TRANSBOUNDARY RIVER BASIN ORGANIZATIONS FOR EFFECTIVE WATER MANAGEMENT

by

SHANNON BONNEY BAUMGARDNER

(Under the Direction of Laurie Fowler)

ABSTRACT

Water shortages and nutrient pollution in a growing number of basins put human water security and aquatic biodiversity at risk. These challenges are harder to tackle in transboundary river basins. Transboundary river basin organizations (RBOs), which manage water based on hydrologic boundaries, and environmental flows are promoted as two solutions. While they show promise for resolving pressing water issues, an evaluation of their effectiveness is needed to determine the potential impact of their more widespread use. I address this need by asking: (1) What are the major governance factors and social processes to consider in developing a transboundary RBO that can affect water management at a basin scale given the current regulatory and political landscape; (2) Are transboundary RBOs effective in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity; (3) Does the Susquehanna River Basin Commission, a transboundary RBO, have sufficient policies and programs to effectively implement environmental flows and does their low flows policy affect low flows at the river basin scale? My results show: (1) Designing transboundary RBOs requires

identification of gaps and opportunities, deliberation with all relevant players on functions, and a process to transition from the current regulatory landscape to one that includes a transboundary RBO. (2) Transboundary RBOs exhibited modest biophysical results, with more strength of evidence for low flows than for total nitrogen flux. Interviews revealed other benefits not captured by biophysical indicators and the importance of regulatory authority, financial capacity, and technical capacity. (3) The Susquehanna River Basin Commission is making a significant improvement in low flows, some progress towards the seasonal flows, and limited progress towards high flows. A concerted effort between all institutions with control over the flow regime is needed to fully implement environmental flow recommendations.

INDEX WORDS: River basin organization, Transboundary, Environmental flows, Mixed methods, Water resources management

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SHANNON BONNEY BAUMGARDNER

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SHANNON BONNEY BAUMGARDNER

| | |
|---|---|
| Major Professor: | Laurie A. Fowler |
| Committee: | Laura German |
| | Seth Wenger |
| | Elizabeth G. King |

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2019

# DEDICATION

I dedicate this to my husband Jacob and son Lucas. Your love and support have inspired me every step of the way.

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# CHAPTER 1

# INTRODUCTION AND LITERATURE REVIEW

Water quantity and quality issues abound, leading to human water security risks and aquatic ecosystem degradation worldwide (Gangloff, Edgar, & Wilson, 2016; Vorosmarty et al., 2010). In many basins water quality is degrading (Davies & Mazurek, 1998; Hamilton, 2010; Stoddard et al., 2016) and nutrient pollution is widespread (Sprague, Oelsner, & Argue, 2017). A growing number of basins are experiencing periodic water scarcity and basin closure, i.e., all water obligations cannot be met during at least part of the year, due to increased water consumption as well as drought frequency and severity (Falkenmark & Molden, 2008; Foti, Ramirez, & Brown, 2012; Molle, Wester, & Hirsch, 2010). Aquatic biodiversity is decreasing at unprecedented rates (Janse et al., 2015; Limburg & Waldman, 2009; Pimm et al., 2014). As many as 20,000 freshwater aquatic species are imperiled or extinct (Vorosmarty et al., 2010) as a result of factors such as inadequate flows or degraded water quality (Gangloff et al., 2016).

River management programs and policies to address both societal and ecosystem needs are generally complicated and difficult in any river system, but particularly so in transboundary river basins, i.e., river basins that cross state or national boundaries (Larson, 2015; Mandarano, Featherstone, & Paulsen, 2008). Fragmentation of water management between different U.S. states and their agencies as well as federal agencies can lead to negative externalities for downstream users and ecosystems (Larson, 2015; Mandarano et al., 2008), including degraded water quality, inadequate water supplies,

and altered flow regimes (Hooper, 2006). Without mechanisms for transboundary cooperation, these negative externalities can lead to water disputes that require congressional intervention or litigation to resolve (Abrams, 2009; Dellapenna, 2005; Starr, 2013).

Two new river management strategies that attempt to overcome these problems are the creation of river basin organizations (RBOs) that operate across state or national boundaries, i.e., transboundary RBOs, and the establishment and regulation of environmental flows. River basin organizations that manage water based on hydrologic rather than jurisdictional boundaries (Schmeier, 2013) have been promoted as better equipped than jurisdictional management to tackle water quantity and quality issues (Dellapenna, 2005; Hooper, 2006; Huffman, 2009; Mandarano et al., 2008). The provisioning of environmental flows, which are the quantity, quality, and timing of water needed by aquatic ecosystems, is a major means of protecting and restoring aquatic biodiversity and ecosystem services (Acreman et al., 2014; Arthington, 2012; Poff et al., 2010). While these emerging forms of river management show promise for resolving some of the pressing water issues challenging the U.S. and other nations, they are currently limited in scope to relatively few river basins (Kendy, Apse, & Blann, 2012). An evaluation of their effectiveness and elements critical to their success is needed to determine the potential impact of their more widespread use.

In this dissertation I aimed to address this need by asking the following questions: (1) What are the major governance factors and social processes stakeholders should consider in developing a transboundary RBO that can affect water management at a basin scale given the current regulatory and political landscape; (2) Are transboundary RBOs

effective in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity; (3) Does the Susquehanna River Basin Commission, a transboundary RBO, have sufficient policies and programs to effectively implement environmental flows and does their low flows policy affect low flows at the river basin scale? I focus my research on river basins that cross state boundaries within the United States. My initial research on how to establish a transboundary RBO was motivated by a request by stakeholders in the Apalachicola-Chattahoochee-Flint (ACF) River Basin in the southeastern U.S. and was the focus of the first research assistantship for my doctoral program. The assumption of our clients was that such an RBO would be necessary to transcend decades of litigation among the ACF states regarding allocation in the basin. As I dug deeper, I decided I needed to directly address the issue of whether transboundary RBOs can and are delivering positive environmental outcomes, which led me to pose research questions 2 and 3.

In Chapter Two, I explore the issues brought to us by a group of stakeholders in the ACF River Basin in order to answer the following: What are the major governance factors that should be considered in developing a transboundary RBO in the current regulatory and political and legal climate and what social processes should be used in that development (research question 1)? Most of the transboundary RBOs endowed with regulatory authority in the U.S. were formed prior to and the establishment of the U.S. Environmental Protection Agency and strong state water management agencies pursuant to the federal Clean Water Act. The current regulatory landscape is saturated with state, federal, and local agencies and laws and in the case of the ACF River Basin, confounded

by ongoing litigation regarding allocation in the basin. I had to consider these factors in my research and recommendations for establishing a transboundary RBO. I describe the evolution of a multi-year collaborative effort through the articulation of distinct research phases, along with their underlying motivations and findings, that framed the partnership's evolution.

In Chapter Three, I asked whether transboundary RBOs are effective in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity (research question 2). I evaluated effectiveness in two ways, first by how well transboundary RBOs manage low flows and nutrients, and second by their regulatory authority, financial capacity, and technical capacity. The evaluation covered the following transboundary RBOs, which are all found in the United States: Susquehanna River Basin Commission, Delaware River Basin Commission, Interstate Commission on the Potomac River Basin, Upper Mississippi River Basin Association, and Ohio River Valley Water Sanitation Commission.

In Chapter Four, I asked if the Susquehanna River Basin Commission, a transboundary RBO, has sufficient policies and programs to effectively implement environmental flows and if its low flows policy affects low flows at the river basin scale (research question 3). To do so, I focused on one transboundary RBO, the Susquehanna River Basin Commission because it is an uncommon example where environmental flows are implemented at the transboundary river basin scale and an RBO. I looked at effectiveness ecologically, whether there were measurable changes to flows that are predicted to benefit ecosystems, and procedurally, whether there were enough policies

and programs to implement the full range of environmental flow recommendations. Specifically, I asked if 1) the Susquehanna River Basin Commission's Low Flow Protection Policy made a significant difference in basin low flows, and 2) the Susquehanna River Basin Commission has enough policies and programs to implement the low, seasonal, and high flow components of the environmental flow recommendations.

In Chapter Five I synthesized my findings and reflected on what my they mean for my larger dissertation goals. I explored the emergent tensions and themes that arose through my dissertation research, which were related to mixed methods, interdisciplinary research, transdisciplinary and collaborative research, and the interplay between litigation and collaborative processes. I proposed areas for future research. Finally, I reflected on the integrative nature of my research and my training in the Integrative Conservation (ICON) Ph.D. program.

An underlying theme to frame my research is integrative conservation. As an ICON and Ecology student I draw from integrative conservation, which promotes collaboration between academic and non-academic actors, approaching issues from multiple disciplines and epistemologies, and acknowledging the tradeoffs between human well-being and biodiversity in conservation initiatives (McShane, 2011). Collaboration between academic and non-academic actors is necessary to tackle the wicked problems, i.e., problems that include high stakes, uncertain facts, conflicting values, and a sense of urgency, facing our environment and society (Agramont, Craps, Balderrama, & Huysmans, 2019; Krueger et al., 2016). The basic tenets of integrative conservation influenced the design and execution of this dissertation. I focus on environmental flows

as a paradigm to conserve and restore aquatic ecosystems because of its reliance on a transparent process to negotiate tradeoffs between human and environmental water needs (Pahl-Wostl et al., 2013). I evaluated transboundary RBOs because they provide a forum for tackling inequities between water users, especially those in downstream states or those representing marginalized uses. A multiyear transdisciplinary collaboration between researchers, students, and stakeholders provided the basis for my attempt to contribute to a wicked problem facing the ACF River Basin. Rather than approaching this issue from purely a scientific perspective, I relied heavily on collaboration between academics and non-academics. Stakeholder and practitioner opinions of effectiveness supplemented empirical knowledge to form a multi-epistemological look at effectiveness. Employing a mixed methodology allowed me to gain a clearer picture of effectiveness and entailed an interdisciplinary research strategy.

In the following literature review I provide background information on the three topics that are foundational to this dissertation. I provide context for the ACF River Basin because it is the basin that I use to answer one of three research questions and my work in this basin inspired the remaining two research questions. As such, an understanding of the ACF River Basin is foundational to knowing the origins of my research and how it evolved. I summarize the pertinent literature on RBOs in order to provide background on a topic covered in all dissertation chapters. For a more thorough literature review on RBOs see Chapter Three and (Bonney, Bickerton, & Fowler, 2012). I provide a conceptual introduction to environmental flows as it is critical to understanding one of my three research questions. I provide further literature on environmental flows in Chapter Four.

## Literature review

### *Apalachicola-Chattahoochee-Flint (ACF) River Basin*

The ACF River Basin is a large transboundary river basin (19,600 square miles) located in the southeastern U.S. that is comprised of the states of Georgia, Florida, and Alabama (Frick, Buell, & Hopkins, 1996). Approximately 90% of the basin's population and 75% of its land area, including the headwaters of both the Chattahoochee and Flint Rivers, are located within Georgia (O'Day, Reece, & Nackers, 2009). The Chattahoochee and Flint Rivers merge at the Floridian border to become the Apalachicola River. While compromising only a small part of the basin in terms of population and area, the Apalachicola dominates in terms of flow and in numbers of endangered or threatened species (U.S. Army Corps of Engineers, 2016b). The ACF River Basin terminates at the Apalachicola Bay, inputting 35% of the freshwater for the entire eastern Gulf of Mexico (Ruhl, 2005).

During much of the time water resources are plentiful but there are critical times when water is scarce, which causes conflicting water demands (Congressional Research Service, 2008). Droughts, particularly multi-year droughts, are particularly troublesome (U.S. Army Corps of Engineers, 2017). Conservative reservoir operations in the Chattahoochee, which entail retaining water in the upper basin to buffer against the effects of drought, and irrigation withdrawals in the Flint can lead to drastically reduced flows to the Apalachicola River and Bay during droughts (Leitman, Kiker, & Wright, 2017). With insufficient flows the endangered and threatened species of the Apalachicola

River and the seafood industry of the Bay are harmed (Havens et al., 2013; U.S. Army Corps of Engineers, 2016a).

The ACF River Basin is ripe for the adoption of new management strategies, as it has been locked in a water conflict for three decades (Ashkenaz, 2014; O'Day et al., 2009). In the 1980's Georgia requested the U.S. Army Corps of Engineers reallocate a portion of Lake Lanier, a reservoir that detains 65% of the basin's water that is only fed by 5% of the basin, for growing municipal demands of metropolitan Atlanta (Leitman, Pine, & Kiker, 2016; U.S. Army Corps of Engineers, 2017). This led to a series of lawsuits between the three states, the U.S. Army Corps of Engineers, and power suppliers (Dellapenna, 2005) with the downstream states concerned about the impact on them of increased withdrawals for Atlanta. In 1997, amid the fury of litigation, an interstate compact was created to settle the dispute (Stephenson, 2000) and a temporary truce was called. The states agreed to develop an allocation formula that would satisfy all the parties and tried for many years to do so (Feldman, 2008). During this time many studies were funded, and models produced (Leitman, 2005). Ultimately the states could not come to an agreement, so in 2003 the compact was dissolved (Stephenson, 2000). Litigation then continued, as it does to this day (Ashkenaz, 2014). Currently the U.S. Supreme Court is deliberating on a suit brought by the State of Florida to equitably apportion the waters of the ACF and to cap Georgia's water use to 1992 levels (Bernadett, 2014).

In 2008, during a rare break in litigation, a handful of water users from the ACF River Basin met to discuss the possibility of forming a stakeholder group (Rooks, 2011). With the facilitation of the U.S. Institute for Environmental Conflict Resolution, the stakeholder group expanded and drafted a charter and bylaws (ACF Stakeholders, 2011).

In 2009 the group was incorporated as a non-profit organization, becoming the ACF Stakeholders (ACF Stakeholders, 2011). The basin was divided into four sub-basins: Upper Chattahoochee, Lower Chattahoochee, Flint, and Apalachicola (ACF Stakeholders, 2015). Fourteen interest groups were decided upon that constituted a comprehensive representation of all the interests in the basin: recreation, water supply, water quality, seafood industry, thermonuclear power, hydroelectric power, navigation, farm and urban agriculture, industry and manufacturing, environmental and conservation, business and economic development, local government, historic and cultural, and other (Rooks, 2011). A 56-member governing board is elected from the general membership, with one representative of each interest group for every sub-basin (ACFS Action Planning Committee, 2011). All large decisions are decided on a consensus basis and procedural decisions require 80% approval (ACF Stakeholders, 2013). The ACF Stakeholders mission is to "change the operation and management of the ACF Basin to achieve equitable and viable solutions among stakeholders that balance economic, ecological, and social values and ensure that the entire ACF Basin is a sustainable resource for current and future generations" (ACF Stakeholders, 2015). To date they have created a developed a regional voice for stakeholders and Sustainable Water Management Plan.

Through this research I, in conjunction with other researchers of the University Collaborative, help the ACF Stakeholders develop their vision as to how they can transition from a transboundary RBO with no formal authority to one that can affect water management at the basin scale; in hopes of resolving this longstanding water conflict.

*Environmental flows*

In the mid-20th century, the concept of minimum instream flows emerged as a response to declining river flows and impacts to fish populations (Zellmer, 2008) and to meeting the requirements of the Clean Water Act (Petts, 2009). Minimum instream flows tend to be static and often are designed to ensure a river's assimilative capacity, most commonly the annual 7Q10 flow, i.e., the lowest flow found for seven consecutive days once in 10 years (Richter, Davis, Apse, & Konrad, 2012). The natural flow regime paradigm replaced static minimum instream flows because a growing body of evidence showed the importance of the quantity, quality, *and* timing of flows to riverine ecology (Annear et al., 2004; Arthington, Bunn, Poff, & Naiman, 2006; Bunn & Arthington, 2002; Poff et al., 1997; Poff & Zimmerman, 2010; Richter, 2009). Environmental flows aim to mimic the natural flow regime while striking a balance between human and ecosystem water demands (Arthington, 2012; Grantham, Mezzatesta, Newburn, & Merenlender, 2013; Martin, Labadie, & Poff, 2015)

Flow-ecology relationships entail understanding and predicting the changes in condition of an ecological or biological indicator in response to changes in hydrology (Davies et al., 2013). The responses may be direct, e.g. reduced flows reduce habitat area for target species, or indirect, e.g. reduced flows reduce habitat area for prey species and in turn reduce food base for target species (Shenton, Bond, Yen, & Nally, 2012), quantitative or qualitative in nature (Arthington et al., 2006), and may take on a variety of forms, e.g., linear, curvilinear, or threshold (Poff et al., 2010; Webb et al., 2012). Hydrologic variables are the components of the flow regime that are used for the

environmental flow recommendations, e.g., high flow pulses (Poff & Zimmerman, 2010). Indicators are metrics used to evaluate progress towards environmental flows recommendations, e.g., area of floodplain inundated in time for fish spawning (Poff et al., 2010). Ecological condition goals represent the future condition of a river desired by basin stakeholders (Kendy et al., 2012). They differ from indicators because they are the desired state of the basin while indicators are metrics used to determine if this desired state is being met.

Not all rivers in a basin are valued in the same way or used for the same purposes. Successful environmental flow policy development is aware of and takes into consideration these differences (Le Quesne, Kendy, & Weston, 2010). An environmental flow standard defines the maximum amount of hydrologic alteration allowed in order to still achieve the desired ecological condition goals (Kendy et al., 2012). These standards can be set as stringent as is needed to meet ecological condition goals; with higher standards for rivers desired by the public to be pristine and lower standards for rivers that are already degraded or desired by the public to be used for economic, rather than environmental, goals. Flow-ecology relationships with a threshold response may have clear benchmarks beyond which ecosystem degradation is unacceptable (Poff et al., 2010; Rosenfeld, 2017). Curvilinear and linear flow-ecology relationships may not have these clear benchmarks, but rather rely on a process of consensus building to determine environmental flow standards (Kendy et al., 2012).

While there is an ever-growing literature about how to define environmental flows, questions remain about how to effectively implement them (Kendy et al., 2012; Le

Quesne et al., 2010). My research helps fill this gap by evaluating the effectiveness of their implementation in a large river basin.

*River basin organizations (RBOs)*

River basin organizations manage water on hydrologic rather than political boundaries (Schmeier, 2013). They are established by compacts, agreements, or legislation (Kenney, 1994). Compacts are formal agreements between states or federal entities, while agreements are less formal (Draper, 2007). While agreements are easier to form than compacts, they may not be as permanent or legally enforceable (Kenney, 1994). Without compelling evidence, states are likely to resist forming highly institutionalized agreements, such as compacts and legislation (Tir & Stinnett, 2011).

For at least a century scholars and practitioners have advocated for water management based on hydrologic rather than political boundaries (Hooper, 2010; Huffman, 2009; Kenney, 1997, 2008; Tarlock, 2008). There are, however, complicating factors such as the complexity of defining river basin boundaries (Herrfahrdt-Pahle, 2014; Huitema & Meijerink, 2017), the common misalignment of surface water and aquifer boundaries (Meijerink & Huitema, 2017; Svendsen, Wester, & Molle, 2005), and the interconnection of once distinct basins by interbasin transfers (Kenney, 2008).

River basin organizations provide benefits like resolving interstate conflicts (Mandarano & Mason, 2013; Tarlock, 2008) and attracting external sources of funding (Interstate Council on Water Policy, 2006). They are far less expensive than the use of litigation to resolve interstate conflicts, somewhere in the range of less than $10 million compared to $100 million or more (Barnes, 2018; Kauffman, 2015). River basin

organizations add value to funding invested by states into a basin (Prince William Conservation Alliance, 2012; Susquehanna River Basin Commission, 2007).

For all the purported benefits of RBOs, there are still questions as to whether they deliver on these promises under which contexts (Earle, Jagerskog, & Ojendal, 2010; Katz & Moore, 2011; Mandarano et al., 2008; Saleth & Dinar, 2004). My research aims to help fill this gap by evaluating whether RBOs deliver benefits, such as improved water quality and low flows, and under which contexts.

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# CHAPTER 2

# TRANSDISCIPLINARY COLLABORATION FOR A TRANSBOUNDARY RIVER BASIN ORGANIZATION IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN

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Shannon Bonney Baumgardner and Laurie Fowler

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## Abstract

The Apalachicola-Chattahoochee-Flint River Basin is the subject of a longstanding water dispute that has eluded resolution because water, once plentiful in the region, is increasingly scarce and the water uses are critically important for economy, ecology, or society. Stakeholders worked with a coalition of universities from around the basin to develop recommendations for a transboundary river basin organization, i.e., an organization that manages water across state lines based on hydrological rather than political boundaries, in order to sustainably manage the basin and help resolve the water dispute. Our research sheds light on the major governance factors that should be considered in developing a transboundary river basin organization that has the ability to influence water at the basin scale in the current regulatory, political, and legal climate, and the social processes that might be used most effectively in that development. While , implementation of our recommendations for a transboundary river basis organization was ultimately stalled by renewed litigation, our collaborative research process provided benefits to researchers, students, and stakeholders alike.


## Introduction

The Apalachicola-Chattahoochee-Flint ("ACF") River Basin is the subject of a longstanding water dispute that is currently being heard by the US Supreme Court, *Florida v. Georgia* (Ashkenaz, 2014). Resolution of the dispute has eluded basin water users for more than three decades in part because the stakes are so high and water, once plentiful in the region, is increasingly scarce, due to climate change and population growth (O'Day, Reece, & Nackers, 2009; Ruhl, 2005). The stakes are high because water

uses found in each part of the basin are critically important for economy, ecology, or society. The ACF River Basin is a hotspot for biological diversity with many at-risk species, including seven federally protected aquatic species (Atkins, 2012; U.S. Army Corps of Engineers, 2017). The Apalachicola Bay, dependent on freshwater inflows from the ACF, supports an economically and culturally important seafood industry (Camp et al., 2015; Huang, 2010) and is a critical nursery for fish throughout the region (Livingston, 2008). Metropolitan Atlanta, close to the headwaters of the Chattahoochee River, is an economic powerhouse for the Southeast (Clark, 2014). By 2050, the metropolitan area is projected to need an additional 288 to 324.5 million gallons per day of water over the 574.5 million gallons of water per day it consumed in 2017 (Metropolitan North Georgia Water Planning District, 2017). Agricultural production in the Flint River Basin, heavily dependent on irrigation, is a primary economic driver in many rural communities of southern Georgia (Georgia Environmental Protection Division, 2006). While during much of the year water is plentiful, during droughts these important water uses are competing (Leitman, Kiker, & Wright, 2017; Leitman, Pine, & Kiker, 2016) and droughts are predicted to increase in frequency and severity (Congressional Research Service, 2008; O'Day et al., 2009; Ruhl, 2005).

Litigation over competing water uses commenced in 1989 when Georgia requested the U.S. Army Corps of Engineers reallocate a portion of Lake Lanier, a large reservoir in the headwater of the basin, for the growing water demands of metropolitan Atlanta (Dellapenna, 2005). Since then numerous lawsuits have been filed by downstream states concerned about the impact of water withdrawals for metropolitan Atlanta and more recently for irrigation in the Flint River subbasin (Ashkenaz, 2014; Dellapenna, 2005).

During a rare break in litigation in 2008, a group of stakeholders from throughout the basin formed the ACF Stakeholders to find solutions to the basin's water conflicts that litigation and politicians were unable to resolve (ACF Stakeholders, 2015). The ACF Stakeholders' mission is to "change the operation and management of the ACF Basin to achieve equitable and viable solutions among stakeholders that balance economic, ecological, and social values and ensure that the entire ACF Basin is a sustainable resource for current and future generations" (ACF Stakeholders, 2015). The governing board is composed of 56 members, one stakeholder representing each of the 14 stakeholder-defined interests in each of the four subbasins: Upper Chattahoochee, Lower Chattahoochee, Flint, and Apalachicola (ACF Stakeholders, 2015). The ACF Stakeholders make decisions by consensus and rotate their meetings around the basin in order to learn more about the interests and challenges in each subbasin (ACF Stakeholders, 2013). The membership of the ACF Stakeholders purposely did not include representatives of state government and agencies in order to provide a forum for discussion without the politicization and gridlock that encumbered previous negotiation attempts (Rooks, 2011). They did, however, state that in time they would determine the best way to bring state representatives and agencies to the table (ACF Stakeholders, 2013). As a stakeholder-driven transboundary river basin organization (RBO) with no state or federal members, the ACF Stakeholders have no formal implementation authority.

In order to accomplish their mission of "changing the operation and management" of the ACF River Basin, the ACF Stakeholders needed to find means to implement their plans and policies (ACFS Action Planning Committee, 2011). One such way was to play

an advisory role to the U.S. Army Corps of Engineers during the process of updating the ACF River Basin Master Water Control Manual (U.S. Army Corps of Engineers, 2017). The ACF Stakeholders tried to accomplish this by developing a Sustainable Water Management Plan to recommend improvements to basin water management (ACF Stakeholders, 2015). To create the Sustainable Water Management Plan, the stakeholders and consultants developed models to simulate river, reservoir, and bay conditions given a set of operational and water use scenarios and compared the model output with stakeholder-defined performance metrics (ACF Stakeholders, 2015). A major element of the plan was the transboundary management of the resource across state lines, especially during periods of limited availability. The ACF Stakeholders worked with a coalition of universities from around the basin, called the University Collaborative, to conduct the "Institutional Options Project" to develop this transboundary management plan element. The approach of the Institutional Options Project was to draw from diverse literatures on water governance and institutions to develop recommendations for a formal transboundary ACF RBO, i.e., an organization that manages water across state lines based on hydrological rather than political boundaries. While already a transboundary RBO, the ACF Stakeholders have no formal authority to influence water withdrawals, discharges, or storage. This research was intended to help the ACF Stakeholders develop their vision for transitioning to a transboundary RBO with formal authority to affect water management at the basin scale. Ultimately, both efforts were affected by renewed litigation in 2013 when Florida petitioned and was approved for an equitable apportionment case against Georgia before the U.S. Supreme Court (Ashkenaz, 2014).

