

International River Basin Organizations, Science, and Hydrodiplomacy

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Abstract: As key venues for interaction and cooperation, international river basin organizations (IRBOs) are significant contributors to hydrodiplomacy in transboundary river basins. As part of their efforts to support hydrodiplomacy, IRBOs engage in the production and use of science. The manner in which that science is produced, and how it contributes to hydrodiplomacy, is not well understood. This paper examines the production and use of science by three IRBOs: the (US – Canada) International Joint Commission, the International Commission for the Protection of the Danube River, and the Mekong River Commission. We find the science produced by the IRBOs to support hydrodiplomacy extends beyond measuring and monitoring to include more advanced and analytical forms of science. In producing science, we observe that the IRBOs balance considerations of capacity, ownership, and how the politics of the basin will influence the production and use of the science. Given the challenge of balancing across these considerations, future research is needed to determine what mechanisms and processes for producing science can best facilitate its use in hydrodiplomacy.

Highlights:

- IRBOs are key institutions supporting hydrodiplomacy in transboundary river basins
- IRBOs produce and use science to support hydrodiplomacy
- When producing science, IRBOs balance capacity, ownership, and politics

Key Words: hydrodiplomacy; science; international river basin organizations; politics; transboundary rivers

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1. Introduction

Around the world, intensifying demands for water resources, changes in the hydroclimatic cycle, and degrading water quality pose threats to humans and ecosystems (Vörösmarty et al., 2010). These risks are of increasing concern for transboundary river basins, where international political boundaries add a dimension of complexity to already challenging governance issues (De Stefano et al., 2010; Munia et al., 2016). Due to the sovereignty of individual countries, transboundary water governance primarily occurs through the negotiation of international relations. Objectives of this diplomacy range from resolving and managing water-related conflicts in the short and long term to harnessing water cooperation mechanisms to promote regional integration (Pohl et al., 2014).

In recent decades, the term hydrodiplomacy has been applied with a normative lens to refer to an approach to relations that seeks to promote, establish, or enhance cooperation, stability, and peace over water (Grech-Madin et al., 2018). Hydrodiplomacy is described as “a dynamic process that seeks to develop reasonable, sustainable and peaceful solutions to water management while promoting or informing cooperation and collaboration among riparian stakeholders” (Klimes, 2018:1362). Hydrodiplomacy leverages technical and social knowledge to inform decision-making in a way that builds trust, emphasizes joint fact finding and learning, and seeks to erode barriers that block more cooperative approaches to shared freshwater resources (Kittikhoun and Staubli, 2018; Klimes, 2018; Susskind and Islam, 2012; UNESCO, 2016). The use of science for dialog is thus a fundamental aspect of hydrodiplomacy (Wilder et al., 2019).

While diplomacy occurs through both formal and informal interactions, and while those interactions occur between not only national-level but sub- and supra- national actors, countries often set up formal institutional mechanisms through which they engage in diplomacy (Klimes, 2018). With respect to transboundary surface and ground waters, these formal institutions for hydrodiplomacy usually involve treaties, which spell out commitments countries make. Countries also form international river basin organizations (IRBOs) to aid in collectively managing their shared water resources (Schmeier, 2015; Shubber and Schmeier, 2018).

As formalized institutions, IRBOs provide a clear a mechanism, and often also procedures for countries to engage in hydrodiplomacy. IRBOs serve as a forum for dialog, negotiation, and dispute resolution (Gerlak and Schmeier, 2016). They provide a structure for regular meetings and communication between member countries, as well as processes for engaging in joint decision-making. IRBOs also contribute to capacity-building among member countries, through technical assistance, trainings, and at times, channeling of donor funds (Gerlak & Schmeier, 2016). Lastly, IRBOs serve as a forum for producing, analyzing, and disseminating data, information, and knowledge (Schubber and Schmeier, 2018).

Over the last two decades the number of IRBOs has grown, in part due to support from international agencies, bilateral aid agencies, and epistemic communities (Blumstein, 2017; Jaspers and Gupta, 2014; Schmeier, 2015). Growth in the number of IRBOs has been accompanied by increasing attention to the institutional design and capacity of IRBOs (e.g., Berardo and Gerlak, 2012; Bouckaert et al., 2018; Schmeier et al., 2015) as well as to how well

IRBOs include and reflect the full scope of stakeholders in transboundary rivers (e.g., Sneddon and Fox, 2006; Suhardiman et al., 2012). Yet a critical element of how IRBOs support hydrodiplomacy – by facilitating the production and use of science – has received scant attention. By science, we refer broadly to knowledge produced through systematic methods. Under this definition, science includes the production of data as well as the analysis and interpretation of it and knowledge from any discipline or topical area (natural, physical, or social).

In this paper, we examine the production and use of science by IRBOs to support hydrodiplomacy. We examine how three well-established IRBOs – the International Joint Commission (IJC), the International Commission for the Protection of the Danube River (ICPDR), and the Mekong River Commission (MRC) – produce and use science to support hydrodiplomacy. We do not present science as a panacea nor do we see science as the only path to diplomacy. Rather our objective is to highlight the manner in which IRBOs produce and use science to support dialog and cooperation in transboundary rivers. Data from our research indicate that, when deciding how to produce and use science, IRBOs carefully consider IRBO and member country capacities, the costs of producing science, and how the process by which the science is produced influences how the science might be interpreted or used instrumentally by member countries. Our findings regarding the extent to which IRBOs produce science, combined with the complexity of decisions regarding how to best produce science, points to the need to apply knowledge from research on science-policy interfaces to the study of hydrodiplomacy.

2. IRBOs and science for hydrodiplomacy

At the international scale, science, as well as the production of science, can catalyze cooperation (Koppelman et al., 2010). Science that is perceived as objective can provide a common ground for international negotiations. Science can also be useful for garnering domestic support for transboundary policies, particularly when it influences the understandings of the national and sub-national stakeholders whose political support or opposition to transboundary policies influence national decision-makers (Pfeiffer and Leentvaar, 2013; Sendzimir et al., 2008). Further, when science is co-produced, the science-production process contributes to cooperation by fostering social learning and fomenting repeated interactions between actors that serve to build networks and channels of communication and trust (Koppelman et al., 2010; Armitage et al., 2015). Conversely, the lack of information, or disagreement over it, can hinder cooperation (Timmerman and Langaas, 2005).

Although scholarly work recognizes the role of science in water governance and transboundary rivers, research to date has primarily focused on the role of IRBOs in the sharing of data, in part because many treaties designate monitoring and data sharing as a responsibility of the IRBO (Gerlak et al., 2013). Consequently, scholars have made many recommendations regarding the value of and needs for data production and information sharing systems (Barreira & Kallis, 2003; Burton and Molden, 2005; Timmerman and Langaas, 2005) and have studied what leads to more or to less effective data sharing (Plengsaeng et al., 2014; Thu and Wehn, 2016). The extent to which IRBOs are engaged in producing and using science to support hydrodiplomacy, and the challenges they face in doing so, has been underemphasized. Beyond data sharing and monitoring, the involvement of IRBOs in science production is not well understood (Schmeier,

2014) and little is known about the on-the-ground practices for producing, sharing, and using scientific knowledge in transboundary river basins (Armitage et al., 2015).

The production and use of science to support relations over transboundary waters is not without complication. *First*, most IRBOs do not have authority to make policy. Rather, IRBOs support and influence decision-making by national-level governments. As such, it is important to understand the direct mechanisms through which IRBOs can make use of science to support hydrodiplomacy, including the venues through which they guide or influence member-country decision-making. *Second*, the extent to which science is taken up by policy depends on a variety of factors. For science to be used, the content, structure, and format of science outputs must match with the needs of policymakers (See e.g., Cash et al., 2002; Kirchhoff et al., 2013; McNie, 2007). Uptake of science also depends on user perceptions of the science, institutional culture, and the frameworks for decision-making (See e.g., Rayner et al., 2005; Weichselgartner and Kasperson, 2010). *Third*, science does not always support all parties equally. Intentionally or inadvertently, the production of science, including its focus, units of analysis, and scale, can serve certain interests. Further, decision-makers often use science strategically to address particular problems, to substantiate favored policies, and/or serve particular interests (Littoz-Monnet, 2017; Saarela and Söderman, 2015; van Enst et al., 2017). Consequently, in transboundary basins, science and technical information do not support hydrodiplomacy. Concerns about vested interests, legitimacy, and the impacts of policies can both influence the use of science and outweigh gains from technical cooperation (Pahl et al., 2014).

