite divergent starting points (Mollinga, 2013). This is similar to Jasanoff's (1987, p. 203) notion of "trans-science" work, which refers to a process of deconstructing scientific knowledge and reconstructing it in policy relevant terms. We found the process of developing boundary concepts to be extremely challenging even though we were largely working within the academic context. As the transdisciplinary literature suggests, the process of developing a common language and shared understanding helped prepare us for the more complex challenge of later applying the framework to case studies bridging the science-society divide (Pohl et al., 2008; Winowiecki et al., 2011).

A large portion of our time together involved developing our shared language. We borrowed our boundary concepts from the ESG project's science plan, which identifies five analytical themes (the "5As") related to the challenge of achieving earth system governance: governance *architectures* (or system of institutions, rules, and decision-making procedures within an issue area); *agency*, especially as it is exercised by actors other than government; the *adaptiveness* of governance processes; their *accountability* and legitimacy in the eyes of those being governed; and the modes of *allocation and access* for distributing the benefits and burdens of environmental protection (Biermann et al., 2010; Fig. 4). We initially chose this approach as a way to fulfill our commitment to advancing the project's science plan as an ESG research center, but also found that the ESG 5A framework provided a neutral starting point and common vocabulary around which to organize our discussions. Although the 5As framework is based in the social sciences, it provided a foundation from which we were able to broadly identify relevant questions across our diverse
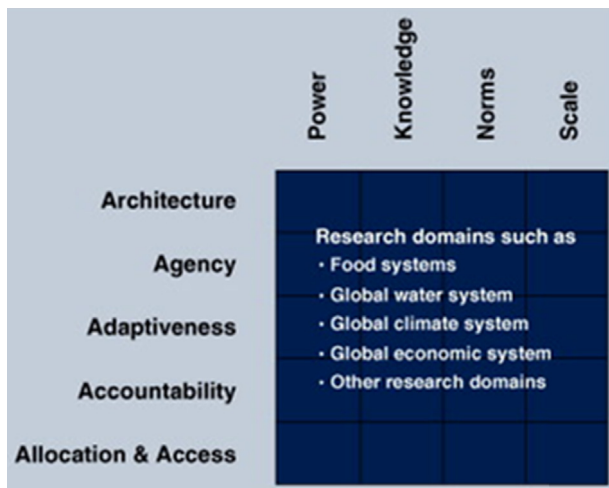

Fig. 4 – The Earth System Governance conceptual framework (Biermann et al., 2010).

disciplinary perspectives. These discussions led to the development of the IMW conceptual framework.

It took several weeks to develop shared understandings of each concept, largely because we had to work through confusion rooted in our diverse disciplinary backgrounds

and use of jargon, requiring investment in understanding each member's respective terminology and epistemology. An important step in this process was a meeting in which we discussed each of the 5As by sharing our own disciplinary perspectives on its meaning, listing key words and questions, and identifying a common set of overarching research questions. This process prompted us to consider the diversity of ideas, assumptions, and research approaches we each contributed.

We also found it helpful to work collectively through a case study of the Collaborative Forest Landscape Restoration Project, which was familiar to all study group participants, in order to reach agreement on how to operationalize each concept. Working together through a focused example helped us clarify our emerging understanding of each A and refine specific research questions, as suggested by Winowiecki et al. (2011). We then completed several assignments reflecting on how these questions might be addressed within the context of our own research. In some instances, we found that research questions did not fit or that we had overlooked a particular dimension of the 5A framework, providing an excellent platform to discuss revisions to the framework and refine our research questions. Through this iterative process, we created a table with a broad overarching question and a series of sub-questions for the revised framework (Table 1).

