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Insights and future directions of transdisciplinary practice in the urban water sector

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Abstract Bringing together stakeholders with different backgrounds and interests to create new understandings and relationships is essential to advance the sustainable management of urban water. This is a transdisciplinary challenge, with multiple benefits but also obstacles and uncertainties in its applicability. Although transdisciplinary practice is believed to be desirable to enable sustainable urban water management, its role is not clear. Thus, the purpose of this paper is to provide insights into transdisciplinary practice in the urban water sector, highlighting advances and research gaps. This analysis draws upon a scoping process from 1970 until now. It concludes that little research explores transdisciplinary practice in the urban water sector. Future research is necessary into organizational processes, disciplinary dynamics, and strategies applied by water practitioners to bring stakeholders together and achieve transdisciplinary practice in the design and implementation of urban water projects. These future directions of research are relevant to water practitioners dealing with urban water management and could lead to the development of practical guidelines to facilitate transdisciplinary practice.

Keywords Transdisciplinary practice · Transdisciplinary research · Urban water management · Water practitioners

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Introduction

Formal and informal knowledge have influenced and played a role in solving complex, multidimensional, and controversial problems associated with contemporary urban water management. Formal knowledge is academic and expert knowledge validated by scientific models and methods. It is provided by various water practitioners trained in different disciplines (Irwin et al. 1999; Edelenbos et al. 2011). Natural and physical scientists and engineers provide technical knowledge to describe how urban water systems work and to develop and analyze diverse technical solutions that provide human benefits. Social scientists reveal the institutional, social, and political contexts of urban water problems, identifying mechanisms and alternatives to facilitate the implementation of technical solutions (Harding et al. 2009). Informal knowledge is practical, traditional, experiential, or non-scientific knowledge applied on specific contexts or locations. Informal knowledge is identified mainly on local communities and citizen experiences managing urban water contexts (Eshuis and Stuiver 2005; Edelenbos et al. 2011; Brugnach and Ingram 2012).

The integration of formal and informal knowledge to address current urban water problems is a social and cultural challenge. Each type of knowledge has a particular set of skills, values, and ethics, and formal knowledge might be considered superior to informal knowledge, creating uneven power relationships. The social behaviors associated with each type of knowledge can lead to poor communication and cooperation between water practitioners, researchers, policy makers, and communities involved in planning and decision-making (Kötter and Balsiger 1999; Tejada-Guibert and Maksimovic 2003; Ramadier 2004; Max-Neef 2005; Wickson et al. 2006; Brown and Farrelly 2009; Harding

et al. 2009; Wen et al. 2014). This goal in the urban water sector is closely related to the interests, principles, and manifesto of transdisciplinarity (Nicolescu 2006). Transdisciplinarity is viewed as a fusion of disciplines (Lawrence and Després 2004), and it is not restricted to formal knowledge as "ideally anybody who has something to say about a particular problem and is willing to participate can have a role" (Klein Thompson et al. 2001, p.7).

Strategies, policies, and contemporary research related to Integrated Urban Water Management (IUWM), and such concepts as the water sensitive city, continually highlight the need to apply integrative, participatory, and transdisciplinary approaches including formal and informal knowledge to address urban water problems (Brown and Farrelly, 2009; Daniell et al. 2010; Mitchell, 2006; Wen et al. 2014; Wong and Brown, 2009; Wong et al. 2011).

Academics and water practitioners working in the urban water sector acknowledge the multiple benefits of transdisciplinary practice. Nevertheless, they are aware of the obstacles, challenges, and uncertainties of transdisciplinary practice. The role and the applicability of transdisciplinary practice are still far from being accepted and institutionalized in the urban water sector. In transdisciplinary practice, the traditional roles and responsibilities of water practitioners change, as they no longer follow rules specific to each discipline or focus on one dimension of the water problems. They work in cooperation with other professionals and users of the water infrastructure (Antrop 2001; Scholz et al. 2006; Fratini et al. 2012b). Comments on this approach are "it's easier said than done" (Ramadier 2004, p.437) and "It is easy to say this but what does this actually mean?" (Ison 2008, p.287). Similarly, few concrete examples of transdisciplinary practice, especially in existing water governance frameworks, can be found in the literature (Klein Thompson et al. 2001; Wickson et al. 2006; Palmen 2011; Lundy and Wade 2011; Jahn et al. 2012; Renner et al. 2013).

Given this context, the purpose of this paper is to explore the state of transdisciplinary practice in the urban water sector, identifying what research is necessary to support transdisciplinary practice by water practitioners. For this purpose, the paper gives a general overview of transdisciplinary research as important background for this study. Then, it provides insights into transdisciplinary research and transdisciplinary practice in the water sector, and, more specifically, the urban water sector, based on a scoping study of publications that contain the keywords "transdisciplinarity," "transdisciplinary research," "transdisciplinary practice," "urban water sector," "urban water management," "water management," and "cities." Based on the scoping study, we suggest further research into transdisciplinary practice undertaken by water practitioners.