3. Research approach

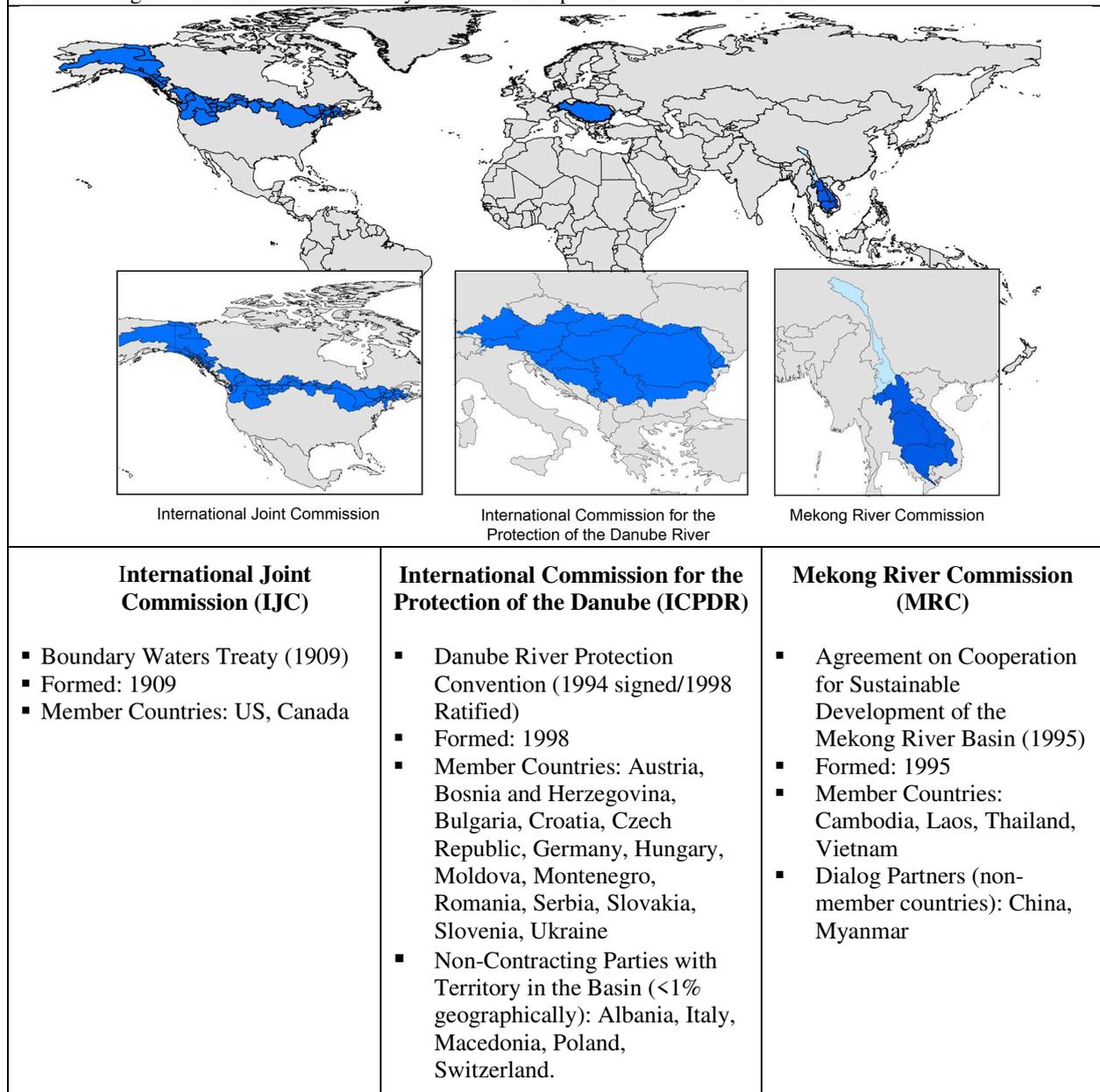
The three IRBOs studied – the IJC, ICPDR, and MRC – support hydrodiplomacy in river basins that, collectively, span three continents. These river basins encompass a broad geographic diversity including variation in environmental and water conditions, history, economics, and political features. These IRBOs are recognized as leaders in transboundary river governance and have been actively generating scientific knowledge (e.g., Chapman et al., 2016; Clamen and Macfarlane, 2015; Houba et al., 2013). As such, they provide an ideal starting point for examining the production and use of science in transboundary river basins.

Analysis of science production and use by the IRBOs involved a multi-stage process. First, we developed a comprehensive catalog of the science produced by the IRBOs between 2010 and 2016 (See Appendix A). To verify and to analyze this list, we drew on the expertise of an interdisciplinary group of practitioners, policymakers, and scholars who work in and study transboundary river basins. These individuals have been both producers and users of scientific knowledge and include representatives from each of the three IRBOs studied here. With funding from National Socio-Environmental Synthesis Center (SESYNC), we hosted three workshops between 2017 and 2019 where this interdisciplinary group discussed in-depth the production and use of science by the IRBOs, with an emphasis on the three IRBOs in the study. During workshops, participants developed a typology of the science produced by IRBOs; solidified methods for development of and verified contents of the dataset of science products; and

discussed opportunities and challenges associated with the production and use of science by IRBOs for hydrodiplomacy.¹

Figure 1. Location of the IRBOs Studied

Note: Dark blue indicates the region covered by the IRBO. Light blue indicates any part of the watershed that is not part of the IRBO. Less than 1% of area of the Danube river basin lies in countries not parties to the ICPDR. Maps created using files from the Transboundary Freshwater Dispute Database and ESRI ARCGIS.²



¹ Workshop agendas and participant lists are available at: <http://udallcenter.arizona.edu/programs-projects/environmental-policy/actionable-science-transboundary-river-basins>

² For additional information see the Transboundary Freshwater Dispute Database, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University at: <http://transboundarywaters.science.oregonstate.edu>.

4. Science and IRBO mandates

Each of the three IRBOs studied here was created as part of a treaty between the IRBO member countries. The treaties were the result of years, sometimes decades, of negotiations and discussions between the countries involved regarding their shared water resources. Although the mission of each IRBO, its structure, and the specific tasks and responsibilities delegated to it reflect the concerns of member countries, the forms of institutionalization support their hydrodiplomacy objectives. Over time, the mandate and responsibilities of each IRBO has broadly expanded, with member countries assigning the IRBO additional roles. Notably, and as described below, in creating each of the IRBOs, member countries granted the IRBOs authority and responsibility for the production of science.

4.1. International Joint Commission

The IJC was formed to aid the US and Canada in protecting their shared rivers and lakes and to prevent and resolve disputes concerning those resources.³ Since the IJC covers multiple waterways, hydrodiplomacy related to one basin is linked to hydrodiplomacy in another basin. Nonetheless, there are strong geographic, socio-economic and cultural differences along the border. Further, states/provincial governments have a strong role in water management in both the US and Canada. As such, the specific focus of hydrodiplomacy actions also varies from basin to basin.

The IJC has two primary functions: it issues orders of approval and it responds to reference. For approvals, the IJC oversees application and operation of projects (e.g., dams, diversions, bridges) that have transboundary impacts or relate to the apportionment of transboundary waters (Congressional Research Service, 2019). In its reference role, the IJC provides advice and conducts studies at the request of governments on issues of joint concern; alerts the governments to emerging issues that might have negative impacts on the quality or quantity of boundary waters or that may possibly lead to conflicts; and assesses progress of projects and efforts to protect the shared waters.

When forming the IJC, the US and Canada explicitly tasked it with the role of serving as an impartial advisor to the two countries (the IJC's aforementioned reference function). As such, the IJC was authorized to examine and report upon the facts and circumstances of the particular questions and matters referred to it (Blaney, 2009). Over the years, and in response to recommendations from references, subsequent agreements between the US and Canada designated specific IJC boards as responsible for directly monitoring and/or compiling and sharing monitoring data. For example, the IJC's International Red River Board (IRRB) has a mandate to maintain monitoring and perform inspections, evaluations, and assessments to determine compliance with water quality and flows objectives agreed to by governments. In doing so, the IRRB encourages and engages in the production and sharing of science.

