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Interdisciplinary research networks and science-policy-society interactions in the Uruguay River Basin

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ABSTRACT

The Uruguay River Basin (URB) that extends along Argentina, Brazil and Uruguay has been the hub of increasing pressures caused by the expansion of industrial agriculture, forestry and infrastructure projects in hydroenergy and transportation. There are growing concerns that the fragmented institutional framework is inadequate to address the growing challenges. Interdisciplinary research networks can contribute to creating perspectives of the basin that are policy and governance relevant. In this paper, we set out to interrogate the potential scope of interdisciplinary research networks (IRNs) for the advancement of basin governance framework for the URB. We envision IRNs as knowledge actors that can open up opportunities to mediate and connect basin actors across different spaces – academic, policy, technical-administrative and social. We highlight a series of pathways to advance networks actions in creating opportunities to fill the gaps of transboundary basin governance, and acknowledge the challenges associated with doing this work in the URB and other basins around the world.

1. Introduction

The governance of transboundary waters is an aspirational goal in basins all over the world and poses complex and often contentious management challenges (Akamani and Wilson, 2011). Transboundary waters extend hydrological interdependence beyond national borders, establishing a link between users from different countries within a single system. The challenge is to manage a system as if it were unique but extremely cut down by legal, social, cultural and institutional issues. Considering that about 263 of the world's rivers are shared by two or more countries accounting for 60% of the freshwater supply, governance of transboundary waters is critical (UN, 2014). Many of the world's transboundary river basins are perceived as important engines of regional economic development, as crucial bases of livelihood resources and as critical sites of biodiversity conservation (Sneddon and Fox, 2006).

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This is no exception for the Uruguay River Basin (URB), a transboundary river sub-basin of the La Plata River Basin, the fifth largest basin in the world (Fig. 1). At 2.200 km long, the river is made up by the confluence of Pelotas and Canoas rivers in Brazil, and its area of influence covers 385.000 km^2 across Argentina, Brazil and Uruguay. The URB is covered by a series of international treaties, bodies and practices set up in the 1960s to foster cooperation between riparian countries on water related issues in a series of areas, mainly hydroenergy and transport, and by bi-national bodies specific to the Uruguay River. There are rising concerns that the institutional framework is inadequate to address the growing challenges facing the basin in a context of increasing strain of natural environments, resource use associated with hydroenergy development, industrial agriculture, planned and unplanned urbanization (Payne, 2011; Saguier, 2018).

The URB hosts economic sectors that are rapidly transforming the land and water use patterns with implications on water use and quality. This is the case of commercial forestry, an expanding agricultural sector of soya bean production as well as irrigated rice agriculture (Silveira and Alonso, 2008; (CIC Plata, 2017a)). No less important, increasing dam development in the upper basin sector promoted ecological changes by water level variation affecting fish populations (Lima et al., 2017). All these activities put pressure over the ecosystems, generate negative externalities or require new infrastructures that will cause negative externalities and environmental impacts. Furthermore, these activities embody a particular extractivist relation to the URB, derived from a combination of export-oriented sectors of natural resource production with weak or inexistent regulatory and policy frameworks at the national and regional levels, that can support a basin level governance for the URB (Gerlak et al., 2019; Saguier 2018).

There is a considerable body of scholarship on transboundary basins examining the role of institutions and regimes in preventing, managing and overcoming conflicts with the aim of fostering cooperation between actors (Berardo and Gerlak, 2012; Wolf, 2007). Researchers have uncovered the many varied tensions between the basin actors related to the use of waters and its environmental services but also over decision and best approaches to manage water and other natural resources. Tensions can be reflected on multiples levels, from international to local level (Feitelson, 2006; Merlinsky, 2017), and have been historically controversial around infrastructure and water quantity (De Stefano et al., 2010). Different levels can have different perceptions of water controversies, political actors do not act like "homogeneous monoliths" (Wolf, 2007: 313). The interplay of conflicting interests and actors (public, private and social at local, national and international scales) intersect in the URB today.

In the absence of transboundary basin governance, frameworks ongoing patterns of water and land use and infrastructure projects will accentuate current unsustainable practices in the basin. Basins are constructed materially and discursively (Cohen, 2015). What is lacking in the URB are interdisciplinary narratives to help visualize the interrelations between physical-biological, society-nature processes taking place as multiple special and temporal scales. Such an approach requires overcoming disciplinary silos, issue-specific perspectives and jurisdictional viewpoints (Dollar et al., 2007). The transboundary system is currently missing integrative policy, actors and public institutions. In this paper, we set out to interrogate the potential scope of interdisciplinary research networks (IRNs) for the advancement of basin governance framework for the URB. We envision IRNs as knowledge actors that can open up opportunities to mediate and connect basin actors across different spaces – academic, policy, technical-administrative and social. This study

Fig. 1. Uruguay river basin.

aims to identify the role that interdisciplinary research networks could play in facilitating the kinds of understandings of basins as multidimensional transboundary systems.