Research approach

A scoping study was chosen to analyze the existing literature on transdisciplinary research and practice in the water and urban water sectors. This literature review technique is commonly used to summarize research findings and identify key concepts or gaps in a field of knowledge (Arksey and O'Malley 2005; Anderson et al. 2008). The scoping study reported in this paper applied the scoping framework developed by Arksey and O'Malley (2005) as it offers an excellent methodological foundation (Levac et al. 2010; Armstrong et al. 2011). This scoping framework consists of six stages:

1. Identifying the research question
2. Searching for relevant studies
3. Selecting studies
4. Charting and collating data
5. Summarizing and reporting the results
6. Making recommendations

The scoping research questions are considered broad by nature. The research question of this paper is as follows: what is known from the existing literature about transdisciplinary practice in the urban water sector? Levac et al. (2010) recommend linking a purpose or scope of inquiry to the research question to facilitate direction, clarity, and focus for the subsequent stages of the scoping framework. The specific purpose linked to the research question in this paper is to identify explicitly the literature on transdisciplinary practice in the urban water sector making recommendations for further research.

Arksey and O'Malley (2005) suggest establishing criteria to identify relevant studies. These criteria need to take into account the necessary number of references related to the research question and practical issues such as financial resources and time for the scoping process. To identify relevant studies, the following criteria were established:

1. Peer-reviewed publications in English were selected for the analysis.
2. The literature was sourced through the electronic bibliographic databases Google Scholar™ and Scopus.
3. Td-net, the Network for Transdisciplinary Research (Swiss Academies of Art and Sciences 2013) is an initiative of the Swiss Academies of Arts and Sciences, and it comprises transdisciplinary lecturers and researchers from Switzerland. This network was used as experts on transdisciplinary research-suggested publications on the topic from 2006 to 2014.
4. References were searched from 1970, when the term "transdisciplinarity" was created, until 2014.
5. Publications were selected for analysis if the titles and abstracts mentioned the keywords transdisciplinarity,

transdisciplinary research, transdisciplinary practice, urban water sector, urban water management, water management, and cities.

In all, 277 publications were initially identified as potentially relevant from the search in the two electronic databases and the td-net, Network for Transdisciplinary Research (Swiss Academies of Art and Sciences 2013). For inclusion in the scoping review, the articles had to contain information relating to some or all of the following:

1. Definitions and principles of transdisciplinarity
2. Transdisciplinary tools, models, or frameworks
3. Outcomes and experiences of transdisciplinary processes developed by researchers and/or practitioners
4. Roles and skills that practitioners should have in transdisciplinary processes

Articles were thoroughly read, especially if there was ambiguity of their relevance according to the guiding research question. Given the research question, 44 references in all were considered eligible for this review. An information matrix was developed to chart or extract data including title, aim of the study, methodology, year, and author affiliation (Pawson 2002; Arksey and O'Malley 2005; Levac et al. 2010). Consequently, an analytical framework was developed in which each article was categorized into one of two main groups: transdisciplinary research and transdisciplinary practice, and subsequent subgroups.

The group of transdisciplinary research was divided into the following subgroups:

1. Definitions, principles, concepts or differences with other disciplines
2. Tools, models, or frameworks
3. Outcomes and experiences of transdisciplinary processes
4. Broad transdisciplinary scope
5. Narrow transdisciplinary scope

Similarly, the group of transdisciplinary practice was divided into the following subgroups:

1. Outcomes and experiences of transdisciplinary processes
2. Roles and skills that practitioners should have in transdisciplinary processes.

The classification of the subgroups reflected how the study selection processes evolved as the authors became familiar with the available literature. In this process, it is important to highlight that articles could be classified in more than one subgroup. The information matrix and analytical framework are given in Online Resource 1. A narrative style was chosen for collating, summarizing, and reporting the results.

Transdisciplinary research

Transdisciplinary research has been conducted in three main areas: transdisciplinary definitions, similarities to and differences from other disciplines; transdisciplinary frameworks; and implementation and outcomes of transdisciplinary research processes.

The first area focuses on transdisciplinary definitions and similarities to and differences from other disciplinary approaches. After 40 years of intensive scholarly discourse, there is still a "war" on transdisciplinary definitions (Nicolescu 2006). In particular, the similarities and differences with other disciplinary approaches are still disputed, especially with "interdisciplinarity", as the two concepts are ambiguous, fuzzy, and are hard to grasp and differentiate (Lawrence and Després 2004; Nicolescu 2006; Klein 2008; Mobjörk 2010; Jahn et al. 2012; Swiss academies of Art and Sciences 2013). According to Apostel et al. (1972), Balsiger (2004), Lawrence and Després (2004), and Ramadier (2004), the term interdisciplinarity has been commonly applied to scientific research involving a number of disciplines, and it is viewed as a mixing of disciplines and articulations of different types of knowledge. One of the definitions of interdisciplinary research is "Mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice" (NAS/NAE/IOM 2005, p.26).