4.2. International Commission for the Protection of the Danube River

³ See The Boundary Waters Treaty. 1909. Canada, United States. <https://www.ijc.org/en/boundary-waters-treaty-1909>

The ICPDR was created to ensure the sustainable and equitable use of waters and freshwater resources in the Danube River basin.⁴ The ICPDR's 14 member countries are quite diverse in terms of their populations, economies, as well as their geography within the basin. Consequently, the importance of the river, as well as the impacts of each country's activities in relation to the river, varies across the basin (ICPDR, 2009). The implication for hydrodiplomacy is that differing combinations of countries are more concerned about and/or more able to engage in transboundary issues.

ICPDR's goals include safeguarding and conserving water, protecting water quality, ensuring healthy river systems, and reducing damage caused by floods and ice hazards. The ICPDR serves as an advisory and facilitating agency; it is tasked with assessing and synthesizing information on the state of surface and groundwater in the basin and acting as forum for countries to identify, coordinate, implement, and review projects. It also assists in basin-wide implementation of the European Union's Water Framework and Floods Directives (Weller and Popovici, 2009).

During the formation of the ICPDR, member countries were particularly concerned with monitoring and data sharing as central aspects of hydrodiplomacy. As part of the treaty forming the ICPDR, member countries committed to undertaking periodic inventories of pollution sources within the basin and of water quality protection and mediation measures to be taken. Member countries also committed to the exchange of information and to undertaking complementary or joint programmes of scientific or technical research. The ICPDR is structured to support those commitments, including through the creation of expert groups, comprised of representatives from each country, that conduct and facilitate technical work to support hydrodiplomacy (ICPDR, N.D.).

4.3. Mekong River Commission

The MRC was established to support the sustainable management and development of water and related resources of the lower Mekong River Basin, while reducing any potentially harmful effects on people, the economy, and the environment.⁵ Neither China nor Myanmar (upper basin countries) are parties to the MRC, although both engage with the MRC and participate in annual dialog meetings. Capacities and interests of MRC member countries vary, as do national interests. The effects of hydropower development on fisheries, on flows, and on sediment transport are strong points of contention across the countries (Kittikhoun and Staubli, 2018). These up-stream/down-stream dynamics and differential capacities manifest frequently in hydrodiplomacy efforts between the lower basin countries.

The MRC is responsible for formulating a Basin Development Plan and for facilitating technical coordination among member countries. This responsibility includes overseeing agreed upon

⁴ See The Convention on Cooperation for the Protection and Sustainable Use of the Danube River. 1994. *Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Moldova, Montenegro, Romania, Slovakia, Slovenia, Serbia, Ukraine, European Union*. Sofia, Italy. <http://icpdr.org/main/icpdr/danube-river-protection-convention>

⁵ See The Agreement on Cooperation for Sustainable Development of the Mekong River Basin. 1995. *Cambodia, Laos PDR, Thailand, Vietnam*. <http://www.mrcmekong.org/about-mrc/mandate/>

procedures for data information exchange and sharing, water use monitoring, maintenance of flows, water quality, and notification prior consultation and agreement of infrastructure projects. The MRC is also charged with promoting dialog and communication among member countries and with its development (donor agencies) and dialog (other neighboring country) partners.

In forming the MRC, member countries committed to substantial policy as well as technical cooperation. As such, the MRC was tasked to regularly obtain, update and exchange information and data necessary to implement the treaty, and to conduct appropriate studies and assessments for the protection of the environment and maintenance of the ecological balance of the Mekong River Basin (MRC, N.D.).

5. Types of science produced and used by the IRBOs for hydrodiplomacy

During the six-year period examined (2010-2016) as part of this study, the three IRBOs collectively produced upwards of 200 individual science products. These science products encompass the full spectrum of issues in transboundary rivers, including water quantity, water quality, ecosystems, hydropower, climate change, geomorphology, wetlands, and river connectivity, groundwater, agriculture, livelihoods, navigation, and land use (see Appendix Table A1). Some of the science products are the result of a one-time effort, while others are an ongoing or regularly repeated endeavor. As explained by workshop participants, this difference occurs because:

“Some science is more issue specific – like the building of a dam – versus other science that is part of more regularized management.” (Participant 1)

As explained by another participant, the science that is produced outside of regularized management often occurs because:

“New challenges emerge and evolve over time. For example, in [IRBO name redacted] today, issues include instream flows, algal blooms, water quality, invasive species, in addition to prior concerns of floods and droughts, and over-appropriation.” (Participant 8)

Science initially produced as a one-time effort, may become regularized, particularly when there is a need to track trends. For example, initial modeling of nitrogen and phosphorus modeling has become a regular component of ICPDR science. Further, it is not uncommon for one science product to serve as an input to another. For example, water quality monitoring data produced feeds into pollution transport models.

Science produced by the three IRBOs was described by workshop participants as including both sensing (observation and measurement) and sense-making (analysis, interpretation, and extrapolation). Drawing on their own experiences and the aforementioned catalog of science by the IRBOs, workshop participants characterized the types of science produced as consisting of four categories: (1) measuring and monitoring; (2) forecasting potential future states; (3) developing new understandings; and (4) reviewing the state of knowledge. Science products may

concurrently span more than one category at once. Table 1 provides illustrative examples of how each type of science has been used by the IRBOs to support hydrodiplomacy.

The most common type of science produced is measuring and monitoring. This includes more than tracking water flows and quality; each IRBO also uses field surveys/in-situ sampling, remote sensing, and secondary data collection to measure a wide scope of topics including to evaluate the physical, ecologic, and socio-economic status of the basin. Measuring and monitoring is common in part because the mandate of the IRBOs includes specific requirements for monitoring and information sharing. Yet, each of the IRBOs also use measuring and monitoring to support hydrodiplomacy activities, beyond data sharing, to evaluate and provide member countries with shared understandings of the current state of the basin. For example, an IJC funded alewife count project in the St. Croix river contributes to shared understandings in the US and Canada of the ecological health of the watershed. Information on the current state of the basin and reference data sets are also needed for analyses of potential future states of the basin and for an evaluation of the potential outcomes of water policies and actions.

Each of the IRBOs also conducts analyses that examine potential or expected future states of the basin. These analyses include short term forecasts about immediately pending conditions, such as floods, droughts, or pollution spills, as well as longer term scenarios analyses that help identify the conditions that could unfold as a result of climate change or development patterns in the basin. IRBOs are uniquely positioned to produce these types of forecasts, in part because of their role in collecting, compiling, and transmitting monitoring data across member countries and because of the historic mission of IRBOs as an information clearinghouse. The short-term forecasts of IRBOs serve to support hydrodiplomacy by raising awareness and providing timely information needed by countries to coordinate their actions or respond quickly to events with transboundary impacts. For example, the ICPDR Accident Emergency Warning System sends out warning to countries when there is a risk of transboundary water pollution. The long-term analyses of the potential future states of the basin also contribute to hydrodiplomacy by serving as the basis for dialog between countries regarding key concerns as well as the expected transboundary and basin-wide impacts of policies and actions.

In addition to providing information on the current or future state of the basin, IRBOs also produce science to fill gaps in understandings of the physical, chemical, and biological processes within the basin, including the impacts of human activities. IRBOs fill knowledge gaps as a way to develop shared understandings of the system – as well as reduce uncertainties that can lead to differences in opinion or debate within diplomacy. In each of the basins in the study, knowledge of both the physical and the human aspects of the basin are incomplete. These knowledge gaps can lead to disagreement among countries regarding whether action is necessary and/or who is responsible for taking action. For example, the topic of sediment transport and how it may be affected by hydropower development is a topic of much debate within the Mekong Basin. By filling knowledge gaps, IRBOs seek to steer countries from stalemates to decisions..