We begin with a discussion of the role of such networks in creating alternative narratives of the URB beyond its current representation as a patchwork of fragmented issues and jurisdictions. We lay out our conceptual and methodological strategy for this objective. In the second section, we discuss infrastructure, land and water use patterns and governance gaps as three dimensions of the URB that pose significant transboundary challenges in terms of present and future prospects of the basin. In this final section, we reflect on the opportunities and challenges of research networks to foster science-policy-society interactions conducive to the advancement of basin governance frameworks for the URB.

2. A theoretical perspective: interdisciplinary research networks as basin actors

Like other sustainability challenges, engaging in the exploration of interdisciplinary thinking is central to the possibility of having adequately assessing, preventing and redressing the problems affecting the URB (Schoolman et al., 2012). Interdisciplinary research is necessary to produce new creative responses and solutions to grand societal and environmental challenges (Lyall and Fletcher, 2013; Max-Neef, 2005). Interdisciplinary research demands that researchers "create collaboratively" and combine "different epistemic perspectives in a synergistic, integrated whole that goes well beyond what each part can accomplish on its own" (O'Rourke et al., 2013: 2). Interdisciplinarity "occurs at the interface between disciplines" (Venot et al., 2015). The integration necessary for interdisciplinary research requires interaction between natural and social scientists, as well as a diverse set of stakeholders and government officials.

IRNs draw together researchers from diverse disciplines to collectively study or investigate a particular issue or context. There is broad recognition of the importance of IRNs in fostering innovative capability, creativity and knowledge (Jooβ et al., 2011; Mountford et al., 2019). The importance of networks is often seen in their ability to co-produce and exchange knowledge and to forge norms concerning the nature and terms of particular issues (Betsill and Bulkeley, 2004; Conca, 2006). IRNs can harness the talents of diverse actors and connect them through ongoing dialogue and engagement to cross disciplinary boundaries that can provide important insights in the ways that basins are seen and represented (Feldman and Ingram, 2009). Networks may serve as brokers, translators in partnership with decision-makers and the broader public (Roy et al., 2013). They could also mobilize and articulate knowledge of issues and processes in the URB that we perceive as disconnected from each other.

IRNs are not without their challenges. It is not uncommon for there to be tension with collaborators during interdisciplinary research due to differences in their methods, theories, or approaches (Roy et al., 2013). Communication between and across research actors is considered to be a significant obstacle to interdisciplinary research efforts (Roy et al., 2013; O'Rourke et al., 2013). Additional challenges can be seen in maintaining momentum between meetings and engagements, lack of clarity around roles within working groups, and ongoing uncertainty of project goals (O'Rourke et al., 2013; Crowston et al., 2015). Strategies around joint planning, transparency in group activities, and building and maintaining a shared common vision can help overcome obstacles to interdisciplinarity (O'Rourke et al., 2013; Pennington, 2008). Access to stable sources of funding is critical for IRNs to able to manage these challenges.

3. Our approach and methods

The URB is the case study to explore the role of IRNs in contributing to facilitate transboundary basin governance. The URB has been a hub of conflicts surrounding the installation of a pulp mill plant in Uruguay between 2005 and 2010 leading to an unprecedented diplomatic problem between Argentina and Uruguay caused by the closing of an cross border bridge by environmentalist groups in opposition to the plant. In 2007 the governments of Argentina and Brazil announced their plans to build the Garabí-Panambí binational dam on the Uruguay River. This was part of renewed interest in hydroelectric infrastructure projects aligned in a framework of South American integration of energy infrastructure some cases associated with rising socio-environmental conflicts and violence (Gerlak et al., 2019; Saguier 2018). The URB has been the less studied than other sub-basins of the greater La Plata Basin, such as the Paraná-Paraguay sub-basin. The URB appeared as good space to explore the complex socio-political tensions between states and societies increasingly marked by growing expectations of social actors to participate in decisions related to the basin (Molle, 2009). In this respect, the URB presented a good opportunity to explore the intersections between research and governance amid an increasingly contested issues and actors.