The Institutional Options Project is an interesting case study that informs both collaborative research processes and the design of transboundary RBOs. Using the ACF River Basin as an example, we hope to shed light on the major governance factors that should be considered in developing a transboundary RBO that has the ability to influence water at the basin scale in the current regulatory, political, and legal climate, and the social processes that might be used most effectively in that development. We begin by discussing the literatures on governance factors for RBOs and social processes for creating RBOs. Next, we present the four phases of research for the Institutional Options Project to show how these governance factors were applied in the design of a transboundary RBO and the social process this entails. We then evaluate how effectively these governance factors and social processes have been applied in developing recommendations for the ACF River Basin.

## Literature review

### *Design and governance elements for effective RBOs*

An RBO manages water on hydrologic rather than political boundaries at the scale of a river basin (Huitema & Meijerink, 2017). In transboundary river basins, i.e., those that cross state or national boundaries, RBOs provide a forum for collaboration, conflict resolution, and building trust (Interstate Council on Water Policy, 2006; Tarlock, 2008). River basin organizations can help mitigate negative externalities on downstream states caused by upstream state water consumption (Mandarano, Featherstone, & Paulsen, 2008). They can help equalize imbalances in power (A. Earle, Jagerskog, & Ojendal, 2010). River basin organizations attract external funding and can lead to synergistic gains

in a state's investment in the basin (Interstate Council on Water Policy, 2006; Kauffman, 2015).

The sources of authority used to create RBOs are varied, but can be categorized as compacts, agreements, or legislation (Kenney, 1994). Compacts are formal contracts between states or between states and the federal government (Draper, 2007). They are difficult to create but carry the force of law (Zimmerman, 2012). Agreements are less-formal arrangements between states, and potentially other players, that are highly flexible and easier to create but less likely to stand up to litigation (Draper, 2007). Legislation is a broad category that can include acts of the federal government or parallel state legislation (Kenney, 1994).

Most examples of transboundary RBOs that can affect water management at the river basin scale were established before state and federal environmental agencies, as well as important environmental legislation (Kenney, 2008). The Environmental Protection Agency was established as a federal agency in 1970 (Environmental Protection Agency, 2018). This was followed shortly after the Clean Water Act of 1972 (Environmental Protection Agency, 2019), which gave the federal government jurisdiction over water quality control that was then delegated to the states (Craig, 2011). In order to comply with the Clean Water Act and to begin to regulate growing water usage, state agencies and associated legislation were established around the country (Huffman, 2008). The majority of transboundary RBOs, especially those with regulatory authority, were created before these events transpired. Early transboundary RBOs often were created during times of crisis, where severe water shortages or pollution threatened basins and there were no other mechanisms to address them (Mandarano & Mason,

2013). During these times of crisis there was widespread recognition of the need for solutions that was shared by the public and decision-makers (Kenney, 2008). Crises still can provide impetus to pursue transboundary water management, however there are mechanisms other than monolithic RBOs to address them (Lankford & Hepworth, 2010). Existing agencies often are reluctant to relinquish resources and authority to newly created RBOs (Meijerink & Huitema, 2017). Transboundary RBOs are more now likely to coordinate, rather than to assume the functions of existing agencies (Kenney, 2008).

Two factors have shifted the political context in which transboundary RBOs are formed and operate. The first factor is the rise of the states' rights movement that emphasizes the primacy of state jurisdiction in water allocation (Craig, 2011). While water allocation is the domain of the states, the balance of power between the states and federal government regarding water management has shifted through time (Ryan, 2007). In the current climate of states' rights, getting states to work together is often challenging because there is a focus on independently managing water within borders rather than ceding authority to a basin organization (Kenney, 2008; Ryan, 2007). The second factor is a distaste for regulations that is currently dominant in our political context (Cecot & Livermore, 2017). This makes a transboundary RBO pursuing functions that increase the regulatory burden, such as regulatory review, less palatable than those where a transboundary RBO takes on an advisory or advocacy role, such as education or data collection (Kenney, 1994).

The great majority of interstate water compacts were created by 1970; of 28 interstate water allocation, water pollution control, and interstate water management compacts, four were ratified after 1970 (International Water Law Project, 2019). When

the source of authority of RBOs is expanded to include agreements and legislation another pattern emerges. Modern examples, i.e., those created after 1970, tend to be established by agreements, such as the Upper Mississippi River Basin Association (Vineyard, 1997), Missouri River of States and Tribes (Matson, 2012), and ACF Stakeholders (Rooks, 2011). There are two compacts created post-1970, the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River Compacts, but they both failed (Feldman, 2008; Leitman, 2005). Two RBOs formed in the Catawba-Wateree River Basin, the Catawba-Wateree Water Management Group and Catawba-Wateree River Basin Advisory Commission, were created during a Federal Energy Regulatory Commission dam relicensing and state legislation (Dyckman, 2011; Vick, Grabow, Miller, & Huffman, 2017). These modern RBOs tend to focus on advisory or advocacy functions (Rooks, 2011; Vineyard, 1997), except for the two compacts that were intended to administer water allocation agreements that ultimately failed (Feldman, 2008; Leitman, 2005). Even accounting for the modern RBOs founded by agreements, the majority of transboundary RBOs were created before 1970, and so much of the scholarly research has focused on older RBOs. We hope to address this gap with this research by highlighting which governance factors and social processes are most important for creating effective RBOs in this modern era. The fact that two modern compacts failed is an additional motivator for this study.

Empowering stakeholders to authentically engage with river basin management is a vital component of governing water effectively (Hooper, 2006; Priscoli, 2004; Priscoli & Wolf, 2009). At the scale of river basin in the United States, it is rare that a transboundary RBO forms that is composed solely of stakeholders, with the intent of

changing water management because they are generally formed through the cooperation of states, particularly governors, or to administer the outcome of equitable apportionment cases (Grant, 2003; Kenney, 2008; Mandarano et al., 2008; Zimmerman, 2012). Stakeholders often do get a voice in transboundary RBOs but through advisory committees, consultation, and other non-voting capacities (Priscoli & Wolf, 2009). Finding ways to authentically engage stakeholders can be a challenge (Akhmouch & Clavreul, 2016; Lacroix & Megdal, 2016). There is a risk that stakeholder participation is token or that stakeholders are to be managed rather than empowered to make decisions on an equal footing to more powerful state and federal representatives (Earle & Mazbener, 2006; Priscoli & Wolf, 2009). Given the importance of empowering stakeholders to have an authentic effect on river basin management, it is troublesome there are so few examples of stakeholders initiating and maintaining a voice in RBOs. This research aims to fill this gap by showcasing an RBO initiated by stakeholders and the process by which it has tried to move from developing a vision for the basin to engaging with state and federal partners to actualize this vision.

*Social processes for creating RBOs*

There has been a shift from an emphasis on idealized models for water management institutions and organizations to a realization that there is no one type of water management institution or organization that is ideal (Interstate Council on Water Policy, 2006; Meinzen-Dick, 2007). Rather water management organizations and institutions should be tailored to basin context (Interstate Council on Water Policy, 2006; Kenney, 1994). Moreover, attempting to transfer model organizations from one river

basin to another can lead to failure and unintended consequences (Meinzen-Dick, 2007). There are, however, lessons that can be drawn from the literature about the process to reform or establish river basin organizations.

Kenney (1994) presents a process for designing transboundary RBOs. The first step, to analyze the current water management situation, ensures that the basin context is known. This analysis involves as assessment of actors and stakes, their resources, and features of the decision-making arena. The analysis is supplemented with interviews with all relevant actors about the strengths and weaknesses of the current management system. Next is to identify deficiencies in transboundary water management that could benefit from reforms. In the next step all the different alternative types of organizations that could address the deficiencies are considered. Subsequently, this list is reduced based on an analysis of basin context. The next step entails developing a strategy for creating the RBOs on the reduced list. The final step, which is supposed to be the most difficult, is to enact this strategy

Institutional design principles have a long history, originating with the work of Elinor Ostrom, who developed eight design principles for common-pool resources management (Ostrom, 1990b). These principles applied originally to small-scale institutions but were later expanded to more large-scale resources regimes (Huntjens et al., 2012). Collective-choice arrangements are important for robust institutions because they allow those most affected by operational rules to modify them (Cox, Arnold, & Tomas, 2010). Also important for transboundary river basin management are the rights of water users to take part in developing their own institutions, such as a process for stakeholders to help design a transboundary RBO (Cox et al., 2010; Ostrom, 1990a).

Approaching an analysis of a problem situation collaboratively, with both academic and non-academic partners, is more likely to have the intended outcome and long-lasting results (Lake & Wendland, 2018). Ignoring basin context or local knowledge can lead to unintended negative outcomes (Hadorn et al., 2008). Wicked problems, such as river basin management, which involve high stakes, conflicting values, uncertain facts, and a sense of urgency, are better resolved with collaborative and interdisciplinary approaches (Agramont, Craps, Balderrama, & Huysmans, 2019; Krueger et al., 2016).

Involving all relevant parties early in the process is essential to the successful design of transboundary RBO (Akhmouch & Clavreul, 2016; Interstate Council on Water Policy, 2006). Leaving out key decision-makers or states can undermine the process because they lack the buy-in necessary adoption (Priscoli & Wolf, 2009). It is common for existing agencies to withhold authorities and resources from newly formed transboundary RBOs (Meijerink & Huitema, 2017). Not fully engaging these agencies early in the process to design an RBO is likely only to exacerbate this situation.

## The University Collaborative and ACF Stakeholders research: Approaches and outcomes

### *Phase One: Developing a common understanding of transboundary RBOs*

The ACF Stakeholders Executive Committee approached faculty with the River Basin Center at the University of Georgia in 2011 and asked them to pull together a collaborative of researchers to tackle an issue of their choice from the ACF Stakeholders 1- and 5-year goals (ACFS Action Planning Committee, 2011). Faculty were selected from universities around the basin in order to ensure geographic representation of all the states. These universities were Albany State University, Georgia Tech, and University of

Georgia in Georgia; University of Florida in Florida; and Auburn and Troy Universities in Alabama. Faculty were also selected to represent a range of disciplinary and institutional knowledges necessary to tackle the ACF River Basin case. The University Collaborative professional expertise included ecology, law, planning, hydrology, and agricultural operations. Once formed, the University Collaborative academic researchers successfully submitted to the ACFS a proposal to research and recommend institutional options for sustainable transboundary management of the basin's water resources that ultimately consisted of four phases (Bonney, Bickerton, & Fowler, 2012). We did this work under contract for payment that was limited to some graduate research stipends and travel costs. The first author served as the graduate student coordinator for this work. The primary aim of this collaboration was to develop recommendations for the sustainable transboundary management of the ACF River Basin. While a secondary goal, it was always intended that these recommendations would be implemented. Our tertiary goals were to improve basin management and help resolve an intractable transboundary water conflict.

The initial goal of Phase One was to develop a common understanding of the full range of options for transboundary water management. We began by looking at a broad range of hydrologically based organizations that crossed state and national boundaries that we called "transboundary water management institutions", which focused on rivers, lakes, and marine environments. We identified all examples of transboundary water management institutions operating under the same water rights allocation regime as Georgia, Alabama and Florida, that of riparian rights, and a few examples from Europe and Australia and assembled a list of 17 organizations. After this initial fact-finding

phase, we focused our efforts on rivers that crossed state boundaries, and thusly transboundary RBOs, rather than transboundary water management institutions more broadly.

We framed our initial research in terms of structure and function based on Kenney (1994), which states that the design of organizations can be thought of as putting together interchangeable blocks based on basin context; the first block is functions and the remaining can be categorized as elements of organizational structure. Based on our review of RBO documents (e.g., bylaws, constitutions, compacts, charters, reports) and literature, we identified two broad categorizations and 13 more specific functions that RBOs undertake. We first categorized RBOs as having a scope that includes one or both of water quantity and water quality. The 13 functions that RBOs broadly engaged in we characterized as: coordination and building collaboration; education; data acquisition, coordination, and dissemination; water conservation; agricultural practices; recreation; restoration; flood control; planning; regulatory review; managing for ecological flows; hydroelectric power; and adaptive management. Of these functions some are more characteristic of hard management, such as regulatory review (i.e., issuing permits for withdrawals or discharges), and some soft management, such as education (e.g., campaigns to raise public awareness about basin issues). Soft management, defined as advocacy and advisory functions, impose the least restrictions on the authority of existing institutions. Hard management functions, which are defined as the capacity to control or implement construction activities and regulation actions often require that existing institutions cede authority to the transboundary RBO. We identified seven elements of structure that are useful for analyzing and designing RBOs, based on a review of Kenney

(1994) and Schmeier (2013). These elements of structure were organizational types and sources of authority, membership, forms of decision-making, committees, staffing, funding, and sunset clauses and opportunities for withdrawing from the institution.

We employed key informant interviews to supplement our reviews of organizational documents and literature, because they provide deeper insights into a case study (Elmendorf & Luloff, 2006; Sofaer, 2002). We specifically hoped to learn what the key informants saw as organizational strengths and weaknesses, as well as their opinions on specific challenges and accomplishments of the RBO. We employed a semi-structured interview methodology in order to accomplish two goals: 1) standardizing the process so interviewers from different disciplines and in different stages (i.e., undergraduate vs. graduate students) would be more likely to collect the same types of information, while 2) allowing for open ended responses that could dig deeper into themes not captured by the interview questions. The process included training for students with the University Collaborative and 17 key informant interviews. We selected executive directors as the intended key informants as they are generally responsible for overseeing staff and interacting with commissioners of an RBO and are perceived as the voice of the institution. We did so in order to increase likelihood that the interviewees would have knowledge of both the technical day-to-day operations of the staff and the political considerations of the commissioners.

In order to present our research to the ACF Stakeholders in a way that facilitated uptake and promoted deliberations necessary to develop their vision for a transboundary RBO in the ACF River Basin we developed a menu of institutional options. We also thought this would be most useful to external audiences who would ultimately be

involved, including state and federal representatives and agencies. The term "menu" was intended to make it clear that there is no one "correct" strategy. This menu of institutional options consisted of archetypical RBOs along a continuum of soft- to hard-management with real world examples, their strengths and weaknesses, and strategies for their establishment. We provided a recommendation for a non-regulatory commission, a limited regulatory commission, and a regulatory commission because the stakeholders had expressed a desire for us to present findings along a continuum of regulatory authority (the University Collaborative, conference call, 5/29/2012). The following paragraph is a brief summary of our menu of institutional options. It is important to note that we were not recommending one option but were providing the tools for future deliberations amongst stakeholders, as well as state and federal representatives and agencies, to determine which type of RBO to pursue.

(1) Non-regulatory commissions, such as the Gulf of Mexico Alliance, provide a forum for discussion, collaboration, and building consensus. They utilize existing institutions to a large extent and as such do not require a transfer of vested powers, which may make them more politically tractable and efficient. Relying on voluntary actions, however, can make it difficult to implement specific actions or to engage influential actors. Non-regulatory commissions do not have access to self-perpetuating funds (e.g. fees or fines), which makes it likely they will need to spend significant amounts of time pursuing grant and other governmental funding. (2) Limited regulatory commissions, such as the Interstate Commission on the Potomac River Basin, perform the same functions as non-regulatory commission but under certain circumstances gain the ability to influence the decision-making process through advising on regulatory issues or

developing enforceable basin-wide policies. The flexibility of this arrangement may harness the benefits of both regulatory and non-regulatory commissions, however, generally requires amending laws to provide the commission with authorities beyond soft management. (3) Regulatory commissions, such as the Delaware River Basin Commission, have the clout necessary to enforce tough decisions that may help to overcome recalcitrant interstate water conflicts. They can increase equity by achieving uniform standards across the basin and are more able to self-fund through fees for services. Regulatory commissions require a high degree of political will because they are difficult to create, as they disrupt existing institutions and require ceding a degree of state sovereignty. (Bonney et al., 2012)

We drafted the Phase One report (Bonney et al., 2012) based on an analysis of the literature review and interviews, then presented the findings to the full governing board at four ACF Stakeholders quarterly meetings. We presented at multiple meetings for a few reasons. First, we wanted to present our findings in digestible amounts, as this was a very large body of information. Second, we wanted to allow the stakeholders ample time to process this information and begin talking amongst themselves and to members of their caucuses, as each governing board member speaks not only for themselves but also for an interest and region. This pace allowed for the stakeholders to be able to ask us questions and for them to begin forming their vision of a transboundary RBO in the ACF River Basin.

There are a few lessons about collaborative processes that we learned in Phase One that may be useful in other basins. Developing a common understanding of a situation, in this case the universe of transboundary RBOs that could be designed, is key

before commencing deliberations on how to approach the situation. We did this by spending multiple meetings explaining what types of transboundary RBOs are out there, their strengths and weaknesses, and what it would require establishing them. This gave stakeholders a common vocabulary and examples they could reference when moving forward with deliberations. We also learned that approaching a situation by breaking it down into manageable pieces, in this case categorizing elements of structure and possible functions, facilitated more open discussions then presenting fully formed recommendations. If we had approached the stakeholders with a fully formed recommendation, such as using the Delaware River Basin Commission as the model for the ACF River Basin, then it would have polarized those stakeholders for and against an RBO with regulatory authority. Instead stakeholders began talking about the types of functions they were most interested in seeing an RBO undertake and the structures that would allow such an organization to accomplish its intended functions.

*Phase Two: Refining the menu of institutional options*

We learned in Phase One that functions should determine RBO structure. So, when drafting the scope of work for Phase Two, we decided to pursue a process to better understand the functions ACF Stakeholders, as well as state and federal representatives and agencies thought most important and why, before going further with recommendations. The University Collaborative did have discretion over proposing the next phase of research, but ultimately it had to be approved by the ACF Stakeholders governing board and as such was subject to their priorities. We proposed the idea of the

interviews to the stakeholders because they provided the richest, most valuable source of knowledge in the previous phase.

The ACF Stakeholders were interested in learning more about how transboundary RBOs attained authorities that would require state and/or federal agencies to cede power, i.e., for hard management functions, and how these functions are coordinated with state and/or federal agencies. This was because there was a lack of consensus within the ACF Stakeholders on how hard management functions should be approached. For example, stakeholders representing interests that were harmed by low flows when water was stored or used upstream were more likely to support functions such as regulatory review, while stakeholders representing interests that would be harmed by sending more water downstream were less likely to support these functions that would significantly alter the status quo. The objective of learning more about hard management functions was to help inform deliberation amongst the ACF Stakeholders and state and federal representatives and agencies.

The goals of Phase Two were to refine the menu of institutional options and to elaborate upon the process for creating the model RBOs presented in the menu of institutional options. In a joint effort between researchers and stakeholders with the University Collaborative, we collaboratively refined the menu of institutional options by a process where researchers solicited stakeholders opinions on those functions which they think should be taken off the table because they are unnecessary, undesirable or not politically viable and those functions which they think are most essential for an ACF transboundary RBO to engage. Additionally, we developed with the stakeholders a process for soliciting this same information about desired and undesired functions from

the state and federal actors. The process we used to refine the menu of institutional options not only accomplishes stakeholder objectives but also is supported by the design principle presented in Kenney (1994), which suggests reducing the list of options based on an analysis of basin context, in this case the desirability of functions.

In order to elaborate upon the process for creating the model RBOs, we conducted four key informant interviews with RBO executive directors and reviews of organizational documents and literature. We identified four transboundary RBOs from Phase One along the continuum of soft to hard management, with a focus on water quantity because this is the primary issue driving the need for transboundary management of the ACF River Basin. Two transboundary RBOs, the Delaware and Susquehanna River Basin Commissions, undertake hard management functions. The third, the Interstate Commission on the Potomac River Basin, gains more authority during droughts and the fourth, the Ohio River Valley Water Sanitation Commission, was considering expanding their role from water quality to include water quantity. The interview guides we developed were specific to each basin and were based on literature reviews that covered the history of the RBO and the functions they undertake that are generally exercised by state or federal agencies. Through these interviews we hoped to learn more about the consensus-building process that facilitated RBO assumption of hard management functions, the actual steps involved for doing so, and the ways RBOs share authority with state and federal agencies. Conducting the interviews before the facilitated group discussions provided specific details to aid the ACF Stakeholders in their deliberations. Themes that emerged during interviews and literature review included issues of state and federal rights, budget constraints, coordination functions, and building trust.

To solicit opinions about functions from the stakeholders, we worked with the ACF Stakeholders' professional facilitator to plan small group discussions. Graduate students working with the University Collaborative facilitated groups of four to six stakeholders at an ACF Stakeholders quarterly meeting. The discussions were to prioritize future information needs and to stimulate thinking on the functions, and to a lesser extent structure, of a transboundary RBO in the ACF River Basin. The priorities that emerged from the small group discussions regarding functions for a transboundary RBO in the ACF River Basin ranged from highest to lesser priorities, with areas for future research and points where consensus could not be reached. The highest priority functions identified were coordination, building collaboration, and planning. High priority functions were agricultural practices, coordination and dissemination of data, ecological flows, education, recreation, water conservation, and water quality. Lesser priorities were flood control, power generation, and restoration. No consensus could be reached on regulatory review, which is the authority of an RBO to approve, deny, or condition permits. The debate was whether a transboundary RBO should just focus on soft management functions like collecting data or assume hard management functions as well. As was suggested above, the debate appears to be between those stakeholders standing to gain from the status quo opposed to regulatory review authority and those standing to gain from more water making it downstream supporting regulatory review authority. Areas targeted for future research include regulatory review, planning, and ecological flows. These areas were targeted for future research the stakeholders could not agree as to their importance for a transboundary RBO in the ACF to undertake. All three were supported most by downstream caucuses. Ultimately resolving the disagreement

over these three issues will require a political process and negotiations, but there is a role for future research to inform these processes.

We drafted the Phase Two report (Bonney, Fowler, Ellis, Masak, & Zwald, 2013) based on an analysis of the literature review, interviews, and small group discussions. In multiple interviews key informants representing the transboundary RBOs discussed the benefits of creating their own niche rather than attempting to replace existing institutions. Both the interviews and literature raised the point that transboundary RBOs most endowed with authorities tended to be created before the Environmental Protection Agency and state agencies were in existence and recently created transboundary RBOs, i.e., after 1970, tend focus on coordinating rather than assuming the authorities of existing agencies (Kenney, 1994, 1995). Based on this fact and the general consensus of which functions should be undertaken by a transboundary RBO that was developed through deliberations and especially in the Phase Two facilitated group discussions, the ACF Stakeholders determined that a transboundary RBO in the ACF River Basin should not attempt to assume functions of existing agencies, but rather fill the existing water management gaps. This led to a decision to use Phase Three to work with the stakeholders to come up with a process for soliciting the opinions about desired and undesired functions for the new transboundary RBO from state and federal agencies, which is also contained in the original scope of work for Phase Three.

The importance of local knowledge was a prominent theme that came out of Phase Two. While there were accounts of how the four RBOs we studied were formed, none of them provided the rich texture of details and context that the interviews provided. The interviews were also particularly helpful in illuminating the ways that the RBOs

currently share regulatory authority through formal and informal relationships with existing state and federal agencies. Another lesson learned is that stakeholder deliberations require adequate time. The stakeholders spent a full day preparing for and participating in the small group discussions. Much valuable information came out of these discussions; however, the time went quickly. Even though the three functions where consensus could not be reached likely will need a political process and negotiations to resolve, multiple days of discussions could have provided a deeper insight as to the source of the disagreement.

*Phase Three: Identifying opportunities for a transboundary RBO*

In collaboration with the stakeholders, we developed the scope of work for Phase Three right after Phase Two ended. It was a natural next step for the ACF Stakeholders' ultimate goal, which was to develop recommendations for a transboundary RBO that could affect water management basin wide that they could advocate for the establishment of to the state and federal agencies. We hoped to identify gaps in the current management of the ACF River Basin in order to find opportunities for a transboundary RBO. We used the gap analysis approach in response to a desire expressed by the stakeholders at the end of Phase Two to fill in gaps rather than assume the authorities of existing state and federal agencies. This approach of identifying gaps is also recommended by Kenney (1994). We strove to identify gaps in four overarching water management functions essential for sustainable management of the ACF River Basin. We proposed these functions because they were determined to be highest priority functions in Phase Two.

The functions were then refined by stakeholders with the University Collaborative and approved by the full ACF Stakeholders governing board.

A major component of our initial scope of work was obtain input on an RBO in the ACF from the states and federal agencies. We developed the approach to do this in Phase Two and tried to incorporate it into the Phase Three scope of work. This would entail a conference for the ACF Stakeholders, the University Collaborative, state agencies, state representatives, federal agencies, and representatives from a few of the transboundary RBOs we studied in previous phases. The goal of this conference would be to educate the agencies and representatives about the benefits of and options for a transboundary RBO and to solicit their opinions about functions they would and would not desire a transboundary RBO to undertake. This objective for Phase Three was put on hold when our funds were limited by the ACF Stakeholders governing board to less than half of what we requested. This was done by the ACF Stakeholders governing board for two reasons. First, the other work being funded by ACF Stakeholders, the development of the model for the Sustainable Water Management Plan, was going over budget quite significantly. Second, it was perceived by the stakeholders that the institutional options work was not time-constrained, whereas the modeling work for the Sustainable Water Management Plan needed to occur immediately in order to help inform comments to the Army Corps of Engineers update to its water control manual. It was decided we would pursue this outreach to state and federal agencies in a future phase of research or as funds became available. In retrospect, this delay in bringing in state and federal players had significant consequences as will be discussed later.