Lastly, the IRBOs conduct scientific reviews. These reviews provide a synthesis of the state of knowledge on a topic, including identifying the boundaries of what is known, identifying gaps in knowledge, and summarizing best practices. These reviews serve to inform member countries as well as to support development of other science products. Scientific reviews constitute a

comprehensive summary of information, and thus contribute to hydrodiplomacy by providing member countries with a consistent, shared basis of knowledge. For example, the ICPDR conducted a review of the latest information on expected climate change and adaptation strategies and used that knowledge to support planning and flood risk-management decisions in the basin. Scientific reviews also indicate where there is consensus across science and/or practitioner communities beyond the basin, thus reducing the potential for disagreement among countries over issues for which these are broadly accepted perspectives.

Table 1. Types of Science Produced and Used by IRBOs to Support Hydrodiplomacy

Types of Science	Examples
Measuring and monitoring the current state of the basin	<ul style="list-style-type: none"> <li data-bbox="491 645 1366 831">▪ IJC: The IJC conducted a survey to document and map existing shore protection measures in the Upper Great Lakes. This survey provided baseline information needed for an evaluation of expected flood impacts to shoreline properties. The evaluation was used by the IJC make recommendations to the US and Canada, supporting decision-making regarding changes to dam operations. <li data-bbox="491 846 1366 1032">▪ ICPDR: The ICPDR developed an inventory of continuity interruptions; disconnected wetlands and floodplains; and hydrological pressure and alterations within the basin. This inventory supported member countries as they worked together to develop a River Basin Management plan under the EU Water Framework Directive, which requires countries plan to achieve good geomorphic status across the basin. <li data-bbox="491 1048 1366 1234">▪ MRC: The MRC coordinates member countries in conducting a biennial survey of benthic diatoms, zooplankton, and littoral and benthic macroinvertebrates throughout the basin. This survey provides countries with shared knowledge of the overall ecological health of the river. This knowledge also supports countries in basin-planning and evaluation of the impacts of development on the basin.
Forecasting potential future states of the basin	<ul style="list-style-type: none"> <li data-bbox="491 1256 1378 1413">▪ IJC: The IJC developed and used a two-dimensional hydrodynamic model of the Lower Pembria River to evaluate the effects of flood mitigation strategies under 10-, 20-, 50-, and 100- year flood events. This analyses supported decision makers as they considered which actions to take to address flooding in the basin. <li data-bbox="491 1429 1378 1552">▪ ICPDR: The ICPDR coordinated risk assessments for basin medium probability and extreme flood events in the basin. These flood risk scenarios supported countries in developing a coordinated basin-wide flood risk management plan. <li data-bbox="491 1568 1378 1693">▪ MRC: The MRC conducted an assessment of the impacts of potential scenarios for development, with an emphasis on the effects of hydropower development along the main stem. The scenarios developed were used to support countries in the creating a Basin Development Plan.
Developing new understandings of the basin	<ul style="list-style-type: none"> <li data-bbox="491 1715 1378 1872">▪ IJC: The IJC analyzed the effects of water temperature conditions on growth and survival of smallmouth bass in Spednic Lake during the first year of life. This knowledge was used raise awareness within both countries about the needs for and potential of restoration of the alewives in the St. Croix basin. <li data-bbox="491 1888 1378 1935">▪ ICPDR: The ICPDR developed a GIS-oriented pollutant transport model to estimate nutrient loading by point and non-point sources into the Danube

and to assess which potential future actions could be used to meet water quality standards for nutrients. This knowledge contributed to developing across countries a shared understanding of the causes and impacts of pollution and supported planning to reduce pollution in the basin.

- **MRC:** The MRC assessed the past, current, and predicted biophysical, sociocultural, and economic impacts of tourism development in the basin. The MRC provided this information to countries to encourage them to consider the sustainable management of water related resources when making decisions related to tourism sites in the basin.

Reviewing the state of knowledge

- **IJC:** The IJC summarized existing science on the occurrence and distribution, human health effects, and economic effects of harmful algal blooms. This synthesis was used by the IJCs Health Professionals Advisory Board to raise awareness across countries and support decisions that may affect health, as agreed to under the Great Lakes Water Quality Agreement.
 - **ICPDR:** The ICPDR conducted a review of projects and studies that address climate change in the basin in order to identify the expected impacts of climate change on water related issues and to identify possible adaptation measures. This review informed countries of their shared climate risks and was used by countries in updating the Danube River Basin Management Plan.
 - **MRC:** The MRC summarized research on fish-pass solutions for both upstream and downstream migration to provide a comprehensive overview of the current state of knowledge. This information was used by the MRC to develop guidance materials for member countries and hydropower developers as well as to support country dialogs that occur as part of the MRC Agreement for Notification and Prior Consultation.
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6. Use of science by IRBOs to support hydrodiplomacy

As described above, each of the IRBOs in this study is engaged in a number of activities that support hydrodiplomacy. Workshop participants characterized these activities as including (1) raising awareness of transboundary water issues, (2) providing advice to member countries, (3) coordinating the activities of member countries, and (4) facilitating dialog across countries. The IRBOs use science as a central ingredient in each of those activities. See Table 2 for select examples for each IRBO.

The IRBOs frequently engage in activities that seek to raise awareness about water-related issues. In raising awareness, the IRBOs seek to generate a shared understanding among member countries and other constituents about the need for potential actions or the impacts of actions across the basin. Awareness building is an important part of hydrodiplomacy, as where an issue is not recognized as a transboundary concern, it will not rise to the policy-agenda (Bardach, 1996). Science is used by the IRBOs for raising awareness in several ways: science is used to identify issues that need to be publicized; science forms part of the content of what the IRBOs communicate; and the process of producing science is used as an awareness raising activity. For example the ICPDR held Danube Water Day, which included public outreach and press conferences, as part of its Joint Danube Survey and the MRC held a Sustainability Forum, which included government representatives, technical experts and the industry professionals, as part of

its science production on sustainable hydropower. These activities, and the awareness they create, serve to legitimize and generate support for IRBO science and recommendations. For example, as explained by one workshop participant:

“[Through awareness raising] decision-makers in the basin are being exposed to good data, information, and science. This makes it difficult for them to say no, we don’t want to [make a decision]. At the same time, when the citizens are getting the information, real pressure for decision-makers is also coming from the bottom up” (Participant 2).

IRBOs also produce science in order to develop and make recommendations to member countries about how to address water-related issues of concern. IRBO recommendations are meant to serve as objective advice to member countries and take many forms including guidance documents, decision-support tools, or policy briefs and reports. These recommendations support hydrodiplomacy by encouraging member countries to adopt similar or synergistic practices thereby, making it easier for countries to cooperate in the future. The recommendations also support hydrodiplomacy by encouraging countries to adopt practices that will either minimize transboundary impacts or provide mutual benefits throughout the basin. For example, the ICPDR developed a manual on flood mapping procedures and the MRC produced a manual on the management of dangerous goods. These guidance documents IRBOs frequently produce and use science in order to develop their recommendations or guidance documents. They use science to illuminate the underlying effects of the water-related actions the IRBO is seeking to address through its recommendations. Lastly, science serves to legitimize the IRBOs recommendations to member countries, providing an evidence base for why their guidance should be followed.

IRBOs also support hydrodiplomacy by coordinating the activities of member countries through strategic planning at the basin level. In conducting strategic planning, IRBOs examine how the separate actions of countries interact with one another and evaluate the expected impact of those across the basin or at the basin level. Both the MRC and the ICPDR engage extensively in basin planning: the treaty forming the MRC tasked it with creation and regular updating of a basin development plan, while the ICPDR received its planning mandate after it had been formed. Member countries viewed the existing ICPDR as the most appropriate institution to aid in their compliance with EU Water and Floods Framework Directives. Science is a key component of strategic planning as in order to develop a plan, the IRBOs need substantial information on the current state of the basin; stressors and changes that may occur within the basin; and the potential effects of management actions. Thus IRBOs frequently engage in measuring, monitoring, and scenarios analyses in order to help guide member countries through the policy decisions related to planning.

Lastly, IRBOs support hydrodiplomacy by facilitating dialog across member countries. All three IRBOs serve as and create forums through which representatives from member countries meet to discuss water related issues as well as to make policy-decisions. These forums range from formal councils with high-ranking officials (e.g., MRC Council, ICPDR Ministerial Meeting) to standing boards and work groups within the IRBO structures that contain representatives from each country (e.g., IJC Boards, ICPDR Expert Groups) to less formal dialogs during workshops and meetings. Science is used by the IRBOs to support this dialog in a number of ways, from a

point of discussion to develop shared understandings to a mechanism for making decisions about actions that may have transboundary effects.