The methodological approach that was adopted focused on the process of creating a new interdisciplinary research network among scholars that specialize in different aspects of the URB. The network was set up to assess and identify the main transboundary issues that affect the URB with the aim of producing a research agenda of priority areas that needs to be explored as part of a sustained effort to build a governance framework for the URB. Members of the network included scholars and specialists from Argentina, Brazil, Uruguay and the United States working in the fields of ecology, energy planning, fisheries, engineering, geography, international hydrologic relations and international water law. Members of the network already had close relations with water management agencies and civil society organizations active in the URB. The process itself of establishing a network and working towards a common research agenda was an opportunity to explore and reflect on the potential of interdisciplinary networks to contribute to governance processes in the URB (Gerlak and Saguier, 2015) In this regard, the methodology prioritized a reflexive approach to learning and to interdisciplinary knowledge production. The funding for the project came from a small grant by the Inter-American Institute for Global Change Research (IAI) that covered activities during 2014–2017.

Conceptual innovation is the end point of interdisciplinary research methodology (Paletz and Schunn, 2010). In our case, producing narratives of the URB that frame the basin as a patch of socio-ecological systems (SES). Interdisciplinarity is at the heart of the

SES approach (Brandt, 2013), especially when it comes to river basin governance (Ortega Uribe et al., 2014; Gain et al., 2020). SESs approaches draw insights on the interactions between social, ecological, and hydrological processes (Cabello et al., 2015) and explicitly recognize connections and feedbacks between human and natural systems (Anderies et al., 2004; Folke, 2006; Gain et al., 2020; Young et al., 2006). From this perspective, river basins can be seen as complex adaptive systems that comprise nested agents: SESs interacting at diverse scales (sub-basin, watershed, catchment, and municipality) across time and space (Levin, 1998; Walker and Salt, 2006). SES represent a conceptual shift toward treating social and ecological processes as integrated, complex systems.

The network convened specialists that had no prior experience of working collaboratively with each other. To facilitate interdisciplinary synergies in the early stages of the network researchers were asked to join interdisciplinary teams divided in three broad areas. These areas were land-use and infrastructure; biodiversity and eco-system functions; transboundary basin governance. This strategy enabled the network to begin articulating a dialogue centered on the assessment of the transboundary issues affecting the basin. At a later stage all researchers had opportunities to contribute to the contents of the other areas too. This process was aimed at weaving narratives of the URB capable of interconnecting issues and processes that affect the basin but which are not regarded as interconnected in complex systems.

Participation in workshops was a key part of the work. We held a series of workshops around crosscutting themes of relevance for the URB: *Hydroenergy and Climate Change* (Buenos Aires 2014); *Crafting an Action Agenda for the Uruguay River Basin* (Itaipú 2016) and *Infrastructure and Financing for a Sustainable Development* (Buenos Aires 2016). The core of the network is composed of academics who are the authors of this paper. However, the workshops also served to articulate with non-academic specialists whose contributions were of most relevance but which played an informal relation with the core members and research process. Particularly, specialists from technical bodies related to water management agencies, environmental NGOs and researchers from the three riparian countries of the URB.[1] Finally, the process of writing collaborative papers by the core of the network members was also an integral aspect of the interdisciplinary research methodology, requiring substantial editing and rewriting in the efforts to converge into a common narrative that articulates the issue areas and disciplinary approaches represented in the network.

4. Uncovering transboundary challenges

This section presents an exploration of key transboundary challenges tied to ongoing changes affecting the sustainability and integrity of the URB. It is the outcome of the interdisciplinary dialogue around discussion the URB as SES to visualize linkages between complex systems.

4.1. Infrastructure

In recent years there has been a resurgence of hydroelectric infrastructure projects in the region, including projects in the URB. While hydroenergy infrastructure has been historically seen as legitimate instruments of state-led development, today there is awareness of the risks that infrastructure and other forms of intervention pose to the sustainability and livelihood conditions in the basin (Saguier, 2018). From being mere natural resources to be exploited for economic growth and/or development priorities, basins are increasingly seen as complex hydrological ecosystems of vital importance for the provision of environmental services and climate change adaptation (UN Water, 2008). The URB has been a hub of infrastructure investments by public and private actors led by the increased economic importance gained by natural resource sectors on the basin (Saguier, 2018).

Presently, there are four large dams currently operating along different points of the URB distributed in the three riparian countries. New ones are planned, including the Garabí-Panambí binational (Argentina/Brazil) hydroelectrical complex which is already in its early stages of assessment (Table 1).