Balsiger (2004), Rosenfield (1992), Stokols et al. (2003), and Gibbons et al. (1994) consider that the main difference between interdisciplinary and transdisciplinary approaches is the higher degree of knowledge integration and strong orientation toward societal problems in transdisciplinarity. Given the multiple definitions, for the purpose of this study, we chose the following definition for transdisciplinary research: "A reflexive research approach that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extrascientific actors; its aim is to enable mutual learning processes between science and society; integration is the main cognitive challenge of the research process" (Jahn et al. 2012, p. 4). It is important to highlight two points of this definition in relation to our study. Firstly, Jahn et al. (2012) and Resweber (2000) consider interdisciplinarity as an integral part of transdisciplinarity. Interdisciplinarity is conceived as the science-driven process needed to generate the new knowledge from interplay and integration of teams composed by researchers and extrascientific actors. In this context, transdisciplinarity sets the frame for dynamics to integrate and evaluate societal and scientific progress. Secondly, mutual learning and integration are core elements and challenges of transdisciplinarity involving actors at different

hierarchical levels or sectors such as academia, industry, business, nongovernmental organizations (NGOs), politics, and the local public (Resweber 2000; Scholz et al. 2000; Klein Thompson et al. 2001; Tress et al. 2003; Max-Neef 2005).

In the literature, it is possible to find several transdisciplinary research frameworks to evaluate and classify the success of transdisciplinarity in research proposals and projects. Despite different contexts, the conceptual models have three common phases:

1. Collaborative problem framing and building a collaborative research team
2. Co-creation of solution-oriented and transferable knowledge through collaborative research
3. Reintegrating and applying the co-created knowledge

The endpoint of the frameworks is the possible contribution to society and scientific progress in terms of the creation of new knowledge within and beyond disciplines (Scholz et al. 2006; Kueffer et al. 2007; Jahn 2008; Pohl and Hadorn 2008a; Wiek and Walter 2009; Jahn et al. 2012). In the phases, different types of knowledge and contextual factors interact efficiently to solve the social and scientific problem (Hirsch Hadorn et al. 2006; Pohl and Hadorn 2007; Stokols et al. 2008a; Jahn et al. 2012). As a consequence, the phases do not have an equal weight, are not strictly linear, and may have feedback loops or overlapping stages in practice (Pohl and Hadorn 2008a; Jahn et al. 2012; Enengel et al. 2012).

Implementation and outcomes of transdisciplinary research processes focus on the analysis and assessment of the conceptual frameworks in research initiatives and centers. Many of these assessments are carried out in the health sector (e.g. Hall et al. 2008; Stokols et al. 2008b; Stokols et al. 2005). The results of these studies identify the need to focus on enhancing quality standards and the community of peers that guide and assess the processes and the role of researchers, program managers, and financial donors (Wickson et al. 2006; Jahn et al. 2012; Brandt et al. 2013).

Transdisciplinary research in the water sector

Transdisciplinary research in the water sector comprises five subgroups: (1) definitions, principles, concepts, or differences with other disciplines; (2) tools, models, or frameworks; (3) outcomes and experiences of transdisciplinary processes; (4) broad transdisciplinary scope; and (5) narrow transdisciplinary scope.

1. Definitions, principles, concepts, or differences with other disciplines: The focus of this subgroup is the definitions and principles of transdisciplinary research for groundwater management and water pollution and human health research initiatives (Scholz et al. 2000; Mollinga 2010). Also included in this subgroup is the identification and description of concepts shared by different disciplines in integrated catchment management (Attwater et al. 2005). The authors of these papers suggest the relevance of new methods of knowledge management and use of shared concepts to complement traditional disciplines and decrease disciplinary boundaries (Scholz et al. 2000; Attwater et al. 2005). Mollinga (2010) also highlights the importance of appropriate time and attention in the implementation of research initiatives to understand better the practical side and trade-offs of transdisciplinary research.
2. Tools, models, or frameworks: Different transdisciplinary tools, models, or frameworks have been designed to improve and facilitate the management of water, sanitation, and public health; catchments; protected freshwater areas; mobile organic xenobiotics in surface waters; and water infrastructures. The objective of the tools, models, or frameworks is to address the lack of communication and participation among actors from different sectors and the poor integration of data from natural and socioeconomic sciences and to overcome diverse social and institutional limitations. Key outcomes of these frameworks, tools, or models are robust theoretical backgrounds (Elliott 2011), perception graphs and causal maps (Döll et al. 2013) and common model structures, meta-modeling language, and interfaces for information exchange, including informal knowledge (Ludwig et al. 2003). Various authors believe that successful application of the frameworks, tools, or models depends on facilitation processes and early involvement of actors (Lawrence et al. 2000); common vision and hierarchy of objectives linked to indicators (Kingsford et al. 2011); and communication structures such as bilateral cooperation, working groups, workshops, and colloquia (Ludwig et al. 2003).
3. Outcomes and experiences of transdisciplinary processes: Despite differences in purpose and length of the studies from this subgroup, it is possible to identify a common interest of the researchers to understand the views of actors defining social and/or scientific problems related to water management and to describe transdisciplinary processes and/or identify mechanisms to integrate knowledge.