Table 1 – Final research questions for each 5As concept.		
Category	Defining question	Sub-questions
Agency	Who is involved in the decision making and what role(s) do they play?	– Who is associated with what internal and/or external drivers? – Who is in favor? Who is opposed? – How a re they involved (design and/or implementation)?
Architecture	What are the governance mechanisms?	– What is the structure of the decision-making process (horizontal, vertical, etc.)? – What is the structure of the rules system (markets, hierarchy, networks, etc.)? – How are decisions made and influenced?
Adaptiveness	How does the system anticipate and respond to change?	– Are the changes short-or long-term? – Are the changes coming from internal or external sources? – What is being impacted? What is adapting to change? – Are the changes coming from internal or external sources? – What is causing the impact(s)? – Is the governance mechanism capable of anticipating issues/problems/crisis? – Where does monitoring fit in?
Allocation and access	How are rights and impacts distributed?	– Who has access to which resources? – Who has access to the decision-making process? – Who is impacted by the decisions and/or the decision-making process? – How are various resources allocated?
Accountability	What are the mechanisms for holding agents accountable to each other, policy goals, and the public good?	– Is the governance mechanism meeting its intended goals? – Who are agents held accountable to? – Who enforces the rules? How are the rules being enforced? – Who are the rules being enforced for? – Is the governance mechanism addressing the needs of internal and external interests? – Are the rules transparent? – What is the process to ensure the governance mechanism meets the public good?

Despite the time and effort required, the process of developing a common language was richly rewarding. One group member appreciated the opportunity "to look at the same set of questions through a different lens but return to a common framework to offer a compatible and complementary narrative." Through our shared language, we began to see areas of overlap and new opportunities for collaboration. We also began to think about our own research in new ways. For example, one member remarked,

"The work that we did parsing out the questions related to each A helped me pinpoint how I might identify the A (accountability) in my research: in terms of recognizing it in the literature and in my interactions with practitioners...it was useful both in identifying concepts in the governance literature (even when they may not have been explicitly named as one of the As to begin with) and also in crafting interview questions with conservation practitioners."

We had different experiences incorporating this *lingua franca* in our disciplinary work. One member "found it challenging to translate that language to my discipline and vice versa," while another integrated the concepts in teaching and found they "shaped the way a cohort of students thinks about collaborative governance."

4.3.   *Boundary object*

Although the boundary concepts identified in the ESG 5As framework allowed us to build a shared language, they did not provide a clear basis for coordinating our research efforts because we each focused on different As in our own research. Through our discussions, we became interested in the connections between the 5As and agreed that research on these interactions could provide a common foundation for our individual research, while generating new research questions about the dynamics of change in environmental governance in the IMW region. For example, how are new governance mechanisms reconfiguring agency in the region, and how do these new forms of agency challenge the existing governance architecture? Exploring these connections could further the ESG agenda, since most ESG-associated research currently focuses on individual As. We also wanted to better integrate the cross-cutting themes of power, knowledge, norms, and scale that are incorporated in the ESG conceptual framework but not clearly integrated in research on the 5As. Finally, we needed a way to account for the social, political, economic, and ecological drivers of change in environmental governance in our research. To achieve these aims, we jointly developed our "boundary object": the IMW conceptual framework (Fig. 5).

Theoretically, a boundary object is a structure that represents shared space between diverse groups (Star, 2010)—in our case, between disciplinary communities. Boundary objects have been described as heuristic mechanisms and processes employed in learning and decision-making contexts that involve conflicting perspectives, diverse ways of knowing, and imperfect knowledge (Mollinga, 2010; Pohl et al., 2008). Their key function is to allow different groups to work together, even in the absence of consensus (Star, 2010). Boundary objects are based on action and structured to accommodate the different informational needs of their users. On the one hand, they should exhibit flexibility and plasticity in order to adapt to participant needs. On the other, they should be robust in their ability to facilitate commonality of use (Star and Griesemer, 1989).