From an SES perspective, hydroelectric infrastructures pose risks for the URB. They represent the main factor of change in the land and river landscape with multiple and cumulative impacts at different scales from local to regional. One of the most direct and immediate impact of dams is on fish fauna but also on fisher communities. The formation of reservoirs usually generates changes in ecological conditions that are difficult to mitigate, often leading to decreasing fisheries and to a loss in quality of fisheries as reservoirs are much less productive than the original rivers (Agostinho et al., 2007; Baigún et al., 2010). Depending on the hydrometric level, these changes can produce an increase of predation and habitat loss for conditions for breeding, nursery and feeding (Pelicice and Agostinho, 2008). In addition, dams block fish migration routes (Agostinho et al., 2007; Pelicice et al., 2015).

These problems are identified in many of the dams in the URB: the *Itá* and *Machadinho* dams in the upper basin lack of fishways and the Borland locks were installed in the *Salto Grande* dam to keep the cycles of species migration, have proven to be largely ineffective (Oldani et al., 2007). In turn, the operation of the *Salto Grande* dam caused permanent changes in the hydrometric levels downstream, as well as changes the frequency of the average annual rising tide of the river before and after filling of the reservoir (Baigún and Oldani, 2005).

All these dams and those planned for the XXI century can impact on fisheries performances and riverine communities' welfare. Artisanal fisheries play a critical role in the livelihoods of artisanal fishing communities by providing food security, nutrition, employment and poverty alleviation (Béné et al., 2007) and most of such fisheries in South America are supported by migratory species

[1] Marcel Achkar, Tamee Albrecht, Sigrid Andersen, Célio Bermann, Maximiliano Bertoni, Silvina Carrizo, Nazaret Castro, Victor Cussac, Alcides Faria, Carlos Fulco, Lily House-Peters, Fernanda Mello Sant'Anna, Brent Milikan, Lucía Mochi, Víctor Pochat, Rubén Quintana, Diego Rodríguez, Héctor Roncati, Silvia Santana and Feline Schön.

Table 1
Planned and operating hydroelectric dams in the Uruguay River Basin.

Hydropower	Phase	Height (m)	Power (MW)	Country/River
Passo da Cadeia	Planned		1680	Brazil (Pelotas River)
Pai-Querê[a]	Planned		290	Brazil (Pelotas River)
Barra Grande	Operating	185	690	Brazil (Pelotas River)
Machadinho	Operating	126	1140	Brazil (Pelotas River)
Itá	Operating	125	1.450	Brazil (Uruguay River)
Foz do Chapecó	Planned	48	855	Brazil (Uruguay River)
Itapiranga	Planned		724	Brazil (Uruguay River)
Panambí	Planned		1048	Argentina-Brazil (Uruguay River)
Garabí	Planned		1152	Argentina-Brazil (Uruguay River)
Salto Grande	Operating	35	1890	Argentina-Uruguay (Uruguay River)

[a] Environmental license denied by IBAMA.
Source: Banco de Información de Geração (BIG-ANEEL) and EBISA (2010).

(Baigún et al., 2016). Furthermore, other changes in livelihood conditions are associated with the flooding of the dams. Preliminary official estimates indicate that *Garabí* (89.0 m)-*Panambí* (130.0 m) together will flood approximately 64,000 ha (which includes 39.000 ha of native forests and 24,000 ha of grasslands). This would result in the resettlement of population (3400 urban and 9200 rural dwellers), affecting areas for subsistence farming but also for commercial agriculture and forestry production, in addition to affecting sections of natural reserves in Argentina and Brazil of great biodiversity and 17 archaeological sites (EBISA-ELECTROBRAS, 2010).

Waterways are another infrastructure intervention that poses challenges to the integrality of the URB as a watershed system. The navigability of the Uruguay River is limited when compared with the Paraná and Paraguay Rivers, which make up the Hydroway Paraná-Paraguay, the main fluvial transportation system of the greater La Plata River Basin (Hamilton, 1999; Gottgens et al., 2001). However, there is an ongoing project to make the *Uruguay River Hydroway* which is aimed at improving the potential of this river commercial transportation. This requires dredging and digging works the middle and lower sections of the river south of the Salto Grande dam, complementary infrastructure such as a side canal and a compensation reservoir, as well as dredging of the ports of Nueva Palmira, Fray Bentos and Concepción del Uruguay. The detrimental impacts of hydroways on rivers, tributaries, islands and coastal areas are well documented (Pringle et al., 2000).