   To understand the views of actors defining a social and/or scientific problem related to water management, Titz and Döll (2009) applied actor modeling for the identification of management strategies for pharmaceuticals in drinking water. De Jong et al. (2008) highlighted the logistical and technical limitations to understanding the hydrology and hydrogeology of Karst areas in Morocco. In the same way, Iglesias and Buono (2009) presented a water policy evaluation in Morocco, Lebanon, and Spain based on a transdisciplinary approach. These studies give different recommendations. Actor modeling is considered

useful to understand the views of actors; however, it cannot take into account the strong effects of power relationships and changing problem perceptions (Titz and Döll 2009). In addition, local public discourse is relevant in the evaluation of water policies. The evaluation should include a certain degree of uncertainty, and qualitative data should be as robust as possible to avoid assumptions (Iglesias and Buono 2009).

Other studies describe transdisciplinary processes and/or identify mechanisms for the integration of knowledge. For instance, Cole (2006) explained the cooperative process of scientists, planners, and local residents in different steps involved in the Motueka catchment futures model (New Zealand). Bohnet (2010) clearly illustrates the outcomes of processes and a range of tools applied in a socioecological framework for the Tully–Murray Basin (Australia), testing effectiveness of the framework in knowledge integration. In the same way, the integration of different types of knowledge to narrow disciplinary boundaries and to contribute practical guidelines is analyzed in the management of Mediterranean streams at a local scale (Gonzalez et al. 2009). The studies describing transdisciplinary processes reveal interesting findings. Cole (2006) believes that horizontal and transversal knowledge integration is fundamental for catchment management but not sufficient to address specific issues. According to this author, the main limitations derive from epistemological reasons and resistance of science to simplify the complexity of the water problems to a single level of perception and reality. Therefore, disciplinary filters and system reduction are needed to tackle water problems. Bohnet (2010) refers to the risk of disengagement of actors in transdisciplinary processes, recommending investigations of roles and accountability of multiple actors in the integration of knowledge. Additionally, Gonzalez et al. (2009) stress the sharing agendas between different sectors and dedicating time to listen and have dialog among actors to facilitate transdisciplinary processes, incorporating new knowledge and visions in the management of socioecological systems.

In reference to mechanisms for the integration of knowledge, Dewulf et al. (2007) investigate cross-disciplinary research collaborations in adaptive water management, emphasizing the mechanisms to diminish misunderstandings and mismatched expectations. The mechanisms are interactive workshops, facilitation, group model building, and concrete case contexts to help in the integration of different frames and increase joint learning and knowledge construction. Moreover, Renner et al. (2013) analyze barriers, challenges, strategies, and mechanisms for integration of disciplines and different types of knowledge in the assessment of five water governance research projects in Austria and Switzerland. The assessment made by Renner et al. (2013) identifies four main challenges: ensuring stakeholder legitimacy and balance, encouraging participation, managing expectations, and preventing misuse of data and results. For each of these challenges, the authors propose strategies such as actor analysis, facilitation of fair debate, building of trust, making participation as easy as possible, establishing rules and responsibilities, clarifying expectations and limitations, and moderating power imbalances.

4. Broad transdisciplinary scope: A group of articles mentions in a general way the need for transdisciplinary approaches to solve water problems. Nevertheless, these articles do not necessarily explain how these transdisciplinary approaches should be developed, making it difficult to assign them to a specific category of the scoping process. Examples of this subgroup are the articles by Kato and Ahern (2008), Haasnoot et al. (2011), Futter et al.(2011), and Bunch et al. (2011).
5. Narrow transdisciplinary scope: In contrast to the subgroup of broad transdisciplinary scope, the subgroup of narrow transdisciplinary scope is characterized by transdisciplinary studies that describe dynamics on specific groups of actors such as researchers, graziers, and actors involved in water user associations or knowledge fields such as ecohydrology. For instance, Patterson et al. (2013) describe professional, philosophical, methodological, project-related, and personal challenges facing early-career researchers interested in transdisciplinary water governance. A typology for graziers of the Bowen Broken Basin (Australia) is developed by Bohnet et al. (2011) based on a transdisciplinary approach to support natural resource management policies and agricultural extension programs. Djanibekov et al. (2012) found that researchers, farmers, and staff members apply social mobilization and institutional strengthening approaches in the water users association of Uzbekistan. The studies identify the strong influence of institutional factors on the level of cooperation among actors and therefore the success of transdisciplinary processes. As a result, a high degree of flexibility is essential in the planning and timeline of key activities (Djanibekov et al. 2012) and spaces for reflection and interactive learning (Patterson et al. 2013).