Notably, a given science produce can be used in multiple ways to support hydrodiplomacy. As explained by one workshop participant:

“There's no single purpose [for a given science product]. For example, if you produce a scenario assessment, you use it to raise awareness and to coordinate activities of countries... when we develop studies or assessments we always think about things like that – about how they raise awareness, how they will influence national plans, how they will change people's behavior and which groups we will need to work with in order to reach those outcomes.” (Participant 3)

Table 2. Examples of IRBO Use of Science When Conducting Hydrodiplomacy

Raise awareness of water-related issues	<ul style="list-style-type: none"> ▪ IJC: The IJC co- sponsored a conference with over 300 participants and chaired sessions on its Aquatic Invasive Species Risk Assessment for the Great Lakes. The conference brought together scientists, policy-makers and the public, contributing to a shared understanding of the issues and supporting dialog on the topic. ▪ ICPDR: As part of its longitudinal survey of water quality, the ICPDR held press events and conducted outreach about the state of the Danube. These events called attention of both the policy and policy-makers about the importance of the Danube and specific water management challenges that need to be addressed. ▪ MRC The MRC held a workshop with government officials from member countries and hydropower developers to discuss its research and guidelines on fish passage, fish-friendly turbines and other topics related to fisheries and hydropower. This workshop served to generate dialog and develop shared understandings about the impacts of hydropower on fisheries and how impacts can be mitigated.
Make recommendations to member countries about how to address water-related issues of concern	<ul style="list-style-type: none"> ▪ IJC: The IJC used its studies of polybrominated diphenyl ethers (PBDEs) to make recommendations to multiple levels of government within both the US and Canada on how they could adopt a life-cycle approach to managing PBDEs. ▪ ICPDR: The ICPDR used its analysis of hydropower practices both within the Danube region and elsewhere to create an assessment matrix for member countries to use when evaluating potential hydropower projects. ▪ MRC: The MRC used its analysis of existing roads and road construction techniques to develop guidelines for countries to use when making-decisions about road design, development, and rehabilitation in floodplains.
Coordinate the activities of member countries through strategic planning	<ul style="list-style-type: none"> ▪ IJC: The IJC used its review of existing watershed and sub-watershed plans for managing phosphorous in the Great Lakes to develop a lake-wide plan that coordinates across the multiple sub-basin watershed and sub-watershed management plans that had been produced by governments in the region. ▪ ICPDR The ICPDR used its preliminary flood risk assessment in developing a basin-wide flood risk management plan. This plan serves as an umbrella for coordinating Danube Countries' National Flood Risk Management Plans

	<p>under the EU Floods Directive.</p> <ul style="list-style-type: none"> ▪ MRC The MRC used its assessment of the state of the basin to develop a Basin Development Strategy, which sets out strategic priorities and actions (projects) in order to harmonize national and regional planning and help secure funding for development projects in the basin.
Facilitate dialog across countries	<ul style="list-style-type: none"> ▪ IJC: The IJC used nutrient studies it funded to support discussions among states/provinces, local governments, and stakeholders regarding reductions in nutrient loading in the Red River Basin. ▪ ICPDR: The ICPDR used its analysis of the chemical and ecological status of the Danube to support discussions among member countries regarding the Danube Basin Joint Program of Measures. ▪ MRC: The MRC used the science it developed as part of its Preliminary Design Guidance for Sustainable Hydropower to support discussion among member countries during the Prior Notification, Prior Consultation process for several proposed hydropower dams.

7. Challenges faced by IRBOs in producing and using science for hydrodiplomacy

Hydrodiplomacy is innately political - it is a process of expression and negotiation of power in decision-making. The production and use of science by IRBOs occur within a political context. Consequently, how science is perceived is a critical concern of the IRBO. For science to support hydrodiplomacy, it needs to be perceived as credible, legitimate, and needs to be useable by IRBO member countries and the full scope of actors involved in transboundary water governance (e.g., Kirchhoff et al., 2013; Cash et al., 2002). Yet what science IRBOs are able to produce, and how that science is produced, is generally constrained by an IRBO's limited staff, technical capacity, and financial resources (e.g., Bakker, 2009; Heikkila et al., 2013). Consequently, when producing science to support hydrodiplomacy, IRBOs must balance considerations of capacity, ownership, and politics.

7.1. Asymmetrical member country capacities

When producing science, IRBOs grapple with the question of how to address variable capacities (technical, human resource, and financial) of member countries. While this issue is more strongly a concern for the ICPDR and MRC, even within the IJC, there are differences in capacities across the US and Canada within varying watersheds along the border. Where member countries have uneven capacities, IRBOs face the challenge of deciding whether to develop more refined science that provides greater insights yet may be beyond other member country capacities. As explained by workshop participants:

“If you do too top notch [science] then it either divides [countries] or it sits somewhere...”
(Participant 1)

“...because the national authorities which are in charge of taking measures to improve stuff - national legislation and national ministries - just don't take it [the science] up because it is beyond their comprehension.” (Participant 2)

Asymmetrical member capacities affect not only use of the science, but also the choice of how to produce the science. When deciding how to produce science, IRBOs have to evaluate the tradeoffs between allowing countries with higher capacities take the lead (either through technical involvement or financial support) versus tailoring the science production to involve all member countries. Allowing higher capacity countries to lead can serve to produce necessary information, yet lower capacity countries may feel excluded or not trust the results of the science.

IRBOs determine how to best address asymmetrical member country capacities on a case-by-case basis. For example, the ICPDR worked closely with member countries in designing and implementing the Joint Danube Survey. Each six-year iteration of the survey involved training and capacity building with the goal of developing compatible capacities and completely turning the survey over to member countries in the future. In contrast, for its initial Climate Adaptation Study, the ICPDR asked Germany to lead the study, while ensuring the study included strong consultation with other partners and member countries.

7.2. Ownership and the use of consultants in producing science

Related, IRBOs also contend with the question of involving or contracting external consultants in the production of science. Producing science requires expertise as well as time. IRBO Secretariats, as well as member country governments, have limited staff, and at times, are not the leading experts on the topics of concerns. By hiring consultants, IRBOs can bring in expertise and provide the human resource capacity needed to produce the science. Yet relying on consultants has implications. While consultants may bring important technical knowledge, if science is produced by consultants, the IRBO and member countries may not have the ability to update or recreate the science in the future. Thus the use of consultants has implications in terms of long-term ownership and use of science that is produced.

Use of consultants also has implications in terms of how the science is perceived by member countries. Where an issue is particularly contentious, use of consultants who are viewed as removed from the politics of the basin can build legitimacy and trust in the science, facilitating the use of the science in hydrodiplomacy. As one workshop participant explained:

“[IRBOs] go to consultants to avoid the appearance of self-serving science. Then they can say ‘We didn't come up with this. We asked the best people’.” (Participant 3)

On the other hand, use of consultants does not solve all credibility issues. As another participant commented:

“You can never get this [decision] right because if you hire experts then you get accused of being externally driven. But if you don't and you produce the science, then you get accused of the science not being good enough. We face this all the time.” (Participant 4)

Further, as another participant commented:

”We see the difference between the use of scientific information that was externally produced, even if it [that science] was originally approved by the Commission, when it

comes to the end – it is an outside product, it is so easy [for the IRBO] to disassociate. If the product comes out and I dislike something in it, if the product comes from us, it is very difficult to disassociate. If it comes from a consultancy and something comes out I don't like, it is very easy put it on the shelf.” (Participant 2)

Another concern is that science produced by consultants is often not be subject to the same degree of oversight as IRBOs or representatives from member countries, and thus the science produced by consultants may not be perceived as credible.