Finally, embankments are another form of infrastructure intervention in the URB that pose significant changes at the watershed level by reducing connectivity between channels and inland wetlands of the islands. They also serve as a form to change land use, since landfilling transforms aquatic ecosystems, mainly wetlands and deltas, into land suitable for extensive livestock production urban development and industrial agriculture, mainly of rice with embankment aimed at irrigation. Though these impacts are still scarce in the URB when compared to the Paraná River basin (Kandus and Quintana, 2016), they could pose a great risk to the delta and its mosaic of wetlands at the end of the lower section of the URB if appropriate protective measures to preserve are not adopted.

4.2. Land-use changes due to industrial agriculture and forestry

The links between land use and water quality has been well documented (De Mello et al., 2018; Giri et al., 2018). The URB is no exception mainly but not exclusively in relation to monoculture agriculture and the forestry industry (CIC Plata, 2017a). The runoff of chemical fertilizers used in industrial agriculture are a source of macronutrients (nitrogen and phosphorus) that cause the eutrophication of water bodies posing threats to biodiversity and water quality (CIC Plata, 2017a; Khan et al., 2014). The use of pesticides in soya agriculture also has been demonstrated to undermine the biodiversity of the basin especially fish and reptiles (Peltzer et al., 2008). Recent studies on the Paraná River basin, that encompasses the URB, found traces of pesticides as part of a cumulative effect of industrial agriculture (Ronco et al., 2016), and exposure to pesticides is associated with a crisis in human health, as there are increasing rates of cancer and birth malformation in areas exposed to fumigations (REDUAS, 2010). Cattle feeding and feedlot pens produces large amounts of manure and animal urine. Manure solutions resulting from surface runoff are composed of numerous chemical constituents whose leaching causes salinization of the soil profile, whoever there is no regulation about the manure manipulation of feedlot pens in this region (Veizaga et al., 2015).

Industrial agriculture and forestry related to the pulp sector have been the leading factors contributing to changing patterns of deforestation and reforestation in the URB since the early-1990s (Jobbágy et al., 2006; Switzer, 2014). Native forests like the Araucaria Forest and Pampa ecosystems located in the headwaters of the Uruguay River, as well the Atlantic Forest in southwestern Brazil, have been reduced considerably in the last decades (Jobbágy et al., 2006). In 1973 the area covered by the Atlantic Forest represented 73.4% of the original surface rapidly reduced to 40.7% in 1989 to reach 24.9% in 1999 (Huang et al., 2007). Deforestation lead to changes in patterns of evapotranspiration and surface runoff (Krepper and Venturini, 2009) which, in turn, amplifies flood risk (Bradshaw et al., 2007). Besides, large scale deforestation affected regional climate beyond the limits of the deforested area (Davis et al., 2019). From the water balance perspective, implanted commercial tree species can compensate to some extent the water absorption functions that native species have. Yet, as the recurrently intense floods registered recent years evidence, changes in land use and in the climate have altered the water balance of the URB thus affecting the responses of the river system (Calvacante et al., 2019).

4.3. Transboundary basin governance

The disconnection between the different institutions with authority over sections of the basin, coupled with citizen demands for information and participation in basin decisions, is another challenge for the URB. The institutional context of the URB is the outcome of a series of treaties signed at the level of the larger La Plata Basin scale between Argentina, Brazil, Paraguay and Uruguay in the late-1960. These treaties were aimed to stimulate water cooperation and management, and coordinate specific projects mainly in navigation and energy (Saguier 2018). This broad institutional governance framework is also complemented by a number of binational treaties. Table 2 displays the organizations and international instruments related to water resources created in the URB specifically for this basin.

From an SES perspective, river basins like the URB demand appropriate multi-level governance due to jurisdictional spaces, but also because basins involve biophysical processes that extend along different spatial and temporal parameters. Effective governance depends on achieving a good fit between the institutional governance arrangements, and ecosystem and social processes (Lebel et al., 2013; Ostrom, 2010; Young, 2002). These conditions are not easily found in the case of the URB.

