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Global surface water quality has been degrading with predictions of negative trends in meeting the Sustainable Development Goal ambient water quality targets (Mead, 2019; WWAP & UN Water, 2019). These water quality impacts can cross borders and impact populations in world's 204 transboundary lake and reservoir basins (ILEC & UNEP, 2016). With risks including potential chronic health effects and impaired livelihoods, water quality trends have direct implications for local communities and can create domestic pressure on the states that manage the resource (Warner & Zawahri, 2012). Although water quality impairments are shared, they are experienced differently by all users. Various structural factors can shape local stakeholders' exposure, impact, and influence on the state's response. Simultaneously, these factors are influenced by the state practices that address the contamination in transboundary lakes. As a result, countries' interactions over water quality are integral to understand how they impact local communities and, consequently, the extent to which communities' needs are represented in the transboundary discourse. This research interrogates this dynamic to evaluate how local actors influence states' behavior over transboundary water quality.

Through utilization of a novel conceptual framework, the impact of stakeholder distributions of power, vulnerability, and risk are assessed for their capacity to shape conflictive and cooperative water interactions between states. Based on an analysis of three case studies in transboundary lakes, stakeholder vulnerability

drove states to initiate cooperation under a narrative of development. As risk increased, the states responded by engaging in high-intensity cooperation to address water quality. Finally, as power increased, stakeholders' concerns became more represented at the transboundary level, initially causing state conflict and resulting in continued cooperation. While stakeholders' distributions showed a clear impact on state action, they were not the sole driver of interactions in the basin. Dynamics between states and international actors also exerted pressure to promote high-intensity transboundary cooperation. These multiple pressures were mutually influencing and created a mixing of scale that drives state interactions.

This understanding of stakeholder influence informs the larger body of literature on transboundary interactions. By understanding triggers for cooperation and conflict, targeted interventions and management strategies can be employed (De Stefano, Petersen-Perlman, Sproles, Eynard, & Wolf, 2017). Through knowledge of stakeholders' role in transboundary processes, information can be harnessed to promote positive cooperation and effectively address global water quality impairments.

Overcoming the Hypolimnion: Stakeholder Influence in Transboundary Water Quality Governance

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Alyssa Jane Offutt, Author

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SECTION 1: Introduction

Global surface water quality has been degrading and contributes to concerns of water scarcity (World Water Assessment Programme [WWAP] & United Nations [UN] Water, 2018). With a range of anthropogenic pollution that enters lakes, rivers, and marsh systems, fresh waters are becoming increasingly compromised. These impacts have implications for the 40% of the global population that lives in the world's 309 transboundary basins (McCracken, Peters, & Wolf, 2018). With potential risks through domestic, recreational, and commercial exposure, these water quality alterations can stress the management and use of transboundary waters.

Water quality degradation is experienced strongly within local, riparian communities. With an often high dependence on the water resource, local stakeholders experience complex impacts from quality impairments. These impacts can be latent, complicating the understanding of causation and mitigation, and as a result, can create greater financial, emotional, and developmental burdens for members of riparian communities. Various factors can influence exposure and impact as a result of water quality impairments (i.e., the distribution of risk and vulnerability) (Zwarteveen et al., 2017). These factors are a result of explicit and implicit social, political, economic, and cultural influences and include occupation, water access and consumption, residence location, and access to alternate food sources, among others (French et al., 2017). Along with access to influence (i.e., distribution of power), these factors can be institutionalized and create a structural inequity. Together these contribute to structural violence that is felt within communities and can prompt action (Galtung, 1969; Watson, 2015).

Despite its local impact, water quality is an international issue. Contaminants are capable of crossing borders, and discharges are often managed at regional, national, and international scales. As a result, transboundary water management has a top-down impact on water quality-related distributions of risk, vulnerability, and power. However, this relationship is not inherently unidirectional. Not only do non-state actors engage in transboundary water management, but domestic actors are capable of altering the states' interactions (Menon, Bavinck, Stephen, & Manimohan, 2015; Warner & Zawahri, 2012). Thus, it is expected that local actors' reaction to impacts can elevate concerns to the transboundary discourse.

A large body of literature has examined which factors shape states' propensity to cooperate and conflict over transboundary waters. Through this understanding, critical policy interventions can be designed and management of systems can be improved (De Stefano et al., 2017). While many authors have considered conditions at the state and international levels of scale, few have interrogated the role of the domestic population. There is evidence that stakeholders influence the states' transboundary interactions, but the extent and pathways of this impact are not fully understood (Warner & Zawahri, 2012). Furthermore, although there is a recognition that structural inequity can lead to insecurity and conflict, its link to transboundary management has not been fully evaluated (McCracken et al., 2018; De Stefano et al., 2017). Through the lens of water quality, these dynamics can be assessed to understand the extent of and how local actors influence transboundary water conflict and cooperation.

To address this pathway, a novel conceptual framework can be used that analyzes the local stakeholders' distribution of power, vulnerability, and risk in comparison to the intensity of transboundary water conflict and cooperation. Through the analysis of distributions, the hydro-political role of individual and all stakeholder groups is assessed in transboundary lake basins. This framework enables the following research questions to be addressed.

1.1 Research Questions

The following research question and sub-questions will be addressed to interrogate the role of stakeholders in transboundary processes.

How do distributions of stakeholder power, vulnerability, and risk shape states' interactions over water quality in transboundary lakes?

- What are the distributions of power, vulnerability, and risk to stakeholders as a result of water quality impacts?
- How do these distributions vary with time?
- What alternate processes influence state interactions?

1.2 Hypotheses

Several hypotheses existed prior to conducting the research. These hypotheses included that stakeholders' power, vulnerability, and risk will influence interactions over transboundary lakes. The states will cooperate or conflict as serves the needs of powerful stakeholders who are experiencing high risk or vulnerability. In general, it is hypothesized that states will chose to cooperate over lakes.

Risk and vulnerability will be highest in riparian communities who have a heavy reliance on the waterbodies for their livelihoods. Power will be highest in sectors that generate financial resources for the state. These distributions will change over time with risk increasing from adverse impacts and changing power dynamic occurring s as groups become dominant in a basin.

1.3 Reflexivity

The author of this thesis is a female, white, middle-class, cisgender, United States citizen. Although every effort is made to avoid implicit bias within this research, this information is provided to inform of any unconscious lenses that may exist in this analysis.

SECTION 2: Literature Review

2.1 Transboundary Lakes

Lakes are a critical resource that support the global population. Along with other lentic waters, lakes contain 90% of the world's available freshwater and provide a broad range of ecosystem services (International Lake Environment Committee [ILEC] & United Nations Environment Programme [UNEP], 2016). Lakes support diverse water use in the form of resource provisioning services, help to manage the global water system through regulating services, and provide aesthetic, spiritual, identity-based associations through cultural services (ILEC & UNEP, 2016). These processes allow lakes to have substantial cultural, economic, and social significance to the communities that rely on them. As a result, lakes are considered "vital" for development and poverty reduction in their basins (UN Water, 2008, p. 1).

Lakes also support the building of connections between populations. With a broad global distribution, many lakes span administrative boundaries. The ILEC and UNEP identified 204 transboundary lakes and reservoirs that are shared by two or more countries (2016). These lakes provide a unique opportunity for exchange and interactions across borders. Transboundary lakes have a close geographic proximity between actors, impacts, and actions at various levels of scale. The lakes also have limited influence of upstream-downstream dynamics enabling similar conditions to be shared amongst actors. As a result, transboundary lakes provide an opportunity to develop interdependence between populations and countries that experience similar benefits and impacts from the waterbody (UN Water, 2008). The joint use of this resource can further promote diplomatic relationships between the adjacent countries (UN Water, 2008). Given the critical functions of transboundary lakes and their influence on international cooperation, it is important to ensure that the lakes remain protected.

2.2 Global Surface Water Quality

Although lakes are an integral resource, they are often at risk of water quality impacts. Global surface water quality has been degrading as a result population growth, urbanization, agricultural practices, industrial activity, and climate change (WWAP & UN Water, 2018). As a result, approximately 40% of lakes were eutrophic between 2008 and 2011 (WWAP & UN Water, 2018). Furthermore, water pollution has increased in almost all rivers of Africa, Asia, and

Latin America since the 1990s (WWAP & UN Water, 2018). Water quality degradation affects both developing and developed countries with a range of impacts on surface waters bodies.

A variety of contaminants contribute to this degradation including hundreds of chemicals that impact surface water bodies (UNEP, 2019). Of these chemicals, nutrients are one the most prevalent water quality pollutants (WWAP & UN Water, 2019). Nutrients are often introduced to waterways through agricultural runoff and the discharge of poorly treated domestic and industrial wastewater. Once in the waterway, nutrients cause eutrophic growth which can impact both ecologic and anthropologic water use and are often accompanied by pathogens and toxic industrial chemicals from wastewater sources (UNEP, 2019). Heavy metals are other common contaminants of concern and have serious health implications at low concentrations. Heavy metals are often introduced to lakes through extractive activity, combustion, geologic weathering, and industrial effluents (Pachana, Wattanakornsiri, & Nanuam, 2010). Other common chemicals include pesticides that are introduced through agricultural applications and emerging contaminants such as pharmaceuticals, hormones, personal care products, perfluorinated compounds, and nanomaterials (WWAP & UN Water, 2019; WWAP & UN Water, 2018). Although the impacts of many contaminants have been identified, there is limited information on the distribution of these chemicals in lakes.

Lakes are particularly sensitive to the increasing water quality degradation. With long residence times and slow currents, lakes are a sink for contaminants. They are vulnerable to aerobic deposition because of their large surface areas and are often in close proximity to anthropogenic sources of contaminants from riparian communities. Although lakes are more capable of buffering environmental stress than lotic waters, they are often not a focus of management, and thus, water quality issues in lakes go ignored (WWAP, 2003). These management challenges are further complicated on transboundary lakes where hydrologic and national boundaries do not coincide. Within lake basins, all states share the impacts of water quality and must actively engage in management to control degradation. Otherwise, contaminant loading in one state can cause concerns for all of the riparian communities in the basin.

Once lakes are contaminated, they are very difficult to remediate and return to their original state. Treatment involves high costs, and complete removal of contaminants can be impossible (UNEP, 2019). However, contamination can also have a significant impact on water use. Water quality degradation can be associated with serious health risks from consumption, recreation, and industrial use. These impacts can lead to water insecurity, eliminate livelihoods, and decrease quality of life. Water quality degradation can further impact ecosystem functioning and shift ecologic communities. These broad impacts are significant but can be challenging to identify due to differences between the perception and experience of water quality degradation.