In sum, the decision regarding the use of consultants is described as:

“...sort of a triangle. Ownership comes down somewhere inside the triangle - you've got capacity, you've got legitimacy, and you've got what I would call political risk - which is how close you associate to it [the science]. And you sort of make a choice driven by those kinds of factors.” (Participant 6)

7.3. Separating science production from politics in the hydrodiplomacy processes

Lastly, IRBOs face the challenge of integrating the production of science into hydrodiplomacy processes. Here, the IRBOs described challenges in both communicating to policymakers from each country the potential contributions of science and keeping the science separate from the political negotiations. Policymakers do not always fully understand what science can accomplish, which leads to differing expectations over what information will be available for decision-making. As explained by one workshop participant:

“When the process starts – that the IRBO is looking for science – it is important to be able to articulate what you want. Because many times - that is the issue. If you are not articulating sufficiently a clear articulation of your objective, if you start too narrow on an important piece – it can lead you to a dead end. And if you start too broad, too vague, then interest groups could drive it to another – not dead end, but counterproductive end... So in this respect I think it's important to get this agreement. It is a consensus building at the beginning regarding what we want to get from this science” (Participant 2)

Where member country representatives do not have a clear expectation about what the science can contribute to hydrodiplomacy efforts, it can lead to tensions or disputes about the process. As another workshop participant explained:

“[it is important] to manage expectations so that policy makers involved understand what science can and cannot do. The limits of the science” (Participant 7)

Another participant added:

“I think often one expectation is the more research you do, the problem will be solved. But if it is a purely or mainly political problem – because interests are so opposed – then more research might get you into more of a stalemate situation” (Participant 1)

In these circumstances, a risk is that the production of science itself can become the object of politics. As explained by one participant:

“The more research you do, the more you know that you don't know enough and so you can't take any decision... So it was clear that all these scientific products would be blocked or would be watered down so far that they wouldn't yield any results anymore - and that's exactly what happened...they [decision-makers] tend to just ask for one more study...” (Participant 1)

(responding): “This is the standard way how to not to make a decision” (Participant 2)

One example of science being co-opted by politics can be seen in the MRC Council Study on Sustainable Management and Development of the Impacts of Mainstream Hydropower Projects. Here disagreement between member countries over the terms of reference for the study led to vast delays as well as the production of a science product that was so large and encompassing that it could not guide decision-making. In another example, in the case of the IJC Study on Options for Managing Lake Ontario and St. Lawrence River Levels and Flows, the regulation plan selected as a result of the study was rejected due to stakeholder concerns that the analysis insufficiently addressed environmental considerations.

8. IRBOs use of science to support hydrodiplomacy: Crafting a future research agenda

Our research depicts how the production of science is a central activity of IRBOs as they seek to support hydrodiplomacy. Science supports hydrodiplomacy by serving to guide, coordinate, and facilitate dialog between member countries. Science produced by IRBOs often becomes the key source of knowledge for researchers, donor organizations, non-profits, and private companies and individuals, who use this information both for their own knowledge needs as well as to put pressure on member countries.

Our study reveals that science produced by IRBOs extends beyond measuring and monitoring the current state of the basin to include science that forecasts potential future states of the basin, develops new understandings of physical and natural processes in the basin, or reviews and synthesizes the current state of knowledge. This finding points to the need to develop clearer pictures not only of the types of science, but of the specific science products that can aid in hydrodiplomacy. As one example, IRBOs would benefit from research that identifies which methods for scenarios analysis best support hydrodiplomacy. A detailed examination of the science produced by IRBOs around the world, would be invaluable. By seeing what science has been produced elsewhere, IRBOs can reimagine what science could be developed and to gather ideas on how to implement that science for their river systems. Further, national level-ministries, donor organizations, stakeholders within basins, and the consultants and academics would have better knowledge of how they can support the production of knowledge for hydrodiplomacy.

Our research also uncovers a set of challenges IRBOs face and must consider when producing science including considerations regarding capacity, ownership, and politics. While it is well recognized that the capacity of an IRBO is a critical determinant of its effectiveness (Bouckaert et al., 2018), and that asymmetrical capacities of countries complicate transboundary

management (Hundertmark, 2008; Karki et al., 2011), the ways in those capacities relate to decisions regarding the production and use of science for hydrodiplomacy has not been explored. As described above, the choices IRBOs make as to how to address these issues when producing the science entail inherent tradeoffs. Better understandings of what those tradeoffs are and under which circumstances producing science using one approach is better for hydrodiplomacy than another would benefit IRBOs around the world. Especially important, given the limited resources and staffing of many IRBOs, is to investigate when and how to draw upon the expertise of external consultants. Although there is some emerging research critically examining the role of consultants in popularizing and promoting models for IRBOs globally (Mukhtarov and Gerlak, 2013) and in international environmental policy (Rietig, 2014), we know of no examination of the impact and implications of involving consultants in the production of science for transboundary rivers governance.

Our findings about how IRBOs weigh considerations of politics when choosing how to produce science also points to the need for greater investigation of how country governments influence the production of science for hydrodiplomacy. Such studies should examine not only the mechanisms through which member countries may seek to influence science production, but also the role of other actors in and outside of the basin. For example, China and Myanmar are not part of the MRC, yet information about or from both countries may be necessary for developing understandings of the basin as a whole. As fewer than half of IRBOs include all countries within the river basin they serve (Schmeier, 2015), this question has broad global relevance.

Ultimately, the decisions IRBOs make in producing science will influence how science can support hydrodiplomacy. This finding points to the importance of developing improved understandings of the science-policy interface within hydrodiplomacy. While a large body of research exists examining the reasons science is or is not used to inform policy (e.g., Kirchhoff et al., 2013; Heink et al., 2015), that literature has not examined the transboundary context. The science-policy interface of hydrodiplomacy involves navigating perspectives and capacities across countries, yet also across the multiple levels of actors (sub- to supra- national) that influence how countries approach their shared water. If IRBOs are to support hydrodiplomacy – in the sense of broadening cooperation to develop lasting, peaceful, and more sustainable solutions – we need to better understand the relationships between politics and the production and use of science in transboundary river basins. Future research might well examine who IRBOs should engage in the science production process, and when those entities should be engaged. Research should also address the question of which mechanisms for engagement that lead to greater uptake of science, and under what circumstances. In addition, how to ensure that science supports rather than detracts from the hydrodiplomacy is an essential topic for study. The time is ripe for a new research agenda to understand what leads to the most effective production and uptake of science to ensure that the science developed meets the needs of the broader basin community, and ultimately, contributes to better transboundary water governance.

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Appendix A: Identifying and Classifying IRBO Science Products (online only)

To identify the science produced by each of the IRBOs in the study, we followed a multi-step process. First, we first reviewed every available link on official IRBO websites, crafting a list of science products mentioned on the website and any science products mentioned or referred to in documents (pdfs) posted on that website. Only English language websites and documents were included. For the IJC and ICPDR, all documents were available in English. For the MRC, only a few (less than 10) documents were posted in other languages. Many of those documents appear to be translations of the English language documents.

Next, we reviewed the IRBO annual reports from 2010-2016 and made a list of all references to science products produced. We then merged the list of science products compiled from the website and the list of science products compiled from the annual reports, removing duplicates. Only science produced between 2010 and 2016 was considered. Science initiated but not completed by 2016 is only included if a .pdf of an interim report detailing the methods and initial results could be located. Though many science products were described both on the website and in the annual report, each science product is only cataloged once. Science that is regularly updated, (i.e., annual monitoring reports) were listed as a single product. For example, the ICPDR regularly collects water quality data, publishing the sum of each year's monitoring data in an annual publication. Yet we only list this science product once in the table below. If a document referenced multiple science products, each product was listed separately. For example, the MRC's annual report describes the many science products produced over the course of the year reported. Science appearing within a policy document, but not explicitly described by the IRBO as a science, was included in the catalog. For example, a Basin Plan may include the production and use of multiple science products.

The list of science products developed using this methodology was then shared with workshop participants who worked for or with each of the three IRBOs. These participants reviewed the list for accuracy. The result is an initial, yet not a comprehensive, catalog of all of science produced by the IRBOs. While the catalog is extensive, science produced by the IRBOs that is not explicitly referenced in annual reports or posted on IRBOs website is not captured by our methodology. We did not review all of the citations in bibliographies of policy and science documents nor did we review proceedings from workshops, conference or other meetings sponsored by or in which the IRBOs participated. Further, it was not possible to identify and list separately all science that that was produced as an intermediary input to a larger science or science that was not finalized and made available to the public. We also were unable to identify science sponsored by the IRBOs that was produced as student theses.