In parallel to the studies on specific groups of actors, an area of knowledge that includes different transdisciplinary perspectives is ecohydrology, which involves different disciplines and relationships from molecular to landscape scales (Zalewski et al. 2009). Three references illustrate this work: Zalewski (2014), Zalewski et al.(2009), and Huili Gong et al. (2010).

Transdisciplinary research in the urban water sector

Within the literature on transdisciplinary research in the urban water sector, 12 references include (1) definitions, principles, concepts, or differences with other disciplines; (2) tools, models, or frameworks; (3) outcomes and experiences of transdisciplinary processes; (4) broad transdisciplinary scope; or (5) narrow transdisciplinary scope.

1. Definitions, principles, concepts, or differences with other disciplines: Research undertaken in the suburbs of Quebec and Strasbourg, France, by Ramadier (2004) is the basis for an analysis of definitions, differences with other disciplines, and challenges of transdisciplinarity in urban areas. The findings emphasize that the principle of unity of knowledge should be modified to articulate disciplines and apply transdisciplinary practices and that researchers need to work more on the integration of methods than on the specific points of view and methodologies of their own disciplines. The researchers' cognitive, personal, and cultural perspectives are the main obstacles in this process.
2. Tools, models, or frameworks: The three points approach tool developed by Fratini et al. (2012b) for urban flood risk management falls into this subgroup. This tool facilitates decision-making processes related to three main areas of work for water practitioners: standards and guidelines for urban drainage systems or technical optimization; increased resilience of urban areas in the context of climate change; and satisfying the needs of different actors for engagement and awareness. Outcomes of the implementation of this tool are multifunctional solutions and opportunities for consensus in a decision-making process involving different actors (Fratini et al. 2012b).

   A framework for integrating different disciplinary languages to strengthen communication and improve social preparedness for climate change, by Fratini et al. (2012a), is another example within this subgroup. This framework was created to fill a gap in standardized methods and guidelines for transdisciplinary processes in urban water management. A water utility company and two municipalities of Denmark are evaluating the framework. The endpoint of this framework is to establish local strategies that encompass individual and collective rules and subjective and objective perspectives to contribute more to integrative approaches in urban water management.

   Similarly, experts from different disciplines established an integrated framework for urban green spaces, including ecosystem services, physicality, experience, valuation, management, and governance (James et al. 2009). The framework provides an alternative structure for research into urban green space that is resilient to changes in knowledge and disciplinary boundaries.
3. Outcomes and experiences of transdisciplinary processes: The papers of this subgroup are represented by five studies examining research programs and collaborative planning of suburbs, collaborative research in demonstration projects, relevance and role of transdisciplinarity at regional scale, and interaction of academics working in urban water science.

   Two studies (Després et al. 2004; Després et al. 2011) explore the interactions of actors in a transdisciplinary research program and collaborative planning for Quebec suburbs. Two main lessons are learned from this process. Firstly, architects, planners, and researchers must be capable of understanding different areas of urban knowledge and get training in knowledge transfer. Secondly, the way of working on collaborative projects is relevant and requires practical guidelines.

   The study of van Herk et al. (2011) evaluates collaborative research in demonstration projects as little research is developed in this crucial topic for an integrated approach to flood risk management. Recommendations from this study are to promote informal and neutral environments where actors have the freedom to discuss perceptions and solutions of the problems. To increase partnerships, the design of the collaborative research should be based on the level of receptivity of actors.

   Tötzer et al. (2011) are interested in, analyzed, and answered three questions relevant to transdisciplinarity at a regional scale: how does transdisciplinarity work in practice?; what are the benefits and limitations of transdisciplinary research?; and how can transdisciplinary research contribute to the long-term process of building sustainable networks and structures in the region? The study concluded that transdisciplinary research offers clear benefits compared to sole expert solutions in cities with long industrial history and traditions. Transdisciplinary research facilitated the communication process and knowledge transfer in different ways, creating socially robust solutions. The limitations of transdisciplinary research are related to the mindset of participants, especially actors that use linear knowledge, path-dependent structures or are skeptical of new procedures. Transdisciplinary research, in practice, is time-consuming, thus, researchers need to be highly cooperative to learn new roles and tasks. Process management is a priority. Concepts and methodologies are important to organize transdisciplinary processes, but these techniques must be adapted to local contexts to increase possibilities of ownership, joint building of knowledge, and implementation of transdisciplinary research.

   Lastly, Wen et al. (2014) gave an overview of the level of cross-boundary interactions in professional networks and collaborations in research publishing in urban water science. The outcomes of the analysis confirmed cross-

boundary interactions. The authors indicate a change from technocratic water engineering to participatory management that includes other disciplines, industry, government, and communities. Despite this change, academic communities are working in a limited way compared with practitioners, who are using broad communication and interaction channels. To increase interactions and collaborations, scientific communities need to understand better the inner workings of practitioners. Congresses and events can be the right spaces for actors to exchange ideas, creating common visions and strengthening the sustainability of urban water management.