The four overarching water management functions essential for sustainable management of the ACF River Basin, identified as the highest priority functions in Phase Two and refined by the University Collaborative and ACF Stakeholders, were: data acquisition, coordination and dissemination; education and outreach; coordination, facilitating collaboration, and resolving conflict; and regulatory coordination and review. We scoured organizational literature, including federal, state, and local water agency reports, and newspaper and journal articles and followed up where necessary with interviews. We found that existing agencies and other actors active in water governance in the ACF Basin are undertaking all four essential water management functions; however, there were noteworthy gaps. A few of these gaps include a lack of a central repository for data needed for informed transboundary management, an underdeveloped web presence for ACF River Basin issues beyond summaries of the litigation, lack of coordination between the states' legislators, and lack of coordinated regulations and policies governing water. We then framed these gaps as opportunities for a transboundary RBO in order to aid deliberations in future phases.

For the data clearinghouse and facilitation functions, an ACF River Basin transboundary RBO could do four things. First it could provide easily accessible, accurate and relevant data to decision-makers, researchers and the general public. Inconsistent data and models used by the states is one of the factors led to a breakdown in negotiations for the ACF Basin Compact (Leitman, 2005). Providing consistent data to decision-makers would help to improve basin-wide planning, even if undertaken by state agencies. Second, it could facilitate new studies to close current gaps in data to better inform decisions. There are areas where incomplete knowledge is a limitation. One major gap is

the effect of low flows on oyster populations, as compared to other factors like sea level rise (Camp et al., 2015; Havens et al., 2013). Third, it could investigate potential for the use of dashboards to display both data and data needs. Data dashboards have been an effective tool for synthesizing and communicating data used by other RBOs, such as Northwest Power and Planning Conservation Council. Fourth, it could investigate the need for and assemblage of real-time data. In certain management contexts real-time data can improve operations, but the need for it would need to be evaluated for the ACF River Basin. (Sheehan, Bonney, Bartenstein, & Easley, 2014)

For the education and outreach functions, we recommended that a transboundary RBO in the ACF River Basin could do the following. First, it could create a web presence for information about the ACF as an entire system and the need to manage it thusly. Improving upon the currently limited web presence could help improve public awareness of the need for transboundary management of the ACF River Basin. Second, it could develop and distribute to the basin's recreational water users' information about the ACF Stakeholders and transboundary management issues. Third, it could create a speakers' bureau to educate the public and decision-makers alike.

For the coordination and collaboration functions, we recommended that a transboundary RBO in the ACF River Basin could do the following. First, it could promote communication and build consensus at a basin-wide scale. This function was highlighted in numerous interviews conducted for Phase One as encouraging trust and preventing conflicts (Bonney et al., 2012). Second, it could develop basin-wide plans. The types of plans and the authority needed to develop them are varied. For instance, the RBO could work with existing agencies to develop a basin-wide drought plan. This could

make responses to drought consistent throughout the basin and would require no authority, just the willingness of the states to cooperate. Alternatively, the RBO could develop a basin water management plan that must be complied with, but this would require the RBO be granted the authority to do so. Third, it could resolve conflicts. Providing a forum for conflict resolution is an important transboundary RBO function (Kenney, 1994; Mandarano & Mason, 2013; Tarlock, 2008).

For regulatory coordination and review, we recommended that a transboundary RBO in the ACF River Basin could do the following. First, it could develop and promote uniform standards. Water withdrawal standards are highly inconsistent between the basin states, with Florida having a highly developed permitting system and Alabama having little more than a process for registering, rather than regulating, withdrawals (Baer & Ingle, 2016). Second, it could review permits with an eye on basin-wide impacts. The RBO could do this in an advisory role, with no authority, or make decisions on or veto permits, which would require authority to do so. Third, it could focus on specific issues such as controlling floods or managing droughts. These involve positive powers, those identified by Kenney (1994) as adding benefits to the basin without taking authority from existing agencies. For example, the RBO could help the agencies with drought preparedness.

We drafted a Phase Three report (Sheehan et al., 2014) and presented our findings at a quarterly ACF Stakeholders governing board meeting. The reaction of the stakeholders to the Phase Three report was generally very positive. There were actions that they could take under their current setup and some that would require the formation of a transboundary RBO with either the authority or clout with the states to affect water

management at a basin scale. As was the case with deliberations through all the phases, there were debates surrounding some of the functions. To some stakeholders the ability to regulate water use and develop implementable drought management plans was a necessity. There were other stakeholders that saw the functions associated with soft management, such as data acquisition, as the most important to pursue. These preferences tended to align with their positionality, with downstream stakeholders preferring hard management and upstream stakeholders preferring soft management approaches.

The gap analysis was primarily intended to help with making recommendations for a transboundary RBO in Phase Four and as such did serve its purpose. There were opportunities that the ACF Stakeholders were already equipped to pursue without being endowed with additional authority, some of which are being pursued. For example, the stakeholders are collaborating on drought management with the federal National Oceanic and Atmospheric Administration's National Integrated Drought Information System (U.S. Institute for Environmental Conflict Resolution, 2017). The remaining opportunities that require more authority did sit on a shelf, but out of necessity, since the new transboundary RBO was not yet created. This is not a reflection on the transdisciplinary process itself or the stakeholders' divergent views, just on the unavailability of mechanisms to pursue all the opportunities identified in Phase Three.

During the latter part of Phase Three the state of Florida petitioned the U.S. Supreme Court and was granted a hearing against the state of Georgia for equitable apportionment of the waters of the ACF River Basin (Ashkenaz, 2014). Equitable apportionment is a process where the U.S. Supreme Court determines if there is harm being caused by water use in one state to another state, and if so it imposes remedial

actions that may include financial compensation, consumption limits, or minimum flow targets (Bernadett, 2014; Tarlock, 1985). Florida sought consumption limits in the state of Georgia, particularly for irrigation withdrawals in the Flint River Basin (Ashkenaz, 2014). The partnerships developed among states in the ACF Stakeholders weren't strong enough and did not include all the actors necessary to prevent the case from being filed. This litigation had a profound effect on our work with the ACF Stakeholders and even more so on the stakeholders themselves. Litigation put the states at an adversarial rather than cooperative stance. This precluded us from reaching out to state and federal agencies in any substantive way, as was originally planned. We did reach out to state agencies to see if we missed any important functions for the gap analysis and check if our understanding of their current operations was accurate but were not successful in soliciting their opinions about transboundary water management. While we were not authorized to solicit opinions of state and federal players during Phase Two or Three, we were always adamant that this was a critical step to pursue during the next phase.

Politicization and use of the of ACF Stakeholders Sustainable Water Management Plan materials as evidence for the U.S. Supreme Court case broke down trust between the stakeholders and caused them to restrict certain materials (U.S. Institute for Environmental Conflict Resolution, 2017). All interim materials associated with the Sustainable Water Management Plan were restricted (ACF Stakeholders, 2017), which limited its usefulness for the U.S. Army Corps of Engineers ACF River Basin Master Water Control Manual update (U.S. Army Corps of Engineers, 2016) that was happening concurrently with the plan (U.S. Army Corps of Engineers, 2017). The University Collaborative advocated successfully to have the materials of the Institutional Options

Project exempt from the confidentiality clause (ACF Stakeholders, 2017). This ensured that our research and deliberations with the ACF Stakeholders could remain transparent and that we could publish based on our research but any communication with the states and their agencies broke down after the lawsuit was filed.

*Phase Four: Tying it all together with recommendations*

In Phase Four we and the ACF Stakeholders collaboratively developed recommendations through a consensus-based process. These recommendations differed from the Phase Three recommendations in a few ways. In Phase Three we recommended all the possible opportunities for a transboundary RBO, but in Phase Four the collaborative process determined which of these functions should be undertaken initially. Moreover, in Phase Four components of the RBO structure were recommended along with different scenarios for its establishment. We, the University Collaborative, recommended that the focus be on establishing a transitional organization or process because we believed it was premature to move forward without input from the states and the U.S. Army Corps of Engineers. The ACF Stakeholders formed a 10-member Caucus Review Group to collaborate with researchers in order to (a) suggest scenarios for bringing together key stakeholders in a transitional capacity to develop the framework for a long-standing and adaptive transboundary RBO, (b) develop recommendations and suggest considerations for creating such an RBO, and (c) provide a discussion of organizational components of representative RBOs that may be instructional when considering the framework of a permanent ACF organization.

The iterative process entailed us developing straw man recommendations based on our interpretation of the literature and interviews, presenting recommendations to the Caucus Review Group, and editing recommendations based on the Caucus Review Group feedback. This process went smoothly, despite some disagreement amongst members, because of frequent conference calls and a transparent process for incorporating feedback. Frequent conference calls allowed us to stay apprised of what the Caucus Review Group members wanted and to communicate through issues. The transparent process for incorporating feedback entailed a spreadsheet with every comment from emails, conference calls, and comments on our documents, with exactly how this feedback was incorporated into our recommendations. Before bringing the recommendations to the ACF Stakeholders governing board the Caucus Review Group had to approve them by a consensus vote and then the governing board did as well. This made for a process which was at times slow and meticulous but led to recommendations that every stakeholder could stand behind.

Researchers and stakeholders identified three scenarios to provide an immediate forum for transboundary water management discussions with all relevant stakeholders and decision makers. These scenarios involve a transitional organization that would ultimately develop the framework and political support for a permanent transboundary RBO. All the scenarios included state and federal representatives because we felt that they were essential in designing a permanent transboundary RBO. (1) The ACF Stakeholders would maintain its current organizational framework with the addition of a new council—the ACF Basin Transition Coordinating Council—that would include representatives appointed by the states and their congressional delegations as well as

members of the ACF Stakeholders. (2) The ACF Stakeholders would provide the organizational home for a new entity but it would amend its membership, leadership, and voting structure to accommodate representatives from the state governments and state and federal agencies. (3) A new organization, independent of the ACF Stakeholders, would be established. Two potential models for this new organization include the Catawba-Wateree River Basin Advisory Commission and the ACT/ACF Comprehensive Study Executive Coordination Committee and Technical Coordination Group. The Catawba-Wateree River Basin Advisory Commission helped broker an agreement that resolved a water dispute between North and South Carolina and was composed of delegates representing a wide range of interests from legislative bodies to nonprofit conservation organizations. The ACT/ACF Comprehensive Study Executive Coordination Committee and Technical Coordination Group oversaw the ACT/ACF Comprehensive Study and process to develop an interstate compact. This compact and the commissions it created were to come into force after the ACF and ACT states agreed upon an allocation formula, which was never accomplished (Leitman, 2005). These groups, however, were instrumental in the development of the compact and study. (Fowler, Sheehan, & Bonney, 2014)

In both the Caucus Review and governing board deliberations there were concerns about how to include powerful state and federal actors without losing the vision, momentum, and voice developed by the ACF Stakeholders through years of consensus building. The fact that all the transitional RBO options were vetted by the Caucus Review Group first did help to smooth deliberations amongst the governing board and increased their actionability. The governing board amended the ACF Stakeholders charter and

bylaws to create an ACF Basin Transition Coordinating Council, which was the University Collaborative's first scenario for a transitional organization. In this scenario state and federal appointees were added along with appointees of the ACF Stakeholders governing board under the auspices of an ACF Stakeholders work group. Selecting the first scenario, which kept the transitional organization as part of the ACF Stakeholders, most safeguarded the stakeholders' voice and vision.

To ensure that all relevant parties, specifically state representatives and agencies, were part of the discussions to develop a permanent transboundary RBO, we forwent recommending specific details. Rather we put forth major elements that should be considered when designing a permanent transboundary RBO. The decision to do so was based on our Phase One report and Kenney (1994). It was our intention that these elements would be deliberated upon by the transitional transboundary RBO. The major elements are membership, advisory committees, authorization, functions, and funding. Based on the previous phases of research and the deliberations to develop their vision of what a transboundary RBO should do, at least initially, the ACF Stakeholders identified four functions as most important for a permanent transboundary RBO to focus its initial efforts. These functions provide the starting point but could be expanded over time as needed. First, the permanent transboundary RBO could act as a data clearinghouse and facilitator of common data standards. Second, it could encourage and facilitate coordination and consensus building and providing conflict resolution services. Third, it could support development of basin-level water management plans, specifically related to conservation and returns, supply augmentation and drought management. Fourth, it could educate the general public and specific stakeholders about the need for transboundary

management and opportunities and strategies for doing so. These results were also received well by the governing board after being vetted by the Caucus Review Group. They were less actionable because they required a transitional organization to have been formed and the commitment of state and federal partners to participate.

The ACF Stakeholders finished their Sustainable Water Management Plan as we were finishing our Phase Four recommendations. They submitted the plan for consideration by the U.S. Army Corps of Engineers in a comment on the ACF Master Water Control Manual draft Environmental Impact Statement (U.S. Army Corps of Engineers, 2016). The U.S. Army Corps of Engineers stated the Sustainable Water Management Plan would not meet several criteria of their study and that they were not able to fully evaluate the Sustainable Water Management Plan because "many of the technical details and assumptions associated with the modeling in support of the ACFS SWMP were embargoed as a result of nondisclosure agreements for each of the ACFS members" (U.S. Army Corps of Engineers, 2016), which is a direct result of the confidentiality clause caused by the lawsuit.

The University Collaborative and ACF Stakeholders jointly developed the Phase Four report (Fowler et al., 2014). The ACF Stakeholders have taken up this report in a few ways. Notably, they included the recommendations in their Sustainable Water Management Plan (ACF Stakeholders, 2015) and created the ACF Basin Transition Coordinating Council. They also published the Phase Four report, along with Phases One through Three, to their website for public and agency consumption (ACF Stakeholders, 2019). The ACF Stakeholders contracted Udall Foundation for Environmental Conflict Resolution to determine next steps for the organization to take to advocate for the use of

the Sustainable Water Management Plan and institutional options by relevant state and federal agencies in the basin. While the immediate recommendations in the Udall Report are for the ACF Stakeholders to concentrate on their focus, sustainability, and operations, the long-term recommendations do suggest engaging federal and state partners to pursue our recommendations for transboundary water management (U.S. Institute for Environmental Conflict Resolution, 2017). The ACF Stakeholders employed a political consulting firm to take the Phase Four recommendations to the three state governments for discussion. The outcome of the discussions is not public, but to our knowledge these discussions may not have happened or if so, they have not gained any traction because of the litigation. In fall 2017, academics with the University Collaborative brought many of the executive directors of the RBOs we studied for the Institutional Options Project to the AL/GA Water Resource Economics Conference to share their stories. State agency members from Georgia and Alabama as well as the former executive director of the Georgia Environmental Protection Division attended this conference as well.

The collaborative writing process appeared to improve the actionability of the findings as the ACF Stakeholders immediately tried to implement the results of the Phase Four work. The collaborative process ensured that by the end of Phase Four there was buy-in to our recommendations. In fact, the entire governing board had to approve our recommendations by a consensus vote. Deficiencies in traction for the recommendations are not because of factors internal to the stakeholders, but rather by litigation and the unwillingness of state agencies and representatives to engage. The timing of collaborative processes is important to harness windows of opportunity. The U.S. Army Corps of Engineers Master Water Control Manual update and the break in litigation provided a

major window of opportunity for transforming water management. But the Sustainable Water Management Plan and Institutional Options Project occurred too late to take advantage of this window of opportunity.

## Discussion

In this chapter we use the ACF River Basin as an example to highlight major governance factors that should be considered in developing a transboundary RBO with the ability to influence water management at that basin scale, given the current regulatory, political, and legal climate. We also illuminate the social processes that might be used most effectively in that development. We do so through a presentation of the four phases of research for the Institutional Options Project done in collaboration with the ACF Stakeholders. In each phase we summarize our research, which governance factors informed our research, and the social processes the phase entailed.

The governance factors we found most important for developing a transboundary RBO in the current regulatory, political, and legal climate were mostly related to organizational functions and how these functions would be shared with existing agencies. The type of organization (i.e., commission, council, or authority), it's membership and decision-making procedures, and sources of funding, while important, were secondary to figuring out functions. To do so, a process of determining exactly what needs to be improved upon in the current water governance regime was vitally important; such as we did through a gap analysis. Once this information is known a process of negotiating which of these gaps should filled by a transboundary RBO is necessary. As we learned in the process a transboundary RBO cannot do everything initially. The process of

negotiating amongst stakeholders and agencies can pinpoint the best places to start, which can then be expanded upon as the newly formed transboundary RBO gains experience and reputation. The importance of conflict resolution and professional facilitation in managing tense transboundary river basins cannot be underestimated. Our deliberative process may have fallen apart numerous times if it weren't for skilled facilitation. Effective conflict resolution mechanisms may have prevented the litigation that so beleaguered our research as well as the breakdown of relations between the ACF Stakeholder.

The primary aim of this collaboration was to develop recommendations for the sustainable transboundary management of the ACF River Basin. While a secondary goal, it was always intended that these recommendations would be implemented. Our tertiary goals were to improve basin management and help resolve an intractable transboundary water conflict. The primary aim of collaboration was effectively accomplished. We, in conjunction with the ACF Stakeholders, were able to develop recommendations for improving management of the basin. These recommendations included options for a transitional organization to design a permanent transboundary RBO, initial functions to be undertaken by the permanent transboundary RBO, and elements of structure that would be important to deliberate upon while designing the permanent transboundary RBO in order to accomplish its intended functions. Our secondary goal of implementing the recommendations was not achieved. We were unable to secure the commitment of states and federal players to engage with the process. This is in part because of the litigation and in part to the lack of buy-in that would have been generated if the states and federal players were part of the process to develop the transboundary RBO

recommendations. Our tertiary goals were in part achieved. The materials produced throughout this process provide a road map forward once litigation is over. Some of the opportunities identified for improving basin management through a transboundary RBO in Phase Three are already being pursued by the ACF Stakeholders in conjunction with a federal agency, for the National Integrated Drought Information System, and with NGO and academic partners, for the development of an online interactive live tour of the basin.

Numerous factors shaped effectiveness of the Institutional Options Project. The consensus-based process for approving interim materials promoted effectiveness. While this process sometimes was slow, ensuring at each step of the way stakeholders were supportive of our recommendations helped the actionability of our research. Integrating literature on transboundary management and collaborative processes throughout all the phases helped ensure we were increasing our chances of effectiveness by learning from the experiences of others and grounded our recommendations in a wider scholarly debate. The stakeholder reluctance to engage the agencies and representatives early in process because of the potential for losing control over the process hindered the Institutional Options Project's effectiveness. The fact that the states have such a long history of conflict and politization of water management makes a reluctance to engage with the states and federal players early on understandable. Even more so because this completely stakeholder-initiated approach to river basin management is quite rare in the United States and there are insufficient models to determine how stakeholders can maintain a central role, rather than being relegated to the sidelines, after engaging more powerful players. Inadequate funding to reach out to agencies and representatives in Phase Three hindered the Institutional Options Project's effectiveness. In hindsight, being aware of the

upcoming litigation and the profound effect it would have on state and federal engagement with the process would have likely put more of an emphasis on raising or allocating funds to this effort in Phase Three. Most importantly, litigation midway during the process hindered the Institutional Option project's effectiveness. If we had made concerted effort to get input of states and the U.S. Army Corps of Engineers earlier in Phase One or Two, there might have been an understanding or at least desire to move forward cooperatively, to prevent the litigation from happening.

Good practices are underlying the formation of the ACF Stakeholders, the University Collaborative, and our collaborative research process. The ACF Stakeholders are a consensus- driven organization that aims to balance stakeholder interests and maximize representation, transparency, and legitimacy. The ACF Stakeholders were designed to ensure the development of mutual trust, inclusive representation based on geography and interest, consensus-based decision making, and professional facilitation and dispute resolution. These are many of the characteristics highlighted in successful management of common pool resources (Ostrom, 1990a). The process of creating the University Collaborative was based on the principles of transdisciplinary and other forms of collaborative research. The ACF Stakeholders were empowered through a collaborative process in which they had the power to make important decisions regarding not only research design, but also research products. The final recommendations were the result of a multiyear iterative and adaptive process that entailed research, stakeholder education, consensus building, and stakeholder input to better target the research. Throughout this process our research design and output were responsive to ACF

Stakeholders goals. All these good practices, however, were not able to overcome the external factors that limited our project's effectiveness.

Our research has wider implications for basins attempting to resolve transboundary water conflicts through cooperative solutions. Transboundary basins are ever more likely to experience conflicts with increased water scarcity but attempting to work through these conflicts cooperatively will not necessarily mean a solution will be reached, even if the process is designed based on best practice. This implies more research is needed to determine under which contexts politics, litigation, and other sociopolitical processes can derail the cooperation and when they are navigated effectively. We can put forward a few lessons in this regard. Litigation may derail collaborative processes when irreversible damage will occur, or a threshold is likely to be crossed and the aggrieved parties feel like they cannot wait for the outcome of collaboration. Political pressure from an important base of voters can cause legislators to forgo collaborative efforts, even if they may be in their best interest. Path dependence, such as is associated with the ACF River Basin's 30-year history of litigation, can favor litigative rather than collaborative approaches.

## Conclusion

Designing transboundary RBOs in the current political, regulatory, and legal climate necessitates a more nuanced approach than needed to be employed when the early monolithic organizations were created. It requires identification of gaps and opportunities for transboundary management, deliberation with all the relevant players as to what functions are important for a transboundary RBO to perform, negotiation with existing

agencies as to which functions they are willing to part with, and a process to transition from the current regulatory landscape to one that includes a transboundary RBO. Engaging with stakeholders in a collaborative research process provided benefits to researchers, students, and stakeholders alike. These benefits include service-learning opportunities for students, the opportunity to move forward research on transboundary RBOs while also effecting change in a real world problem for researchers, and providing a forum for stakeholders to develop their vision for transboundary water management based on the experiences of other basins and academic research. Working through transboundary water conflicts using best practices for collaborative processes and transboundary governance doesn't necessarily mean that the conflict will be resolved.

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# CHAPTER 3

# CROSSING BOUNDARIES AND BRIDGING DIVIDES: RIVER BASIN ORGANIZATION EFFECTIVENESS IN THE UNITED STATES

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Shannon Bonney Baumgardner, Laura German, Seth Wenger, Laurie Fowler, and Lizzie King

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## Abstract

Water shortages and nutrient pollution in a growing number of basins put human water security and aquatic biodiversity at risk. These challenges are harder to tackle in transboundary river basins. Transboundary river basin organizations, which manage water based on hydrologic boundaries, are promoted as a solution to these challenges, but there is a need to evaluate if they are truly effective. We evaluated the effectiveness of transboundary (interstate) river basin organizations in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity. We did so through a mixed quantitative and qualitative approach that employed biophysical indicators and a conceptual framework on the key features of river basin organization effectiveness. We found modest biophysical results, with more strength of evidence for low flows than for total nitrogen flux. The interview results help to explain the factors promoting and hindering the achievement of minimal low flows and nutrient reduction. Our results provide further evidence that river basin organization do have positive effects, biophysical and other, in transboundary river basins.

## Introduction

Water quantity and water quality management issues are mounting and present urgent problems to be resolved in the coming decades (Hanjra & Qureshi, 2010; Jury & Vaux, 2007; Panjabi, 2014; Watkins, 2006). Droughts and excessive consumption have led to water shortages during at least part of the year in a growing number of basins in the United States and around the world (Falkenmark & Molden, 2008; Foti, Ramirez, &

Brown, 2012; Molle, Wester, & Hirsch, 2010). This puts water security at risk for humans and threatens aquatic biodiversity (Vorosmarty et al., 2010). Low flow frequencies are higher in many U.S. basins due to water withdrawals during dry periods, which can reduce aquatic habitat area, degrade water quality, dry riparian wetlands, and disrupt biogeochemical cycles (Arthington, Naiman, McClain, & Nilsson, 2009; Atkinson, Julian, & Vaughn, 2014; Rolls, Leigh, & Sheldon, 2012).

Water quality degradation is widespread (Davies & Mazurek, 1998; Stoddard et al., 2016). Despite improvements in certain areas, water quality is declining in many basins due to non-point source pollution (Alvarez, Asci, & Vorotnikova, 2016; Andreen, 2016; Gavrilescu, Demnerova, Aamand, Agathos, & Fava, 2015; Murray, Thomas, & Bodour, 2010), of which nutrients are the most ubiquitous and constitute the "most widespread chemical stressor in U.S. streams" (Sprague, Oelsner, & Argue, 2017), p. 253). Excess nutrients are associated with eutrophication, harmful algal blooms, and hypoxia (Allan & Castillo, 2007; Wetzel, 2001), and contribute to the degradation of freshwater communities (Ansari & Gill, 2014). The state of biological health is declining in river basins globally (Janse et al., 2015). Populations of many commercial fish and endangered species are dwindling, along with measures of aquatic biodiversity (Camp et al., 2015; Limburg & Waldman, 2009; Pimm et al., 2014).

There are particular challenges to tackling water management problems in transboundary river basins (Larson, 2015; Mandarano, Featherstone, & Paulsen, 2008). Managing water quantity and quality in the transboundary (interstate) river basins of the United States entails multiple states independently managing their portions of the basin, with federal agency involvement on specific issues, such as the Clean Water Act. This

fragmented governance system is prone to negative externalities for downstream users (Larson, 2015; Mandarano et al., 2008), such as degraded downstream water quality or suboptimal flow regimes, which can harm communities, economies, and ecosystems (Hooper, 2006). When basins encompass multiple states these negative externalities often lead to water disputes that, in the absence of mechanisms for cooperation, can only be resolved through litigation or congressional intervention (Abrams, 2009; Dellapenna, 2005; Starr, 2013).