Countries favor bilateral cooperation for specific projects or studies on the use of water resources. This weakens the potential performance of organizations like Administrative Commission of the River Uruguay (CARU), through which Argentina and Uruguay cooperatively manage the Uruguay River, or the Intergovernmental Coordinating Committee (CIC), which is the coordinating mechanism of the larger La Plata Basin, representing Argentina, Bolivia, Brazil, Paraguay and Uruguay. Further, the degree of interaction between these commissions, and general lack of investment by state in these two organizations threatens their viability and performance. The degree of integration between CIC and CARU is quite fragile, to the extent that the agreement establishes restricted to technical cooperation for conducting research projects or joint development. Furthermore, because the other organizations that deal with hydroenergy cooperation (Table 1) have not been incorporated into the larger research agenda for CIC, the hydroenergy agenda in the basin is disconnected from a more comprehensive, multi-issue governance approach. Energy integration maintains a certain autonomy from broader basin governance issues like biodiversity, water quality and sustainable development – which serves to hinder effective basin governance. As a result, riparian cooperation is limited and narrow on specific issues, it takes place in delimited portions of the river and remains largely ineffective or lacking (Hochstetler, 2003; Mello Sant'anna and Villar, 2015; Saguier, 2018; Siegel, 2017).

Just as biophysical and socioeconomic processes drive change in river basins so too do institutional performance and governance structures (Pahl-Wostl et al., 2012). The politicization of the basin is rendering the arrangement of treaties and bodies that make up the institutional framework for the URB out of touch with the growing social demands for participation and access to information in different decision-making processes in relation to the basin, particularly with respect to infrastructure issues. The organizations of the URB have no mandate or institutionalized participatory mechanisms to engage local communities in deliberative processes over decisions concerning the basin. They were not designed to be receptive to social demands for accountability and democratic

Table 2
Organizations in the Uruguay river basin.

Water organizations	Main goals	International Instrument
Administrative Commission of the River Uruguay (CARU)	Development of the Uruguay river stretch	Statute of the River Uruguay (Argentina and Uruguay, 1975)
CARU's scientific committee	To monitor the water quality in the Uruguay River	Agreement by exchange of notes between the Argentine Republic and the Eastern Republic of Uruguay concerning the establishment of a scientific committee within the Administering Commission of the Uruguay River (Argentina and Uruguay, 2010)
Joint Uruguayan-Brazilian Commission for the Development of the Quaraí River Basin (CRQ)	Development of the Quaraí River Basin	Cooperation agreement for the use of natural resources and development of the Quaraí River Basin (Brazil and Uruguay, 1991)
Salto Grande Joint Technical Commission (CTM)	Operation of the Salto Grande Hydropower Complex	Agreement concerning the utilization of the rapids of the Uruguay River in the Salto Grande area (Argentina and Uruguay, 1946) The Agreement to regulate agreement (Argentina and Uruguay, 1973)
Coordinating Commission (CR)	To coordinate and execute the treaty between Binational Energy Enterprises (EBISA) and Brazilian Electric Power Plants (ELETROBRÁS)	Treaty for the development of shared water resources of neighboring sections of the Uruguay River and its tributary, the Rio Pepiri Guaçu (Argentina and Brazil, 1980)
Joint Technical Commission for the realization and updating of inventory study of the Argentina/Brazil binational stretch of the Uruguay River	To conduct the review and Inventory Study Update of the Uruguay River	Additional protocol (Argentina and Brazil, 2007) Cooperation treaty between EBISA and ELETROBRÁS (Argentina and Brazil, 2008) Joint declaration of the Presidents from Brazil and Argentina February 22, 2008 Declaration over the development of shared water resources of neighboring sections of the Uruguay River and its tributary, the Rio Pepiri Guaçu River (2011)

Source: CIC plata, 2017b.

participation. Instead, they envision their role as "technical" actors within a narrow understanding of water policy in which scientific and technical interventions on the basin are seen as disconnected from society and from increasing pressures for the legitimatization of water policy.

The renewed interest in the investment of large-scale infrastructure in the basin has been a source of socio-environmental conflicts in the three riparian countries comprised by the basin. These conflicts manifest the deficit of existing governance institutions and practices in light of new citizenship demands for public deliberation, many of which respond to top down infrastructure specific projects (Merlinsky, 2017; Molle, 2009; Saguier, 2018). In particular, demands to a right to participation in decision making over the basin and for accountability with respect the social and environmental negative implications of infrastructure projects. The Garabí-Panambí hydro complex has been a particular contentious issue in this respect. Here the processes of Environmental Impact Assessment (EIA) are a site of contestation where governance deficits are confronted with the growing pressures of citizenship demands emerging from grassroots advocacy work from local communities in the basin (Gerlak et al., 2019).

These citizen demands and conflicts are not being aggregated into common policy and institutional frameworks that would facilitate basin governance. Moreover, scientific formulation and engineering solutions evolved to find technical solutions to complex water problems that have not been joint to effective societal and political solutions. In general, complex formulations have not been an integral part of long-term and adaptive resolutions of the URB water problems (Islam and Repella, 2015). Governance gaps of the URB result from a narrow view focused on hydroenergy and transport infrastructure. Many of the issues and actors that make the URB a hub of conflicting interests and processes remain outside on the margins of the formal agenda and ongoing cooperative efforts undertaken by the three riparian countries.