4. Broad transdisciplinary scope: Examples of this subgroup are the framework for multifunctional landscapes and urban ecosystem services related to water (Lundy and Wade 2011) and the study of people's awareness, perceptions, attitudes, and preferences in water management in Auckland and Christchurch, New Zealand (Kviberg, 2010).
5. Narrow transdisciplinary scope: Research into the need for a transdisciplinary framework and the identification of variables for institutional capacity for urban stormwater planning (Brown et al. 2001) fall into the narrow scope of transdisciplinarity in the literature. In addition, transdisciplinarity is considered as one of the governance challenges for climate change adaptive capacity in the city of Santiago de Chile (Barton 2013).

Transdisciplinary practice

Parallel to transdisciplinary research committed to understanding transdisciplinary definitions, principles, or differences with other disciplines; to create frameworks, models, or tools; and to implement or assess outcomes of transdisciplinary research processes, transdisciplinary practice is influenced by and takes place in different life-world contexts as well. For the purpose of this paper, transdisciplinary practice is defined as roles, interactions, processes, and experiences of state or local governments, regional agencies, industry, local community groups, indigenous people, NGOs, or private consultant firms to implement projects on the ground in order to solve societal problems. In some cases, the projects might be supported by researchers; however, the practitioners are the main actors responsible in implementing the projects. Insights and empirical evidence into these life-world experiences and local contexts are highly desirable to understand the role and applicability of transdisciplinary practice (Bammer 2005; Max-Neef 2005; Kueffer et al. 2007; Klein 2008; Wiek and Walter 2009; Lang et al. 2012). Fields that have to date demanded transdisciplinary practice are resilience of ecological and social systems, post-normal science and environmental research, landscape ecology, global change, systems and complexity, ecological economics, professional development and education, and health (Attwater et al. 2005). From these fields, most of the studies of transdisciplinary practice have been in the health sector, especially in early childhood special education and early intervention. These studies are written mainly by practitioners rather than by researchers (e.g Chapman and Ware 1999; Rapport et al. 2004; King et al. 2009; Bell et al. 2010; Bock Hong and Reynolds-keefer 2013).

Transdisciplinary practices in the water sector

Transdisciplinary practice in the water sector is addressed in four articles written by practitioners and researchers from 2009 to 2013. These articles are part of the subgroups (1) outcomes and experiences of transdisciplinary processes and (2) roles and skills that practitioners should have in transdisciplinary processes.

1. Outcomes and experiences of transdisciplinary processes: In this subgroup, one study (Daniell et al. 2010) analyzes objectives, conflicts, and negotiations in project teams for participatory water management processes in Australia and Bulgaria. These dynamics are part of a process called co-engineering. Outcomes of the study are that language barriers are not necessarily limitations in the design and execution of participatory water management processes. On the contrary, language barriers might be drivers for stakeholder appropriation, collective learning, and skills transfer. Similarly, diversity in co-engineering groups is challenging. Nevertheless, the application of integrative negotiations and collaborative work can bring opportunities and positive effects in the management of different profiles in the groups. Another paper in this subgroup (Lynch et al. 2012) is the analysis of the legacy and common interests of the indigenous Yorta Yorta people in the management of the Murray–Darling Basin, Australia. Customary law and practices of the Yorta Yorta suggest that shared regional governance with consensus on the outcomes, adaptive planning with longer time horizons, and mutual respect are central for sustainable basin management.
2. Roles and skills that practitioners should have in transdisciplinary processes: A good example of this subgroup is the relevance of transdisciplinary teams and individuals in the management of southern African river basins by Nienaber and Jacobs (2010). Six traits are identified to develop transdisciplinary individuals, such as to be able to build networks and to discuss topics accepting multiple points of view. Societal conscience and the ability to think in a complex interlinked way are highly recommended. The paper suggests modest positionality from a transdisciplinary individual perspective, admitting

the complexity of problems and the lack of perfection in the solutions.

In parallel, Mollinga (2009) identified the attitudes, challenges, and opportunities for water practitioners working in the transdisciplinary agricultural water sector. Literally, the challenges are (a) internalizing ecological concerns into water systems design, management, and governance; (b) shaping the coevolution of the water technological/infrastructural system and the water social system from a human development perspective; and (c) constructive involvement of the water control systems-associated interest groups in the design, management, and governance of these systems. To cope with these challenges, water practitioners need to apply conceptual, instrumental, behavioral, and institutional design skills. Conceptual and instrumental skills can help to understand the multidimensionality of water and establish water systems for different uses and users. Behavioral and institutional design skills are important so that water practitioners can participate actively in design, management and governance processes.

Transdisciplinary practices in the urban water sector

In relation to the urban water sector, the scoping process identified two articles related to the subgroup outcomes and experiences of transdisciplinary processes. These articles are written by practitioners and researchers from Australia. There were no identified articles related to the subgroup of roles and skills that practitioners should have in transdisciplinary process.