In response to concerns over decreasing water quality, the global community incorporated ambient water quality into the Sustainable Development Goals (SDGs). SDG 6.3 aims to "… improve water quality by reducing pollution, eliminating dumping and minimizing releases of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally." (UN General Assembly, 2015, p. 22). This SDG represents a commitment towards minimizing water quality degradation and reducing risk in all water sources. However, progress towards the goal has been stalled due to a lack of data, attention, and funding (Mead, 2019; WWAP & UN Water, 2019). This lack of progress threatens global transboundary lakes and can increase stress on hydro-political relationships between riparian countries.

2.3 Transboundary Interactions: Conflict and Cooperation

The quality and quantity of transboundary waters mutually influence the interactions between states. Governance of water resources provides space for both conflict and cooperation between actors. At the level of the state, these transboundary water interactions are often cooperative which enables a greater sharing of resources to solve challenging problems (Wolf, Yoffee, & Giordano, 2003; Trist, 1983). This cooperation is also likely to improve decisions, implementation, and preparation for future challenges, effectively "… building understanding, building support, and building capacity" (Wondolleck and Yaffee, 2000, p. 23). While there are many benefits to cooperation, it is not inherently good. Cooperation can cement power imbalances that are masked by the collaborative process (Hardy & Phillips, 1998). These interactions can further perpetuate a status quo and disadvantage less powerful actors (Zeitoun & Mirumachi, 2008).

Conflict, conversely, is not inherently bad. Conflict can be used as a means to contest power and promote more innovative management and sustainable cooperation (Zeitoun et al., 2017; Hardy & Phillips, 1998; Mirumachi & Allan, 2007; Zeitoun et al., 2014). However, conflict can also yield high costs, limit water equity across states, and place a disproportionate burden on domestic communities. Therefore, it is critical to understand the factors that shape both conflict and cooperation to ensure that the needs of states can be addressed. This understanding will further inform policy interventions and can improve management of water systems (De Stefano et al., 2017).

A breadth of literature has sought to understand why states conflict or collaborate over water resources. Many of these theories consider conditions that exist at the level of the state. Wolf et al. posit that states primarily cooperate in the face of environmental stressors because there is sufficient institutional capacity or positive historic relationships that can absorb the shock of the stress (2003). They further suggest that because many water quality impacts are "creeping" problems, due to an increasing accumulation of impacts, states are generally able to absorb the changes in water quality and thus maintain cooperation (Wolf et al., 2003, p. 43). De Stefano et al. build on this analysis by considering which basin stressors lead to inter-state tension and assess multiple lines of evidence including the institutional capacity of river basins (2017).

Critical transboundary analysis presents a different explanation for cooperation. The theory suggests that conflict and cooperation are not mutually exclusive and can coexist (Mirumachi & Allan, 2007). In this context, the exertion of power causes cooperation to occur (Warner et al., 2017). The theory suggests that a dominant actor, or hegemon, is capable of pressuring other actors to cooperate over water resources through control and consent (Zeitoun & Warner, 2006). Hydro-hegemony can also elicit conflict through mechanisms to contest the "exercise" of power including coercive, leverage, and transformative means (Zeitoun et al., 2017, p. 274). Although the critical transboundary analysis originally focused on states as potential hydro-hegemons, the theory has been expanded to recognize the potential dominance of non-state actors (Warner et al., 2017).

Finally, Sadoff and Grey consider the benefits of cooperation over water resources and suggest that when the benefits outweigh costs, states will engage in cooperative behavior (2002). They argue that cooperation generates benefits to the river through ecosystem management, benefits from the river through economic opportunity, reduction of costs because of the river through decrease in tension among states, and benefits beyond the river through increased collaboration beyond water (Sadoff & Grey, 2002). As a result, these benefits have a variety of environmental, economic, social, and political gains that can be reaped from cooperation, and thus, incentivize cooperative behavior. Similarly, Zawahri suggests that states will cooperate over any highly developed transboundary waterbody because so many interdependencies exist that cooperation is needed to maintain investments (2008).

While the state is often the focus of analyses, the global scale is also assessed for its influence on transboundary water interactions. Critical transboundary analysis acknowledges that non-state actors or ideologies can be a hydro-hegemon (Warner et al., 2017; Furlong, 2006). However, hegemony designates that a given actor or idea wields power to dictate basin interactions. The potential for an external hydro-hegemon is limited in most basins, especially in the absence of a supranational government. However, international actors are also capable of exerting influence through other mechanisms. First, greater global attention can be used to pressure the conflictive or cooperative actions of the state. This attention is gathered through international media coverage and domestic and international coalitions (Xie et al., 2017; Warner & Zawahri, 2012). International donors can also exert influence through funding requirements (Petersen-Perlman, Veilleux, & Wolf, 2017). Often, states are required to cooperate through building institutions to access funds (Petersen-Perlman et al., 2017). Finally, international actors can impact how cooperation occurs by providing guidance and principles, such as the tenants of international water conventions (Mirumachi & Allan, 2007).

Although many studies have considered factors and actors that influence transboundary interactions, gaps in literature exist. In spite of its global presence, there is limited understanding of the role of water quality in transboundary basins (De Stefano et al., 2017). Therefore, water quality degradation requires further evaluation. Furthermore, although there is a recognition that structural inequity can be experienced at various scales and that disproportionate water use can lead to insecurity and conflict, these patterns have not been directly linked to transboundary management (McCracken et al., 2018; De Stefano et al., 2017; Warner & Zawahri, 2012). As a result, the influence of stakeholders should be investigated. Finally, most research evaluates transboundary river basins. As geographic and hydrologic conditions differ on transboundary lakes, there is a different context for interactions that must be assessed.

To address factors that shape interactions, the distinction between interactions must be understood. Transboundary water conflict and cooperation are not binaries and often exhibit varying intensities in how they are performed. These classifications are captured in various frameworks. Multiple frameworks present conflict or cooperation on a spectrum. The Basins at

Risk intensity scale identifies interactions based on their severity of conflict or of cooperation (Wolf et al., 2003). Sadoff and Grey similarly present a continuum for cooperation that reduces risk for conflict through increasing cooperation intensity (2005). However, it is also possible that actors engage in multiple, dynamic interactions that can simultaneously conflict and cooperate (Mirumachi & Allan, 2007). The Transboundary Waters Interaction NexuS (TWINS) framework captures this coexistence of cooperative and conflictive interactions (Mirumachi & Allan, 2007). The TWINS framework maps changes in historic interactions between two entities to understand the varied intensities of conflict and cooperation. Through analyzing the history of conflict and cooperation against the dynamics within the basin, it is possible to see the relationship among temporal interactions in lake basins.

2.4 The 'Territorial Trap' and Stakeholder Influence

Although analysis of transboundary conflict and cooperation tends to focus on states as the primary actors (i.e., the 'territorial trap'), they are not the only actors who participate in transboundary interactions. Non-state actors engage in transboundary water management and are also capable of influencing the state and its interactions (Menon et al., 2015; Warner & Zwahari, 2012). The 'territorial trap' often assumes that the state is a homogenous actor that represents the views and interests of its domestic population; however, this assumption overlooks contestation within the state and the agency of non-state actors (Warner et al., 2017). The assumption also misses how actors' reaction to impacts can effectively elevate conflict or cooperation to the transboundary discourse. Therefore, in order to comprehensively assess transboundary water conflict and cooperation, it is critical to unpack the state and understand the effects and impacts of local actors that underly and drive state interest.

Various literature has indicated how the domestic population can influence transboundary interactions. Putnam suggests that states engage in a two-level game which balances domestic and transboundary politics when determining interactions between states (1988). His theory proposes that there must be sufficient advantages gained through transboundary interactions to satisfy domestic actors (Putnam, 1988). The concept of the two-level game theory parallels many understandings of scale in environmental management. In literature, local, state, and international actors are often perceived to interact within their relative sphere and exert influence on the other levels of scale as a unit. This perception is similar to the stratification of water temperatures in lakes, where water mixes in separate levels and exerts pressure only along the temperature boundaries. Within lakes these levels include the hypolimnion at the bottom, the epilimnion at the surface, and the thermocline that separates both layers. These layers are likened to common perceptions of scale as presented in Figure 1. Although this conception of scale is pervasive in literature, it misses that groups are not homogenous and there is a greater resolution of scale within the groups (Brown & Purcell, 2005). Furthermore, scale is constructed and produced by actors (Brown & Purcell, 2005). This research will broadly consider scales as global, state, and local for simplicity of analysis, but acknowledges that this perception is produced. This research will further interrogate the boundary of influence by developing an improved understanding of local groups.

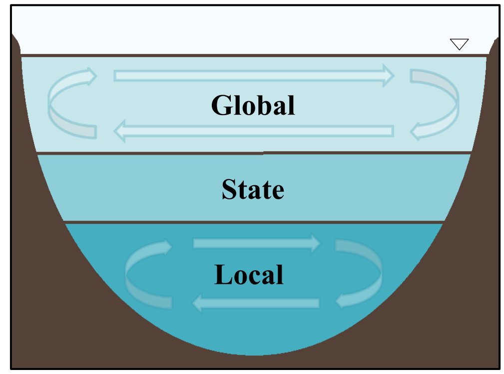

Figure 1. Common conceptions of scale and interactions (Offutt, 2020).

Several empirical studies have assessed the connection between domestic actors and transboundary water interactions. Warner & Zawahri discuss how domestic power is operationalized to impact the state, and primarily hegemonic powers (Warner & Zawahri, 2012). They suggest that through participating in action that counters or checks the state, that states may be more willing to cooperate (Warner & Zawahri, 2012). Domestic pressure was also observed to influence state conflict. As a result of local influence, Hungary abandoned the Gabcikovo-Nagymaros Project with Slovakia which caused conflict over treaty obligations (Bekker, 1998). These studies have shown evidence of impact but have not fully addressed the range of factors in which impact occurs. Additionally, in each of these cases, local actors are not the sole considered influence but contribute to processes.

While these studies have provided valuable insight, they have not extensively interrogated the role of local actors. Warner & Zawahri have focused on the exertion of power without a full consideration of the motivation of actors (2012). Their work also looks at drivers for cooperation without consideration of conflict. The Hungary and Slovakia case study further demonstrates impact without a full evaluation of the process or the differences in the domestic scale. Domestic actors are kept within their own 'territorial trap' and not evaluated for differences in influence or interest. Therefore, to fully understand the capacity of domestic stakeholder influence, a broader analysis is needed that responds to the nuances of transboundary water quality degradation.

2.5 Stakeholder Analysis

Stakeholders are actors who are generally interested, concerned, or affected by water governance (Department for International Development, 2003). Within this work, a stakeholder is operationally defined as any actor who considers themself a stakeholder. Stakeholders exist at all levels of scale; however, in the context of this study, stakeholder groups represent the local actors within the basin. Stakeholders can be individuals or groups, and are represented in this study as groups to simplify analysis.