Forming RBOs entails costs (Interstate Council on Water Policy, 2006; Marshall, 2013; McCann, 2013; McCann, Colby, Easter, Kasterine, & Kuperan, 2005) such as financial resources for operations and projects (Kauffman, 2015), political/public capital, and time. Moreover, a newly formed RBO is an additional governance layer (Huitema & Meijerink, 2017) that may involve, for example, competition for funding with established jurisdictional water management agencies and a perceived burden on regulated communities. Considering this, there's a need to evaluate if RBOs are truly effective in resolving the urgent water management problems facing interstate river basins to determine whether forming new RBOs or continuing support for existing RBOs is a good use of resources. We evaluate the effectiveness of transboundary (interstate) RBOs in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity. In the following literature review we define RBOs and outline key institutional features associated with RBO effectiveness. Next, we present biophysical indicators and a conceptual framework that we then use to evaluate RBO effectiveness.

## Literature review

River basin organizations (RBOs), which transcend political boundaries to manage water resources based on hydrologic boundaries (Schmeier, 2013), have been promoted as better equipped to resolve water management problems than separate political jurisdictions (Dellapenna, 2005; Hooper, 2006; Huffman, 2009; Mandarano et al., 2008). River basin organizations may be established by compacts, agreements, or legislation (Kenney, 1994). Compacts are legally binding arrangements between states, or between states and the federal government, which require congressional approval, whereas agreements, such as resolutions and interagency agreements, are less formal (Draper, 2007). Non-compact agreements are easier to create and may be more flexible than compacts; however, they may not carry the same force-of-law and permanence (Kenney, 1994). States are likely to resist setting up highly institutionalized agreements, such as compacts, unless there is compelling evidence that the benefits will outweigh the costs (Tir & Stinnett, 2011).

Scholars and practitioners have been calling for water management based on hydrologic rather than political boundaries for at least a century (Hooper, 2010a; Huffman, 2009; Kenney, 1997, 2008; Tarlock, 2008). Despite the acceptance of hydrologic rather than jurisdictional boundaries for water management amongst many scholars and practitioners, there are complicating factors. Defining river basin boundaries is not necessarily straightforward (Herrfahrdt-Pahle, 2014; Huitema & Meijerink, 2017). Surface water and aquifer boundaries rarely align (Meijerink & Huitema, 2017; Svendsen, Wester, & Molle, 2005). Interbasin transfers increasingly connect once distinct river basins (Kenney, 2008). River basin management improves the spatial fit between

water resources and water management institutions but can create misfits between water management institutions and other sectors (Herrfahrdt-Pahle, 2014; Moss, 2012).

Adequate finances, trained staff, and enough authority to implement policies were identified as three of the attributes of best practice for effective river basin management based on an extensive literature review and series of expert interviews (Hooper, 2006, 2010b). While often intertwined, each of these three institutional features are discussed separately below.

Numerous scholars have posited that RBOs with the authority to compel compliance with plans, agreements, or policies are more effective than those without this authority (McLaughlin Mitchell & Zawahri, 2015; Schmeier, 2010). Enforcement mechanisms may increase compliance with water quantity agreements in transboundary river basins because they reduce incentives for free riding and overharvesting (Tir & Stinnett, 2011). Water treaties with enforcement mechanisms were found to be more likely to lead to reduced conflicts and resolution of the issues leading to the treaties (McLaughlin Mitchell & Zawahri, 2015). Transboundary coordination mechanisms have failed without sufficient or appropriate authorities (Kenney, 1994). A lack of authority is also cited as one reason RBOs may underperform (Dinar, Correa, Farolfi, & Mutondo, 2016; Dombrowsky, Hagemann, & Houdret, 2014; Larson, 2015; Morris & Loe, 2016). As an organization created by executive decree rather than enshrined in national law, the Tárcoles River Basin Commission in Costa Rica has not been able to fulfill its intended functions because it lacks the authority to do so (Blomquist, Ballestero, Bhat, & Kemper, 2005). However, one empirical study found a negative, but not significant, relationship between binding decisions and regime effectiveness (Bohmelt & Pilster, 2010). These

studies suggest RBOs with the authority to compel compliance can be more effective but leave unanswered questions about the contexts in which regulatory approaches are more effective than 'soft management' approaches, such as providing a forum for communication, information sharing, or coordination.

Adequate funding is essential for river basin management (Blomquist, Dinar, & Kemper, 2005; Hooper, 2006; Kauffman, 2015; Raadgever, Mostert, Kranz, Interwies, & Timmerman, 2008). The financial and technical resources available to RBOs help increase their adaptive capacity (Heikkila, Gerlak, Bell, & Schmeier, 2013), which in turn improves performance (Bettini, Brown, & Haan, 2015; Imperial, 1999; Kauffman, 2015). The risk of RBOs underperforming because they are not endowed with adequate resources is a recurrent theme in the literature (Dinar et al., 2016; Dombrowsky et al., 2014; Larson, 2015). Inadequately defined funding sources and inconsistent funding is a "major obstacle" facing the Tárcoles River Basin Commission that limits its effectiveness (Blomquist, Ballestero, et al., 2005, p. 24). The ineffectiveness of the Tárcoles River Basin Commission caused by inadequate authorities and funding was so apparent that the Costa Rican government created another basin commission in response (Blomquist, Ballestero, et al., 2005). The Mackenzie River Basin Board, of Canada, is also limited by inadequate funding and authorities as well as by being understaffed, narrowing its role in the basin and challenging its ability to implement basin-wide policies (Morris & Loe, 2016). Existing agencies may be reluctant to cede authorities and resources to RBOs (Dinar et al., 2016; Flynn, 1982; Meijerink & Huitema, 2017).

It is not just the magnitude of finances that matter, but also that they are consistent and the level of autonomy they provide the RBO (i.e., self-funding mechanisms such as

taxes provide more autonomy than external-funding mechanisms such as grants and appropriations) (Blomquist, Dinar, et al., 2005). The greatest success for decentralized river basin management is associated with consistent and mixed funding, which includes federal (or central) governmental appropriations, stakeholder (e.g., state governments and water users) dues, and generated revenues (i.e., water use charges or permit fees) (Dinar et al., 2005). It is not only the RBO budget that matters, but the budgets of agencies that are members of or collaborate with RBOs. In the Rogue River Basin, Oregon, declining budgets caused numerous federal agencies to withdraw from the interagency collaborative Rogue Basin Restoration Technical Team (Margerum & Whitall, 2004).

Technical capacity, including well trained permanent staff, is also associated with RBO performance in case studies globally (Blomquist, Dinar, et al., 2005; Dinar et al., 2005; Hooper, 2010b; Meijerink & Huitema, 2017). Sufficient levels of funding and trained staff were identified as critical for RBO performance in 11 case studies, promoting performance when available and hindering it when lacking (Huitema & Meijerink, 2017; Meijerink & Huitema, 2017). They are also identified as two determinants of successful municipal water management organizations (Wolff & Hallstein, 2005) as well as decentralized water governance in Haiti, Rwanda, and Florida (Stoa, 2014). Human, technical, and financial resources are all identified as important for successful environmental collaboration, in river basins and more broadly (Koontz & Thomas, 2006; Silveira, Junier, Huesker, Qunfang, & Rondorf, 2016). An interview with the Guadalquivir river basin authority revealed that, even with a sizeable staff, there are still not enough staff to complete all the organization's mandated functions (Blomquist, Giansante, Bhat, & Kemper, 2005). Some river basin organizations, such as the

catchment management agencies of South Africa, are consolidated to ensure each has adequate financial and technical capacity (Meissner, Funke, & Nortje, 2016).

A good reputation gained through staff seen as experts and impartial may also help to overcome deficiencies in authority. Even though the Brantas Basin Corporation, Indonesia, does not have much authority, the perceived impartiality of its staff enables the organization to develop "good working relationships" with both stakeholders and governmental agencies and promotes it being seen as a "legitimate authority for the activities it carries out" (Bhat, Ramu, & Kemper, 2005, p. 39). In a review of eight river basin organizations Blomquist, Dinar, et al. (2005) found consistent and adequate funding, along with a perception that the organization and its officials are unbiased, to be two critical components of success.

## Methods

Quantitative and qualitative methods were used to test RBO effectiveness. We paired qualitative methods with quantitative because river basin organizations provide benefits not measured by biophysical indicators (e.g., nutrient export or low flows), such as resolving interstate conflicts and attracting external sources of funding. Conflict management is an often-cited benefit of river basin management (Tarlock, 2008) and RBOs may reduce the likelihood of equitable apportionment cases before the U.S. Supreme Court (Interstate Council on Water Policy, 2006; Mandarano & Mason, 2013). The costs of cooperation may be modest compared to the costs of non-cooperation. Many RBOs have a budget of less than $10 million per year (Kauffman, 2015), whereas the average equitable apportionment lawsuit costs significantly more; the current Supreme

Court litigation between the states of Florida and Georgia has cost an estimated $100 million thus far, and the case is not over (Barnes, 2018). River basin organizations also bring financial investments into basins (Cannon, 2000; Interstate Council on Water Policy, 2006). The Environmental Protection Agency has reserved funding for water quality initiatives undertaken by interstate agencies, meaning an additional pool of funding beyond what states are entitled to individually under Section 106 of the Clean Water Act (Code of Federal Regulations Title 40 §35.162). River basin organizations add value to each states' individual funding. For every $1 spent on the Susquehanna River Basin Commission (SRBC) flood forecasting system there are an estimated $20 worth of benefits to the basin (Susquehanna River Basin Commission, 2007). When trying to convince Virginia not to withdraw from the Interstate Council on the Potomac River Basin (ICPRB), the organization estimated that the State of Virginia receives more than 350% in benefits for its membership dues (Prince William Conservation Alliance, 2012).

The quantitative analysis involved the development of two biophysical indicators to test the relationship between RBO presence (independent variable) and trends in low flows and nutrient loads (dependent variables). We also tested the alternative model that these dependent variables were associated with precipitation rather than presence of RBO. For the qualitative evaluation of effectiveness, we develop a conceptual framework on the key features of RBO effectiveness based on a literature review and use this to evaluate each RBO, drawing primarily on semi-structured interviews with key informants from RBOs and supplementing this information with publicly available organizational literature (bylaws, compacts, agreements, budgets, and other documents). We used data analysis triangulation techniques for biophysical and interview data (Duffy, 1987; Jick,

1979) in order to provide a deeper understanding of RBO effectiveness than would be possible with either data source alone. Different components of the methodology are explained in greater detail in the sections to follow.

*Effects of RBOs on Low Flows: 7-day low flow trends*

We first tested whether the presence of an RBO was correlated with fewer declines in 7-day low flows, i.e., the lowest mean flows for seven consecutive days in a year (Risley, Stonewall, & Haluska, 2008), over the past 35 years. We identified all river basins in the continental United States that cross state boundaries. To reduce the likelihood that the legal system for water rights confounds results, we filtered the basins to select those based on riparian rights doctrine of law, which is based on reasonable use and found primarily in the eastern United States (Dellapenna, 2002). We filtered the basins to select those whose sizes were between 14000 and 27500 square miles, to reduce the likelihood that basin size confounds results. We categorized river basins as study basins if they had an RBO that operated at the river basin scale and had adopted policies or programs specifically targeting low flows; otherwise they were categorized as control basins. The filters resulted in three study basins and nine control basins (Table 3.1).

For each basin, we used low flows data from one location near the basin outlet because they reflect management actions taken throughout the basin. We identified the USGS streamgage that is closest to the mouth of the basin with daily discharge data free from long gaps between 1982 and 2017. Three gages had missing data in this range, of up to five years. We calculated annual 7-day low flows then log transformed them. We conducted three linear regressions: first, to predict 7-day low flows based on year, i.e., 7-

day low flows trend; second, to predict 7-day low flows trend based on presence of RBO; and third, to predict 7-day low flows trend based on precipitation. To calculate precipitation, we clipped gridded 2.5° monthly precipitation data (Schneider, Becker, Finger, Meyer-Chistoffer, & Ziese, 2018) to river basin boundaries and averaged across the river basin for the years 1982-2017 (Pierce, 2017; R Core Team, 2018). Given the small sample size it we predicted it was not possible to include precipitation and RBO presence into one model, so we compared them based on Akaike weights corrected for small sample size (AICc) calculated in R (Mazerolle & Linden, 2019), for four models (including a model with RBO presence and precipitation to test our prediction): (1) flows ~ precipitation, (2) flows ~ RBO, (3) time trend null model, and (4) flows ~ precipitation + RBO.

*Effects of RBOs on Water Quality: Total nitrogen flux*

We next tested whether presence of an RBO was correlated with fewer increases in total nitrogen flux trends over the past 20 years. We identified all river basins in the continental United States that have long-term continuous total nitrogen data. We did not apply additional filters for three reasons. We experienced a lack of data and wanted to keep the sample size up. There is less heterogeneity for total nitrogen flux than for low flows. The federal Clean Water Act has nationwide coverage, whereas the nation is divided amongst different water use doctrines. The model used to calculate total nitrogen flux normalizes flows, reducing some heterogeneity between different basin sizes. We categorized river basins as study basins if they had an RBO that operated at the river basin scale and had regulatory control over water quality or was directly involved with

developing nutrient criteria or water quality standards. These filters resulted in five study basins and three control basins (Table 3.2).

For each basin we used total nitrogen flux data from one location near the mouth of the basin because they reflect management actions taken throughout the basin. We located the sampling site closest to the outlet of the basin with at least 100 samples of total nitrogen (nitrate + nitrite + ammonia + organic-N, water, unfiltered) with no fewer than six samples per year between 1997 and 2017. We first located sampling sites from US Geological Survey. If no sampling sites met the criteria, then we opened the search to the Water Quality Portal (National Water Quality Monitoring Council, 2018) and data published by the Chesapeake Bay Program (Chesapeake Bay Program, 2018). We used discharge data to model total nitrogen flux from the closest USGS streamgage with no greater than three consecutive days missing data between 1997 and 2017. We interpolated across data gaps to ensure a continuous discharge (R Core Team, 2018). We calculated total nitrogen flux in R (Hirsch & De Cicco, 2015) with the Weighted Regressions on Time, Discharge, and Season (WRTDS) model, which is a generalized non-linear additive model that normalizes the results by discharge (Lee et al., 2016). The WRTDS model estimates daily concentration and flow normalized flux over the time period based on discharge, season, trend, and a random factor (Hirsch, Moyer, & Archfield, 2010). It has been shown to perform better than other models to estimate nutrient flux (Hirsch, 2014; Lee et al., 2016). We log transformed flow normalized total nitrogen flux. We conducted four linear regressions: first, to predict flow normalized total nitrogen flux based on year, i.e., the total nitrogen flux trend; second, to predict total nitrogen flux trend based on presence of RBO; third, to predict total nitrogen flux trend

based on precipitation; fourth, to predict total nitrogen flux trend based on precipitation and RBO presence. We used the same methods as for the 7-day low flows to calculate precipitation and compare models. The models included: (1) total nitrogen flux ~ precipitation, (2) total nitrogen flux ~ RBO, (3) null model, and (4) total nitrogen flux ~ precipitation + RBO.

*RBO Effectiveness: Interview and organizational data*

The ACF Stakeholders University Collaborative conducted semi-structured interviews in 2012 with one key informant from 17 RBOs located throughout the United States and based on the interviews developed institutional recommendations for sustainable transboundary management for the ACF Stakeholders (see Introduction chapter) (Table 3.3) (Bonney, Bickerton, & Fowler, 2012). These interviews covered RBO structure, function, strengths, and weaknesses (Bonney et al., 2012) and provide more nuanced information on RBO effectiveness and the factors underlying this.

To evaluate effectiveness, we developed a conceptual framework based on a review of the literature on the characteristics of RBOs that enhance or constrain their effectiveness. The RBO representatives' views on effectiveness, organizational strengths, organizational weaknesses, and challenges were our primary source of insight and gauge on effectiveness. We used organizational literature (bylaws, compacts, agreements, budgets, and other documents) to supplement interviews for specific information if it was not discussed during the interviews: membership, founding agreement, functions, budget size, staff size and expertise, number of technical groups, and specific actions that

constitute regulatory authority. The framework encompasses three key conditions identified as crucial to RBO effectiveness:

**Regulatory authority.** While there is debate in the literature, we hypothesized that having regulatory authority and ability to ensure compliance with decisions enhanced RBO effectiveness. We evaluated regulatory authority based on two sources. We looked to organizational literature to identify whether an RBO can enact and enforce rules, such as through civil penalties. We identified all instances in interviews where regulatory authority is discussed directly or closely related subjects such as RBO rules and standards.

**Financial capacity.** We hypothesized RBOs with adequate and stable sources of funding would be more effective. We evaluated funding adequacy by the interviews. If the interviews point out they are lacking funding, or their budget contributions are being reduced, then we labeled this inadequate funding. We evaluated funding stability by the source of funds, which is learned through the interviews or a review of organizational documents. Funds derived from congressional or state appropriations as well as fees for services or taxes are considered stable, while grant funding were considered unstable.

**Technical capacity.** We hypothesized RBOs with greater technical capacity, as evidenced by permanent scientific and policy staff as well as technical groups, would be more effective. We looked for evidence of technical capacity in organizational literature and the interviews. From the organizational literature we determined staff size, staff expertise, and number of technical groups. We used the interviews to look for evidence that the staff or technical capacity helps the RBO accomplish its goals or is seen as an

organizational strength and alternatively, lacking them hinders RBO operations or is seen as an organizational weakness.

We used the conceptual framework to evaluate interview data and used both the organizational documents and interview data to create a summary table. All other qualitative results we presented were based on knowledge gained during the interviews. We coded interview transcripts or interview summaries, available for all the study basins, with MaxQDA 2018 (VERBI Software, 2017) in order to identify themes in the interview data. To do so, we identified codes matched to each element of the framework: regulatory authority, financial capacity, and technical capacity.

## Results

### *RBO effectiveness based on biophysical results*

We found that study basins had positive trends for 7-day low flows, while all but one control basin had negative trends for 7-day low flows (Table 3.4). The Merrimack River Basin, a control basin, had the greatest improvements in 7-day low flows of all basins, followed by the Susquehanna River Basin and Delaware River Basin (both study basins). The largest declines in 7-day low flows were all control basins. Of the four models that we tested to predict low flows, we found the model of RBO presence was the best supported, with an AICc weight of 50% (Table 3.5, Figure 3.1). The next best supported model was the null model (31%), followed by precipitation (13%), and precipitation + RBO (6%).

While the model of RBO presence was not likely, we did find patterns in the nitrogen flux data. We found that all but one study basin had negative trends for flow

normalized nitrogen flux, one control basin had a positive trend for flow normalized nitrogen flux, and two control basins had negative trends (Table 3.6). While most basins had negative trends, the most negative trends were study basins and the most positive trends were control basins. The model of RBO presence had an AICc weight of 9% (Table 3.7, Figure 3.2). The model of precipitation (45%) and the null model (42%) were the two best supported models. The model including both precipitation and RBO presence was least supported (4%).

*RBO effectiveness based on interviews and organizational literature*

**Regulatory authority:** Based on both organizational literature and interviews we found RBO regulatory authority to vary along a continuum between no regulatory authority, limited authority to monitor for compliance during droughts, and authority to set or enforce standards (Table 3.8).

While not universal, the interviewed RBOs representatives tended to cite regulatory authority as an organizational strength (e.g., DRBC) or the lack of regulatory authority as an organizational weakness (e.g., SRBC). The one exception was the ICPRB representatives, which cited a lack of regulatory authority as both a strength and weakness. On the one hand, as an organization with no regulatory powers, the ICPRB was said to rely on bringing people to the table to communicate through issues. The ICPRB was considered to be a commission that is part of the states, which allowed them to work with state agencies through interdepartmental and interagency agreements rather than having to bid on projects. Without regulatory powers the ICPRB was thought to be "not a threat to any of the parties" and because of a "non-partisan approach to problems"

the "parties are usually comfortable working with us" (ICPRB, phone interview, Claire Ellis, March 2012). On the other hand, the non-regulatory nature of the ICPRB was also viewed as a weakness because the "potential for dealing with a water quality issue or a water quantity issue could be much easier to solve with a regulatory group" (Ibid). The same interviewee provided an example of the U.S. Supreme Court case between Maryland and Virginia over a proposed water intake. The ICPRB did not mediate this interstate conflict, but it was perceived that the mediation and a potential cooperative solution "could have been much easier to do under a regulatory framework." This was said to contrast with the Delaware River Basin Commission, an RBO with regulatory authority, which, according to ICPRB and DRBC representatives, was able to mediate a good faith agreement to prevent further U.S. Supreme Court litigation over inadequate supplies to meet amount decreed to New York City during drought. The Upper Mississippi River Basin Association (UMRBA) was observed to lack not only regulatory authority but also authority to implement their policies, and instead rely on the completely voluntary actions of state and federal agencies for implementation. The UMRBA representative expressed a desire to be more of an implementing organization such as through the authority provided under Section 106 of the Clean Water Act.

The Delaware River Basin Commission (DRBC) representative said regulatory authority provided them with "more clout" than "some basin commissions that are just planning and education" (DRBC, phone interview, Damien Brychcy, March 2012). He went on to suggest that in basins with "some really knotty issues…the compact organization really needs to have some authority; it should not just be a planning organization" (Ibid). In order to prevent river basins organizations from being "toothless

and ineffective" the SRBC representative said RBOs need to have "real authority," or "even some regulatory authority to get anything done" (SRBC, phone interview, Kelly Robinson, March 2012). Without this and long-term commitments of the parties, there was said to be the risk that when faced with tough issues "one of the parties is just going to say well forget it, we're leaving", as there is "really no commitment there" (SRBC, phone interview, Kelly Robinson, March 2012). The Ohio River Valley Water Sanitation Commission (ORSANCO) representative cited regulatory authority as an organizational strength that reduces interstate conflict because "it's understood that when states are writing their own NPDES permits or writing their own standards that their starting point is our minimum set of standards" (ORSANCO, phone interview, Claire Ellis, March 2012).

**Financial Capacity:** Based on both organizational literature and interviews we found the annual budgets between 2016-2018 were to range from $2.4 and $7.9 million and were paid through a combination of member dues, project and permit review fees, federal appropriations, grants, and miscellaneous sources (Table 3.8).

Funding, or a lack thereof, was cited as an important factor in RBO success in most of the interviews. The RBOs were said to be feeling budget crunches when the interview was conducted in 2012. In the Delaware River Basin these were perceived to be due in part to the federal government not paying its share of member dues and financial hardships experienced by member states leading to incomplete payment of member dues from states as well. The jurisdictions of the Potomac River Basin were all said to be experiencing budget crunches. It was even observed that Virginia zeroed the ICPRB out

of its budget and threatened to leave the compact around the time of the interview in 2012. Federal appropriations for the ICPRB were said to have ceased in 1994, as they did with river basin commissions around the country (ICPRB, phone interview, Claire Ellis, March 2012), because of a report from the Heritage Foundation arguing that river basin commissions are entities of the state, not the federal government, and therefore funding them is fiscally irresponsible (Utt, 1995). The ICPRB, SRBC, and DRBC were said to be authorized to receive annual federal support in the 2007 Water Resources Development Act, but despite their attempts the ICPRB only received one year of funding as of the interview. Like other river basin commissions, the SRBC said it lost its federal appropriation in the 1990s and state funding was cut back as a result of the recession. Insufficient funding caused two UMRBA programs were observed to go dormant as of the interview.

In addition to the impact of periods of economic hardship, the growth of state regulatory programs was thought by the DRBC representative to make it difficult to get the states to cooperate and harder to gain the attention of the regional commissioners. He went on to say that the "world needs more river basin commissions and ways to bring people together to manage resources across boundaries…each state has to give up a little of their sovereignty to make it work and for them to come together and so it's a hard concept in hard [economic] times" (DRBC, phone interview, Damien Brychcy, March 2012).

Several RBO representatives indicated that "worrying about funding can take you off mission" (DRBC, phone interview, Damien Brychcy, March 2012). State contributions were observed to be a minor component of the ICPRB budget; the

remaining budget came from grants and contracts. Without independent funding sources to work on compact responsibilities the ICPRB was perceived to be "dependent on finding willing funders" and "chasing the money" (ICPRB, phone interview, Claire Ellis, March 2012). So even if the ICPRB commissioners prioritized issues, it was observed they still struggled to determine which issues they could get funded. Alternatively, the ICPRB representatives perceived this as an organizational strength because projects can be deferred or slowed down if other priorities arise.

Some RBOs were observed to have more stable sources of funding, but still needed additional funds for special projects or initiatives. The core funding of ORSANCO, for example, was observed to be stable from year-to-year and additional funding was procured from project-specific grants. Federal appropriations were said to be rather large for some basins, such as the Chesapeake Bay or Great Lakes, compared to other basins, such as the Ohio, Susquehanna, Delaware, or Potomac river basins. The ORSANCO representative hoped to obtain more sustainable source of funds from the federal government. State appropriations, said to be a generally stable source of funding, constituted the majority of the SRBC funding. Additional SRBC funds were said to be sourced from grants and project review fees. It was observed that project review fees were not guaranteed to be stable as they rely on development occurring. The DRBC had access to member dues and project review fees, but at times DRBC staff was said to try to source additional funds by advocating for appropriations in state and federal legislatures (DRBC, phone interview, Damien Brychcy, March 2012).

The lack of taxing authority or a "real charging authority" was cited as an organizational weakness by the DRBC and SRBC representatives . It was thought that

state legislatures may be reluctant to provide RBOs self-funding authority because the legislatures "want to have a say on what goes on" (SRBC, phone interview, Kelly Robinson, March 2012).