One paper (Edwards et al. 2007) suggests how the different stormwater programs of local governments should move from a multidisciplinary way of working to transdisciplinary approaches to manage water in Melbourne. The authors identify resistance to change at local government level. Nonetheless, each organization is in a different stage of change, and multiple strategies are contributing to make a difference in the stormwater programs. Some of the strategies are the identification of opportunities, joint implementation target setting, and community engagement. Participation of consultancy organizations offering specific services and knowledge in different topics is also valuable. Other ways to improve transdisciplinary practices are investment in internal resources and constant institutional capacity building. Knowledge brokers, correct governance tools and evaluation, and evolution programs are fundamental for feedback and better understanding of the collaboration and organizational change processes.

The second paper (Fam et al. 2013) describes organizational learning processes in a corporatized urban water utility. Sustainable systems of service are tested and analyzed by different staff and residents. Different outcomes are established from this process of organizational learning. The paper recognized the value of strategies to facilitate communication and collaboration between departments, staff, and residents. Adopting qualitative social research, regular meetings, and spaces to share different points of view are important to capture unexpected insights of the actors and analyze outcomes of projects, translating individual learning to organizational learning.

Transdisciplinary practice applied by urban water practitioners

The literature analysis revealed different insights of transdisciplinarity in the water and urban water sectors. Transdisciplinary practice in these sectors is in a growing phase. Concrete evidence exists of the contribution of transdisciplinarity to achieve robust societal solutions to water problems and clear interests of academia and practitioners to expand cross-boundary interactions in different scenarios, at different scales. In this evolution, advances are reflected in the identification of common languages and structures, use of actor-based modeling, typology of actors, establishment of frameworks and tools, and assessment of transdisciplinary projects. Future directions for transdisciplinary practice include process management, knowledge integration, and organizational learning and change.

The scoping process located few studies in transdisciplinary practice. This research gap is confirmed by authors such as Apgar et al. (2009); Bock Hong and Reynolds-keefer (2013); Bohnet (2010); King et al. (2009); Munasinghe (2001); and Ryan-Vincek et al. (1995). According to these authors, there is a lack of research in life contexts outside academic circles or research initiatives A tendency to discard local and traditional types of knowledge is common, and few investigations involved relationships of different disciplines and roles and responsibilities of multiple stakeholders for knowledge integration. Specifically, research on the practitioner perspective is very limited. Increased knowledge is needed of (1) roles, responsibilities, and experiences of practitioners in transdisciplinary processes, (2) structures and support of transdisciplinary processes involving practitioners, and (3) types of services developed and delivered by practitioners through transdisciplinary practices. In the urban water sector, practitioners are professionals with backgrounds in hydrology, civil engineering, ecology, town planning, landscape architecture, and social science among others. These professionals learn and take different decisions, based not only on different technical skills but also on different personal skills, such as negotiation, active listening, networking, or leadership, in engaging with communities and other disciplines to manage urban water resources (Brown et al. 2005).

We suggest analyzing urban water projects in order to understand how water practitioners work in terms of

transdisciplinary practice. Through these analyses, it should be possible to understand what promotes or hinders this disciplinary approach and its contribution to the management of urban water resources and the transition to water sensitive cities. Authors such as Pohl and Hadorn (2008b) recommend research on how practitioners understand and structure societal problems in specific projects to enrich the theory, methodology, and formalization of transdisciplinary practice. Daniell et al. (2010) claim few studies are analyzing project teams that design and organize participatory water management processes. Research is needed in leadership and networks in these teams as well, to understand better the dynamics and effects of co-engineering on participatory water management processes.

Integrated urban water management in Australia has advanced in documenting and reviewing the learning-by-doing in the planning and implementation of "demonstration sites". These pioneer experiences contribute to the acceptance of wider practices by the water industry (Mouritz 2000; Mitchell 2006).

Three areas are considered important to analyze in urban water projects: (1) mapping the chronological development of organizing processes, (2) understanding the disciplinary dynamics and interactions; and (3) describing the mechanisms and strategies applied by individuals and organizations to facilitate transdisciplinary practices. We believe that these three areas could contribute to the creation of an explanatory framework of transdisciplinary processes and dynamics developed by water practitioners in urban water projects. This type of framework is needed in transdisciplinary practice. Abstract scientific concepts need to be understood locally and include human and temporal dimensions. In this way, transdisciplinary practice is more inclusive, facilitating decisions relating to water problems and the establishment of effective transdisciplinary teams (Apgar et al. 2009).

Organizational processes related to urban water projects

We suggest analyzing the sequence of organizational activities and events related to the decision-making processes of urban water projects. This analysis would provide insights on the way water practitioners frame a problem, establish a team, assign responsibilities, and integrate knowledge to deliver different outcomes. Aspects of institutional capacity, such as human resources, intra and interorganizational capacity, or external rules and incentives for urban water management, suggested by Brown et al. (2005), are an appropriate guide for identifying and understanding the organizational processes of the water projects. The contextual factors for transdisciplinary collaboration by Stokols et al. (2008b) are also relevant to this analysis.