Stakeholders are often analyzed in water conflict and policy for a variety of reasons. Stakeholder analyses enable decision makers to understand which stakeholders would support and contest a given interaction or project in order address concerns and harness support (Department for International Development, 2003; Phi, Hermans, Douven, Van Halsema, & Khan, 2015). As a result of this process, the decision-maker is able to intervene in order to ensure that a policy or interaction can be implemented. Traditional stakeholder analyses often consider the interest and influence of actors to evaluate how engaged stakeholders will be and what power they have to alter the outcome. These analyses are similarly considered for application of a policy through the motivation-ability (MOTA) framework, which considers motivation and ability (i.e. a modification interest and influence; Phi et al., 2015). A traditional interest and influence analysis is presented in Figure 2. This analysis can be used at various levels of scale including transboundary analyses. Therefore, a stakeholder analysis can be used evaluate the interest of influence of local actors in shaping state action.

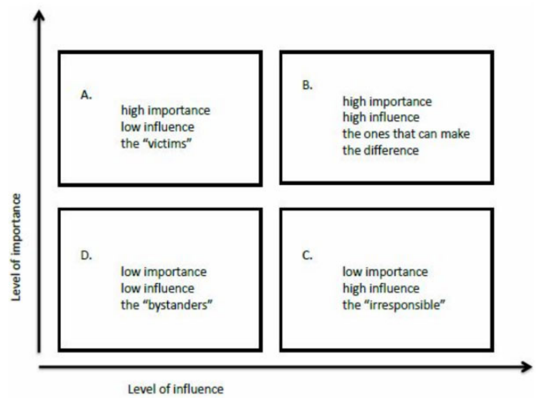

Figure 2. Interest and influence matrix of stakeholder analyses (Wageningen University and Research, 2012).

An analysis of stakeholders not only informs interactions but also enables comparison between actors. Zwarteveen et al. suggest that water governance should be framed in terms of "distributions" that highlight patterns of inequity (2017, p. 1). They establish that distributions span topics of water and risk, voice and authority, and knowledge and expertise (Zwarteveen et al., 2017). These distributions can then inform social power that exists between actors in the basin (Bakker & Morinville, 2013). Through an analysis of distributions, disparities between actors can be identified, and the impact of state and transboundary interactions can be understood. Furlong and Watson have demonstrated how transboundary interactions can filter down to domestic stakeholders and cause injustice between actors (2006; 2015). Furlong further argues that an understanding of these distributions can add nuance to conflict and cooperation (2006). Given the transboundary impact on local distributions, analysis of inequity can be used comprehensively evaluate water interactions.

Environmental justice is defined by the United States Environmental Protection Agency (USEPA) as the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (2020). They further specify that equal environmental protections and access to governance are required to have achieved environmental equity (USEPA, 2020). This concept of environmental justice aligns with the idea of structural violence that was proposed by Galtung (1969). Galtung proposes that structural violence occurs when a process prevents societies from meeting their basic needs (1969). In essence, structural violence violates environmental justice, and is experienced when there are large disparities between groups or when all groups are kept from access to a safe environment.

Degrading water quality can lend itself to concerns of environmental justice and structural violence within basins. Poor water quality can prevent communities from meeting their basic needs to derive water, food, and livelihoods from available sources. Furthermore, disparities in distributions of power (e.g., voice and authority), vulnerability (e.g., knowledge and expertise, environmental laws), and risk can indicate violations of environmental justice in a basin. These violations have direct ramifications for stakeholders in the basin and can generate inequities that jeopardize the sustainability of cooperative domestic management (Zeitoun et al., 2014; McCracken et al., 2018). Given the instability that can result from distributions, it is likely that conflict will result, and that this contention could strengthen stakeholder motivation and impact on a transboundary interactions (Bakker & Morinville, 2013). Therefore, in order to comprehensively consider stakeholders in transboundary processes, power, vulnerability, and risk must be considered.

2.6 Power

Power is the ability to influence decision making and others and is innate in water governance (Kemerink-Seyoum, 2018). For this reason, stakeholder analyses represent power through the analysis of influence. Power can be performed in both visible and invisible spaces. Visible power relates to formal authority and procedures that relate to decision making, whereas invisible power, or Foucauldian power, shapes internalized perceptions and norms (Gaventa, 2006). Gaventa also suggests that power can be "hidden," and imbedded in the processes of and access to decision making (2006, p. 29). As a result, power can have a substantial influence in the actions and perceptions in water governance.

Power is derived from a variety of sources and can be difficult to analyze given the complexity that underlies visible and invisible power. Various frameworks have been proposed to classify sources of power for analysis including those by French and Raven, Zeitoun et al., and Mirunachi and Allan (1959; 2017; 2007). While these frameworks provide a useful opportunity to understand power, they specify how power is exerted as opposed to the capacity for influence and this focus limits analyses (Nye, 1990). To address the complex dynamics in sources of power, an alternate power classification must be considered.

A framework for collaborative governance power was proposed by Purdy and Jones and identifies formal authority, resources, and discursive legitimacy as sources of power (2012). The framework considers both visible forms of power (including formal authority and resources) as well as Foucauldian power in discursive legitimacy. The collaborative governance framework, however, focuses primarily on the discourse over policy (e.g., participants, process, design, and content) and misses the potential for policy application (Purdy & Jones, 2012). Additionally, the framework is constructed for collaborative processes which does not apply to all transboundary decisions. Therefore, while not all of the criteria provided by Purdy and Jones can be directly applied to the transboundary discourse, the broad categories of their framework can be used to inform the relative power of stakeholders.

This framework can be strengthened through incorporation of other sources of power. The MOTA framework proposed by Phi et al. addresses the ability, or "power," of stakeholders to implement policies (2015). Within the framework, institutional, financial, and technical abilities are considered to be sources of power because they are related to the capacity of actors to engage and implement management. Sabatier and Weible propose an additional form of power through advocacy coalitions which enable actors to pool resources and overcome their original level of influence (2007). Finally, other sources of power can be drawn from vulnerability literature which considers elements of level of influence, rights and freedoms, and prestige (French et al., 2017; Prescott-Allen, 2001; Cutter, Boruff, & Shirley, 2003).

Additionally, an alternate source of power can be considered when addressing how actors influence the state. Generally, the state has greater formal authority than stakeholders and establishes the formal pathways for communication. As this research focus on the influence of stakeholders, the Purdy and Jones power categorization may not fully represent the role of the state in dictating opportunity. Therefore, in order to encompass the preferences of the state, a fourth category "state interactions" can be added to analysis.

2.7 Vulnerability

The concept of vulnerability is addressed by several disciplines; however, it can be argued that political ecology is at the heart of vulnerability (Oliver-Smith, 2004). Hilhorst and Bankoff suggest that by separately interrogating vulnerability, analyses can overcome the "all-too-technocratic" perspective of environmental stressors (2004, p. 1). In effect, vulnerability addresses the social, political, and economic factors that affect actors' ability to cope with water quality impacts. This conceptualization of vulnerability varies from climate change literature as it does not consider the probability and magnitude of an impact (Brooks, 2003; Cardona et al., 2012). This approach of biophysical impacts is, instead, captured in the analysis of risk. Vulnerability has a wide range of definitions in literature of which some imply marginalization (Cardona et al., 2012). However, in the context of this study, vulnerability assesses the resilience to environmental stressors (Cardona et al., 2012).

Various environmental hazards, climate change, development, and water-related vulnerability literature propose indicators to assess vulnerability. These indicators more broadly fall into five categories including regional development, economic, education, political, demographic, and cultural vulnerability as presented in Table 1.

Table 1. Categories and indicators of vulnerability from literature.

Broad Category	**Vulnerability Indicators**
Regional Development	• Infrastructure and lifelines (sewers, bridges, water, comms, and transport) (Cutter et al., 2003)

Broad Category	Vulnerability Indicators
	• Wealth for infrastructure (Prescott-Allen, 2001) • Type of water supply infrastructure (Perles Roselló, Vías Martinez, & Andreo Navarro., 2009) • Alternate water sources and emergency plans to access these supplies (Perles Roselló et al., 2009) • Ecosystem/water: diversity of inland water (Prescott-Allen, 2001) • Existence of alternatives (Perles Roselló et al., 2009) • Medical services and health care (Cutter et al., 2003) • Rural/urban fraction (Cutter et al., 2003) • Population growth (Cutter et al., 2003) • Food and shelter (Prescott-Allen, 2001)
Economic	• Poverty level (French et al., 2017; Prescott-Allen, 2001) • Socioeconomic status (income) (Cutter et al., 2003; Pearce, Richardson, Mitchell, & Shortt, 2010; Prescott-Allen, 2001) • Economy (Prescott-Allen, 2001) • Wealth (Prescott-Allen, 2001) • Occupation (Cutter et al., 2003) • Level of migration (French et al., 2017) • Diversity of production (French et al., 2017) • High sector water usage (French et al., 2017) • Dependence on groundwater (Perles Roselló et al., 2009)
Education	• Education status/education (Cutter et al., 2003; Prescott-Allen, 2001) • Literacy (French et al., 2017) • Knowledge and culture (Prescott-Allen, 2001) • State of Knowledge (Prescott-Allen, 2001) • Risk awareness and training (French et al., 2017) • Communication (Prescott-Allen, 2001) • Social information systems (Perles Roselló et al., 2009) • Knowledge and perception of hazard (Perles Roselló et al., 2009) • Reaction to danger and catastrophe (Perles Roselló et al., 2009)
Political	• Rights and freedoms (Prescott-Allen, 2001) • Governance (Prescott-Allen, 2001) • Institutions (Prescott-Allen, 2001) • Law (Prescott-Allen, 2001) • Peace (Prescott-Allen, 2001) • Crime (Prescott-Allen, 2001) • Civil Order (Prescott-Allen, 2001) • Preventative standards and protection systems (Perles Roselló et al., 2009) • Standards and emergency plans (Perles Roselló et al., 2009) • Groundwater protection standards (national, regional, provincial, and municipal) (Perles Roselló et al., 2009) • Individual responsibility towards contamination (Perles Roselló et al., 2009) • Equity-distribution of benefits and burdens (Prescott-Allen, 2001)
Demographic	• Number of people per household/family structure (French et al., 2017; Cutter et al., 2003) • Presence of sensitive groups or special needs groups (French et al., 2017; Cutter et al., 2003)

Broad Category	Vulnerability Indicators
	• Age and fragile age groups (Cutter et al., 2003; Pearce et al., 2010; Perles Roselló et al., 2009) • Socially deprived groups (Perles Roselló et al., 2009) • Gender (Cutter et al., 2003)
Cultural	• Presence of assets with a special patrimonial value [cultural, environmental ethnographic) (Perles Roselló et al., 2009) • Social networks and connections (Cutter et al., 2003) • Social cohesion (Perles Roselló et al., 2009)

These broad categories have direct implications for how populations are able to respond to water quality risk. Regional development addresses the physical capacity to address water quality impacts. It considers the availability and proliferation of water treatment technologies, infrastructure, and access to medical care in the event that a community is exposed to water quality risks. Economic vulnerability addresses the capacity of communities to find alternate livelihoods if their original work is impacted by water quality. Economic vulnerability also considers the purchasing power of communities to negate the impacts of water quality (e.g., bottled water, health care, food from outside of the basin). Educational vulnerability considers a community's capacity to understand the sources and impacts of risk so that they can alter behavior accordingly. Educational vulnerability also considers the capacity to access certain channels of communication (e.g., to the state and external actors). Political vulnerability assesses if there are political systems in place to protect a community from sources of water quality impacts. This vulnerability considers the governance and regulatory enforcement of water resources. Demographic vulnerability considers the make-up of the community which can impact how risk is experienced. Although these demographics can have varying implications as dependent on context, some are consistent for water quality impacts. For instance, health risks from contaminants often vary by age with children and elderly persons at greater risk of complications. Finally, cultural vulnerability assesses the support of the community for the waterbody itself or for the capacity to help each other in the event of an impact.