River basin organizations are said to attract outside funding that can increase the total investments into the basin. The ICPRB was observed to procure money from other sources to help the states, in essence "multiplying their dollars" (ICPRB, phone interview, Claire Ellis, March 2012). This allowed them to "justify" or "promote" themselves to the states, which helped because "some of the jurisdictions don't see the need [for the ICPRB] from time to time" (Ibid).

**Technical capacity:** Based on the organizational literature we found staff size was commensurate with RBO functions, with the smallest staff of seven found in an RBO focused on fostering communication and the largest staff of 66 found in an RBO responsible for a substantial amount of regulatory review. Based on both organizational literature and interviews we found technically oriented committees comprised of commissioners, staff, agencies, water users, or other stakeholders also bolstered RBO technical capacity (Table 3.8).

Numerous RBO representatives cited the technical capacity provided by the staff as a key organizational strength in the interviews. River basin organization representatives described the staff in the highest regard with phrases such as a "really strong technical background" (DRBC, phone interview, Damien Brychcy, March 2012) or a "reputation for technical excellence" (ICPRB, phone interview, Claire Ellis, March 2012).

Staff size, technical expertise, and impartiality were the top three strengths RBO representatives cited when discussing their staff. While the DRBC staff was sizeable compared to some RBOs, it is still smaller than that of state water agencies, which was said to allow it to be more flexible in order to finish projects more quickly if that is what a state needed. The SRBC had the largest staff of interviewed RBOs, which was said to nearly double from 30-35 to 60-65 in order to keep up with the regulatory demands caused by a rapidly expanding natural gas industry. In contrast, the UMRBA was said to have only four permanent staff and three temporary staff for specific projects. Contractors were said to be used sometimes when technical expertise needed. No initiatives driven by the staff were said to occur; rather, the states chose priorities and UMRBA found the money needed to pursue those initiatives.

The DRBC staff were perceived to have some technical expertise that the state water agencies did not have. The ICPRB staff was perceived to be "not political", but rather composed of scientists and engineers, and can "do sound science in support of what the states need" (ICPRB, phone interview, Claire Ellis, March 2012). Trust in ICPRB technical capacity was observed to go beyond the states. The utilities that are parties to the Water Supply Coordination Agreement were said to be able to override the ICPRB's water supply decisions made during droughts, but that had only happened on one occasion in 40 years. "The water utilities have faith, have trust, in our process, in our support, and in our decision making, to get them through a drought, to get them through a tight period of time" (ICPRB, phone interview, Claire Ellis, March 2012).

A large technical capacity was perceived to allow RBOs to pursue organizational goals related to water quantity or quality, which was commonly used to assist member

states. The ICPRB was said to provide technical assistance to the states for TMDL modeling, and assessments to support their determinations of water quality impairments. The SRBC, DRBC, and ORSANCO were also said to assist states with the development of TMDLs. The ORSANCO was said to help states draft their biennial assessments required by the Clean Water Act for the mainstem Ohio River.

## Discussion

Results from the biophysical, interviews, and organizational data provide complementary findings on RBO effectiveness. The 7-day low flows study basins showed positive trends, while all but one control basin showed negative trends. This, combined with the fact that the precipitation model was quite unlikely compared to RBO presence for 7-day low flows, is suggestive of RBO effectiveness. Of the study basins, low flows improved the most in the Susquehanna and Delaware River Basins. Both have RBOs with regulatory authority pertaining to water withdrawals. The gains in the Susquehanna River Basin may in part be attributed to the many policies and programs targeting low flows, including project review, permitting, and reservoir storage for low flows augmentation. Additionally, the SRBC has consumptive use mitigation requirements, where certain users must pay a fee or augment water to offset consumptive use, and a low flow protection policy, where certain users must cease withdrawals when flows fall below a certain threshold (Zhang & Balay, 2014).

The Merrimack River Basin had the largest improvements in low flows, making it an outlier as compared the other control basins with worsening low flows. Robust jurisdictional water management offers an explanation. New Hampshire's Rivers

Management and Protection Program Act (RSA 483), established in 1988, protects designated rivers by ensuring "in-stream flows are maintained" through measures specific to river classification (RSA 483). The instream flows established by this program are binding as they "shall be enforced" through water management plans and permits compliant with the plans (RSA 483:9-c). Both the Upper and Lower Merrimack River became designated rivers in 1990 (New Hampshire Department of Environmental Services, 2017). In addition to the protections afforded by the Rivers Management and Protection Program, the Souhegan River, a tributary of the Merrimack, was one of two rivers in the Instream Flow Pilot Program (Watershed Management Bureau, 2015). The Merrimack River Watershed Assessment study is a collaboration between the U.S. Army Corps of Engineers, a bi-state community coalition, and state agencies that aims to achieve "flow conditions to support uses such as drinking water supply, recreation, fisheries, and aquatic life support" through a watershed management plan (CDM, 2006). While the state of Massachusetts does not have its own instream flows protections, the combination of New Hampshire's Rivers Management and Protection Program and the collaborative Merrimack River Watershed Assessment Study seem to be protecting low flows. Robust jurisdictional management does appear to provide another path towards sustainable low flows in interstate river basins, especially if enough of a basin is in one state; however, it is still the exception rather than the rule, which is illustrated by decreasing low flows in all other control basins in this study. Moreover, it is unclear if there are examples of effective jurisdictional low flows management in conflict-prone river basins where cooperative solutions are not likely.

Nitrogen flux is decreasing in all basins except for those in the Midwest. The decreases were greatest in the study basins. While the Upper Mississippi River Basin does have increasing nitrogen flux, unlike the other study basins, its rate was considerably less than that of the Midwestern control basin with increasing nitrogen flux, Missouri River Basin. Technical capacity may play a role in the nitrogen flux patterns seen. With a very small staff as well as a need to hire contractors for certain technical tasks, the UMRBA had a limited technical capacity and it was the only study basin with increasing nitrogen flux. This contrasts with the four other study basins that all had a large technical capacity for assessing and/or managing nutrients. Regulatory authority, specifically the ability to implement policies, may also play a role in nutrient management. The Upper Mississippi River Basin Association interview suggested that it may be more effective if it had implementing authority. The DRBC, SRBC, and ORSANCO all can implement policies. The ICPRB, in a basin with nitrogen flux declines at least twice that of the other basins, did not have implementation authority but instead relied on its technical capacity and trust developed with state agencies to promote implementation of its policies. As the ICPRB is able to achieve such large reductions in nitrogen flux without regulatory authority, RBO regulatory authority may not have the same effect for nutrient management as it does for low flows. The ICPRB did not have regulatory authority, but had higher declines in nutrients than the ORSANCO, which did have regulatory authority. More data points would be needed to elicit the role of RBO regulatory authority for transboundary nutrient reduction.

Federal regulations offer an alternative explanation for the nitrogen flux patterns seen. The federal 1990 Clean Air Act Amendments are responsible for reduced

atmospheric nitrogen deposition and consequently reduced riverine nitrate concentrations (Eshleman & Sabo, 2016; Gabriel, Knightes, Dennis, & Cooter, 2014). Reductions are heterogeneous (Mast, 2013) and can be masked by agricultural nitrate pollution (Gabriel, Knightes, Cooter, & Dennis, 2018; Gabriel et al., 2014; Lindsey, Berndt, Katz, Ardis, & Skach, 2009), and thus may be confounding the effects of RBO presence and precipitation. The Savannah River Basin has total nitrogen reductions comparable to three of the study basins. There are TMDLs for the Savannah River and Savannah Harbor. While the TMDLs do not include nutrients directly, they influence total nitrogen because the dissolved oxygen TMDL for Savannah Harbor limits nitrogenous oxygen demand (The Georgia Department of Natural Resources, 2007), and the sediment TMDL for the Savannah River limits agricultural sources of sediment (US EPA Region 4, 2005). The effect of nutrient and nutrient-related TMDLs is likely an important factor in declining total nitrogen trends. Federal water quality regulations may even the playing field for nutrient management in transboundary river basins. There are no federal water quantity regulations, but rather this is left to the states.

The biophysical results weakly suggest that RBOs may be effective in managing for low flows. The biophysical results do not provide statistical support for RBO effectiveness in managing nutrients but do suggest further lines of inquiry. The interview results, on the other hand, help to explain the factors promoting and hindering the achievement of minimal low flows and nutrient reduction.

Regulatory authority is generally pointed to as an organizational strength in the interviews. Those RBOs with regulatory authority more effectively managed low flows than those without it. While both the SRBC and DRBC are authorized for permit review,

the SRBC has the authority to regulate uses for more purposes, such as consumptive use mitigation. This additional authority could be why the SRBC is the most effective in managing low flows. The inability to regulate all water uses was found to hinder RBO effectiveness in other basins. In the Elbe River Basin (Dombrowsky, 2008), the effectiveness of water quality management is low when it is contingent upon behavioral changes of those not regulated; a similar situation to agricultural nutrient management in the Upper Mississippi River Basin, which requires the cooperation of the agricultural community not under the jurisdiction of the UMRBA. The ICPRB does not have regulatory authority and of the RBOs that manage low flows is the least effective. Interestingly, a lack of regulatory authority does not inhibit the ICPRB's effectiveness in managing nutrients, implying other factors interact with regulatory authority in promoting effectiveness. The importance of regulatory authority was most clear for low flows management but mixed for nutrient management, and additionally, was mixed in the interviews; a result that is consistent with the debate about the importance of regulatory authority in the literature (Bohmelt & Pilster, 2010; Kenney, 1994; McLaughlin Mitchell & Zawahri, 2015; Tir & Stinnett, 2011).

The interview results point to a lack of funding adequacy and stability as a challenge to overcome. This is seen most clearly in the difference between effectiveness managing low flows and the SRBC's large and relatively stable budget compared to the ICPRB's need to chase funding. The contrast between ICPRB's financial capacity and that of the UMRBA and their ability to manage nutrients further supports the importance of financial capacity in explaining RBO effectiveness. It is no surprise that nearly all the interviewees discussed the importance of adequate finances, based on the widespread

discussion of its importance in the literature (Blomquist, Dinar, et al., 2005; Hooper, 2006; Kauffman, 2015; Raadgever et al., 2008). Just as is predicted in the literature (Dinar et al., 2016; Meijerink & Huitema, 2017), numerous RBOs discussed the propensity of the state and federal government to withhold financial and other resources. This withholding of financial resources is especially troublesome since financial capacity is so important for RBO effectiveness.

The importance of technical capacity is a recurrent theme in the interviews. Representatives of the RBOs almost universally discuss their staff as a strength or lack thereof as a weakness. A striking example of the importance of technical capacity can be seen in the case of the ICPRB. While this RBO doesn't have regulatory authority, it is the most effective in managing nutrients. This could be in part explained by the good reputation the ICPRB has developed with the states through their technical expertise and perceived impartiality. While the states and water utilities don't have to implement the ICPRB's policies, they most often do. In contrast the UMRBA appears to be hindered by its lack of technical capacity. It has not effectively managed nutrients and has a staff of only seven, which is quite small for such a large basin.

In sum, the limited biophysical response to RBO presence contradicts the literature that predicts RBOs will be better suited to tackle interstate water management (Dellapenna, 2005; Hooper, 2006; Huffman, 2009; Mandarano et al., 2008), but this may be explained by factors raised in the interviews such as RBOs lacking funding, staff, or regulatory authority. Nevertheless, given all the natural variability among basins and the idiosyncrasies of different RBOs and political systems, we might expect the signal of the RBO to be swamped by the noise, especially in a small dataset. The fact that we see even

a small effect suggests that RBOs may provide biophysical benefits in transboundary river basins, particularly for low flows, but we would need more cases to establish stronger and more nuanced relationships.

The primary weakness in this study, inadequate sample size to account for all the major confounding variables, is due to the low number of RBOs meeting the study criteria and a scarcity of long-term continuous nutrient data. In some basins reduced atmospheric nitrogen deposition can be a larger driver than best management practices in reducing stream nitrates (Eshleman & Sabo, 2016). This makes attributing total nitrogen reductions to RBOs or precipitation difficult. A more complete effectiveness test requires a counterfactual, i.e., what would have happened if the RBO were never created (Dombrowsky, 2008; Hovi, Sprinz, & Underal, 2003). A basin with increasing nutrients, such as the Upper Mississippi River Basin, could have even greater nutrient increases if it weren't for UMRBA's actions. When lacking a no regime counterfactual it is challenging to assess organizational effectiveness. Unfortunately, the institutional goals are too broad and the data too sparse for a no regime counterfactual calculation. Assessing institutional effectiveness in achieving environmental quality objectives runs the risk of natural variation and exogenous factors masking institutional performance (Mitchell, 2008).

This study presents a range of future inquiries to pursue. It would be fruitful to explore how cooperation arises in transboundary river basins without RBOs, such as the Merrimack, and to compare the effectiveness of low flows or nutrient management in these basins to those with RBOs. Another line of inquiry would be to look at conflict prone areas for differences in effectiveness between RBO, state, and federally dominated low flows or nutrient management. It would be particularly interesting to explore the role

of coordination and cooperation mechanisms in determining the effectiveness of managing low flows or nutrients in these basins. Creative means to account for major confounding variables, such as TMDLs and the Clean Air Act, should help to elucidate RBO effects on nutrient management. These inquiries would be facilitated by enlarging the sample size through using streamgages throughout basins, incorporating international basins, or selecting water quality indicators with more data, such as dissolved oxygen. Expanding the sample size through these means would introduce other confounding variables, so would have to be done carefully. With a large sample size, the effect of institutional design features, such as regulatory authority and technical capacity, could be further explored, which would help with making specific recommendations for the design of new RBOs.

## Conclusion

Through this study we aimed to determine if five transboundary RBOs in the United States are effective in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity. We did this through evaluating effectiveness in two ways, first by how well these transboundary RBOs manage low flows and nutrients, and second by their regulatory authority, financial capacity, and technical capacity. This study had modest biophysical results, with more strength of evidence for low flows than for total nitrogen flux. The interviews revealed other benefits not captured by biophysical indicators that may help to explain why RBOs are pursued even if dramatic biophysical results aren't realized. In whole this study is not a smoking

gun needed to justify creating new RBOs across the nation. But it does provide further evidence that RBOs do have positive effects, biophysical and other, in transboundary river basins. The low flows results do suggest a benefit in pursuing RBOs in water-scarce transboundary river basins. As pressures on our water resources rise, it becomes ever more essential to pursue innovative governance mechanisms, such as transboundary RBOs or robust jurisdictional pollution and low-flow control regulations, in order to ensure long term viability for society, economy, and the environment.

## Tables and figures

**Table 3.1. Basins for 7-day low flows indicator**

| Basin | Area ($mi^2$) | RBO | Details |
|---|---|---|---|
| Delaware | 14119 | (1) Delaware River Basin Commission | (1) Federal-interstate agency with flow management program that regulates certain withdrawals and diversions |
| Potomac | 14700 | (2) Interstate Commission on the Potomac River Basin | (2) Interstate commission with cooperative water supply operations during low flows |
| Susquehanna | 27500 | (3) Susquehanna River Basin Commission | (3) Federal-interstate agency with Low Flow Protection Policy and that regulates large withdrawals and most consumptive uses |
| | | *Control Basins* | |
| ACF | 20355 | (4) ACF Stakeholders, (5) ACF Basin Commission | (4) No low flows program, no authorities, 57) Defunct |
| ACT | 20950 | (6) ACT Basin Commission | (6) Defunct |
| Connecticut | 11250 | (7) Connecticut River Conservancy, (8) Connecticut River Joint Commission, (9) Connecticut River Gateway Commission, (10) Interstate Environmental Commission | (7) Advocacy group with no low flows program, (8) Doesn't include all states and advisory group with no authority, (9) No low flows program and in lower basin only, (02) No low flows program and in lower basin only |
| Hudson | 14000 | (11) Hudson River Watershed Alliance, (12) Hudson River Estuary Management Advisory Committee, (13) Hudson River-Black River Regulating District, (14) Interstate Environmental Commission | (11) Alliance of NGOs with no authority, (12) Advisory group focused on estuary, (13) Group that captures and stores water in reservoirs to reduce floods and augment flows but only for upper part of basin, (14) No low flows program and in lower basin only |
| Merrimack | 5010 | (15) Merrimack River Watershed Council, (16) Merrimack River Valley Flood Control Commission, (17) Upper Merrimack River Local Advisory Committee, (18) Lower Merrimack River Local Advisory Committee | (15) Advocacy group with no authority and no low flows program, (16) Appears to be defunct, (17) (18) Advisory groups with no authority only focused on parts of the basin |

| | | | |
|---|---|---|---|
| Pearl | 8760 | None | |
| Pee Dee | 7221 | (19) Yadkin/Pee Dee River Basin Association | (19) Advocacy group with no low flows program |
| Roanoke | 9680 | (20) Roanoke River Bi-State Commission, (21) Roanoke River Basin Association | (20) Forum for communication and cooperation, no low flows program, (21) Advocacy and advisory group, no low flows program |
| Savannah | 9850 | (22) Savannah River Basin Advisory Council, (23) Savannah River Basin Partnership, (24) Savannah River Committee | (22) Advisory group only in part of basin, (23) Partnership between state agencies on specific issues, no low flows program, (24) Forum for communication, may be defunct |

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(1) https://www.state.nj.us/drbc/about/
(2) https://www.potomacriver.org/about-us/, https://www.potomacriver.org/focus-areas/water-resources-and-drinking-water/cooperative-water-supply-operations-on-the-potomac/
(3) https://www.srbc.net/about/about-us/
(4) http://acfstakeholders.org/#
(5) https://www.lrpa-usa.com/files/pdfs/articles/Compacts-Failure.pdf
(6) https://www.lrpa-usa.com/files/pdfs/articles/Compacts-Failure.pdf
(7) https://www.ctriver.org/about-us/
(8) http://www.crjc.org/about-crjc/
(9) http://ctrivergateway.org/mission/
(10) http://www.iec-nynjct.org/about.who.htm#
(11) http://www.hudsonwatershed.org/about-us.html
(12) https://www.dec.ny.gov/about/46924.html
(13) http://www.hrbrrd.com
(14) http://www.iec-nynjct.org/about.who.htm#
(15) http://www.merrimack.org/web/restoring-merrimacks-fish/
(16) https://appointments.state.ma.us/BoardDetail.aspx?brdid=160238
(17) https://www.merrimackriver.org/about/
(18) http://www.nashuarpc.org/about/related-organizations/lmrlac/
(19) https://www.yadkinpeedee.org/about-the-association
(20) https://law.lis.virginia.gov/vacode/title62.1/chapter5.5/section62.1-69.37/
(21) https://rrba.org/about/what/

(22) https://sites.google.com/site/savannahriverbac/
(23) http://www.savannahriverbasin.org/index.html
(24) http://savannahriverbasin.org/Documents/committee.html

**Table 3.2. Basins for nitrogen flux indicator**

| Basin | Area ($mi^2$) | RBO | Details |
|---|---|---|---|
| Delaware | 14119 | (1) Delaware River Basin Commission | (1) Federal-interstate agency that writes water quality regulations that are enforced by state agencies |
| Ohio | 189422 | (2) Ohio River Valley Sanitation Commission | (2) Interstate commission that writes water quality standards and tracks some dischargers |
| Potomac | 14700 | (3) Interstate Commission on the Potomac River Basin | (3) Interstate commission that assists state and federal agencies with writing TMDLs and water quality criteria |
| Susquehanna | 27500 | (4) Susquehanna River Basin Commission | (4) Federal-interstate agency that assists state and federal agencies with writing TMDLs and looks for water quality impacts while regulating water diversions into basin |
| Upper Mississippi | 190000 | (5) Upper Mississippi River Basin Association | (5) Association of states and non-voting federal agencies that provides forum for communication, coordination, and cooperation for agencies with water quality regulatory roles |
| | | *Control Basins* | |
| ACT | 20950 | (6) ACT Basin Commission | (6) Defunct |
| Missouri | 529350 | (7) Missouri River Association of States and Tribes, (8) Missouri River Recovery Implementation Committee | (7) Defunct, (8) Forum for communication to advise federal restoration program, no water quality regulatory role |
| Savannah | 9850 | (9) Savannah River Basin Advisory Council, (10) Savannah River Basin Partnership, (11) Savannah River Committee | (9) Advisory group with no regulatory role, in part of basin only, (10) Partnership between state agencies for communication and cooperation, jointly developed TMDL for harbor, (11) Forum for communication, may be defunct |

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(1) https://www.srbc.net/regulatory/regulations/
(2) http://www.orsanco.org/programs/pollution-control-standards/, http://www.orsanco.org/programs/
(3) https://www.potomacriver.org/focus-areas/water-quality/
(4) https://www.state.nj.us/drbc/programs/quality/, https://www.state.nj.us/drbc/library/documents/WQregs.pdf, https://www.srbc.net/our-work/fact-sheets/docs/tmdls-in-the-srb-.pdf, https://www.srbc.net/regulatory/regulations/, https://www.srbc.net/regulatory/policies-guidance/docs/use-lesser-quality-waters-resolution-2012-01.pdf ; https://www.srbc.net/about/about-us/
(5) http://www.umrba.org/wq.htm
(6) https://www.lrpa-usa.com/files/pdfs/articles/Compacts-Failure.pdf
(7) website no longer online
(8) http://www.mrric.org
(9) https://sites.google.com/site/savannahriverbac/
(10) http://www.savannahriverbasin.org/index.html
(11) http://savannahriverbasin.org/Documents/committee.html

**Table 3.3. Interview details**

| River basin organization | Interviewee position |
|---|---|
| Delaware River Basin Commission | Executive director |
| Interstate Commission on the Potomac River Basin | Executive director, director of program operations, director of CO OP operations |
| Ohio River Valley Water Sanitation Commission | Project coordinator |
| Susquehanna River Basin Commission | General counsel |
| Upper Mississippi River Basin Association | Executive director |

**Table 3.4. Study basins 7-day low flow trends**

| Basin | Low flow trend (%) | Study or control basin? |
|---|---|---|
| Susquehanna | 0.35 | study |
| Delaware | 0.25 | study |
| Potomac | 0.03 | study |
| Alabama-Coosa-Tallapoosa | -1.79 | control |
| Pee Dee | -1.41 | control |
| Apalachicola-Chattahoochee-Flint | -1.11 | control |
| Pearl | -1.00 | control |
| Roanoke | -0.72 | control |
| Savannah | -0.59 | control |
| Hudson | -0.18 | control |
| Connecticut | -0.06 | control |
| Merrimack | 0.46 | control |

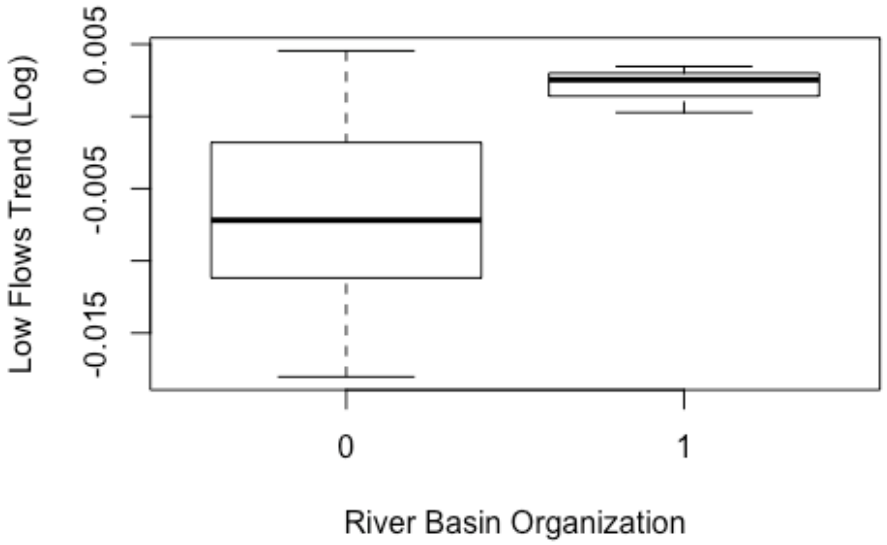


**Figure 3.1. Linear model for 7-day low flow trends and river basin organization presence**

**Table 3.5. AICc weights for 7-day low flows models**

| Model | K | AICc | Delta_AICc | AICcWt | Cum.Wt | LL |
|---|---|---|---|---|---|---|
| flows~RBO | 3 | -80.41 | 0 | 0.5 | 0.5 | 44.71 |
| Null model | 2 | -79.44 | 0.97 | 0.31 | 0.81 | 42.39 |
| flows~precip | 3 | -77.75 | 2.66 | 0.13 | 0.94 | 43.38 |
| flows~RBO+precip | 4 | -76.2 | 4.22 | 0.06 | 1 | 44.95 |

**Table 3.6. Study basins nitrogen flux trends**

| Basin | Nitrogen flux trend (%) | Study or control? |
|---|---|---|
| Potomac | -1.41 | study |
| Delaware | -0.64 | study |
| Ohio | -0.58 | study |
| Susquehanna | -0.48 | study |
| Upper Mississippi | 0.15 | study |
| Missouri | 1.25 | control |
| ACT | -0.27 | control |
| Savannah | -0.5 | control |