During the workshops, this catalog was used to support discussion about the production and use of science by the IRBOs. Drawing on this catalog, along with their own expertise, workshop participants developed a typology of science products produced by IRBOs (see Section 5). Development of the typology was a iterative process: workshop participants started by creating an initial brainstorm of categories and, through the process of discussing how individual examples of science products fit into those categories, revised the typology to the one presented in this paper. A similar process was used to identify the activities through which IRBOs use science to support hydrodiplomacy (see Section 6).

Table A1: IRBO Science Products Identified, by Topic Addressed

Water Quantity: examines water flows and levels, floods, droughts, forecasting and early warning systems

- IJC**
- Adaptive management assessment for the Lake Ontario - St. Lawrence River System
 - Comparison of runoff into Lake Ontario
 - Survey of shoreline protection structures in the Lake Ontario - St. Lawrence River System and development of model of water balances
 - Extension of the use of the Global Environmental Multi-Scale Atmospheric model and the Canadian Precipitation Analysis hindcasts to provide a longer historical estimate of precipitation patterns.
 - Update to historical hydrologic and hydraulic datasets for the Lake Ontario – St. Lawrence River System
 - Flood forecasting and inundation mapping for the Lake Champlain – Richelieu River Watershed
 - Evaluation of the impacts of potential regulation plans for the Lake Ontario – St. Lawrence River System.
 - Evaluation of the impacts of potential regulation plans for Lake Superior
 - Development of 2-d hydrodynamic models for the Rainy River
 - Refinement of 2-d hydrodynamic models for the Rainy River to further examine dam performance
 - Development of a 1-d hydrodynamic model for the Namakan Chain of Lakes
 - Summary of 2014 flooding in the Rainy River
 - Application of Streamstats GIS tools to the Rainy River
 - Review of potential methods for identification of natural flow and then calculation of natural flows for the Red River Basin
 - Extension of the 2-d hydrodynamic model for the Red River Basin and use of it to simulate flood scenarios
 - Simulation of flood scenarios in the Lower Pembina River Basin
 - Modeling of potential flooding and flood mitigation scenarios in the Lower Pembina River Basin
 - Plan of study to identify flood mitigation measures and the impacts of flooding in the Lake Champlain – Richelieu River Basin
 - Development of a data warehouse on natural flow for the St. Mary – Milk Rivers
 - Review of past studies on regulation and compensation in the Great Lakes – St. Lawrence River System`
 - Assessment of the efficacy of the river monitoring system to detect reductions in the capacity of flows in the Okanogan River
 - Analysis of water levels needed to meet projected 2040 water demands from Lake Osoyoos
 - Evaluation of criteria for drought declarations for Lake Osoyoos
 - Comparison of flows and levels for Rainy Lake and Namakan Reservoir under multiple rule curve scenarios
 - Monitoring of hydrologic conditions in transboundary river basins and lakes
- ICPDR**
- Examination of the impacts of the 2015 Drought

MRC

- Survey of the potential effects of water scarcity and drought in the basin on member countries
- Assessment of flood risk in the basin
- Analysis of the June 2013 flood
- Analysis of the 2010 floods
- Inventory of flood risk management measures by country
- Development of harmonized flood mapping procedures for the basin
- Assessment of the risks of floods and droughts in the basin
- Collection of data and mapping of low flow conditions in 2010 and comparison with historic data
- Use of satellite imagery for a flash flood guidance system
- Evaluation of the methodology used in the flash flood guidance system
- Annual summary of member country flood reports
- Near real-time hydrometeorological monitoring
- Review of best practices and development of guidelines for roads and floods
- Pilot study on the social impacts of floods
- Interactive map on the extent of water in the basin
- Annual compilation of data and report on the hydro-meteorological condition of the basin
- Global telecommunication system for rapid collection and exchange of weather information
- Mapping of drought via satellite
- Evaluation of the operational system for flood forecasts
- Inventory of domestic and industrial water use
- Assessment of flood protection and flood plain infrastructure and creation of future scenarios
- Application of the Integrated Quantity and Quality Model (IQQM) software to the basin to simulate flows
- Application of the ISIS software to the basin to simulate tidal influences, flow reversal and over-bank flow in the Tonle Sap River

Water Quality: *examines sources, sinks and transport of nutrients, sediment, metals, other hazardous substances and emerging contaminants*

IJC

- Assessment and map of phosphorous levels and phosphorus monitoring programs in the Lake Erie Basin
- Assessment of Great Lakes water quality indicators
- Analysis of phosphorous loadings in the Great Lakes – Lake Erie Ecosystem
- Analysis of atmospheric deposition of phosphorus to freshwater lakes
- Inventory of nutrient management efforts in the Great Lakes
- Analysis of status, causes and controls of cyanobacterial blooms in Lake Erie
- Review of science regarding nutrient loading in Lake Erie, including a SWAT model prediction of sub-basin loading sources, an analysis of atmospheric deposition, and an examination of model input parameters
- Study on microplastics in the Great Lakes
- Analysis of polybrominated diphenyl ethers (PBDEs) in the Great Lakes
- Evaluation of effectiveness of IJC programs and measures under the Great Lakes Water Quality agreement

- Review of existing science and knowledge gaps regarding water quality in the Lake of the Woods
- Modeling of nutrient loads and transport in the Red and Assiniboine River Basins
- Assessment of approaches for nutrient management in the Red River Basin
- Red River Basin nutrient modeling
- Evaluation of the water quality sampling network in the Souris River Basin
- Identification of water quality issues that affect human health in the St. Croix Watershed
- Effects of Zosel Dam Water Regulation on Osoyoos Lake Water Quality
- Monitoring of water quality and assessment of trends in transboundary river basins and lakes

ICPDR

- Development of an inventory of accident risk spots and contaminated sites
- Development of an accident early warning system
- Assessment of potential environmental dangers from industrial plants
- Annual compilation of national accident reports
- Identification of priority areas based on past assessments and accidents
- Assessment of risk of water bodies failing to achieve good ecological status by 2021
- Assessment of nitrate loading and nitrate vulnerable zones in the basin
- Development of a model to examine nutrient loading and transport (MONERIS)
- Comparative analysis of potential models for examining nutrients (SWAT, MONERIS, and GREEN)
- Review of the preparedness of countries to comply with the EU detergents phosphate ban
- Synthesis of efforts to address nutrient pollution in the basin
- Collection of data on priority substances causing failure to achieve good chemical status
- Development of a ranked list of priority substances in the basin
- Investigation of the implications of implementation of the EU Directive on the assessment of chemical status
- Joint Danube survey of water quality
- Development of a water quality database
- Inventory of wastewater emissions
- Inventory of wastewater treatment plant status
- Inventory of industrial discharges
- Identification of priority (hazardous) substances
- Compilation of water quality monitoring data in the Transnational Monitoring Network

MRC

- Quality control analysis of the Transnational Monitoring Network
- Compilation of member country water quality monitoring data
- Development of a water quality report card
- Analysis of measured sediment and nutrient loads in the basin
- Mapping of member country monitoring of water discharge and suspended sediment
- Development of water quality information maps

- Analysis of the availability of sediment and nutrient data for assessing basin development scenarios
- Application of the Soil and Water Assessment Tool to the Mekong for simulating water quantity and quality
- Application of the WUP-FIN hydrodynamic model to examine hydrology, erosion and water quality
- Application of the eWater Source Model to the basin to simulate sediment and nutrient routing and transport

Ecosystems & Fisheries: examines biomonitoring, fisheries, invasive species

IJC

- Analysis of the fatty acid content in Great Lakes Fish Species
- Evaluation of ecological indicators for the Great Lakes
- Evaluation of existing ecosystem indicators for the Great Lakes
- Study of sturgeon spawning in the Rainy River
- Risk assessment of fish parasites and pathogen's in Devil's Lake – Red River Basin
- Biomonitoring in the Red River Basin
- Assessment of the availability of information to determine instream flow requirements for aquatic life in the Red River Basin
- Analysis of historical small mouth bass habitat in Spednic Lake
- Development of an adaptive management plan for alewife in the St. Croix watershed.
- Count of river herring in the St. Croix watershed
- Analysis of the effects of meteorological conditions on the survival of small mouth bass in the first year of life in Spednic Lake
- Mapping of food webs in the St. Croix watershed
- Investigation of methods that can be used to incorporate ecosystems into requirements for regulating water levels in Lake Osoyoos
- Monitoring of ecosystem health in the Rainy River-Lake of the Woods Watershed
- Comparison of habitat for and the status of multiple plant and animal species (macroinvertebrates, aquatic vegetation, several fish, bird and herptile species) in Rainy Lake, Namakan Reservoir, and Rainy River under the 1970 and 2000 rule curves