Together, these elements of vulnerability shape a community's response to water quality and the relative impacts of any degradation that occurs. While a variety of indicators are useful in this analysis, some are context dependent (e.g., rural/urban fraction, socially deprived groups), and therefore, an assessment of vulnerability must either be tailored to a specific area or limit criteria in order to assess universal trends.

2.8 Risk Assessments

While vulnerability address the capacity to buffer impacts, risk considers the frequency and magnitude of impacts. Social sciences research often defines risk as a consideration of vulnerability and the probability and exposure to look at the potential for damage (Cardona et al., 2012; Brooks, 2003). However, with water quality impacts, the "hazard" is actively occurring, and therefore, the probability of occurrence does not improve understanding. A more technocratic approach considers water quality risk through the magnitude of impacts and exposure to those impacts (Means, 1989). This approach is often used to address contaminated sites and determine the requirements for remediation. Contaminated site risk assessments also often consider the toxicity of a given impact and exposure pathways (e.g., ingestion, inhalation, dermal, etc.; Means, 1989). These studies require a wealth of chemical data, an understanding of site-specific matrices, and a clear designation of how actors interact with the site.

While contaminated site risk assessments consider the body burden of chemicals, and thus the manifestation of risk in physical health, they often do not consider other risks in the potential for damage. These risks include impacts to the livelihoods of water users and impacts to the food security to communities. Vulnerability analyses capture these concerns, to some extent, through consideration of if water is used for livestock or farming (French et al., 2017; Perles Roselló et al., 2009). Given that the risk within this study considers the biophysical impacts of water quality, these broader conceptions of impact must be considered.

2.9 Hydro-politics of Transboundary Lakes

Through the analysis of power, vulnerability, and risk, stakeholder distributions can be better understood. Together, these elements create a modified stakeholder analysis that considers influence (i.e., power) and interest (i.e., vulnerability and risk). Analysis of these three components also introduces a beneficial lens to transboundary interactions. Power is often discussed when considering interactions of scale and transboundary dynamics. Warner & Zawahri have specifically connected power of domestic actors to transboundary interactions which can be further explored through this research (2012). The analysis of vulnerability introduces elements of political ecology that Furlong argues can provide a unique perspective on transboundary cooperation (2006). Limited research has utilized the social, political, and economic factors that are highlighted through political ecology to assess transboundary water management (examples include Menon et al., 2015; Bakker, 1999; Rathgeber, 1996). Therefore, inclusion of vulnerability would further build the connection between the political ecology framework and transboundary processes. Finally, an incorporation of risk considers the biophysical factors of water quality that may impact interactions between states. This analysis extends transboundary analyses beyond the common bounds of water quantity to introduce the unique and complex impacts that occur from water impairments. Through this modified stakeholder analyses in connection to transboundary interactions, the role of stakeholders in transboundary processes can be better understood.

Transboundary lakes provide a unique opportunity to study these interlinkages. Within lake systems the close geographic proximity between impacts and the actions of different levels of scale (including state negotiations over transboundary resources) enables an easier exchange of actors across the waterbody and within the state. Additionally, lakes maintain hydrologic mixing which limits the influence of upstream-downstream dynamics. The absence of these dynamics provides a greater opportunity for shared benefits as any alteration of behavior will benefit the state itself and not just its downstream neighbor (Warner & Zawahri, 2012).

This proximity and hydrologic characteristic can help to more clearly define relationships between actors, water resources, and discourses that temporally share water quality impacts. Through analysis of transboundary lakes, the role stakeholder distributions can be linked to transboundary water conflict and cooperation, and indicators can be defined to more comprehensively identify and mitigate negative peace and conflict in the future.

SECTION 3: Methods

3.1 Research Design

Mixed methods are used to address the research questions and evaluate the relationships of inequity, water quality, and transboundary water conflict and cooperation. In order to evaluate the role of stakeholders in shaping transboundary interactions over water quality, a novel conceptual framework is applied to three case studies. The framework compares relevant transboundary interactions between states with a modified stakeholder analysis that assesses the relative power, vulnerability, and risk of stakeholder groups leading up to each time point. A graphical representation of the modified stakeholder analysis is overlain with the tracking of state interactions. Through the analysis of the history of interactions in conjunction with the temporal stakeholder analysis, patterns can be drawn to highlight the role of stakeholders in transboundary processes.

Three case studies are selected for analysis. These case studies include transboundary lakes that have or are currently experiencing known water quality degradation (Williams, 2015; Lubovich, 2009; Ostendorp, Schmieder, & Jöhnk, 2004). The analysis is bound to transboundary lakes in order to minimize the influence of upstream-downstream dynamics and to more easily evaluate the proximity of actors in the basin. The case studies also represent lakes that have a large population within their basins as it was assumed that large lakes would generate more research, publicly available information, and greater state engagement. A most different case design was used to select case studies that represent different geographic locations, water quality impacts, and governance structures. These case studies included the basins of Lake Titicaca, Lake Victoria, and Lake Constance. Although only three case studies were selected, there are likely many other transboundary lakes that are experiencing water quality impairments. However, because there is a lack of extensive water quality data collection, these three lakes were chosen for their availability of information, size, and fit within the most different case design (Mead, 2019). Within the analysis, only the riparian countries from each basin are analyzed. The history of transboundary interactions and stakeholder analysis is considered based on the major state interactions identified in literature over a 200-year time period.

3.2 Conceptual Framework

The conceptual framework connects a novel stakeholder analysis (i.e., the modified analysis) to an existing framework of interactions. This framework not only expands the understanding of stakeholders, but provides a unique way to connect stakeholder distributions to state interactions. Within each basin, the history of interactions considers the extent of co-existing transboundary water conflict and cooperation between state actors. The interactions are selected to designate major points in time when there is a shift in conflict and cooperation intensity or when there is an interaction that is relevant to water quality in the lake. This analysis uses the existing TWINS framework to classify and track interactions (Mirumachi & Allan, 2007).

The modified stakeholder analysis evaluates the elements, power, risk, and vulnerability for each major stakeholder leading up to the given time periods. In effect, this analysis captures actors' capacity for influence (i.e., power) and interest (i.e., exposure and impact). The distinction between risk and vulnerability is made to tease out the biophysical relationship with water quality from the structural inequities between stakeholders (Cardona et al., 2012; Smith, 2004). As a result, risk is categorized based on the potential for water quality exposure and effects, while vulnerability considers the greater social, political, and economic factors that shape the capacity to cope with impacts (Cardona et al., 2012). The analysis of stakeholder power, vulnerability, and risk leading up to each major state interaction is completed based on specified metrics that are tailored to water quality in transboundary lakes.

Within the stakeholder analyses, multiple components of power, vulnerability, and risk are assessed. Each component is classified based specified metrics as high, medium, or low to capture the broad trends that were occurring. In order to combine these components and compare power, vulnerability, and risk across stakeholders and interactions, the qualitative classifications are also assigned a value. These values are then summed and provide a numerical value for the total relative power, vulnerability, and risk for each stakeholder at each point in time. Although assigning values to this analysis may provide a false sense of accuracy, the values are presented to enable a clearer comparison between stakeholders and interactions (Phi et al., 2015). Additionally, a limited resolution (high, medium, and low) was selected to minimize the potential subjectivity of assigning values to qualitative rankings. As a result, the values should only be used to assess broad trends without overemphasizing minor differences in values.

The components and metrics of power, vulnerability, and risk are established as a result of a literature review that pulls heavily from concepts of political geography, water quality risk, environmental hazards, environmental justice, and climate vulnerability literature. Although there is potential overlap in the components of power, vulnerability, and risk, the conceptual framework makes every attempt to avoid redundancy in considered data to avoid biasing the analysis to one line of evidence. Therefore, although certain metrics may fit into multiple categories, they were limited to one category in the conceptual framework.

The modified stakeholder analysis is applied to five stakeholder groups within each basin. Groups were selected over individuals to represent a broader range of the basin population. Although there are more than five stakeholder groups that exert influence on transboundary interactions in each basin, only five were selected to bound the analysis. Stakeholders were chosen based on frequent occurrence in literature, direct interaction and use of the lakes, and their relative fraction within the basin (with preference given to groups that represent a larger subset of the basin population). This selection of often mentioned groups enables greater access to stakeholder information.

3.3 Data Collection

Data is collected based on specified metrics for transboundary interactions, power, vulnerability, and risk as detailed in the following section. Several lines of evidence are collected within categories based on availability of data. Qualitative data is collected from a variety of sources in literature including papers, studies, and media (i.e., newspapers). Quantitative data is collected from publicly available datasets presented by the United Nations Development Programme (UNDP), the World Bank, Espacio Investiga (the historical index of human development), Transparency International, and Reporters Without Borders (RSF; 2020; 2020; Prados de la Escosura, 2019; 2020; RSF, 2020). All information is gathered from publicly available sources that were accessed through Google search engines and the Oregon State University library database. To search for information, key words that related to the framework criteria were used. Document review focused primarily on sources written in English although several sources in Spanish were also used and interpreted by the author. Bias was identified in several of the sources and was addressed by gathering additional documents and perspectives. A review of approximately two hundred documents was completed to gather data.

Data is collected for each stakeholder group leading up to each interaction within the basin; however, stakeholder specific and basin specific data could not be located for each time point. When varying sources of data are used, stakeholder specific information is prioritized, followed by basin specific data, and then country specific data. Additionally, when data at specific time points cannot be located, assumptions are made based on temporal patterns and multiple lines of evidence. Any assumptions are clearly stated within the analysis. Additionally, while attempts are made to gather data for each metric, not every metric is addressed at each point in time because of data gaps the bounds of the analysis. Any gaps in data are addressed in the high, medium, and low classification of the data analysis.