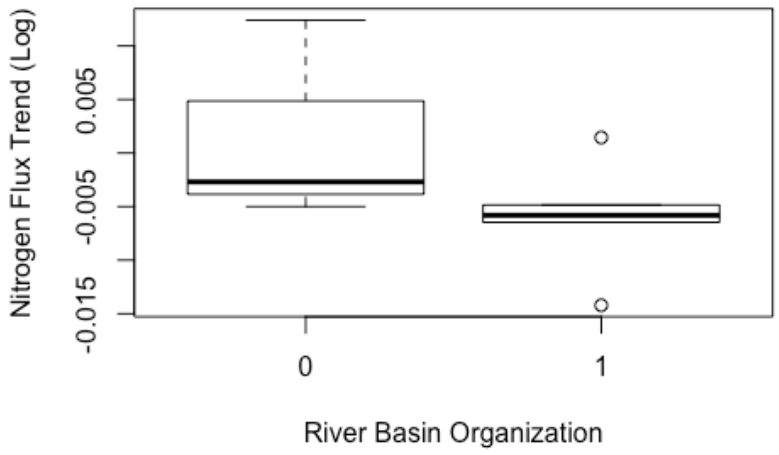


**Figure 3.2. Linear model for nitrogen flux trends and river basin organization presence**

**Table 3.7. AICc weights for nitrogen flux trends models**

| Model | K | AICc | Delta_AICc | AICcWt | Cum.Wt | LL |
|---|---|---|---|---|---|---|
| N flux ~ precipitation | 3 | -50.04 | 0 | 0.45 | 0.45 | 31.02 |
| Null model | 2 | -49.92 | 0.11 | 0.42 | 0.87 | 28.16 |
| N flux ~ river basin organization | 3 | -46.74 | 3.3 | 0.09 | 0.96 | 29.37 |
| N flux ~ precipitation + river basin organization | 4 | -45.21 | 4.82 | 0.04 | 1 | 33.27 |

**Table 3.8. River basin organization institutional features**

| RBO | Members | Functions | Funding | Technical capacity | Regulatory authority |
|---|---|---|---|---|---|
| Delaware River Basin Commission (1961 compact) | Governors and their alternates, presidential appointees (USACE). 5 members. 4 states and federal government. | Plans, policies, and projects for basin water resources. Develop and advocate for uniform policies. Project review. | Primarily member dues and fees for services (project review), but also grants from the EPA and other sources. $6.3 million for FY 2018. | Staff of around 30 (over 5 subject areas and directorate) and advisory committees (currently 7). | Enacts and enforces rules and regulations to implement compact, for projects and facilities, and basin plan. Relies on reviews by state agencies. Alleges non-compliance in courts. Civil penalties or settlement agreements for non-compliance. |
| Interstate Commission on the Potomac River Basin (1948 compact) | Legislators or their appointees, presidential appointees, Mayor of DC or appointees. 18 members. 4 states, DC, federal government | Evaluations and reports for water quality and aquatic life. Recommends management actions and facilitates cooperation. Technical lead for water supply cooperative. | Mostly grants for specific projects. Small portion member dues. Water supply cooperative funded by water utilities. $2.4 million in 2016, no new budget public. | Staff of 19 (currently) over 4 subject areas and administration, Section for Water Supply Operations, and committees. | No regulatory authority. The CO OP section monitors for compliance with Water Supply Coordination Agreement and coordinated water supply operations manual during droughts. |
| Ohio River Valley Water Sanitation Commission (1948 compact) | Governors or their appointees, presidential appointees. 24 members. 8 states and federal government. | Discharge standards, biological assessments, monitoring and studies, emergency response for spills and discharges, promotes public participation. | Member contributions and federal grants. Past private foundation support (water resources management committee). $3.5 million in FY 2017, | Staff of 20 (currently), 19 committees including technical committee. | Establishes rules, regulations, and standards to implement compact. All members must comply. Issues orders for non-compliance and files action in court to enforce order. |

| | | | | | |
|---|---|---|---|---|---|
| | | | no new budget public. | | |
| Susquehanna River Basin Commission (1970 compact) | Governors or their appointees, presidential appointees (USACE). 4 members. 3 states and federal government. | Comprehensive plans and uniform policies. Compliance and enforcement, monitoring, project review, and water supply allocation. | Permit review fees, member contributions, and grants. Mostly permit review fees from natural gas companies. $7.9 million for FY 2018. | Staff of 66 (currently), over 6 subject areas and 5 committees. | Enacts and enforces rules and regulations to implement compact and basin plan. Investigates and determines compliance with rules, regulations, or water quality standards. Files action in court in case of non-compliance. Civil penalties for non-compliance. Encourages uniform enforcement programs by state water quality agencies. |
| Upper Mississippi River Basin Association (1981 joint resolution of governors) | Governors' appointees (state agencies); non-voting federal advisory committee. 14 state members but each of 5 states gets vote. 10 represent-atives from 6 federal agencies. | Facilitation and cooperation between states and federal government. Exchange information. Comments on projects, policies, and programs. Develop agreements. Consensus building and develop regional voice. | Member dues and project specific funding agreements with federal agencies, as well as project specific support from foundations. Budget not public. | Staff of 7 (currently) and 6 committees. | No regulatory authority. |

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# CHAPTER 4

# WHERE THE RUBBER MEETS THE ROAD: THE EFFECTIVENESS OF ENVIRONMENTAL FLOWS IMPLEMENTATION IN THE SUSQUEHANNA RIVER BASIN

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Shannon Bonney, Seth Wenger, Laura German, Laurie Fowler, Lizzie King

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## Abstract

Freshwater biodiversity and water security are predicted to continue declining in the face of increasing water consumption, water pollution, and global change. Environmental flows offer an avenue to stem the widespread declines seen in aquatic biodiversity and enhance the ecosystem services on which humans depend. There is a need to critically assess environmental flows implementation and we do so through an evaluation of the Susquehanna River Basin. We look at effectiveness in two ways, ecologically in terms of altering basin low flows and procedurally in terms of policies and programs to implement recommendations. We found the Susquehanna River Basin Commission is making a significant improvement in low flows, some progress towards the seasonal flows, and limited progress towards high flow. Our results show a concerted effort between all institutions with major control over the flow regime is needed to fully implement environmental flow recommendations.


## Introduction

An estimated two-thirds of freshwater mussels, half of crayfish, and 40% of freshwater fishes and amphibians are at risk in the United States (Master, Flack, & Stein, 1998). These declines can be attributed, in large part, to insufficient instream flows and altered hydrologic regimes (Bunn & Arthington, 2002; Dudgeon et al., 2006). Freshwater biodiversity and water security are predicted to continue declining in the face of increasing water consumption, water pollution, and global change (Vorosmarty et al., 2010; Xenopoulos et al., 2005). Environmental flow are water left instream to benefit aquatic and riparian ecosystems as well as ecosystem services that consist of the

magnitude, frequency, duration, rate of change, and timing of ecologically relevant flow regime components (Richter & Thomas, 2007) (Acreman et al., 2014; Poff et al., 2010; Yarnell et al., 2015). Environmental flows offer an avenue to stem the widespread declines seen in aquatic biodiversity and enhance the ecosystem services on which humans depend (Arthington, 2012; Gopal, 2016).

The Ecological Limits of Hydrologic Alteration ("ELOHA") is a holistic framework to assess ecological response to hydrologic alteration and develop environmental flow recommendations (Figure 4.1) (McManamay, Orth, Dolloff, & Mathews, 2013; Poff et al., 2010) that 19 river scientists, convened by The Nature Conservancy, developed in 2010 (Arthington, 2012). The ELOHA framework entails building a hydrologic foundation of baseline and developed hydrographs throughout a basin (Caldwell et al., 2015), classifying stream types (Mackay, Arthington, & James, 2014), and describing flow-ecology relationships to predict changes in an ecological indicator in response to changes in hydrology (Davies et al., 2013). The social process of the ELOHA framework relies upon the flow-ecology relationships and societally desired conditions for negotiating tradeoffs between ecosystem and human water demands (Martin, Labadie, & Poff, 2015). The ELOHA framework is designed for application to large regions because recommendations can be for stream types rather than for individual reaches (Poff et al., 2010), making it ideal for transboundary river basins.

While the ELOHA framework is being used to develop environmental flow recommendations in a growing number of locations, full application of the ELOHA process has been primarily in small basins and watersheds (Swirepik et al., 2016). There are few examples where environmental flow recommendations are implemented, and

even fewer examples where implementation effectiveness is assessed (Le Quesne, Kendy, & Weston, 2010). For example, the Interstate Commission on the Potomac River Basin, in conjunction with The Nature Conservancy and the U.S. Army Corps of Engineers, conducted a sophisticated environmental flows study in the Middle Potomac (USACE, TNC, & ICPRB, 2013). However, neither the Interstate Commission on the Potomac River Basin nor its member states have adopted the array of mechanisms necessary to implement these environmental flow recommendations. The Susquehanna River Basin is an uncommon example of a large river basin where the ELOHA framework was applied and recommendations implemented.

The Susquehanna River Basin, in the northeastern United States, is 27,510 square miles and is comprised of portions of Pennsylvania, New York, and Maryland (Figure 4.2) (Zhenxing Zhang & Balay, 2014). The Susquehanna River Basin Commission ("SRBC") is a federal-interstate compact commission established by the Susquehanna River Basin Compact in 1970 to "enhance public welfare through comprehensive planning, water supply allocation, and management of the water resources of the Susquehanna River Basin" (Susquehanna River Basin Commission, 2018c).

In 2010, the SRBC partnered with The Nature Conservancy (TNC) and the U.S. Army Corps of Engineers (USACE) to develop ecosystem flow, i.e., environmental flow, recommendations for the Susquehanna River Basin using the ELOHA framework (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). The partners used expert opinion and published literature to develop hypotheses about ecosystem responses to flow alteration, which provide the basis for the recommendations (DePhilip & Moberg, 2010). The environmental flow recommendations consist of ten

flow statistics that characterize low, seasonal, and high flows to be maintained on an annual, interannual, monthly, or seasonal basis (Table 4.1) (DePhilip & Moberg, 2010). The environmental flow recommendations are written as an allowable diversion from reference conditions, rather than a streamflow (DePhilip & Moberg, 2010). The partners used minimally altered index gauges to characterize flow regimes and a pre-alteration period of record as a baseline to compare water withdrawal scenarios (DePhilip & Moberg, 2010). In ungauged reaches where reference gauges were not available, the SRBC developed regression equations to estimate monthly percent exceedance flow, baseflow, mean flow, and low flow (Balay et al., 2016). Phase two of the study proposed to further explore implementation strategies but has not been funded; nevertheless, the SRBC has begun implementation (John Balay, personal communication, 2/2/2018).

The SRBC uses a variety of tools to implement the environmental flow recommendations(Susquehanna River Basin Commission, 2012b). The 2012 Low Flow Protection Policy (LFPP) and Technical Guidance set low flow thresholds that vary depending on drainage area and on a monthly basis (Figure 4.3) (Susquehanna River Basin Commission, 2012a, 2012b). Once flows fall below the low flow thresholds, the regulated water community (i.e., water users that meet or exceed minimum thresholds for withdrawals, diversions, or consumptive water uses, and are not grandfathered uses) employs passby flows, which entail temporarily ceasing water withdrawals (Zhenxing Zhang & Balay, 2014). The LFPP sets the size of *de minimus* withdrawals, which are withdrawals that are so small that they are not required to meet the LFPP. The SRBC accounts for the cumulative impacts of *de minimus* withdrawals in its determination of water availability, which in turn influences the permit review process (Balay et al., 2016).

The SRBC may choose to impose more rigorous standards for exceptional quality waters or encourage the use of impaired waters (e.g., abandoned mine discharge) by setting the threshold higher than the LFPP prescribes in other areas (Susquehanna River Basin Commission, 2012b).

Significant amounts of time and money are being invested in creating environmental flow recommendations using the ELOHA process (Kendy, Apse, & Blann, 2012; Le Quesne et al., 2010). Moreover, in many river basins providing water needed for environmental flows requires tradeoffs with other social and economic water uses (Martin, Powell, Webb., Nichols, & Poff, 2017; Rheinheimer, Liu, & Guo, 2016). There is a need to critically assess the outcomes of the ELOHA process and environmental flows implementation to ensure these investments and tradeoffs result in successful ecological outcomes, i.e., implementation results in a measurable change in flows that is predicted to benefit ecosystems and that the flow changes do in fact benefit ecosystems (Pahl-Wostl et al., 2013). We help to fill this gap by addressing the first condition of success: implementation results in measurable changes to flows that are predicted to benefit ecosystems. We do so through an evaluation of the effectiveness of the SRBC in implementing environmental flows in the Susquehanna River Basin. We look at effectiveness in two ways, ecologically in terms of altering basin low flows and procedurally in terms of policies and programs to implement recommendations. Specifically, we ask: has the Low Flow Protection Policy made a significant difference in basin low flows? Does the SRBC have sufficient policies and programs to implement the low, seasonal, and high flow components of the environmental flow recommendations for the Susquehanna River Basin? By looking at both changes in flows and in policies and

programs to implement recommendations, we hope to gain a clearer picture of effectiveness.

In the following literature review we discuss the importance of managing for low, seasonal, and high flows. We also discuss implementation strategies that have proved effective in other basins.

## Literature review

During dry conditions, low flows help provide refuge for aquatic biota, dilute wastewater, and help sustain water temperatures as well as dissolved oxygen (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). Seasonal flows are the typical flows for a given month or season characteristic of the reference period that describe variation between wet and dry seasons as well as between wet and dry years (DePhilip & Moberg, 2010). River regulation reduces the variability of flows between seasons (Graf, 2006). River regulation alters the seasonal flow regime by reducing flows during wet conditions and releasing them for use during dry conditions (Richter & Thomas, 2007) and in certain basins during the autumn drawdown period, to make space for storing spring rains, which in these basins typically overlaps with the time of year that flows are naturally the lowest (Watts, Richter, Opperman, & Bowmer, 2011). Seasonal flows are important because they provide persistent habitats and ensure longitudinal connectivity between habitats (Kendy et al., 2012; Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). High flows provide cues for spawning and migration, shape the channel and floodplain, connect the stream and floodplain, introduce coarse woody debris, and flush sediments (Poff et al., 1997). While

environmental flows assessments recommend multiple components of the flow regime, implementation often focuses on minimum flows or flows for specific species (Hirji & Davis, 2009b; Pahl-Wostl et al., 2013). It is, however, essential to restore all components of the flow regime in order to derive the full host of ecosystem benefits to be gained through environmental flows (Le Quesne et al., 2010).

Having mechanisms for codifying environmental flows in laws and regulations is a basic enabling condition for successful implementation (Harwood, Tickner, Richter, Locke, & Johnson, 2018). Policies to enact these laws and regulations are also necessary (Horne, Acreman, O'Donnell, & Arthington, 2017). Ensuring a resource regime has a high relative extent, i.e., that it manages a high proportion of everything that is being used, helps to reduce overexploitation of a resource (Gerber, Knoepfel, Nahrath, & Varone, 2009). Water permitting helps to distinguish legitimate from non-legitimate users and uses and thusly defines the boundaries of the resource, which is a key feature of effective management of common-pool resources (Cox, Arnold, & Tomas, 2010; Ostrom, 1990).

Regulatory mechanisms for implementation are numerous but can be categorized into the broad categories of limiting withdrawals and providing water rights for the environment (Harwood et al., 2018). It is seen as more cost effective and easier to limit withdrawals than to try to reallocate water for the environment after basin resources are fully allocation (Le Quesne et al., 2010). In Michigan, new water withdrawal permits can be denied in order to achieve environmental flow standards; however, current uses are exempted (Le Quesne et al., 2010). In lieu of complete denial of permits, an approach may be taken where permits are issued, but conditions are placed where withdrawals are

limited or ceased as flows decrease (Dyson, Bergkamp, & Scanlon, 2008). This is referred to by different names in different areas, such as hands-off flow in the United Kingdom (Dyson et al., 2008) and passby flows in the Susquehanna River Basin (Susquehanna River Basin Commission, 2012a). To ensure effectiveness there must not be a large time lag between when flows fall below a threshold and when water users are told to reduce or cease withdrawals (Dyson et al., 2008) as well as mechanisms for monitoring and enforcement (Hirji & Davis, 2009b). Conditioning permits rather than denying them allows for continued water development while protecting low flows (Dyson et al., 2008). To meet seasonal flow targets, water managers can restrict water withdrawal rates (Zhenxing Zhang & Balay, 2014) and incentive off-stream reservoirs (Le Quesne et al., 2010).

Compared to the restrictive management of limiting water withdrawals, active management is achieved through reservoir operations (Dyson et al., 2008). Reservoir releases can be used to augment low flow conditions (Hirji & Davis, 2009a; Kendy et al., 2012; Konrad, Warner, & Higgins, 2012). Releases are made from the three dams of the Hells Canyon Project to enhance success during migration of juvenile Chinook salmon (McManamay & Troia, 2016). Reservoir releases are another way to support continued water development while also ensuring adequate low flows (Dyson et al., 2008; Kendy et al., 2012). Reservoir reoperation to reduce autumn drawdown helps to restore the seasonal flow regime (Konrad et al., 2012). Dam reoperation in the Savannah River Basin aims to restore of seasonal flows by reducing autumn drawdown and high flows by releasing spring pulses (Richter & Thomas, 2007; Ward & Meadows, 2009). Reducing and delaying autumn drawdown in the Green River, Kentucky, helps to restore seasonal

flows and improves success of mussel brooding (Konrad et al., 2012). A growing number of basins are operating reservoirs for high flow pulses, including floods and bankfull events, in order to achieve ecosystem restoration goals (Cross, 2011; Konrad, 2010; Uehlinger, 2003; Warner, Bach, & Hickey, 2014; Watts, Ryder, Allan, & Commens, 2010). High flow pulses can be used to restore channel morphology, such as was done for sand bars below the Glen Canyon Dam, and increase habitat quality (Cross, 2011). These releases are also used to increase access to floodplain habitat (Konrad, 2010; Light, Vincent, Darst, & Price, 2006).

In order to accomplish flood damage reduction and high flows goals concurrently, environmental flows can be released, where safe, when there are storms (Porse, Sandoval-Solis, & Lane, 2015). Environmental flow releases during storms can allow for deliberately inundating specific floodplains, while also preventing the flood pool for overfilling, in order to reduce flood damage to infrastructure and maximize ecosystem benefits (Porse et al., 2015; Richter & Thomas, 2007). When faced with the potential of inundating floodplain development of a nearby city if small flood recommendations were implemented, those involved with the Savannah River Basin environmental flows project discussed building a flood bypass to route floodwaters around the city (Richter & Thomas, 2007). Infrastructure upgrades or design considerations for new projects are often needed in order to provide the high flows recommendation for environmental flows (Hirji & Davis, 2009b).

## Methods

We evaluated environmental flows implementation effectiveness using both quantitative and qualitative methods. We used quantitative methods to determine if there was a significant increase in days above the low flow threshold after the LFPP was updated in 2012. The LFPP is amenable to this analysis because it has a single start date and covers the entire basin, in contrast with the other mechanisms to implement environmental flows that are occurring incrementally on a project or permit basis. It will be 13 years before the cumulative effect of all activities to implement environmental flows can be fully assessed because methods to calculate flow regime changes, such as the Indicators of Hydrologic Alteration (Richter, Baumgartner, & Powell, 1996; The Nature Conservancy, 2009), generally require at least 20 years of pre- and post-impact data (Richter, Baumgartner, Wigington, & Braun, 1997; The Nature Conservancy, 2009). Consequently, we evaluate the effectiveness of policies and programs targeting seasonal flows and high flows, as well as non-LFPP policies and programs to implement low flows, using qualitative methods only. The qualitative analysis of effectiveness is based on a literature review of organizational documents and peer-reviewed articles, as well as a key informant interview. The key informant interview supplements the literature when there are gaps in the literature pertaining to details about SRBC policies and programs.

### *Quantitative*

We calculated low flow threshold values using the 'Percent Exceedance Value Method' described in the LFPP Technical Guidance (Susquehanna River Basin Commission, 2012b), for every USGS stream gauge with continuous discharge values

from 1980-2018 that is included in the LFPP Technical Guidance table of monthly percent exceedance flow values (Susquehanna River Basin Commission, 2012c, Attachment E). These filters resulted in low flow threshold values calculated for 86 stream gauges throughout the basin.

We retrieved discharge data and site information from the U.S. Geological Survey (U.S. Geological Survey, 2019). We determined the drainage area for each stream gauge and used it to assign each stream gauge to an Aquatic Resource Class based upon the criteria listed in the LFPP Technical Guidance (Susquehanna River Basin Commission, 2012b, table 1, p. 5). We used the aquatic resource class to determine which percent exceedance flow value formed the low flow threshold, based on the criteria set forth in the LFPP Technical Guidance (Susquehanna River Basin Commission, 2012b, table 3, p. 13). We determined the monthly low flow threshold in cubic feet per second using the stream gauge number and monthly percent exceedance flow value using Attachment E of the LFPP Technical Guidance (Susquehanna River Basin Commission, 2012c). We classified daily discharge for each stream gauge as one if it was greater than or equal to the low flow threshold for that month and stream gauge, and a zero if it was less than the low flow threshold.

We retrieved the Global Precipitation Climatology Project monthly mean precipitation data (Adler et al., 2018) from the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA (ESRL Physical Sciences Division, 2019; Pierce, 2017). We calculated a single monthly mean precipitation value by averaging all 2.5° grid cells located within the basin. We calculated the 12-month Standardized Precipitation Index (SPI) from the monthly mean precipitation with the R package SPEI (Begueria & Vicente-Serrano,

2017). The SPI is a method to characterize meteorological drought that standardizes precipitation values based on the long-term mean (McKee, Doesken, & Kleist, 1993; National Center for Atmospheric Research, 2019). We used a 12-month SPI because it correlates most strongly with stream flows and reservoir levels (World Meteorological Organization, 2012). The twelve-month SPI compares twelve consecutive months of data to the same twelve-month period in all other years of data (World Meteorological Organization, 2012).

We used a generalized linear mixed model to test for an increase in exceedances of the low flow threshold after 2012 while accounting for drainage area and SPI. We included a random intercept for gauge to account for a lack of independence of repeat samples at each gauge (Jiang, 2007). We specified a binomial distribution and logit link function, with parameters estimated using maximum likelihood by the Laplace Approximation in the R package lme4 (Bates, Maechler, Bolker, & Walker, 2015; Cariveau, Jr., Bishop, & LaGrange, 2011). We fit the model with data between 1980 and 2018 at 86 gauges throughout the basin. The binary response variable, "Above LFPP", was assigned a value of 1 for days with flows greater than or equal to the low flow threshold, and zero otherwise. The full model was:

*Above LFPP ~ Standardized Precipitation Index + Drainage Area + 1|Gauge + Before or After 2012*

We also fit a second model that differed only in that it did not include the fixed effect "Before or After 2012". We calculated Akaike weights determine which model was more likely. All calculations are carried out in R (R Core Team, 2018).

*Conceptual framework*

To evaluate the effectiveness of the SRBC policy tools for implementing environmental flows, we developed a conceptual framework based on review of the literature on environmental flows science and implementation. The conceptual framework was based on the premise that attention to low, seasonal, and high flows is necessary (Le Quesne et al., 2010). The conceptual framework consisted of seven indicators to determine if there are sufficient mechanisms to ensure low, seasonal, and high flows targets can be met:

**Presence and magnitude of exempted uses**. Managing a high proportion of a resource being used helps to reduce its overexploitation (Gerber et al., 2009). We hypothesized environmental flows are more effectively implemented if there are no or negligible exempted uses. We coded the literature and interviews for reference to exemptions and grandfathered uses to determine presence and specifically looked for estimates on the number or volume of grandfathered permits to determine magnitude of exempted uses.

**Ability to place conditions on permits for low flows**. Conditioning permits can protect low flows while also allowing for continued water development (Dyson et al., 2008). We hypothesized the ability to place conditions on permits for low flows increases environmental flows implementation effectiveness. We coded the literature for evidence of this ability, which in the Susquehanna River Basin included search terms like “passby flows” and “consumptive use mitigation”. We also coded the interviews for mention of limitations to placing conditions on permits to protect low flows.

**Modified reservoir operations for low flows**. Storing water in reservoirs during wet times allows for its release later to meet low flow targets (Kendy et al., 2012). We hypothesized reservoir operations should be modified in order to effectively implement environmental flows low flows targets. We coded the literature and interviews for evidence of this occurring. Search terms included “flow augmentation”, “conservation storage” & “low flow”, and “conservation release” & “low flow”.

**Ability to place conditions on permits for seasonal flows**. Limiting withdrawal rates and expediting permit for off-stream reservoirs can help to protect seasonal flows (Le Quesne et al., 2010; Zhenxing Zhang & Balay, 2014). We hypothesized this ability enhanced effective environmental flows implementation. We employed a similar process as for evaluating permit conditions for low flows, but instead focused on seasonal flows by using the keywords “seasonal flow” and “withdrawal rate”.

**Modified reservoir operations for seasonal flows**. Seasonal flows that are altered by reservoirs can be restored through reservoir reoperations, such as through delaying or reducing drawdowns (Konrad et al., 2012; Richter & Thomas, 2007). We hypothesized modified reservoir operations were necessary to implement seasonal flow recommendations in basins, such as the Susquehanna River Basin, where there are large reservoirs capable of modifying seasonal flows. We employed similar methods as for modified operations for low flows, except coded for terms like “autumn drawdown” and “seasonal flow”.

**Modified reservoir operations for high flows.** Releasing high flows from reservoirs can help restore channel morphology, habitat, and reconnect floodplains (Cross, 2011; Konrad, 2010). We hypothesized modified reservoir operations were

necessary to implement high flow recommendations in basins with flood control reservoirs. We employed similar methods as for low and seasonal flows, except we coded for terms like “spring pulse”, “small flood”, and “bankfull event”.