ICPDR

- Identification of priority habitat for sturgeon
- Measures for ensuring fish migration at transversal structures
- Study on fish migration at the Danube and Iron Gates
- Sturgeon monitoring
- Study of fish migration at the Gabcikovo dam
- Study of ex-situ conservation for sturgeon
- Guidance on invasive alien species
- Identification of the distribution of invasive species and calculation of a biocontamination index
- Analysis of the distribution of long and medium term fish migrants in the basin
- Joint Danube survey of biological status

MRC

- Development of a guidebook on indigenous fish populations
 - Fish monitoring and analysis of trends in monitoring data
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- Analysis of time series data on the Cambodian Dai fishery
- Synthesis of research on inland fisheries in Lao PDR
- Biomonitoring of benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates to gauge aquatic ecosystem health
- Assessment of the distribution and relative abundance of larval and juvenile fisheries in the mainstem of the Mekong River
- Assessment of fisheries habitat and fish yield in the basin
- Development of a handbook on freshwater zooplankton species
- Development of a methodology for identifying ecologically sensitive areas and application of the methodology to a pilot in the Sre Pok Sub-basin
- Development and application of a model to examine the impacts of dams on fish

Hydro-electric: *examines the potential for, design of, or impacts of hydropower on the basin*

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| ICPDR | <ul style="list-style-type: none"> ▪ Development of hydropower case studies and good practices ▪ Assessment/inventory of hydropower generation, the status of water bodies in relation to hydropower, and the legal and policy frameworks influencing hydropower ▪ Guiding principles for hydropower |
| MRC | <ul style="list-style-type: none"> ▪ Review of research on fish passage through large dams and applicability to Mekong mainstem dams ▪ Review of research on the effectiveness and economics of fish friendly turbines ▪ Technical review of the proposed Don Sahong Hydropower Project ▪ Environmental impact assessment of the proposed Don Sahong Hydropower project ▪ Technical review of the proposed Xayaburi Hydropower Project ▪ Strategic Environmental Assessment of current and future hydropower projects in the basin ▪ Development of a rapid basin-wide hydropower sustainability assessment tool ▪ Development of guidelines for evaluation of hydropower reservoirs ▪ Creation of a database of current and proposed hydropower projects ▪ Development of improved environmental and socio-economic baseline information for hydropower planning ▪ Integrated analysis of sustainable management and development of the basin, including the impacts of mainstem hydropower projects ▪ Creation of hydropower development scenarios |

Climate Change: *examines projections and/or impacts of future climate change, identifies mechanisms for and the status of implementation of adaptation*

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| IJC | <ul style="list-style-type: none"> ▪ Interactive effects of nutrient inputs and climate change on the Lake Erie fish community ▪ Assessment of the potential implications of climate change on water levels management in Lake Osoyoos |
| ICPDR | <ul style="list-style-type: none"> ▪ Study on potential climate change adaptation measures and current adaptation status |
| MRC | <ul style="list-style-type: none"> ▪ Development of an interactive atlas that shows the expected effects of climate change ▪ Review and analysis of climate adaptation strategies and trends in climate adaptation planning and identification of applicability to member countries |
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- Analysis of the expected impacts of climate change on flow regimes in the basin
- Development of a set of indicators on climate change and a basin-wide climate change monitoring system
- Review of the availability of observed meteorological data in the basin for use in climate change analysis
- Review of transboundary climate change adaptation strategies
- Assessment of expected climate changes impacts on drought
- Status report on climate change in the basin

River Channel and Riparian Corridor: examines wetlands, continuity, or geomorphic status

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| IJC | <ul style="list-style-type: none"> ▪ Detailed vegetation community aerial coverage and taxonomic data referenced to elevation and seasonal water levels in eight Lake Ontario coastal wetlands. ▪ Updated Lake Ontario wetland meadow marsh modelling tool |
| ICPDR | <ul style="list-style-type: none"> ▪ Hydromorphic assessment of the basin to identify continuity disruptions; disconnected wetlands and floodplains; and hydrologic pressures and alterations (impounded river sections, abstractions, hydropeaking) ▪ Identification and prioritization of river segments in need of continuity restoration |
| MRC | <ul style="list-style-type: none"> ▪ Survey of baseline channel morphology near Kong Phi Luang Rapids to evaluate potential rock removal for improving navigation safety |

Groundwater: addresses aquifers, groundwater, bank filtered water

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| IJC | <ul style="list-style-type: none"> ▪ Review of the Status and State of the Knowledge on Groundwater in the Great Lakes ▪ Groundwater quality monitoring in the Poplar River Basin |
| ICPDR | <ul style="list-style-type: none"> ▪ Assessment of chemical status and abstractions in groundwater basins ▪ Inventory of bank filtered water and groundwater abstractions ▪ Groundwater abstraction and water quality monitoring ▪ Inventory of measures implemented in groundwater basins of poor quality |
| MRC | <ul style="list-style-type: none"> ▪ Development of maps of groundwater basins and areas for groundwater monitoring |

Agriculture: examines production of food within the basin

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| IJC | <ul style="list-style-type: none"> ▪ Study of wild rice recovery upon removal of cattails |
| ICPDR | <ul style="list-style-type: none"> ▪ Identification of measures undertaken by each member country to address agricultural water pollution ▪ Investigation of the impacts of agricultural policy on nutrient loading in the basin |
| MRC | <ul style="list-style-type: none"> ▪ Assessment of the multifunctionality of paddy fields for flood mitigation, aquatic ecosystem restoration, soil productivity, and farmer's income. ▪ Pilot survey to assess irrigation water use efficiency ▪ Compilation of data on the irrigation sector in each member country ▪ Assessment of risks in the agriculture sector to ecology, livelihoods and food security for rural communities ▪ Assessment of irrigation, by region ▪ Evaluation of the impacts of irrigation on social, environmental and economic conditions and the creation of irrigation development scenarios ▪ Assessment of agriculture and land use trends and the creation of development scenarios |
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Livelihoods & Economics: *examines socioeconomic conditions or the economy of the basin*

- ICPDR** ■ Economic analysis of member countries in relation to water use and the economy
- MRC** ■ Development of baseline data on socio-economic conditions within the basin, reliance on water resources, and resilience to change in those resources
- Evaluation of the environmental impacts of tourism
- Creation of macro-economic assessment methods for analysis of development scenarios
- Creation of socio-economic assessment methods for analysis of development scenarios

Other: *examines prominent issues not listed above, including navigation and land use, data harmonization, health, etc.*

- IJC** ■ Hydrographic data harmonization
- Assessment of water-related health issues in the Lake of the Woods and Rainy Lake
- Development of a web mapping portal
- Comparison of the effects of the 1970 and 2000 rule curves on cultural resources, tourism, and property damage near Rainy Lake, Namakan Reservoir, and the Rainy River
- ICPDR** ■ Study to facilitate common understanding of risk assessment terms
- Inventory of protected areas
- Development of Danube Reference Datasets
- Geographic characterization of the basin
- Development of typology/classification system for water bodies in the basin
- Development of the Danube GIS
- Development of the Danube Atlas of Global Change
- MRC** ■ Determination of baseline conditions and risk assessment related to the transport of dangerous goods at the Chiang Sean Commercial Sea Port
- Pilot project for helping to manage the transport of dangerous goods at the Chiang Sean Commercial Sea Port
- Creation of an interactive GIS of the basin
- Creation of an interactive web portal for data and information sharing
- Creation of a planning atlas
- Assessment of scenarios of basin-wide development for use in Integrated Water Resources Management in the basin
- Atlas of deep pools in the basin
- Global Satellite map
- Development of land cover maps
- Review and analysis of potential strategies for benefit sharing
- Website for the public to share studies and news
- Assessment of the current status of navigation, potential development scenarios, and impacts of potential development
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