3.3.1 Transboundary Interactions

To analyze the conflictive and cooperative intensity of transboundary state interactions, the history of interactions in each basin is first assessed. Transboundary interactions consider coexisting conflict and cooperation as based in the TWINS framework (Mirumachi & Allan, 2007). Within the case studies, all transboundary water interactions are considered, not only those related to water quality. A broader range of interactions is included because patterns of behavior are often interlinked and can indirectly relate to quality. The history of interactions is investigated and tracked within a timeline of each basin, and the criteria used to analyze the type and intensity of interaction is collected based on the TWINS framework criteria presented in Table 2.

Table 2. Criteria for transboundary state interactions as established by Mirumachi and Allan (2007).

Category	**Criteria**
Intensity of Conflict	• Existence in the public domain • Actions taken (e.g., emergency action, violence)
Intensity of Cooperation	• Extent of shared goals • Extent of joint action • Commitment to future costs and constraints

3.3.2 Power Axis

Stakeholder power is determined based on an analysis of the sources of power at each major event. These sources of power are related to capacity to influence the state. Within this analysis, sources of power include formal authority, resources, discursive legitimacy, and state interest as specified in Table 3. The power categories in this study broadly capture the sources of power proposed by Purdy and Jones with an additional category of state interest (2012). The criteria within each category is adapted from various sources in literature and professional judgement.

Table 3. Sources of power (adapted from Purdy & Jones, 2012; Phi et al., 2015; Sabatier & Weible, 2007; French et al., 2017).

Category	Criteria
Formal Authority	• Institutionalized participation in transboundary water governance • Level of influence in decision making • Use of indirect authority/legal rights
Resources	• Existence of a representative, organized group • Extent of the organized group (size and spatial extent) • Use of coalitions • Technical and financial resources need to implement projects, access public attention, and distribution information
Discursive Legitimacy	• Prioritization of issues • Capacity to frame the dominant narrative • Methods and frequency of expression of voice • Public support for position • Freedom of press to express position
State Interest	• Relative contribution to the gross domestic product (GDP) • Relation of assets with a special patrimonial value (cultural, environmental, etc.) • Political interest • Active investment within the stakeholder group

3.3.3 Vulnerability Axis

Stakeholder vulnerability represents the capacity of the stakeholder to buffer change and accounts for the social, economic, and political factors that influence water quality impacts. Vulnerability within the context of this study is not used to imply that communities are marginalized or lack agency. This analysis addresses buffering capacity for water quality impacts without incorporating the context dependent factors that address access (i.e., implicit biases). The exclusion of these context dependent factors enables a greater standardization of the analytical framework for global application. Although multiple aspects contribute to vulnerability, only four primary categories are selected within the scope of analysis for ease of data access and interpretation. Within this study vulnerability is analyzed by the categories of regional development, economic, education, and political vulnerability as specified in Table 4. The categories of vulnerability and criteria are based analysis of proposed indicators from environmental hazard, environmental justice, vulnerability, and human development index literature.

Table 4. Sources of vulnerability (adapted from French et al., 2017; Cutter et al., 2003; Pearce et al., 2010; Prescott-Allen, 2001; Perles Roselló et al., 2009; UNDP, 2009).

Category	Criteria
Regional Development	• Extent of water treatment access • Existence of water supply facilities and infrastructure • Access to alternate water sources • Population growth of the region
Economic	• Occupation • High sector water usage • Diversity of production/regional single sector economic dependence • Poverty rate • Gross national income (GNI) per capita
Education	• Risk awareness/training on water issues • Access to water quality data • Illiteracy rate • Average/expected level of education obtained
Political	• Existence of regulatory protection • Enforcement of regulatory protection • Existence of regional water management • Reliability of government systems (corruption)

3.3.4 Risk *Axis*

Risk is determined based on an engineering definition which considers the frequency and exposure pathways of a particular impact (Means, 1989). This analysis of risk addresses biophysical impacts and enables an approach that may communicate more directly with a state that has a technocratic perspective. Consideration of impact and exposure is modeled after the human health assessments that are used in risk analyses of contaminated sites. However, this analysis is significantly simplified to overcome an absence of data and toxicological analysis. The criteria for impact and exposure are provided in Table 5. Within the social sciences, risk analyses often consider vulnerability and frequency of impact (Cardona et al., 2012). This consideration of vulnerability is covered within the vulnerability axis.

Table 5. Sources of risk related to exposure to the water quality impact and frequency of exposure (adapted from Means, 1989; French et al., 2017; Perles Roselló et al., 2009).

Exposure Pathway	Water Quality Impact	Frequency of Exposure
Ingestion (water)	• Health risks from ingestion of water • Availability of water source	• Magnitude of impact • Frequency of exposure
Ingestion (aquatic biota, irrigated crops, and/or livestock)	• Health risks from ingestion of biota, crops, or livestock (via bioaccumulation) • Food insecurity resulting from water quality impacts	
Dermal Contact (domestic and/or recreational)	• Health risks from dermal contact with water	
Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	• Impact on functioning of sector (e.g., intake pipes) • Impact on supply of sector (e.g., fish stocks) • Impact on the market of the sector (e.g., a decrease in tourism interest because of water quality)	

3.4 Data Analysis

The data is analyzed and classified based on criteria in the following sections. Given variability of available data for the analysis of power, vulnerability, and risk, multiple options are given for classification of high, medium, and low. When multiple criteria are presented, they are listed in the order of preference for classification. Consistent with data collection, classification of criteria was preferred in the following order: stakeholder specific data, basin specific data, and country specific data.

3.4.1 Transboundary Interactions

The history of transboundary water interactions is evaluated to designate where there is a shift in conflict and cooperation intensity or an interaction and time period that is relevant to water quality management. These interactions include major developments related to water quality but also consider non-quality related interactions to understand existing patterns. Based on this analysis, between five and seven interactions are selected for each basin. To analyze the selected interactions over each transboundary lake, the major events are classified and mapped based on the TWINS criteria presented in Table 6 (Mirumachi & Allan, 2007).

Table 6. Classification of conflictive and cooperative interactions as based on the TWINS framework (Mirumachi & Allan, 2007).

Intensity	Criteria
Conflictive Interactions	
Non-politicized	The issue is minimal to the state or not within the public domain.
Politicized	The issue is on the political agenda and some resources are being reallocated to address the issue.
Securitized/ Opportunized	The issue is seen as a threat or opportunity that is sufficient enough to justify emergency action outside of the bounds of political procedure.
Violized	The issue justifies violent confrontation.
Cooperative Interactions	
Confrontation of Issue	There is acknowledgement that the issue exists, but states are not participating in joint action and do not have shared goals.
Ad hoc	States are participating in joint action but do not share goals.
Technical	States have shared goals but are not participating in joint action.
Risk-averting	States are participating in joint action and have shared goals but are unwilling to commit to future constraints (i.e., will not commit to unforeseen future costs).
Risk-taking	States are participating in joint action, have shared goals, and have committed to future constraints (i.e., unforeseen costs and risks).

3.4.2 Power Axis

The criteria used to rank the sources of power are presented in Table 7. The quantified values are identified in parenthesis. Within the resources category, stakeholder organizations are mentioned. These stakeholder organizations include organizations that are mentioned in literature for their engagement in transboundary governance and do not include all organizations in the basin. This limitation was used because power within this context addresses the capacity to influence the state over transboundary interactions.

Table 7. Criteria for power rankings based on the sources of power specified in Table 3. The quantitative values assigned to the rankings are listed in parenthesis.

Power Source	Ranking	
Formal Authority	High (3)	a. There is a transboundary government institution that has formalized participation of stakeholders with influence over decisions (i.e., delegated power, partnership, placation, or consultation [Arnstein, 1969])

Power Source	Ranking	
	Medium (2)	a. There is a transboundary government institution that has formalized participation of stakeholders with i. limited influence over decisions through information supply (i.e., informing, therapy, or manipulation [Arnstein, 1969]) ii. inconsistent involvement of the entire stakeholder group (i.e., participation on a case by case base), or iii. involvement contingent on state conditions b. There is a national, regional, or local government institution that has formal or informal participation of stakeholders with influence over decisions (i.e., delegated power, partnership, placation, or consultation [Arnstein, 1969]) c. There is informal governance with strong influence over decisions (i.e., delegated power [Arnstein, 1969])
	Low (1)	a. There is a transboundary government institution with little to no participation of stakeholders b. Stakeholders are involved in national, regional, or local government institutions and have limited influence over decisions through information supply (i.e., informing, therapy, or manipulation [Arnstein, 1969]) c. Stakeholders are not engaged in governance
Resources	High (3)	a. There is an organization that specifically represents the stakeholder and i. is transboundary with broad participation in all countries, or ii. has the capacity to implement projects or produce and distribute information b. There is an organization that represents the stakeholder in one country and the stakeholder group represents a majority fraction of the basin c. The stakeholder has a strong coalition with i. sufficient stakeholder groups to constitute a majority, or ii. an actor that has high formal authority, the capacity to implement projects, or the capacity produce and distribute information
	Medium (2)	a. There is an organization that specifically represents the stakeholder group and i. is transboundary without broad participation in all countries, or ii. does not have the capacity to implement projects or produce and distribute information b. There is an organization that represents a broad range of stakeholders and i. is transboundary with broad participation in all countries, or ii. has the capacity to implement projects or produce and distribute information c. There is no organization, but the stakeholder group demonstrates an ad hoc capacity to organize d. There is no organization, but the stakeholder group represents a majority fraction of the basin or a specific country e. The stakeholder group has a strong coalition with other stakeholder groups but together, constitute a minority fraction of the basin population f. The stakeholder group has weak or loose coalition with other stakeholder groups
	Low (1)	a. There is no organization that represents the stakeholder and

Power Source	Ranking	
		i. the group represents a minor fraction of the basin or a specific country, and ii. the group has not demonstrated an ad hoc capacity to organize
Discursive Legitimacy	High (3)	a. The stakeholder group's position is prioritized in political processes and/or the stakeholder group has framed the dominant narrative that is addressed b. The stakeholder group frequently exerts their voice in public spaces or in direct connection to the state and the state reacts to this expression c. There is broad public support of the stakeholder group's position d. The stakeholder group is viewed as credible when presenting information in public spaces
	Medium (2)	a. The stakeholder group frequently exerts their voice in public spaces or in direct connection to the state but i. the government does not react to this expression, or ii. the group or representation of the group is not perceived as credible b. There is some public support for the stakeholder group or the perspective of the stakeholder group c. The public voice of the group is perceived as credible or representative of the stakeholders but rarely presents information or opinion in public spaces d. The stakeholder's perspective has been considered in transboundary management and there is freedom of the press (considered "good" or "very good")
	Low (1)	a. The stakeholder group does not exert their voice in public spaces b. There is no clear public support for the perspective of the stakeholder group c. The stakeholder's perspective has not been considered or is discredited in transboundary management d. Freedom of the press is inadequate (considered "bad," "problematic," or "non-existent")
State Interest	High (3)	a. The states have demonstrated interest in the stakeholder group or group's interests as a result of transboundary studies, projects, or cooperation b. The stakeholder group contributes a large percentage to the state GDP for at least one riparian country i. The percentage of GDP is >30% ii. The sector is one of the top 5 GDP earners in the state, or iii. The sector is expressed as a major contributor to the GDP c. The stakeholder group holds a political interest to the government of at least one riparian country d. The stakeholder group contributes economically through the region in alternate manners (i.e., exports or foreign investments) in a manner that is expressed as important to the state e. The stakeholder group is perceived to be prioritized by the state
	Medium (2)	a. The states have expressed interest in the stakeholder group or group's interests but have not demonstrated interest through transboundary studies, projects, or cooperation