**Programs for flood damage reduction and high flows.** Implementing high flows can be dangerous to development in the floodplain but there are ways to mitigate for this through moving development out of floodplain, rerouting flood waters around development, and focusing floods in areas where floodplains are not developed (Porse et al., 2015; Richter & Thomas, 2007). We hypothesized that programs that jointly target flood damage reduction *and* achieving high flows for environmental purposes would enhance environmental flows implementation. We also hypothesized infrastructure upgrades or planning for environmental flows during project design were needed for effective high flows implementation. We coded the literature and interviews for search terms like zoning, buyouts, infrastructure, and floodplain combined with terms like ecology, ecosystem, “high flow”, “environmental flow”, and “spring pulse”.

We applied the evaluative framework to a literature review and a supplementary key informant interview. The literature reviewed (Table 4.2) includes primarily organizational literature and some peer-reviewed literature. We used the following search terms on the SRBC website’s search engine: high flow, low flow, seasonal flow, ecological flow, LFPP, consumptive use, withdrawal permit, grandfathered permit, and regulated use. We combined these search terms with “Susquehanna River Basin Commission” on Google, Google Scholar, and Digital Library of the Commons. The criteria we used to screen the resulting literature were that it was either organizational literature or peer-reviewed literature and that it mentioned SRBC policies or programs to

target low, seasonal, or high flows, including the environmental flows study. To fill in gaps left by the literature, we conducted two key informant interviews with the Manager of Planning and Operations at the SRBC. These gaps pertained to the second phase of the environmental flows study that was never completed, the trajectory of current programs, the specific ways environmental flows are implemented, and the registration and effect of grandfathered permits. We conducted two key informant interviews with one expert because we were looking for specific information rather than personal opinions and the expert directly oversaw the programs in question.

## Results

*Quantitative*

The model showed a significant change in days above the low flow threshold after 2012. All fixed effects of the model were statistically significant at less than 2e-16 (Table 4.3). Drainage area, Standardized Precipitation Index, and observations after 2012 had positive effects on days above low flow threshold. There was a 66% greater chance (1.9 greater odds) of being above the low flow threshold after implementation of the 2012 LFPP. The predicted probability of being above the low flow threshold before the 2012 LFPP was almost 89% and it rose to more than 93% after the 2012 LFPP was implemented (Figure 4.4). As Standardized Precipitation Index increases, i.e., greater precipitation, there was a 65.6% greater chance of being above the low flow threshold per standard deviation of SPI. As drainage area (z-scaled normalized) increases there was a 61.7% chance per standard deviation of drainage area of being above the low flow threshold. Standardized precipitation index and after 2012 were the most correlated

parameters (Table 4.4). The random effect, gauge, had a variance of 0.33 and standard deviation of 0.58, indicating there was a small variation in days above the low flow threshold between stream gauges. Depending on the stream gauge, the predicted probabilities of being above the low flow threshold ranged from just above 70% to just below 100% (Figure 4.5). The Akaike weights showed the model with before or after 2012 was more likely (100%) than the null model without before or after 2012 (0%), providing further evidence that days above the low flow threshold were significantly different after the 2012 LFPP update.

*Conceptual framework*

The environmental flow recommendations focused on whole flow regimes (DePhilip & Moberg, 2010), but the primary regulatory mechanism for implementation targeted low flows (Opperman et al., 2018; Susquehanna River Basin Commission, 2018a). There were policies and programs in place to target other components of the flow regimes, but they appeared to be constrained in their ability to significantly alter seasonal and high flows at a basin scale.

**Presence and magnitude of exempted uses**. Not all water uses were regulated by the SRBC; uses that were initiated prior to adoption of the SRBC regulations, called grandfathered uses, were exempt (Balay et al., 2016). In January 2018 the SRBC established a program to register grandfathered permits (Susquehanna River Basin Commission, 2017a). If these permit holders register by December 2019, they can continue to be exempt from the SRBC permitting process (Susquehanna River Basin

Commission, 2017b). Permittees submit five years of water use data, from which the SRBC determines a specific quantity of consumptively used water that will be grandfathered (Susquehanna River Basin Commission, 2017a). Permittees then must periodically report the amount of water withdrawals and consumptive use, but they are still exempt from LFPP and consumptive use mitigation requirements (Susquehanna River Basin Commission, 2017b). This water will continue to be grandfathered until there is a change in facility ownership, location of withdrawal, water use, or until the amount of water requested to be withdrawn is increased (Susquehanna River Basin Commission, 2017a).

Several efforts--extensive outreach before the registration process commenced, splitting the process into three stages, offsetting the registration costs in the early stages, and allowing water users to submit data already submitted to state agencies--increased the palatability of the registration process (John Balay, personal communication, 4/30/2019). Despite a smooth registration process (John Balay, personal communication, 4/30/2019), there was still some pushback from certain grandfathered users against the SRBC registration program (Pennsylvania Chamber of Business & Industry, 2017). Without the power to place restrictions on grandfathered or unregulated withdrawals, LFPP effectiveness may be limited. The SRBC estimated there are more than 700 grandfathered permits that account for as much water use as all other permits managed by the SRBC, almost one billion gallons per day (Susquehanna River Basin Commission, 2017a). This means the SRBC policies can only target at most 50% of the flows, as the other 50% are grandfathered. Once the registration process is complete the quantities and locations of

grandfathered permits will be publicly available (John Balay, personal communication, 4/30/2019), allowing for a determination of their effect on LFPP effectiveness.

**Ability to place conditions on permits for low flows**. The SRBC's consumptive water use regulation, adopted in 1976 and updated in 1996, required consumptive uses over a certain exempted amount to be mitigated during critical low flow conditions (Susquehanna River Basin Commission, 2008). There were exemptions for grandfathered uses and public water supply that were not diverted out of the basin (Susquehanna River Basin Commission, 2008). Prior to permit approval, applicants selected a way to meet the consumptive use mitigation requirements, which included augmenting flows in equal amounts to consumptive uses using water stored in surface or underground facilities, ceasing consumptive water use, reducing withdrawals in amounts equal to consumptive use and using alternative surface or underground sources, using sources that provide conservation releases, or paying the SRBC for consumptive use (Susquehanna River Basin Commission, 2008, 2017c). Many project applicants chose monetary payments (Susquehanna River Basin Commission, 2017c). The SRBC invested these funds in water storage to mitigate consumptive water use (Zhenxing Zhang & Balay, 2014). Consumptive use mitigation was required by the consumptive water use regulation of 1976 rather than the LFPP, but in conjunction with the LFPP helped to achieve the low flow components of the environmental flow recommendations.

The successful implementation of the LFPP and consumptive use mitigation required conditions for passby flows or conservation releases to be placed on permits. Conditions can be placed on new permits or on existing permits up for renewal, which was every 5 years for natural gas and 15 years for all other water withdrawals

(Susquehanna River Basin Commission, 2018b). Many permits have not yet come up for renewal since the LFPP was updated seven years ago. The SRBC can only open permits (i.e., alter an existing permit) if there was evidence of environmental harm, which was why the conditions were placed on new permits or those up for renewal (John Balay, personal communication, 4/30/2019). New permits were increasingly likely to be conditioned with passby flows because passby flows were assessed cumulatively (John Balay, personal communication, 2/2/2018)(Balay et al., 2016). The natural gas industry, for example, was relatively new to the basin and had shorter permit lengths; consequently, comparatively more natural gas water withdrawal permits were conditioned with passby flows (Richenderfer et al., 2016). Approximately 50% of all existing withdrawal permits subject to the LFPP were conditioned with passby flows, but approximately 85% of withdrawal permits for the natural gas sector were conditioned with passby flows (John Balay, personal communication, 2/2/2018). For these reasons, the coverage of permits conditioned with passby flows was heterogeneous (Balay et al., 2016). The SRBC simulated the effectiveness of passby flows in its Cumulative Water Use and Availability Study and found passby flows to be least effective in some watersheds with the lowest water availability because there were fewer permits with passby restrictions (Balay et al., 2016).

**Modified reservoir operations for low flows**. The SRBC maintained storage in multiple USACE reservoirs to augment low flows when they dropped below predefined low flow targets, including Curwensville Lake (EA Engineering, 2012), Cowanesque Lake (Susquehanna River Basin Commission, 2013), and Whitney Point (Susquehanna River Basin Commission, 2018a). The SRBC and U.S. Army Corps of Engineers spent

two years studying modifications to the operation of F.J. Sayers Dam and Reservoir to improve environmental conditions without diminishing other authorized purposes; but the project ended with no operational changes because of marginal environmental returns, potential recreational effects, and public feedback (U.S. Army Corps of Engineers, 2018a; U.S. Army Corps of Engineers, 2019). There is currently another reservoir operations feasibility study underway at Tioga-Hammond Lakes (Susquehanna River Basin Commission, 2018d). An estimated 400 million gallons per day more water for consumptive use mitigation will be needed by 2025 (Susquehanna River Basin Commission, 2008). The SRBC was pursuing projects to increase their conservation release capacity, including in the abandoned Billmeyer Quarry (Susquehanna River Basin Commission, 2008, 2018d).

**Ability to place conditions on permits for seasonal flows**. Seasonal patterns in low flows were reflected by low flow standards set by month rather than year (Opperman et al., 2018; Susquehanna River Basin Commission, 2018a), but this did not go as far as to protect seasonal flows as set forth in the flow recommendations (Figure 4.3, Table 4.1). The SRBC had the authority to place conditions on permits to protect seasonal flows by limiting withdrawal rates to a percentage of the monthly median or passby flows when proposed withdrawals could affect seasonal flows individually or cumulatively (Susquehanna River Basin Commission, 2012b; Zhenxing Zhang & Balay, 2014). Whether these conditions were placed on withdrawal permits was within SRBC discretion, with the agency considering the TNC seasonal flow recommendations (Susquehanna River Basin Commission, 2012b). Conditions can only be placed on new or renewed permits and regulated users, which left out grandfathered and unregulated

uses as well as those permits which were not yet up for renewal (Balay et al., 2016; Susquehanna River Basin Commission, 2017a, 2018b).

**Modified reservoir operations for seasonal flows**. Autumn drawdown and spring refill reservoir operations can alter seasonal flow regimes (Warner et al., 2014; Watts, Ryder, Allan, and Commens, 2010). A few USACE reservoirs modified their operations to reduce or eliminate autumn drawdown in order to provide water for low flow augmentation, including Whitney Point Lake where the 7-foot winter drawdown was eliminated (Susquehanna River Basin Commission & U.S. Army Corps of Engineers). The SRBC partnered with USACE on these projects and continued to explore future partnership opportunities (Susquehanna River Basin Commission & U.S. Army Corps of Engineers).

**Modified reservoir operations for high flows**. There were several challenges faced by the SRBC in attaining high flow components of the environmental flow recommendations. Water withdrawals, the SRBC's realm of influence, generally were not large enough to affect high flows (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). Federal and private reservoirs in the basin had a limited capacity to store water for augmenting stream flows (DePhilip & Moberg, 2010) (John Balay, personal communication, 2/2/2018), making it unlikely small floods and flow pulses can be achieved in lieu of naturally wet conditions. The Baltimore Division of the USACE and private hydropower owners licensed by the Federal Energy Regulatory Commission operated most of the reservoirs in the basin that can affect high flows (DePhilip & Moberg, 2010). Flood damage reduction was an important authorized purpose for the federal reservoirs, as the basin is prone to significant flood risks

(Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). The USACE is currently investigating expanding flood damage reduction efforts in the New York section of the Upper Susquehanna River Basin after significant flooding in 2006 and 2011 (U.S. Army Corps of Engineers, 2018b). Reservoirs were drawn down in autumn and winter, then refilled with heavy spring rain to mitigate flood risks (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012). This process attenuated the high flows that would provide small and large floods in unregulated systems (Burke, 2009; Graf, 2006).

**Programs for flood damage reduction and high flows**. There was no evidence that the SRBC had programs, or partnerships, to achieve both flood damage reduction and high flows targets. Allowing for floods when there are structures in the floodplains and infrastructure can lead to significant damages and financial losses (U.S. Army Corps of Engineers, 2018b). There may be opportunities to provide small floods in certain locations and with precautions such as relocating and modifying buildings and infrastructure (Porse et al., 2015; Richter & Thomas, 2007). This would require a significant departure from the status quo but has the potential to provide many ecosystem benefits; particularly reconnecting the channel to the floodplain, which would enhance biogeochemical cycling and increase habitat (Arthington, 2012; Poff et al., 1997). A detailed analysis of where relocating and modifying buildings and infrastructure would be needed to determine exactly where these actions would be beneficial, but generally it would be areas that would have high ecological benefits combined with low social and economic costs.

## Discussion

The results of the quantitative analysis show a significant increase in days above the low flow threshold after the LFPP was updated in 2012. The effect is seen despite the large variation between stream gauges and in drainage area. This provides strong evidence for the effectiveness of SRBC policies targeting low flows. The timing does lend weight to the assumption that the change in days above low flow threshold can be attributed in part to the LFPP; however, it is impossible to separate the effects of consumptive use mitigation and withdrawal limits. Regardless, SRBC policies targeting low flows are making significant changes to basin low flows.

Results of the qualitative analysis show mixed effectiveness, with greater success in implementing the low and seasonal flows recommendations. The SRBC has the authority to implement the seasonal flow recommendations through conditioning water withdrawal permits. Additionally, they have partnered with USACE on projects that help to restore seasonal flows by reducing or eliminating the autumn drawdown and spring refill periods, however these projects are still few. This does suggest potentially effective implementation mechanisms for seasonal flows. But it will take years before the implementation outcomes can be evaluated quantitatively. High flows appear to be beyond the SRBC realm of influence, making it unfair to evaluate how effectively the SRBC is implementing the high flow recommendations. Nevertheless, there is still room to further develop relationships with the entities that can significantly affect high flows and to explore options for achieving flood damage reduction concurrently with spring pulses.

There is still a need to determine the institutional and infrastructural changes necessary for influencing all the flow regime components to achieve the full range of environmental flows recommended for the Susquehanna River Basin and river basins globally. A topic of interest is whether having a large reservoir capacity to augment flows and infrastructure to distribute this environmental water is necessary to achieve environmental flows recommendations. More research is needed to determine if withdrawal limits and placing conditions on both grandfathered and regulated withdrawal permits is sufficient, or if dam reoperation and transfers of water rights to environmental purposes are also necessary to meet environmental flows recommendations.

Despite an ever-growing number of watersheds developing environmental flow recommendations and policies, there are still few cases where these recommendations and policies are implemented (Le Quesne et al., 2010). Regardless of how well the process is designed or how sound the science is to base the environmental flow recommendations, there appears to be a failure to adopt sufficient mechanisms to implement environmental flow recommendations at the river basin scale. The Susquehanna River Basin Commission has taken significant steps to implement environmental flows at a transboundary river basin scale. It has adopted a wide array of programs and appears to be doing everything it can within its realm of influence. Yet, it still needs the cooperation of other entities, particularly the USACE and the Federal Energy Regulatory Commission, to ensure all components of the recommended flow regime are achieved.

## Conclusion

This study evaluates how effectively the SRBC is implementing the low, seasonal, and high flow components of the environmental flow recommendations. We found the SRBC is making a significant improvement in low flows through the LFPP and other policies and programs targeting low flows. We found some progress towards the seasonal flow recommendations and limited progress towards the high flow recommendations.

The SRBC is doing innovative, extensive, and effective work in their realm of influence, regulation of water withdrawals. Yet, their authority does not extend to the whole flow regime. The results of our analysis indicate that a concerted effort between all institutions with major control over the flow regime is needed to fully implement environmental flow recommendations. Without the cooperation of the USACE and the Federal Energy Regulatory Commission it is unlikely that high flow recommendations, particularly small floods and pulses, can be achieved. Furthermore, even in their realm of influence the SRBC is limited by grandfathered uses and waiting for permits to be up for renewal. Despite these challenges the SRBC has made significant headway towards implementing the low flow components of the environmental flow recommendations.

Environmental flows science has progressed from minimum flows to addressing whole flow regimes. But do institutional, political, legal, and infrastructural constraints limit options for implementing environmental flows at the transboundary river basin scale to either minimum flows or pulsed flows from reservoirs? If so, addressing these constraints will be essential to successful implementation of environmental flow recommendations. In resource-limited basins this may prove to be as important as

developing increasingly sophisticated tools to define environmental flows, otherwise the flow targets cannot be met.

# Tables and figures

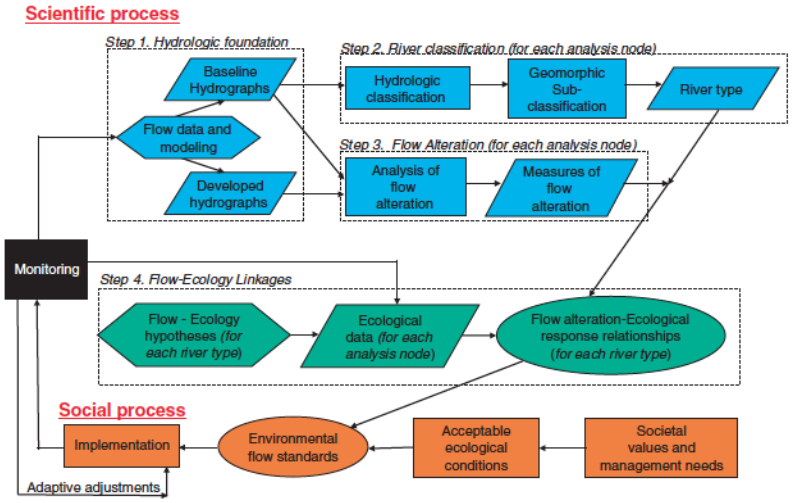


**Figure 4.3.** ELOHA Framework (Poff et al. 2010, p. 151)


**Figure 4.4.** Map of Susquehanna River Basin and sub-basins (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012, p. 1)

**Table 4.4.** Environmental flow recommendations for Susquehanna River Basin (De Philip and Moberg 2010, p. 69)

| Season | Flow Component | Flow Statistic | Flow Recommendations | | |
|---|---|---|---|---|---|
| | | | Headwater streams < 50 sq mi | Streams and small rivers (50 – 200 sq mi) | Major tributaries and mainstream (>200 sq mi) |
| Annual and Interannual Events | High Flows | Large flood | Maintain magnitude and frequency of 20-yr flood | Same for all streams | Same for all streams |
| | | Small flood | Maintain magnitude and frequency of 5-yr flood | Same for all streams | Same for all streams |
| | | Bankfull | Maintain magnitude and frequency of 1 to 2-yr high flow event | Same for all streams | Same for all streams |
| All Months | High flows | Monthly Q10 | < 10% change to magnitude of monthly Q10 | Same for all streams | Same for all streams |
| | Seasonal flows | Monthly Median | Between 45th and 55th percentiles | Same for all streams | Same for all streams |
| | | Monthly Range | ≤ 20% change to area under curve between Q10 and Q75 | Same for all streams | Same for all streams |
| | Low flows | Monthly Low Flow Range | No change to area under curve between Q75 and Q99 | ≤ 10% change to area under curve between Q75 and Q99 | ≤ 10% change to area under curve between Q75 and Q99 |
| | | Monthly Q75<br>Monthly Q95 | No change | No change | No change |
| Fall | High flows | Frequency of events > Monthly Q10 | NA | NA | Maintain 1-5 events |
| Summer | | Frequency of events > Monthly Q10 | Maintain 2-8 events | Maintain 2-8 events | Maintain 2-8 events |

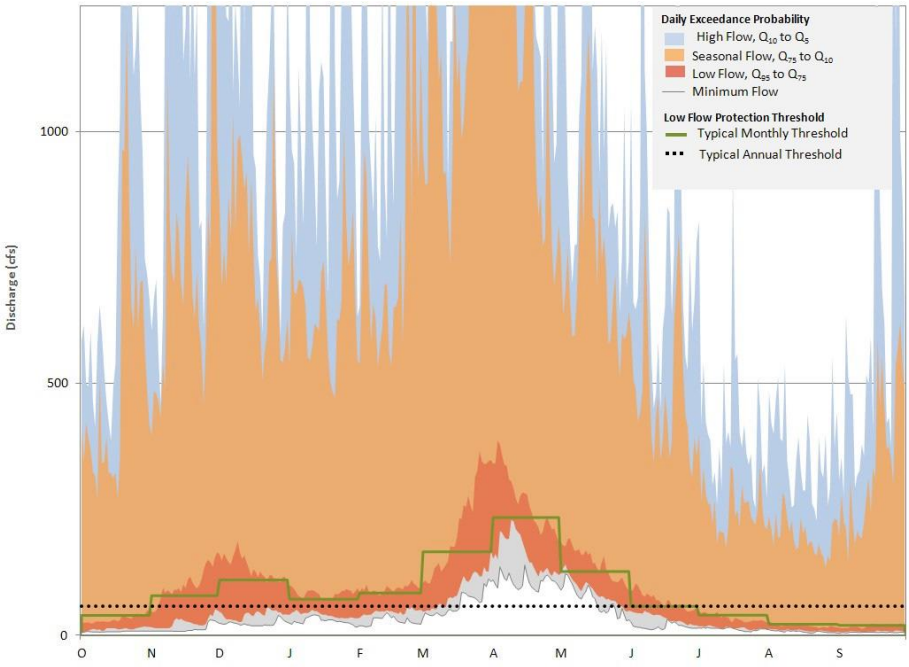


**Figure 4.5.** Comparison of environmental recommendations, annual LFPP, and monthly LFPP (Susquehanna River Basin Commission, 2012b, p. 2)

**Table 4.5.** Literature review matrix

| Reference | Type | Notes |
|---|---|---|
| (Balay et al., 2016) | SRBC document | Determines consumptive use, water availability with different metrics (including ELOHA), and mitigation measures (passby flows, CU mitigation, use reductions) effects. |
| (DePhilip & Moberg, 2010) | TNC report to the SRBC & USACE | Report detailing environmental flow recommendations. |
| (EA Engineering, 2012) | Contractor's report to SRBC | Overviews water storage for augmentation at Curwensville Lake. |
| (Kendy et al., 2012) | TNC document | Presents SRB environmental flow recommendations as a case study and puts into context with other cases. |
| (Liu, Zhang, & Balay, 2017) | SRBC document | Overviews use of reference gauges for passby flows. |
| (Opperman et al., 2018) | Peer-reviewed article | Discusses SRBC environmental flow recommendations. |
| (Richenderfer et al., 2016) | SRBC document | Discusses natural gas shale development and passby flows effect, overviews SRBC regulatory role. |
| (Shank & J.R. Stauffer, 2015) | Peer-reviewed article | Says surface water withdrawal effects on macroinvertebrates limited possibly due to passby flows. |
| (Shank, Balay, & Richenderfer, 2017) | Book chapter | Overviews regulation of natural gas shale development, includes passby flows. |
| (Susquehanna River Basin Commission & U.S. Army Corps of Engineers) | SRBC USACE fact sheet | Overview Whitney Point Lake project modification to augment low flows, eliminates autumn drawdown. |
| (Susquehanna River Basin Commission, 2005) | SRBC fact sheet | Overviews storage for consumptive use mitigation at Curwensville Lakes. |
| (Susquehanna River Basin Commission, 2008) | SRBC document | Plan for consumptive use mitigation. |
| (Susquehanna River Basin Commission & U.S. Army Corps of Engineers, 2012) | SRBC and USACE document | USACE ecosystem flows report phase 1. |
| (Susquehanna River Basin Commission, 2012a) | SRBC document | Low Flow Protection Policy. |
| (Susquehanna River Basin Commission, 2012b) | SRBC document | Technical guidance for LFPP. |
| (Susquehanna River Basin Commission, 2012c) | SRBC document | Technical guidance for LFPP appendices. |
| (Susquehanna River Basin Commission, 2017a) | SRBC factsheet | Overview of registration for water uses that pre-date SRBC regulations. |
| (Susquehanna River Basin Commission, 2017d) | SRBC document | Overview of projects that includes those related to environmental flows. |
| (Susquehanna River Basin | SRBC document | Overview of projects that includes those |

| | | |
|---|---|---|
| Commission, 2018d) | | related to environmental flows. |
| (Susquehanna River Basin Commission, 2018a) | SRBC document | Most recent comprehensive plan for SRB. |
| (Susquehanna River Basin Commission, 2018b) | SRBC document | SRBC regulations as recorded in code of federal regulations. |
| (Susquehanna River Basin Commission, 2019) | SRBC website | Overview Billmeyer Quarry Consumptive Use Mitigation Project. |
| (Zhenxing Zhang & Balay, 2014) | Peer-reviewed article | Overviews consumptive use and water withdrawal management. |
| (Z. Zhang, Balay, Bertoldi, & MaCoy, 2016) | Peer-reviewed article | Discusses process of using ELOHA standards to set water capacity and availability. |

**Table 4.6.** Model fixed effects results

| Variable | Estimate | SE | Z value | P |
|---|---|---|---|---|
| Intercept | 2.046 | 0.57 | 35.733 | <2e-16 |
| Standardized Precipitation Index | 0.645 | 0.003 | 215.855 | <2e-16 |
| Drainage area (z-score normalized) | 0.475 | 0.057 | 8.284 | <2e-16 |
| Before or after 2012 | 0.664 | 0.008 | 84.074 | <2e-16 |

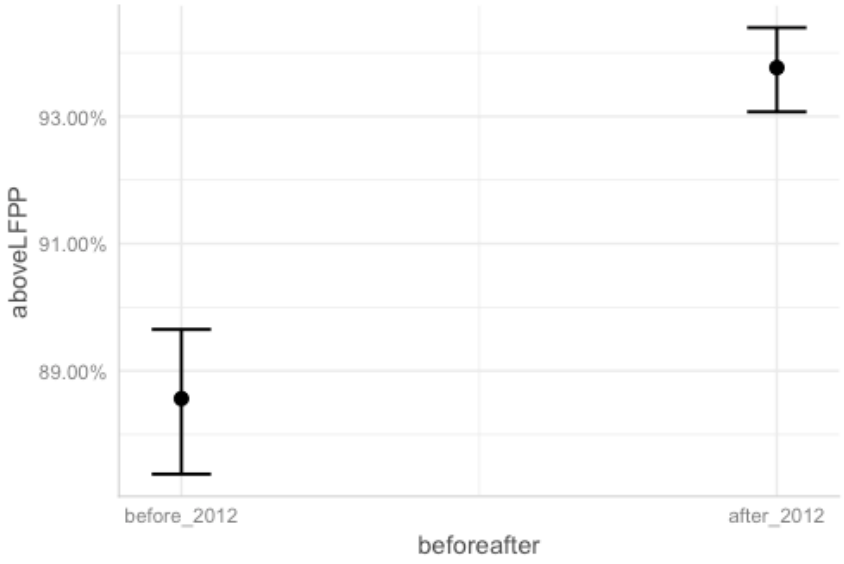


**Figure 4.6.** Predicted probabilities of being above low flow threshold

**Table 4.7.** Correlation of model fixed effects

| | (Intercept) | SPI | Drainage area |
|---|---|---|---|
| SPI | 0.014 | | |
| Drainage area | 0.000 | 0.002 | |
| Before after 2012 | -0.014 | 0.122 | 0.000 |

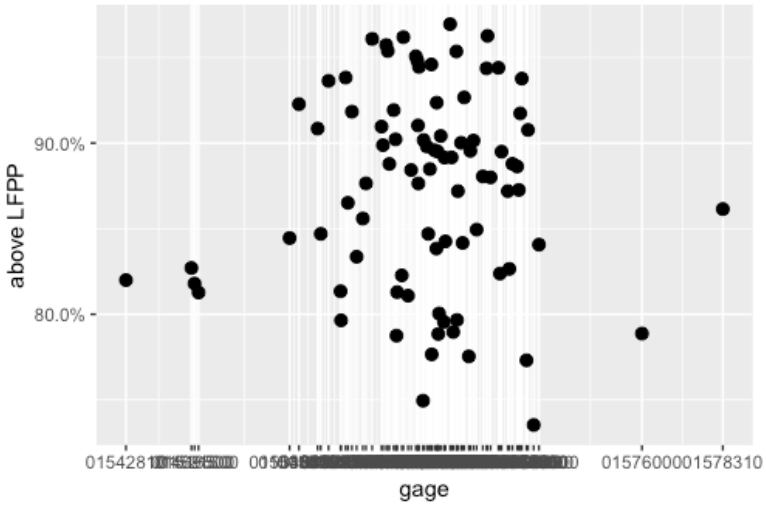


**Figure 4.7.** Predicted probabilities of being above low flow threshold for each stream gauge

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# CHAPTER 5

# CONCLUSION

Through this dissertation I strove to answer the following research questions: (1) What are the major governance factors and social processes stakeholders should consider in developing a transboundary RBO that can affect water management at a basin scale given the current regulatory and political landscape; (2) Are transboundary RBOs effective in achieving two of the most prominent environmental objectives, managing low flows and nutrient loads, given their regulatory authority as well as their financial and technical capacity; (3) Does the Susquehanna River Basin Commission, a transboundary RBO, have sufficient policies and programs to effectively implement environmental flows and does their low flows policy affect low flows at the river basin scale? I initially researched how to establish a transboundary RBO because of a request by stakeholders in the Apalachicola-Chattahoochee-Flint (ACF) River Basin to do so in order to transcend decades of litigation among the states regarding allocation in the basin. As I dug deeper, I decided I needed to directly address the issue of whether transboundary RBOs can and are delivering positive environmental outcomes, which led me to pose research questions 2 and 3.