Our boundary object needed to integrate research on the interactions between different aspects of environmental governance while remaining flexible and modular enough to be used alongside other disciplinary frameworks and theories. Frameworks provide an opportunity for general analysis and applicability to a variety of theories and methods by providing a universal set of elements relevant to the phenomena at hand (Ostrom, 2011). As such the IMW framework provides the opportunity to incorporate appropriate theories and methods from across multiple disciplines to identify salient ecological and social drivers and outcomes of environmental governance processes. In addition, the practitioner perspective was
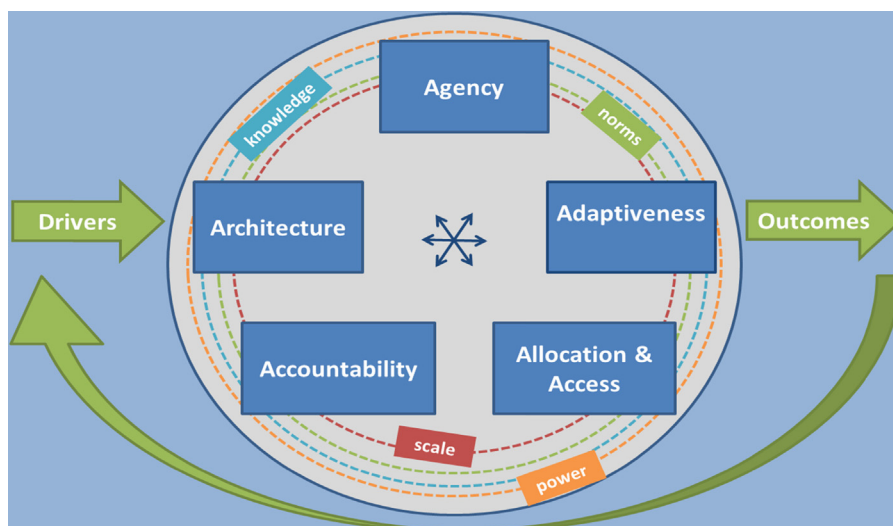

Fig. 5 – The IMW conceptual framework.

incorporated by drawing on the past experience of group members who had worked for or with stakeholders, such as private citizens, local government, federal agencies, private businesses, and/or non-profit sector organizations. We developed the IMW conceptual framework with the intention of it being used by a broad spectrum of practitioners and researchers, and thereby identify it as a transdisciplinary framework.

The individual case studies focused on drivers, outcomes, and changes to a particular A (contingent on the case characteristics or the author's particular interests), exploring how these changes in one dimension of environmental governance were shaping other dimensions. One participant observed, "The flexibility/generic nature of the IMW framework is both a strength and a challenge in application to research. The broad questions laid out within our framework were not as helpful to me as the framework itself, and the visualization of the relationship(s) between different components. Knowing where to start with the framework and what direction to take was initially challenging." Ultimately, there was considerable variation in how the framework was applied to our individual research projects, reflecting the tensions of departmental demands and expectations. For some, the IMW framework was central to their research design, whereas for others it peripherally informed their general research approach.

Our work followed what Mollinga (2010) calls the "assessment route" to developing a boundary object, involving practical frameworks for mapping and evaluating a particular situation. The assessment route involves creating boundary objects, which Mollinga describes as a common strategy to accomplish integration across disciplinary work in the natural resource management field (Mollinga, 2010). We created a simplified model for the evaluation of environmental governance change in the IMW region. We developed the IMW framework to inform the direction of our individual research, providing a common structure to address central questions and themes reflected in our boundary concepts, while remaining flexible enough to accommodate our unique cases. While general, the IMW adds value as a tool for addressing complexity in environmental governance systems, crossing disciplinary and professional boundaries, and for integrating different types of data and research approaches within a single structure.

The IMW framework emerged from our boundary concept discussions, and examining the connections between the 5As, honed our understanding of each concept. As identified in the literature, diagramming was critical to developing our framework (Winowiecki et al., 2011). We spent many hours working through various iterations, visualizing the relationships between the 5As, and considering how each might contribute to understanding environmental governance change in the IMW region. This process led us to the overarching research question for our work: How is the system of environmental governance changing in the IMW region? Because we recognized the importance of identifying and understanding drivers of change and assessing the outcomes of these changes for long-term resilience of the IMW social–ecological system we were better situated to first address the internal environmental governance relationships.

This laid the foundation for subsequent case study research focusing on the external drivers and outcomes, as well as interactions between the 5As.