Power Source	Ranking	
		b. The states have expressed interest in the region but not a specific stakeholder and have demonstrated this interest through transboundary studies, projects, or cooperation c. The stakeholders hold some political interest to the government of at least one riparian country but have not been perceived to be prioritized d. International actors have expressed interest in the stakeholder group as a result of studies or projects although the states have not expressed interest e. The stakeholder groups contributes a to the GDP of at least one riparian country
	Low (1)	a. The states have expressed interest in the region but have not demonstrated that interest through transboundary studies, projects, or cooperation b. The stakeholder group is largely ignored by the state c. The stakeholder group has been disadvantaged by prioritization of another stakeholder group d. The stakeholder group does not contribute to the GDP of the region

3.4.3 Vulnerability Axis

The criteria used to rank stakeholder vulnerability are presented in Table 8. The quantified values are identified in parenthesis. The quantitative data is broadly classified based on thresholds within the HDI indices. Prior to 2009, the UNDP classified development as low, medium, high, and very high (UNDP, 2009). Given the quantity of data that was obtained prior to 2009 and the alignment of available data with the pre-2009 HDI criteria, these thresholds were used for most of the quantitative data analysis. These thresholds designate the difference between high and medium vulnerability and medium and low vulnerability (0.5 or 50%, 0.8 or 80%, respectively) in the regional development, economic, and education categories. The HDI thresholds were also determined to be appropriate for the analysis of water access and poverty as the SDGs aim for all citizens to have an improved water access and poverty alleviation (UNDP, 2020). With a medium vulnerability threshold of 50%, this analysis addresses that the majority of the population must have access to basic improved water treatment to have some reduction in vulnerability. Given the inclusion of water access and poverty reduction in the SDGs, these criteria are also prioritized in the classification of vulnerability.

Several quantitative indicators also have specific thresholds. The World Bank designates annual thresholds of low, lower-middle, upper-middle, and high-income countries (2019). When available, the GNI per capita data was compared against the annual thresholds. Finally, in the post-2009 HDI calculation, education is calculated based on the mean years of education. This calculation considers the thresholds of education based on the mean years of education divided by fifteen. The analysis uses the current HDI thresholds to generate the low, medium, and high thresholds for mean years of education to account for the method that uses the specific parameter. Additionally, the pre-2009 HDI methodology considered literacy with a two-thirds ranking and enrollment with a one-thirds rating when calculating the education parameter. Based on available data, mean years of education is substituted for enrollment, and literacy is also considered more heavily in analyses. Finally, in the absence of alternate thresholds, 33% and 66% are utilized as thresholds between high, medium, and low vulnerability.

Table 8. Criteria for the ranking of vulnerability as based on the sources specified in Table 4. The quantitative values assigned to the rankings are listed in parenthesis.

Vulnerability Category	Ranking	
Regional Development	High (3)	a. Less than 50% of the population has basic or improved drinking water access b. Less than 50% of the population has access to high quality drinking water c. Greater than 50% of the population has basic or improved drinking water access but large population growth (relative to the rest of the respective countries) has occurred in the region exceeding the capacity of existing infrastructure and has caused substantial decreases in water access
	Medium (2)	a. Between 50% and 80% of the population has basic or improved drinking water access b. Greater than 80% of the population has basic or improved drinking water access but large population growth (relative to the rest of the respective countries) has occurred in the region exceeding the capacity of existing infrastructure and has caused substantial decreases in water access
	Low (1)	a. Greater than 80% of the population has basic or improved drinking water access b. There are alternate water resources that are likely affiliated with improved water access and are not at risk for contamination related to the lake
Economic	High (3)	a. Greater than 50% of the population is living below the poverty line, and/or b. The employment opportunities are subsistence and i. There is low diversity of production in the region or ii. There is a high dependence on water resources c. The employment generates a financial income but i. There have been large losses in the sector or d. Income is assumed to be consistent with the remainder of the country and the income parameter is low (<0.5) or the GNI per capita is considered low based on the World Bank annual thresholds e. The income parameter is low (<0.5) or the GNI per capita is considered low development based on the World Bank annual thresholds

<table>
<tr><th>Vulnerability Category</th><th colspan="2">Ranking</th></tr>
<tr><td></td><td></td><td>f. The sector has not yet been established in the region</td></tr>
<tr><td></td><td>Medium (2)</td><td>a. The employment generates a financial income, poverty in the region is medium (> 20% and <50%), and
i. There is diversity of production in the region,
ii. There is low dependence on water resources, or
iii. The industry is growing or thriving generating substantial financial resources for participants
b. The employment generates a financial income, poverty in the region is high (>50%), and
i. The industry is growing or thriving generating substantial financial resources for participants that are anticipated to exceed income of the average stakeholders within the basin
c. Poverty is medium (> 20% and <50%) and
i. The income parameter is medium (<0.8 and >0.5) or
ii. The GNI per capita is considered medium (e.g., lower-middle or upper-middle income) based on the World bank annual thresholds
d. Poverty is low (<20%) and
i. There is limited diversity of production in the region and
ii. There is high dependence on water resources
e. In the absence of alternate data sources, the income parameter is medium (<0.8 and >0.5) or the GNI per capita is considered medium (e.g., lower-middle or upper-middle income) based on the World bank annual thresholds</td></tr>
<tr><td></td><td>Low (1)</td><td>a. The employment generates a financial income, poverty in the region is low (<20%) and
i. There is diversity of production in the region,
ii. There is low dependence on water resources, or
iii. The industry is growing or thriving generating substantial financial resources for participants
b. Poverty is low (< 20%) and
i. The income parameter is high (>0.8) or
ii. The GNI per capita is considered high (e.g., high income based on the World bank annual thresholds
c. In the absence of alternate data sources, the income parameter is high (>0.8) or the GNI per capita is considered high (e.g., high income) based on the World Bank annual thresholds</td></tr>
<tr><td>Education</td><td>High (3)</td><td>a. The population has limited to no risk awareness and
i. Literacy is considered low (<50%) or
ii. When the literacy percentage is not available, the literacy calculation is low (<0.5)
b. There is a low rate of literacy with the literacy percentage (<50%) or in the absence of the literacy percentage, the literacy calculation is low (<0.5)
c. There is a medium rate of literacy with the literacy percentage (>50% and <80%) or in the absence of literacy percentage, the literacy calculation is medium (>0.5 and <0.8) and
i. The average years of education are considered low (<8.25 years)
d. In the absence of alternate data, the average years of education are considered low (<8.25 years)</td></tr>
</table>

Vulnerability Category	Ranking	
	Medium (2)	a. The population has some risk awareness and/or some access to data and i. Literacy in the region is considered medium or high or 1. With the literacy percentage as medium or high (>50% or 80%, respectively) or 2. When literacy percentage is not available, the literacy calculation is medium or high (>0.5 or >0.8, respectively) ii. The average years education are considered medium or low (<10.49 years or <8.25 years, respectively) b. There is a medium rate of literacy with the literacy percentage (>50% and <80%) or in the absence of literacy percentage, the literacy calculation is medium (>0.5 and <0.8) and i. The average years of education are considered medium (>8.25 years or >10.49 years, respectively) c. There is a very high rate of literacy (>90%) and i. The average years of education are considered low (<8.25 years)
	Low (1)	a. The population has a high risk awareness and access to data and i. Literacy in the region is considered medium or high 1. With the literacy percentage as medium or high (>50% or >80%, respectively) or 2. When literacy percentage is not available, the literacy calculation is medium or high (>0.5 or >0.8, respectively) ii. The average years education are considered medium or high (>8.25 years or >10.49 years, respectively) b. There is a high or very high rate of literacy with the literacy percentage (>80% or >90%, respectively) or in the absence of literacy percentage, the literacy calculation is high (>0.8) and i. The average years of education are considered high (>10.49 years, respectively) c. There is a very high rate of literacy (>90%) and i. The average years of education are considered medium (>8.25 years and <10.49 years) d. There is a medium rate of literacy (<80% and >50%) or in the absence of literacy percentage, the literacy calculation is medium (>0.5 and <0.8) and i. The average years of education are considered high (>10.49 years)
Political	High (3)	a. There are not water regulations in a majority of the countries b. There are water regulations in all countries but they do not all address pollution controls and i. Laws are not enforced, ii. There are high rates of non-compliance, or iii. There is a medium-high level of corruption in public officials which implies lack of enforcement (corruption index <66% and <33%, respectively) c. There are regulations in a majority of countries that address pollution controls and i. Laws are not enforced, ii. There are high rates of non-compliance, or iii. There is a medium-high level of corruption in public officials which implies lack of enforcement (corruption index <66% and <33%, respectively)

Vulnerability Category	Ranking	
	Medium (2)	a. There are regulations in all countries that address pollution controls and i. Laws are not enforced, ii. There are high rates of non-compliance, or iii. There is a medium-high level of corruption in public officials which implies lack of enforcement (corruption index <66% and <33%, respectively) b. There are water regulations in all three countries but they do not all address pollution controls and i. Laws are enforced, ii. There is a low level of corruption in public officials which can imply greater enforcement (corruption index >66%), or iii. Enforcement of regulations is implied based on a lack of reporting of non-compliance c. There are regulations in a majority of countries that address pollution controls and i. Laws are enforced, ii. There is a low level of corruption in public officials which can imply greater enforcement (corruption index >66%), or iii. Enforcement of regulations is implied based on a lack of reporting of non-compliance
	Low (1)	a. There is harmonized legislation in all riparian countries that are enforced b. There are regulations in all three countries that address pollution controls and i. Laws are enforced, ii. There is a low level of corruption in public officials which can imply greater enforcement (corruption index >66%), or iii. Enforcement of regulations is implied based on a lack of reporting of non-compliance

3.4.4 Risk *Axis*

The metrics to determine risk are presented in Table 9. The value for each criteria is labeled in parenthesis. Water quality impacts are considered based on a binary response of if the impact exists. The exposure is considered based on the common ranking of high, medium, and low. The approximate risk is determined by multiplying the quantitative values of impact and frequency of exposure.