In Chapter Two I established and subsequently evaluated a process to develop recommendations for transboundary governance in a highly litigious river basin experiencing periodic water scarcity. The goal was to directly inform development, adoption and implementation of a transboundary RBO in the study basin and others with

a similar context. In Chapter Three, I evaluated effectiveness in two ways, first by how well transboundary RBOs manage low flows and nutrients, and second by their regulatory authority, financial capacity, and technical capacity. My goal was to determine whether the establishment and continued support for transboundary RBOs is a good use of limited resources and, if so, to elucidate reforms that may help to increase their success. In Chapter Four, I evaluated whether there is hydrological and procedural evidence that the Susquehanna River Basin Commission, a transboundary RBO, is implementing environmental flows effectively at a river basin scale and determine the potential for wider implementation. The scope of my analysis was limited to river basins that cross state boundaries within the United States.

The process by which a transboundary RBO that can affect water management at a river basin scale can be formed in current times is hard to speak to because our efforts to do so in the Apalachicola-Chattahoochee-Flint (ACF) River Basin have yet to come into fruition. But there are lessons that our research team learned that could prove beneficial in other basins. It does seem that employing a transdisciplinary approach was helpful for making recommendations regarding both governance factors to include in an RBO as well as the social process for developing the organization. By involving both academia and stakeholders in the process, the recommendations had a foundation in both theory and practical relevance. The collaboration also had benefits for students, produced knowledge about RBOs, and helped the stakeholders evolve their concept of transboundary governance of the ACF River Basin.

The main barriers to transboundary governance effectiveness were the unwillingness of the state and federal partners to engage with the process, as well as the

litigation midway through the research project. There are strategies that others may employ to increase their chances of successfully forming a transboundary RBO. One is to include all relevant parties in the discussions regarding options for transboundary management from the start. By excluding state agencies from the beginning of these conversations, for example, we lack a complete understanding of both the political and technical constraints of collaborative management that would ultimately need to be overcome and we might prejudice the states against collaboration if they feel that a solution has been developed without their input. Another strategy is to find a way to coordinate, rather than try to replicate or replace, functions already undertaken by other agencies. It is unlikely that an agency will be willing to give up their current authority to manage water resources within their jurisdictional boundaries except in exceptional circumstances. In basins with a long history of litigation, a process to ensure a continued forum for conflict resolution and highly skilled facilitation is warranted (Kenney, 1994; Leitman, 2005). It is also realistic to expect that during periods in which the states are engaged in litigation, it is unlikely that real progress toward collaboration can be achieved unless upstream as well as downstream states perceive that it is in their interest to resolve the conflict out of court. Taking maximum advantage to advance discussions regarding transboundary management in periods free of litigation is essential. Had the ACFS involved the states in their work developing a Sustainable Water Management Plan and Options for Transboundary Water Management earlier in the process, it is possible that litigation might have been averted but since that did not occur, once the Supreme Court lawsuit was filed, states totally shut down regarding discussions on transboundary management and collaboration.

The support shown for effective management of low flows by transboundary RBOs in other basins, such as the Susquehanna and Delaware River Basins, suggests this route is promising for the ACF River Basin because this is the basin's most contentious issue. Unfortunately, it does not seem that the supporting features for managing low flows in other basins are currently found in or desired by stakeholders and agencies of the ACF River Basin. Notably, there is insufficient support for a transboundary RBO with regulatory authority. There is also no history of state or federal agencies providing financial or technical capacity to the ACF Stakeholders. But there are still paths forward, such as focusing on coordinating rather than replicating or replacing existing state and federal agency functions. If the equitable apportionment case ends with Georgia being mandated to curtail its water use, I believe there is a strong potential that the momentum for transboundary governance of the ACF River Basin will gain traction again.

My results did provide some evidence that transboundary RBOs improve environmental outcomes. Transboundary RBOs have helped prevent the decline or even improved low flows in the study basins, which provides some quantitative evidence of effectiveness. Some reasons for this effectiveness appear to be that the RBOs, such as the Susquehanna River Basin Commission, have adequate regulatory authority to protect low flows, or they have the technical capacity to implement programs that improve low flow conditions. These gains are in spite of the fact the RBOs are inadequately financed and funding sources are often unstable. I found strong evidence that the Susquehanna River Basin Commission improved low flows basin-wide after implementing a Low Flow Protection Policy. This is another situation where the combination of regulatory authority, technical capacity, and financial capacity increase RBO effectiveness. The

Susquehanna River Basin Commission has enforceable ways to implement the Low Flow Protection Policy, such as through passby flows and conservation releases. It also has the technical capacity to model flows and set permit conditions for both gauged and ungauged reaches. It has the financial capacity to monitor compliance with its Low Flow Protection Policy and to purchase storage for low flow augmentation. There was not the same strength of evidence for the impact of transboundary RBOs on water quality. Precipitation was instead shown to be the more likely driver of water quality changes. It is possible that precipitation and other factors, such as federal legislation, e.g., reductions in nitrogen pollution cause by the Clean Air Act, were masking an RBO effect. Other factors may have limited RBO success. All RBOs showed signs of inadequate funding. The RBOs studied for water quality had a greater range in regulatory authority and technical capacity, with at least one lacking both.

Based on my research, I would say there is a benefit to forming transboundary RBOs, although if not fully implemented with adequate finances, authorities, and technical capacity, they may not be the panacea they are sometimes proposed to be. My results reveal transboundary RBOs benefit situations where low flows jeopardize ecosystem and social well-being across state lines, by helping to prevent the continued decline of flows during low flow conditions. There is, however, a model of state-based water management in one basin, the Merrimack River Basin, to manage low flows effectively through an environmental flows policy. It is important to note this appears to be a rare situation, since no other control basins are effectively managing low flows. This does warrant further investigation as to whether effective environmental flows policies implemented at the state level could accomplish similar results as RBOs. There are other

benefits to forming RBOs that can also help to justify their establishment, such as resolution of interstate conflicts and increased trust amongst basin states. Forming transboundary RBOs does have transaction costs at least initially, which could be spent developing and collaborating on parallel state policies instead. But there are enough benefits it seems that at least in some contexts forming transboundary RBOs is justified despite the initial costs; particularly so in basins where effective state collaboration is unlikely because of litigation. Some reforms that may help to increase RBO success would be to ensure adequate and stable funding as well as to improve technical capacity.

When evaluating whether environmental flows are implemented at the river basin scale by the Susquehanna River Basin Commission, I determined that certain components of the flow regime are implemented quite effectively but there is room to improve other components. The Susquehanna River Basin Commission is successful in satisfying low flows standards; however, seasonal flows are only partially achieved and high flows are not effectively implemented. The effectiveness of their low flows policies and initial groundwork towards managing seasonal flows shows there is potential to implement environmental flows at the basin scale. They are, however, limited by their inability to regulate high flows. This is because the capacity of the reservoirs is limited compared to the basin inflows and the U.S. Army Corps of Engineers, the agency in charge of the major reservoirs, is not willing to lose any flood damage reduction capacity and, as such, is not a willing partner. For environmental flows to be achieved in large basins the cooperation of all agencies and stakeholders that have the potential to influence the flow regime is required so a focus on facilitating interagency collaboration is justified.

My research uncovered  an example of successful state-based environmental flows management in the Merrimack River Basin which is almost entirely located in the state of New Hampshire. The strong evidence of effectiveness may not have been seen if the basin's land area was more evenly divided amongst multiple states. Potentially all states within a basin could all pass parallel environmental legislation, but there is no evidence that this has occurred and been effective in other basins.

## Reflections on emergent tensions and themes in research

In the following sections I reflect on emergent tensions and themes in my research, in order to distill lessons that may be useful for others. These tensions and themes are related to mixed methods, interdisciplinary research, transdisciplinary and collaborative research, and the interplay between litigation and collaborative processes. I then propose areas for future research. I finish by reflecting upon the integrative nature of my research and my training as an Integrative Conservation (ICON) Ph.D. student.

### *Mixed methods*

To evaluate RBO effectiveness, I strived to achieve results using a quantitative approach in order to facilitate the uptake of my research by legislators and existing agencies, which often rely on positivist assessments of policies such as cost-benefit analyses (Sharp et al., 2011). The problem with such an approach is relying solely on a positivist perspective fails to capture the complexity inherent in water governance. There are a great number of benefits to transboundary water governance that may not translate to river basin scale changes in flows or nutrients. Some of these benefits emerged from

the interviews and literature review I conducted with members of the University Collaborative. River basin organizations mitigate interstate conflicts, provide a forum for adaptive management, and often rely on consensus-building that enhances trust between members (Bonney, Bickerton, & Fowler, 2012). Moreover, transboundary RBOs are not monolithic institutions. Each organization is embedded through formal and informal relationships in a complex array of organizations responsible for water management (Vatn & Vedeld, 2012). Quantitative approaches would be unlikely to be sufficient to study these informal relationships.

Employing a mixed approach allowed me to capture a more complete picture of RBO effectiveness than would a quantitative approach alone. Through a quantitative approach I was able to look at basin scale changes to water flows or nutrients. Through a qualitative approach I was able to evaluate other forms of effectiveness and to interpret why the basin-scale patterns in flows and nutrients are seen. Both approaches to evaluating effectiveness are necessary because effectiveness is multidimensional. To clarify why this is so, consider two extremes. Would one consider an RBO that makes great strides in managing low flows and nutrients effective if it did so at the expense of transparency, legitimacy, or public participation? In the long run alienating basin stakeholders to make such dramatic changes may lead to backlash, undermining the sustainability of these changes (Ross & Connell, 2016). Moreover, effective natural resource governance in democratic societies is about both the process and the product. Good natural resources governance is characterized by transparency, legitimacy, and inclusivity (Lockwood, Davidson, Curtis, Stratford, & Griffith, 2010).

*Interdisciplinary research*

There is a tension between breadth and depth in interdisciplinary research that I contended with throughout the development of my dissertation. In order to achieve the proper breadth to do both quantitative and qualitative research I sacrificed some depth. My qualitative arguments are not as developed as my quantitative ones. This tension between breadth and depth is something that is characteristic of interdisciplinary research (Hackett & Rhoten, 2009). I attempted to overcome a deficiency in training for qualitative methods through coursework, background research for the dissertation, and soliciting guidance and feedback from experts. Another potentially effective way to gain this expertise would be to collaborate with other doctoral students. This co-production of dissertation research is a novel approach to interdisciplinary education that has the benefit of allowing for enough depth across disciplines, but is still constrained by institutional barriers (Hackett & Rhoten, 2009). The ICON program at the University of Georgia has been working towards overcoming these institutional barriers, paving the way for more effective collaborative interdisciplinary research in the future.

My qualitative arguments have both strengths and weaknesses when judged by the standards of other qualitative analyses of institutional effectiveness. One strength was the use of interviews from a handful of basins to help to determine if there is convergence in the themes raised, in the hopes of reducing the possibility that a theme is an anomaly compared to other river basins. The evaluative framework I applied is based on case studies of river basins from around the world. This helps to enhance the generalizability of the concepts used. My qualitative arguments, however, have some substantial weaknesses that may be attributed to my strongly ecological and positivist training. At a

fundamental level I did not theorize my qualitative arguments sufficiently at the outset. There is a real risk that I fell prey to, the tendency for natural scientists to integrate qualitative methods without a deep knowledge of the underlying theories. The pressures of an output-oriented short time frame for the transdisciplinary research process necessitated that the research team and I focus on one interview per basin, which limited a richer understanding of different stakeholder's views on effectiveness. Of particular loss is the knowledge that could have been gained from interviewing members of the RBOs as well as regulated or vulnerable communities, such as local water users.

*Transdisciplinary and collaborative research*

Transdisciplinary research is research guided by the intention of addressing important societal problems that relies on collaboration between academic and non-academic actors (Brandt et al., 2013). Research, such as this, which is developed collaboratively between academic and non-academic partners to address a problem situation has been said to more likely to lead to the intended outcomes and lasting results (Lake & Wendland, 2018). It has also been said to help prevent unintended negative outcomes caused by ignoring local knowledge, context, and scientific uncertainty (Hadorn et al., 2008). Transdisciplinary research is said to be better equipped than traditional research to address wicked problems, i.e., problems that include high stakes, uncertain facts, conflicting values, and a sense of urgency (Agramont, Craps, Balderrama, & Huysmans, 2019; Krueger et al., 2016). The collaboration between the University Collaborative and the ACF Stakeholders was transdisciplinary in that it included academic and non-academic participants working on a real-world issue from multiple

disciplines. This issue was high stakes and characterized by conflicting values and a sense of urgency. Throughout the process we paid attention to context and local knowledge, by analyzing the context to identify management gaps, i.e., context, to craft our recommendations and by relying on the knowledge of stakeholders, i.e., local knowledge, to determine which functions our recommendations should include.

Conducting transdisciplinary research had benefits but presented challenges. There were at times disconnects between stakeholder and academic objectives. The primary objective of the stakeholders was to produce actionable knowledge for the ACF River Basin. While this was an important objective driving the University Collaborative research, students and professors were also driven by different objectives. Professors within the collaborative had the additional objective of creating a quality service-learning experience for students. Graduate students, like myself, had the objective to develop generalizable research with relevance beyond the basin. This research would also have to stand up to the rigors of the peer-review process and help meet departmental requirements.

Another academic objective that influenced our research was providing service-learning opportunities for undergraduate students. In our experience, there was a tension between engaging students to accomplish service-learning goals and the rigor by which research methods are adhered to. For example, we had issues with students straying from interview guides, not recording interviews, or not understanding concepts discussed in the interviews. We attended to the rigor of the research by including standardized methods and training sessions to guide the students. Students from different disciplines have different learning goals and competencies they bring to the research project. It is

imperative to ensure all students understand the methodologies being employed and the importance of adhering to the standardized procedures. Recording the interviews allowed the project managers to review the data in order to ensure it was high quality and consistent between students. For example, it was beneficial to ensure consistency between law and environmental science students that had different levels of understanding of legal and scientific concepts. This is particularly important when students have opportunities to probe deeper during the interviews, such as was the case with the semi-structured interviewed we conducted. It is worthwhile to have students learn how to use the recording equipment during the training sessions and to test the equipment before employing it in the field. This would ensure, for instance, that all of the interviews were recorded properly and were audible. A final recommendation is to have mechanisms for ensuring students' mastery of the background materials and methods before their research commences.

At times there were disconnects between the relevance of the research for stakeholders and what would be recommended based purely on our academic findings. For example, the RBO management of low flows was found to be useful in basins, such as the Susquehanna and Delaware River basins, but this approach was not relevant to the stakeholders because they lacked consensus that the RBO should engage in regulating flows. Engaging the ACF Stakeholders throughout the research process ensured the research was relevant for their needs and the recommendations were those they could stand behind. This at times required us to modify our recommendations and change the direction of our research. For example, a recurrent theme in the interviews was that regulatory authority was essential for actually resolving long-intractable water quantity

conflicts. But deliberations after multiple presentations of our research to the ACF Stakeholders and the facilitated group discussions, led to the recommendation of creating an organization with full regulatory authority being taken off the table. Ultimately, this was because of politics as there would be such political backlash trying to get Georgia to cede regulatory authority to a transboundary RBO. Buy-in to the recommendations by the ACF Stakeholders because they helped craft them was essential for promoting the recommendations to state and federal players. If the University Collaborative had tackled the project based purely on the goal of objectively constructing recommendations based on academic research, there's a possibility that the recommendations would not have been relevant, realistic, or desired by agencies and stakeholders alike. Regulatory approaches may be needed to ensure enough flows make it downstream during droughts but taking these approaches off the table could limit the ability to achieve this, resulting in a tradeoff between political palatability and effective flow management.

*Interplay between litigation and collaborative processes*

The recommendations for creating a transboundary RBO with the ability to influence water management basin-wide has yet to be implemented in the ACF River Basin, at least partly a result of a U.S. Supreme Court lawsuit that was filed as we were developing them. The lawsuit was filed ostensibly as a result of one member of the ACF Stakeholders bringing interim modeling products created for that organization's Sustainable Water Management Plan to the attention of concerned parties in Florida. These results bolstered the argument that Florida's interests are being harmed by water consumed in Georgia. The lawsuit was filed quickly so as not to run afoul of the statute

of limitations on initiating litigation after alleged harm, in this case the collapse of the oyster industry in the Apalachicola Bay, so there was no time to bring the parties together to discuss the information outside a court setting. There was possibly no inclination to do so either; because they had not been involved in the work of the ACFS, the state agencies and political representatives did not enjoy the same trust and goodwill that was being developed among the other stakeholders. The effect of the lawsuit was to break down the trust among ACF Stakeholders that was hard-earned through years of collaboration. This led to a confidentiality clause that hindered the transparency of the modeling conducted for the Sustainable Water Management Plan, which limited its uptake by the U.S. Army Corps of Engineers. The lawsuit also put state officials and agencies at an adversarial stance, which directly hindered our ability to include them in the transdisciplinary research process and thwarted any traction our recommendations may have until after the conclusion of litigation. Our research and recommendations did lead to positive outcomes, nonetheless. It furthered the mission of the ACF Stakeholders as is shown by the inclusion of these recommendations in the Sustainable Water Management Plan, and hopefully provide a path forward once the ongoing litigation is concluded.

There are times when the threat of litigation leads to further collaboration rather than to adversarial stances. For example, the threat of another equitable apportionment case led New York, New Jersey, Pennsylvania, Delaware, and New York City to use the Delaware River Basin Commission to negotiate the Flexible Flow Management Program. This situation contrasts with the ACF River Basin because the Delaware River Basin Commission was able to provide a forum for conflict resolution and collaboration, whereas the ACF Stakeholders was not. This may be because, in contrast to the Delaware

River Basin Commission, the ACF Stakeholders membership does not include state representatives, which are the parties to the litigation. Litigation, rather than collaboration, may be the outcome when circumstances are so dire that irreversible damage may occur, or a threshold is likely to be crossed. Florida representatives may feel that the oyster fishery collapse is irreversible and could not wait for collaborative processes. The threat of litigation can provide incentive promote to collaboration instead, but only if each party believes that they have something to lose if litigation ensues and is therefore willing to develop a negotiated, rather than court-driven, solution. It is speculative, but in this situation, Georgia may not feel that it has something to lose because it is sure it will win, or it is worth the gamble of litigation given the political and management costs of curtailing agricultural water use. The political pressure from an important base of voters (i.e., farmers or oysterman) could lead the governors to forgo collaborative efforts. The deep path dependence associated with a 30-year history of litigation and a failed compact between the states could be preventing collaborative approaches, while favoring litigation. On the other hands, the ACFS was developed specifically to show politicians including the governors, that the major stakeholders in the basin support collaborative efforts rather than litigation.

*Future studies*

There are many directions for future research that can improve upon the methods or provide further support for the results of my dissertation. A follow-up study that explicitly identifies and attempts to overcome the implementation barriers for the recommendations developed for the ACF River Basin would help to enhance probability

of successful implementation in this basin and others. The barriers could be identified through follow-up interviews with all involved parties (e.g., states and federal agencies and representatives) that cover what has hindered their user group from implementing the recommendation and their perceptions regarding the same by other actors in the basin. This could be combined with the use of the Institutional Analysis and Development framework (Ostrom, 2011) to analyze the situation for a more comprehensive understanding of the external and endogenous factors shaping the likelihood of uptake. Once the factors shaping the likelihood of uptake are understood, opportunities for adjusting them to promote adoption of the recommendations could be identified and acted upon. This process would involve identifying implementation barriers, defining alternatives for intervention to overcome barriers, assessing alternatives with stakeholders and through pilot projects, implementing alternatives, evaluating their results, and starting the process anew based on the results. This process would pull from the literatures on adaptive management and participatory action research, i.e., collaborative research developed in an iterative fashion with the purpose of addressing a shared problem or achieving a shared goal (Lake & Wendland, 2018).

Further studies on RBO effectiveness would be aided by increasing the sample size through expanding to international basins or to biophysical indicators with more data. Conducting interviews with a wide range of actors, both from the RBO and others, would allow for a more robust qualitative analysis of RBO effectiveness. A follow-up study on the Susquehanna River Basin Commission allowing for enough time to realize the results of policy implementation would bolster quantitative evaluations of the full flow regime. Follow-up interviews with other actors, particularly the U.S. Army Corps of

Engineers and The Nature Conservancy, could further describe successes and barriers to implementation of the environmental flow recommendations. Moreover, an analysis of water withdrawal permits and grandfathered uses would provide a more spatially explicit look at effectiveness.

## Concluding thoughts

To conclude, I would like to reflect on whether my research is truly 'integrative' and how my training as an ICON student improved my research. I do believe my research is integrative because it explores a problem from multiple disciplines (e.g., hydrology, ecology, policy, and anthropology) and epistemologies, attempts to reconcile human and ecosystem tradeoffs, engages with non-academics to solve a real-world problem, involves strategic communication (e.g., presenting findings to stakeholders), and involved collaboration with researchers and students from various disciplines. There are areas where my research could have been more integrative. I could have focused more on social equity and consequences to human well-being. I could have explored the issues with a more critical lens in order to evaluate the assumptions of transboundary water management, with a hope that more innovative solutions to these issues would emerge. Notably, I could have collaborated with other ICON students in order to increase the depth achieved in each of the relevant disciplines.

My training as an ICON student prepared me for this dissertation. It exposed me to different disciplines and epistemologies, as well as the importance of approaching a problem through more than one [methodology or lens?]. It caused me to question the limits of using just a positivist perspective to research, which was my dominant training

until that point. It gave me the understanding that seemingly intractable issues, such as resolving transboundary water conflicts, required tough tradeoffs and that win-win scenarios are not always possible. The training in strategic communication that I received as an ICON student allowed me to collaborate effectively with non-academic partners. After my time as an ICON student, I feel prepared to enter the world as an agile scientist ready to take on some of humanity and the environment's most beleaguering problems.

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