5.   Final reflections and lessons learned

The realm of environmental governance is inherently complex, demanding navigation of many kinds of boundaries (including jurisdictional, cultural, and disciplinary), and consideration of multiple scales (Sternlieb et al., 2013). It is a topic particularly well suited for transdisciplinary research, and we find the boundary literature provides effective metaphors for describing this process in retrospect. While we have acknowledged that the transdisciplinary research process is time and labor intensive, we propose that incorporating these boundary ideas into process design in advance of the research endeavor could improve its opportunities for success.

Our experience highlights the critical importance of the boundary setting overall as described by Mollinga (2010), and particularly the external boundary setting (see also: Pohl et al., 2008; Wiesmann et al., 2008). We find it hard to imagine that transdisciplinary research can be organized effectively from within one particular discipline. Rather, it requires a neutral space (both physical and intellectual) where individuals from multiple disciplines can reasonably expect their perspectives and contributions will be valued. Our affiliation with more established entities like the ESG research network legitimized our efforts, as did the resources granted to us from SoGES. Our findings reinforce what other studies have shown: the transdisciplinary process requires time and space to develop working relationships, to build trust and legitimacy, and to select working practices (Harris et al., 2008; Lang et al., 2012). Group research efforts could be jeopardized if funding or institutional space run out before these are established.

Funding is likely to remain a considerable obstacle for future transdisciplinary research (Pohl et al., 2008). At a minimum, such efforts should employ administrative support. One of the challenges for securing funding has to do with the process of writing proposals, which typically requires a priori statements of research goals, hypotheses, and methods. It is difficult to write such proposals for transdisciplinary research given that these are negotiated during the course of the research. We were fortunate to have access to funding explicitly designated for this purpose.

In terms of the internal setting, we attribute much of our success to the commitment of individual participants, as identified by Morse et al. (2007). Our experience suggests that transdisciplinary research is not for everyone; participants should be amenable to intellectual risk-taking and to the ambiguities that emerge from the interactions of different academic cultures and languages. More training is needed to build capacity for transdisciplinary research (Jakobsen et al., 2004), but in the absence of explicit training, we found that our ability to communicate complex ideas across disciplines and to a broader audience was facilitated by working through our boundary concepts. The mutual respect built during this process created a sense of community, which in part kept

contributors coming back. While physical proximity and interaction was part of this experience, our internal organization was heavily dependent on information sharing technology.

Without the ESG 5A framework it is unclear how we would have organized our discussions of boundary concepts and developed our *lingua franca*. Boundary concepts materialize through interaction; we could have spent months exploring different frameworks and searching for core concepts. The ESG framework, which is not tied to a particular discipline, made our work more efficient by providing a reasonably neutral vocabulary to start the dialectical process of negotiating meaning and direction. Even so, articulation of assumptions, disagreements, and misunderstandings over terms, though time consuming, were important to the co-construction of new knowledge.

Finally, we wish to re-emphasize the importance of the transdisciplinary *process* (Pohl et al., 2008; Wiesmann et al., 2008) from an inside view, especially as it pertains to environmental governance. In the words of one of our members:

> ''The IMW research group provided an informal, quasi-departmental home for like-minded scholars from other departments. While I think the university recognizes the value of transdisciplinary research, its own structure and momentum can make it difficult to do this sort of work for reasons ranging from time to incentives. The IMW group was especially helpful because it provided a forum for hashing out governance ideas and concepts that are so critical to understanding the interactions of social-ecological systems, and which can seem so opaque if one hasn't studied them explicitly.''

Also worth highlighting is the valuable experience of simultaneously participating in, analyzing, and reflecting upon the transdisciplinary process. The perspective one gains participating in such a process can strengthen the capacity for future transdisciplinary work involving stakeholders and non-academics. With changing environmental governance trends in the IMW and beyond, we anticipate that the ability to work across boundaries will be ever more valuable. We encourage others to consider both the process and the end result in their research design, as the route chosen can alter the final destination.

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