Table 9. Criteria for the ranking of risk as based on the categories specified in Table 5. The quantitative values assigned to the rankings are listed in parenthesis.

Risk Component		Ranking
Water Quality Impact	Yes (1)	a. The water quality impacts or has reached a sufficient level to negatively impact the given exposure pathway. These negative impacts can include human health risk through consumption (directly or via bioaccumulation), contribution of water quality impact to food insecurity, impaired mobility through dermal exposure, or affect on

Risk Component		Ranking
		functioning of livelihood (e.g., clogged pipes), livelihood supply (e.g., fish stocks), or the market in general (e.g., water quality impacts on the tourism industry).
	No (0)	a. The water quality does not negatively impact the exposure pathway b. There are some negative impacts from the water quality but these are outweighed by positive impacts from the water quality c. There are some water quality impacts but they have not reached a sufficient level to negatively impact the given exposure pathway
Frequency of Exposure	High (3)	a. There is a daily exposure to the stakeholder
	Medium (2)	a. There is some exposure to the stakeholder or b. There is daily exposure to the stakeholder but the impact is likely minimal
	Low (1)	a. There is limited or no exposure to the stakeholder or b. There is some exposure to the stakeholder but the impact is likely minimal
Approximate Risk		Water Quality Impact * Frequency of Exposure

3.4.5 Compilation of Framework

Following the classification of each category, the total stakeholder power, vulnerability, and risk are calculated by summing the quantitative values. These summations are then broadly considered as high, medium, and low. The thresholds are established based on a summation where the majority of categories are designated as high (10-12), medium (7-9), or low (0-6) and are used for ease of discussion. The low designation captures the possible low range for power and vulnerability (4-6) as well as the extended range that can exist for the analysis of risk (0-6). Within each basin, the stakeholder groups are compared against one another and also together. An average stakeholder value of power, vulnerability, and risk is calculated for each event to broadly compare the temporal trends of transboundary interactions. The analysis of an average also enables large differences in stakeholders to be observed. Although the small differences in the quantitative values should not be emphasized due to limitations of a qualitative analysis, the values can be used to indicate broader differences, including stakeholders who are considered an "outlier" from the average. Outliers in distributions are considered as stakeholders whose power, vulnerability, or risk at a given time point is 2 or more points from the average power, risk, or vulnerability at that event. This gap represents a difference between a low and high designation in one category and therefore, is assumed to represent a greater trend occurring. Outliers will be considered when they adversely impact stakeholders (i.e., decrease in power or increase in vulnerability and risk).

The stakeholders are mapped along three axes of the conceptual framework for each transboundary interaction and overlain with the TWINS framework. This analysis illustrates temporal shifts and a clearer connection between power, vulnerability, risk, and interactions. Based on the observations of these relationships and indications in literature, the relationships of stakeholder power, vulnerability, and risk with state transboundary water interactions are assessed. Literature justifications for interactions are considered to provide an additional line of evidence for analysis. To avoid misrepresenting correlation as causation, other theories that explain motivation for selected interactions are also considered. These theories, including institutional capacity, critical transboundary analysis, cost benefit analysis, and international influence, provide additional lines of evidence for influence and to enable the theories to engage with the stakeholder processes.

SECTION 4: Results

4.1 Lake Titicaca

Lake Titicaca is a high elevation transboundary lake located between Bolivia and Peru with a basin that extends into part of Chile. With an average volume of approximately 930 km^3, the lake is situated within the greater Titicaca-Poopo-Desaguadero-Salar del Coipasa (TPDS) basin which is home to approximately 3.0 million people (Mamani-Salinas, 2013). As a result of its large riparian community, the lake is experiencing multiple water quality stressors. A legacy of mining has led to historic and ongoing loading of heavy metals (including lead, arsenic, mercury, and cobalt) into the lake and its tributaries (Monroy, Maceda-Veiga, & de Sostoa, 2014). Other anthropogenic pressure is exerted on the basin with a high contaminant load from untreated or poorly treated domestic and industrial waste, cow excrement, and sedimentation from agricultural areas (WWAP, 2003). Given the volume of Lake Titicaca, it was previously assumed that water quality impacts would be diluted and have a minimal impact. However, the presence of persistent contaminants, industrial and population growth, localized mixing, and climate driven and anthropogenic lowering of the lake's volume have developed increasing degradation of water quality. These pollutant sources have led to eutrophic conditions, dispersion of duckweed, metals and pathogen health risks, and alterations to the ecosystem that affect the basin's population.

Although a wide range of stakeholder groups exist in the basin, five were selected that are closely tied to Lake Titicaca. The stakeholder groups are separated based on their spatial distribution (i.e., urban versus rural) and occupations. The selected groups include inhabitants of large cities/municipalities, rural communities (fishing based), rural communities (non-fishing based), the mining industry, and the tourism industry. It is important to note that there is some overlap in stakeholder groups; however, the spatial and occupational distinction is expected to capture a variety of differences in power, vulnerability, and risk.

4.1.1 Primary Transboundary Interactions

Within the TPDS basin, which will be referred to as the Lake Titicaca basin for simplicity, Bolivia and Peru have a long history of engagement that has been primarily cooperative. A limited chronology of transboundary water interactions, water quality degradation, and conditions in the basin are presented in Figure 3. The primary transboundary water interactions, their conflictive and cooperative classification, and justification are included in Table 10.

Table 10. Conflict and cooperation intensity of major transboundary interactions in the Lake Titicaca basin.

Event	Conflict Intensity	Cooperation Intensity
1955-1957 Joint Ownership Agreement Signed	Non-politicized	Technical
	• Bolivia and Peru have a positive history of cooperation, having been allies during the War of the Pacific and engaging in limited actions to promote development in the basin (Sierra, 2018; Orlove, 2002). • The government of Peru ratified a joint ownership 1957, but Bolivia did not due to "internal criteria" (Mancilla García, 2013; Martínez Gonzales & Zuleta Roncal, 2007, p.45). • Although Bolivia did not ratify the treaty, both countries maintained good relationships with regular meetings to reaffirm their commitment to working together (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, both countries had political instability during this time period which may have contributed to a lack of prioritization of the lake.	• The two countries signed an agreement of "indivisible and exclusive joint ownership of both countries of the waters of the lake" (Rieckermann, Daebel, Ronteltap, & Bernauer, 2006). This agreement encompasses the watershed of the system (WWAP, 2003). The goals of the convention were to encourage development without impacting navigation or fishing on the lake (Priscoli & Wolf, 2010; Martínez Gonzales & Zuleta Roncal, 2007). • The history of joint development, convention's goals, and commitment to joint ownership indicate that the countries had joint action and shared goals (Mancilla García, 2013). However, although a commitment to ownership was made, the agreement had not yet been ratified and no financial promises were made. • During this period, the countries separately conducted research with some limited coordination and independently requested technical assistance from the European community (Priscoli & Wolf, 2010; Martínez Gonzales & Zuleta Roncal, 2007). • Given that the action taken during this time period was largely independent but with shared goals, the cooperation intensity is considered to be technical.
1986 Ratification of the Agreement	Non-politicized	Risk-averting
	• Upon ratification of the agreement, the countries continued to cooperate and did not exhibit any politicized conflictive behavior.	• Both countries began to take greater joint action through the initiation of SUBCOMILAGO, the Joint Sub-commission for the Development of the Integrated Region of Lake Titicaca, and through the creation of a Master Plan with support of the European Commission (Priscoli & Wolf, 2010; Rieckermann et al., 2006;

Event	Conflict Intensity	Cooperation Intensity
		Martínez Gonzales & Zuleta Roncal, 2007). • While the sub-commission and development of the plan were necessary for joint management of the basin, they represented a limited commitment as there was an end date to activities. Given the lack of commitment to unforeseen future costs and constraints, the cooperation intensity is considered risk-averting.
1996 Establishment of the ALT	Non-politicized	Risk-taking
	• Both countries committed to joint action via exchange of notes and commitment by their respective foreign ministries and congresses (Mancilla García, 2013; Martínez Gonzales & Zuleta Roncal, 2007). No tension between the states was reported.	• Both countries committed to working together and created a body that is recognized by international law and has autonomy in technical, administrative, and financial matters (Mamani-Salinas, 2013). The Autonomous Binational Authority of Lake Titicaca (ALT) can also establish and enforce regulations within the scope of the Master Plan although it is not fully independent of both governments (WWAP, 2003; Mosello, 2008). • The ALT has an “indefinite” duration and has a budget that includes equal contributions from both countries (Martínez Gonzales & Zuleta Roncal, 2007, p. 62; WWAP, 2003). • Given the indefinite duration and relative autonomy of the organization, the cooperation intensity is considered to be risk-taking.
1997-1998 Ratification of RAMSAR	Non-politicized	Risk-taking
	• No tensions between the states were reported.	• The scope of the Master Plan, which supports 20 years of actions in the basin, was primarily focused on regulation of water volume with an implied commitment to ecosystems (Mancilla García, 2013; WWAP, 2003). • In 1997 and 1998, the countries more concretely committed to environmental conservation by becoming signatories to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (RAMSAR; Mancilla García, 2013). • Although the countries became signatories separately and in different

Event	Conflict Intensity	Cooperation Intensity
		years, the commitment to both the treaty and the ALT represent a greater scope of international cooperation between the states. Therefore, their actions are considered risk-taking.
2009-2010 Withdrawal of Bolivian Support	Politicized • Bolivian officials held concerns that the ALT was biased towards Peru based on projects, data interpretation, and the nationality of the ALT director (Mancilla García, 2013). • This time period coincided with publicized tensions between the presidents of both countries related to neoliberal mining policies (AQ Editors, 2010). • Bolivia stopped funding the ALT in 2009 in attempt to initiate a restructuring of the organization (Mancilla García, 2013). There was also speculation that the Bolivian government weakened its technical body, the Bolivian Operation Unit (UOB) to pressure negotiations (Mancilla García, 2013). • This action altered an allocation of resources, halted the functioning ALT projects in Bolivia, and "jeoparadize[d]" the ALT's achievements (Martínez Gonzales & Zuleta Roncal, 2007, p. 85). This action is considered politicized because it is a behavior that is within the bounds of normal procedure in order to alter patterns of cooperation.	Risk-averting • Bolivia and Peru remained members of the ALT and bound by the 1957 agreement. However, the defunding of the organization (albeit temporary) demonstrated a lack of commitment to the organization and to unforeseen future costs. • Given the joint action, shared goals, but lack of commitment, the cooperation is considered risk-averting.
2016 Bi-national Commitment and Current Status	Non-politicized • In 2011, the governments negotiated a reform of the organization (Mancilla García, 2013). • No conflict has been reported and the ALT is celebrated for maintaining positive relationships and smooth operation (Mamani-Salinas, 2013.; Priscoli & Wolf, 2010).	Risk-taking • The organization is functional and both countries have made large investments in the actions of the ALT (Barolini, 2016). • This continued participation and structure of the ALT implies that risk-taking cooperation is occurring.