Disciplinary dynamics and interactions of project teams

The urban water sector needs to learn about participatory levels and teamwork appropriate to management processes and outcomes (Daniell et al. 2010). Therefore, we suggest investigating the disciplinary dynamics and interactions applied in urban water projects. For this purpose, firstly, it is important to recognize the main characteristics and similarities and differences of transdisciplinary practice in relation to other disciplinary approaches. It is important to acknowledge a continuum starting from unidisciplinarity or monodisciplinarity, multidisciplinarity, interdisciplinarity, to transdisciplinarity as well. The applicability of each discipline in this continuum depends on the complexity of the problem and the level of cooperation among actors (Lawrence and Després 2004; Ramadier 2004; Max-Neef 2005; Nicolescu 2006; Jahn et al. 2012).

Secondly, continuous participation of multiple actors is highly desirable in transdisciplinary processes, but the assessment of transdisciplinary projects shows diverse consultative and participatory dynamics. For instance, the participation of different social actors takes place mainly in the initial or final phase of the processes, while the data analysis or middle phase is often developed by researchers (Pohl and Hadorn 2007; Elzinga 2008; Mobjörk 2010; Enengel et al. 2012).

Thirdly, disciplinary dynamics and interactions in urban water projects could be displayed in a typology that can clarify the role and applicability of transdisciplinarity in this sector. The conceptual framework created by Fratini et al. (2012a) to facilitate the integration of different disciplinary approaches in order to address urban complexity is relevant to this purpose. The co-engineering participatory water management processes in the Australian and Bulgarian context might be useful as it is a pioneer study of project teams that design and organize participatory water management processes (Daniell et al. 2010).

Mechanisms and strategies to bring actors together

The participation and diversity of actors involved in transdisciplinary processes may be very low as transdisciplinarity faces many cognitive, conceptual, and personal challenges (Ramadier 2004). In this sense, studies that focus on how and to what extent individuals are establishing teams and networks to allow transdisciplinary processes are needed (Bass and Avolio 1994; Jackson and Stainsby 2000; Katzenbach and Smith 2001; Gratton et al. 2007). For this reason, we suggest analyzing the formal and informal mechanisms and strategies applied by transdisciplinary individuals to bring actors together and develop urban water projects. This knowledge may be useful to understand the decision-making process, integration

of knowledge, and the acceptance of transdisciplinary practices by other individuals involved in urban water projects. The literature in urban water management considers that it is fundamental to understand the role of these leaders (e.g., Brown et al. 2013; Meijerink and Huitema, 2010; Taylor, 2010). Different studies identified the skills and attributes of these leaders. For example, dependant on the group of professionals, these leaders can manipulate and transfer local and scientific knowledge and information through diverse templates and narratives facilitating cognitive and decision-making processes (Payton et al. 2003; Suddaby and Greenwood 2005; Battilana et al. 2009; Thornton et al. 2012). Similarly, they put in practice negotiation, persuasion, conflict management, and diplomacy strategies in a very creative way and, through different levels of trust, legitimacy, and power, bring unexpected people to participate in the processes (Forester 1999; Uhrwing 2003; van Mansfeld 2003; Mollinga 2009; Williams 2012; Edelenbos et al. 2013).

Concluding comment

This paper has described the main characteristics and areas of interest of transdisciplinary research and practice, giving special attention to the water and urban water sectors. From a review of the literature, it is apparent that knowledge of transdisciplinarity is in a growing phase. Research has shown interest in finding common concepts and languages to articulate disciplines. Models, typologies, frameworks, and tools are designed to strengthen communication among actors and facilitate decision-making. Transdisciplinary processes are describing the different views of actors and identifying mechanisms to integrate knowledge. The literature indicates a need to tackle social and institutional limitations such as resistance to simplify knowledge; uneven power relationships; unclear roles and responsibilities; and lack of practical guidelines, among others. Several studies suggest informal and formal spaces such as interactive workshops and channels, group model building, and concrete case contexts to discuss the perceptions of actors, create common visions, and establish roles and rules. However, a gap exists in research focusing on transdisciplinarity in life contexts developed by water practitioners. The little research on transdisciplinary practice addresses firstly, attitudes, conflicts, challenges, and opportunities for transdisciplinary individuals and teams and, secondly, organizational learning processes to move from multidisciplinary to transdisciplinary approaches. These studies on transdisciplinary practice indicate as priority the increase of knowledge on process management, knowledge integration, team management, and organizational learning and change. Therefore, future research in transdisciplinary practice in the urban water sector can be linked with the understanding of organizational processes, disciplinary dynamics, and strategies that water practitioners are using to bring stakeholders together and to achieve transdisciplinary practice related to water agendas. The understanding of these topics can contribute to an explanatory framework, increasing the empirical knowledge and practical experience needed in transdisciplinary practice. This framework could support water practitioners in identifying, understanding, and enhancing areas where they are developing transdisciplinary practice to manage urban water resources in an integrative way.

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