5. Moving interdisciplinarity forward: science-policy-society interactions

Our review of key transboundary challenges in the URB reveal patterns of infrastructure intervention, land use changes and governance gaps. These challenges suggest an insufficient fit between the institutional governance arrangements and socio-ecological processes. The assessment of interlocking processes discussed in the previous section indicates the need to move beyond current approaches to the URB focused on an infrastructure agenda, top-down decisions and jurisdictional fragmentation covering discrete sections of the basin. What is needed is to set in motion the kinds of science-policy-society dialogues conducive to developing a transboundary basin governance framework which is currently lacking in the URB. Though this is still an aspirational and long-term process, in this section we reflect on what opportunities and limitations IRNs face to contribute to this endeavor.

5.1. Harnessing opportunities for interdisciplinary research networks

Facilitating knowledge and data exchange: A significant opportunity can be found by interdisciplinary networks is to act as hubs for the integration, sharing and circulation of knowledge and data that can be valuable for policy and social participation in basin governance issues. Presently, there are some good practices in the basin around data sharing and participatory approaches that network actors can study and learn from – and use to inform future policymaking to better draw from and engage local communities and promote knowledge integration (German et al., 2007). The functioning of a fishery council in different small scale fisheries in Uruguay, including one located in Salto (Uruguay River) as part of a new management approach represents a good example of how management can be improved by the application of an ecosystem approach to fisheries (Garcia et al., 2003) including stakeholders' involvement and innovative interactions encompassing fisheries, political, social, economic and institutional/legal axis. Another example is the experience of the program of environmental participatory education Cultivating Good Water (*Cultivando Agua Boa*), implemented by the Itaipú binational dam on the Parana River basin since 2003 (Vitorassi et al., 2011) is a valuable antecedent to inform comparable initiatives for the URB. Similarly, the binational Argentina-Uruguay laboratory for joint monitoring of water quality can be examined for its effectiveness in data harmonization. By examining the potential of data exchange and participatory approaches like these, networks are practicing interaction and interdisciplinarity in ways that can potentially shape and inform new approaches.

The interdisciplinary element of knowledge production and circulation enables the visualization of the URB as a SES in ways that reveals the interconnectedness of issues and processes across spatial and temporal scales. This is critical to move beyond the disciplinary, jurisdictional silos as well as to expand the range of issues that affect the basin in connection to infrastructure. In the hands of networks, interdisciplinary knowledge can be seen as opportunities to frame the URB in terms of transboundary basin narratives that engage across different communities - academic/science, policy, technical and the general public. Networks can act as knowledge brokers, translating research-based information and practices into languages that can related to the specific narratives of the different institutional/public and social stakeholders in the basin. This role of research networks to act as capillary bodies intersecting actors and processes that are otherwise disconnected. This presents the opportunity to make more accessible much-needed environmental information in policy decision-making and democratic public deliberation. Though networks are not a substitute for real participatory processes, they can also facilitate participation through information.

Interconnecting governance scales: Research networks can help articulate different levels of governance processes that are not being connected in processes of norm production, institution building and policy by public and social actors. The *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean* (so called "Escazú Agreement") is an example of this. The Agreement is relevant for the development of shared norms, practices and regulatory cooperation in the Environmental Impact Assessment and other instruments that can be used for the development of a transboundary governance framework for the URB. The joint assessment of the basin according to shared principles enables territorial environmental

planning of the basin, incorporating all the issues that generate conflicts and associated environmental problems. This would require harmonization of common standards and methodologies as part of a collective set of principles and procedures or protocol at the basin level, including social assessments, consideration of cumulative impacts and inclusive, participatory approaches (Grill et al., 2015). This legally binding agreement will provide a common framework for URB countries to harmonize common standards and protocols with respect access to environmental information related to basin policies and impacts that will be vital for the development of co-ordinated strategic environmental assessment instruments and for enhanced public participation in governance policies and decision making. Argentina and Uruguay have recently ratified the Agreement but Brazil is nowhere close to doing so. IRNs working on the URB can contribute as a science diplomacy actor, drawing the attention about the relevance of this regional agreement for the prospects of tackling many of the issues that are sources of controversy in the basin.

5.2. Overcoming challenges for interdisciplinary research networks

A word of caution about "experts": Researchers are often consulted as "experts" to inform public debates in policy and general public debates. Though this can be an opportunity for network members to advance an interdisciplinary agenda for the basin, it can also be the case that "experts" are called in to legitimize top-down decisions that need to be presented as credible to a broader public – in discussions of legislation reform projects, project investment decisions, support of government policies, impact evaluation processes, etc. Likewise, private industry with particular interests in the basin can also resort to "experts" for legitimization. Efficiency arguments of experts have long-dominated water management practices emphasizing the highest economic value and neglecting equity or fairness concerns (Gerlak and Ingram, 2018). Civil society groups, as those that oppose large scale infrastructures, can also be a space for "expert" views that can help advance advocacy causes to a broader public or else as sources of technical information that can be difficult to obtain. In different ways, science-policy-society interactions navigate the waters of contested credibility and legitimacy (Cash et al., 2002), since neither science, politics nor society are ever neutral realms and thus are always subject to respond to pressures for accountability and effectiveness (Jasanoff, 2004).

Time for trust and relationship building: In addition, there is the ongoing challenge of building trust relationship with policy and social actors that are relevant for network's potential to facilitate interdisciplinary thinking through science-policy-society interactions. While avoiding being captured by the particular interests of state and private actors, networks also need to engage with them in ways that allows for deliberation and genuine exchange to take place. This can prove to be a challenge when issues that are part of network's research focus are sources of political debate and social contestation where there is little if any consensus in society and among the political forces. Our experience with the URB project shows that the treatment of contentious issues, such as the decisions to prioritize investment infrastructure with large dams and hydroways, have resulted in reluctant compromise of water management authorities to engage with the network in a formal and publicly visible way. The working relationship with some of the public authorities related to water and energy management, which participated in different phases of the project, remained ad hoc and informal. Workshops were the main space for interacting with them. Relationships with social actors were very rich during joint assessments and exchanges during workshops; yet less intense during the writing of academic publications as outputs of the project. In a different way, the experience of this interdisciplinary endeavor reinforced the academic core of the network membership, representing different science disciplines and dimensions of the URB. Relations with policy and social actors proved essential to sharing information and articulating a network narrative of the URB, even while occupying a less central role in the research process.

The need for reliable funding: Access to stable funding sources along time is an important challenge of networks potential to maintain a research program and activities. In a context of underfunded national scientific systems keeping networks alive proves to be a problem. Moreover, the ways that funding schemes of most international funding bodies are designed, where only activities but no research salaries can be covered, adds to the problem. This results in researchers having little incentives to engaging in interdisciplinary projects, as disciplinary criteria still dominates the norms of professional development and prestige in academia and publication venues almost everywhere. This also presents the organizational challenge of managing the different roles and actual commitments of network researchers. With fewer material and institutional incentives to dedicate time to interdisciplinary research there is a tendency for projects to rely on centralized organization of functions and responsibilities. This is surely a challenge for networks whose potential to contribute to transboundary basin frameworks rests on their capacity to undertake sustained decentralized work and roles. To offset these inertias, resources need to be committed. Interdisciplinary research is expensive.

Regional-Global structural tensions: Networks do not work in a vacuum. The URB is in a region that is undergoing a reversal from governmental efforts in the past to build regional governance frameworks in different policy areas (Riggirozzi and Wylde, 2018). The end of such a regionalist moment does not facilitate networks efforts to bring about cooperative initiatives between states through research. Furthermore, this is particularly challenging at a time when the relation between science and politics is being undermined by rising ideologies of climate and environmental denial as seen in Brazil with the Bolsonaro government and entrenched productivist views of development that underpin unsustainable practices across states and economic actors in the basin. IRNs can only hope to manage such adverse tensions in the best possible ways but they are not capable of offsetting the limits that these tensions pose for the future prospects of realizing a transboundary basin for the URB.

IRNs can act as agents in the articulation of basin narratives as socio-ecological systems. Narratives of socio-ecological systems reveal the interconnected and interdependent relations between issues and processes in a basin as they unfold across temporal and spatial scales. These set of relations make up a basin as a distinct hydrological system embedded in socio-economic, political and biophysical dynamics: the basin as a distinct territory. This view of basins does not prevail in the URB, or else not in ways that can translate into much needed transboundary governance frameworks. Indeed, we believe that many of the governance gaps in the URB could be addressed by having alternative understandings of the basin. Here is where IRNs have a facilitating role in constructing

narratives, negotiating meanings and mediating dialogues at the intersection of science-policy-society processes. A first step in realizing this potential is for IRNs to see themselves as basin agents.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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