4.1.2 Power, Vulnerability, and Risk Classification

A summary of the categorized analysis of power, vulnerability, and risk for each of the analyzed stakeholders and given time periods is represented in Table 11. The comprehensive analysis and justification for the low, medium, and high designations can be found in Appendix A. This detailed analysis of power, vulnerability, and risk analysis are located in Table 19, 20, and 21, respectively.

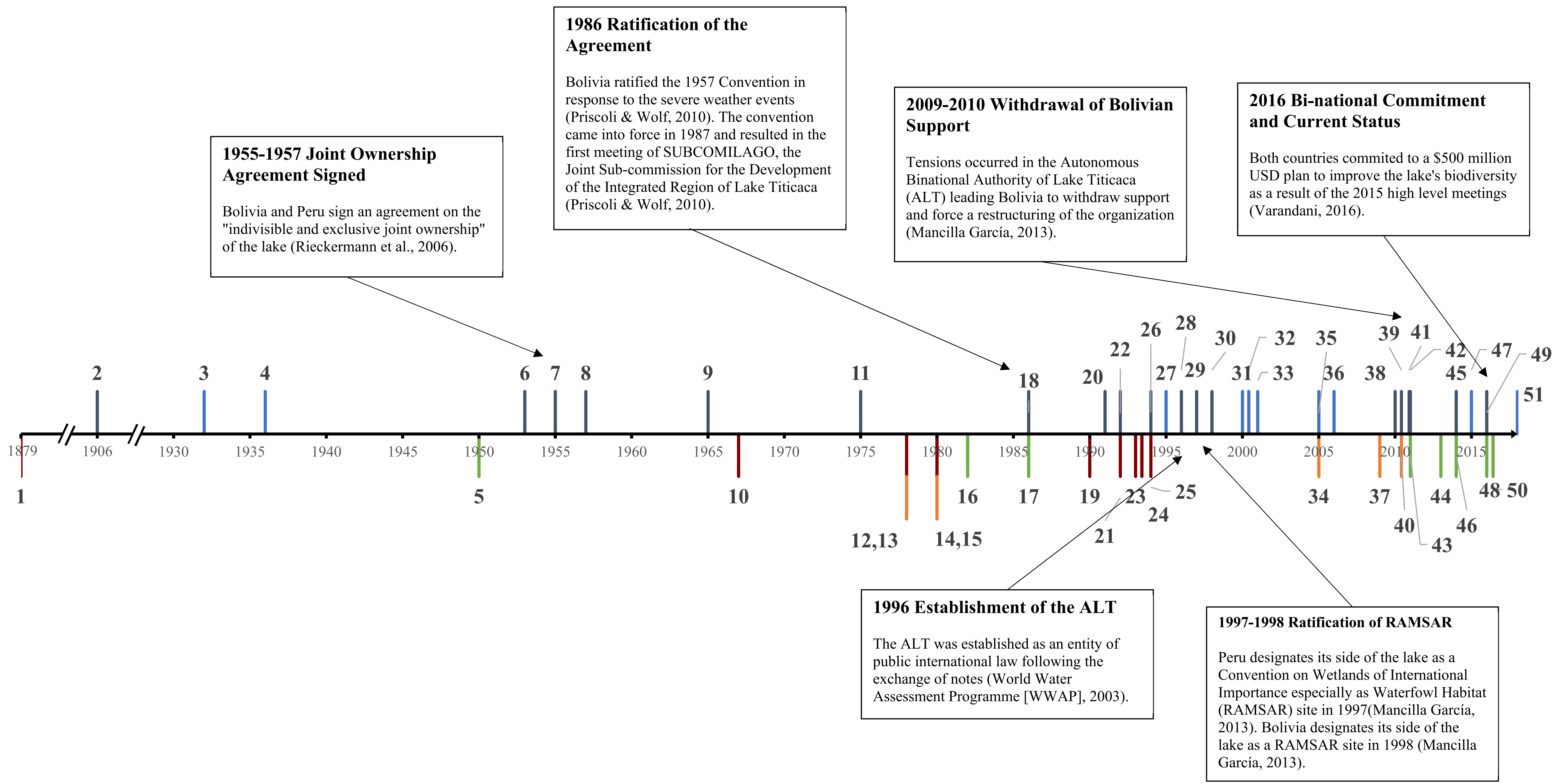

Figure 3. Timeline of state interactions, joint actions and programs, biophysical trends, international and state actions, and stakeholder actions in the Lake Titicaca basin.

Transboundary State Interactions (**Dark Blue**)

Event	Description
2	The first cooperative efforts to manage the TDPS basin started in 1906 (Sanjinés-Goytia, 2001 as cited in Rieckermann et al., 2006).
6	In the mid-1950s, a proposal to divert lake water to Chile was made which initiated both countries' interest in conducting studies (WWAP, 2003).
7	Both governments signed an agreement on the "indivisible and exclusive joint ownership" of the lake (Rieckermann et al., 2006).
8	The SUBOMILAGO commission was created by an agreement to foster economic development while maintaining the volume and navigability of the lake (Priscoli & Wolf, 2010).
9	The presidents of both countries reaffirmed their interest in joint studies and worked on transportation projects in the region (Martínez Gonzales & Zuleta Roncal, 2007).
11	Both presidents again, reaffirmed their interest in joint studies of the lake (Martínez Gonzales & Zuleta Roncal, 2007).
18	Bolivia ratified the 1957 Convention in response to the severe weather events (Priscoli & Wolf, 2010). The convention came into force in 1987 and the first meeting of SUBCOMILAGO occurred (Priscoli & Wolf, 2010).
20	Both countries requested support of the European Union to develop a Binational Master Plan (Priscoli & Wolf, 2010).
22	A treaty was signed to create the ALT after the exchange of notes (Mancilla García, 2013; Zilov, 2013).
26	The financial statues for the ALT was approved through an exchange of notes of the Ministers of Foreign Affairs (Martínez Gonzales & Zuleta Roncal, 2007).
28	The ALT was established as an entity of public international law (WWAP, 2003).
29	Peru designates its side of the lake as a RAMSAR site (Mancilla García, 2013).
30	Bolivia designates its side of the lake as a RAMSAR site (Mancilla García, 2013).
38	Bolivia publicly condemned Peru's extraction regulations (AQ Editors, 2010).
39	The governments committed to sharing access to the Pacific Ocean (Dialogo, 2010).
41	Tensions occurred within the ALT leading Bolivia to withdraw support and force a restructuring of the organization (Mancilla García, 2013).
42	An ALT project, in collaboration with the United Nations Environment Programme (UNEP), was halted by the Bolivian ministry of Foreign Affairs because the approval process was not considered "representative" (Mancilla García, 2013, p. 302).
45	The two countries agreed to demarcate the lake borders (teleSUR/lgc-TP, 2016).
49	Both countries commited to a $500 million USD plan to improve the lake's biodiversity as a result of the 2015 high level meetings (Varandani, 2016).

Joint Actions and Programs (**Blue**)

Event	Description
3	Both governments agreed to study the lake fisheries to help to develop the region (Orlove, 2002, García, 2013). Peru also ratified the joint ownership agreement.
4	As a result of the joint study, rainbow trout and whitefish were introduced into the lake (Orlove, 2002).
27	The Binanational Master Plan for the Control and Prevention of Floods and for the Use of Resources of the TPDS System was approved (Priscoli & Wolf, 2010).
31	The ALT initiated dredging of the Desaguadero River (Zilov, 2013).
32	The ALT conducted a study on the lake's biodiversity in the early 2000s (Mancilla García, 2013).
33	A dam was constructed along the Desaguadero River to promote flood control (Priscoli & Wolf, 2010).
35	Evo Morales became President of Bolivia and initiated a restructuring of the Bolivian government and in turn, the ALT (Mancilla García, 2013).
36	The Ministries of Foreign Affairs give the ALT a mandate to mitigate pollution in the bays (Mancilla García, 2013).
47	A High Level Commission proposed the Guidelines and Actions for Environmental Recovery of Lake Titicaca and its Biological Diversity to the relevant ministries of both countries (Ministry of Foreign Relations of Bolivia, 2016).
51	Both countries sought to accelerate construction of sewage treatment plants (Bnamericas, 2018)

Biophysical Trends (**Green**)

Event	Description
5	In the 1950s, the introduced trout began to impact the lake through consumption of endogenous fish and introduction of diseases (Mancilla García, 2013). The trout were managed and developed as a source of income, especially in Peru (Mancilla García, 2013).
16	A drought from 1982-1983 caused significant economic losses in agriculture (Priscoli & Wolf, 2010).
17	Flooding from 1986-1987 caused significant economic damage to agriculture and industry (Priscoli & Wolf, 2010).
43	UNEP published a report highlighting heavy metals within the lake (Mancilla García, 2016).
44	A large fish kill occurred in Puno Bay as a result of asphyxiation from the sewage loading (van Eerten, 2016).
46	Lake Popoo, a downstream lake in the system, had a large fish kill related to mine waste (Associated Press, 2016).
48	A large frog kill occurred on the shore of a Peruvian tributary to the lake (van Eerten, 2016).
50	A drought affected the region leading both countries to declare a state of emergency (Bnamericas, 2018).

International and State Actions (**Red**)

Event	Description
1	The War of the Pacific was initiated between Bolivia, Chile, and Peru (Sierra, 2018). The war was ended in 1884.
10	The Bolivian Constitution came into effect (Martínez Gonzales & Zuleta Roncal, 2007).
12	Peru created the Titicaca National Reserve (Orlove, 1991).
14	Peru initiated the Special Binational Project of Lake Titicaca (PELT; Mancilla García, 2013).
19	Both countries began to decentralize water management (Mancilla García, 2013).
21	Peru gave Bolivia a strip of coast line (Gozzer, 2018).
23	The Ministry of Sustainable Development and Environment was created in Bolivia (Martínez Gonzales & Zuleta Roncal, 2007).
24	The Peruvian Constitution was established (Martínez Gonzales & Zuleta Roncal, 2007).
25	The Bolivian Constitution was amended (Martínez Gonzales & Zuleta Roncal, 2007).

Stakeholder Actions (**Orange**)

Event	Description
13	The Titicaca National Reserve caused conflict over the management of reeds between the local community and the Peruvian government (Orlove, 1991).
15	In the 1980s, a regional economic depression affected the region, decreasing mining activity and increasing poverty (WWAP, 2003). Rural to urban migration was increased during this time period.
34	A "water war" occurred in El Alto (Mancilla García, 2016, p. 1114).
37	Large protests over mining occur in Peru (Williams, 2015).
40	Environmentalists groups actively criticized the ALT (Mancilla García, 2016).

Table 11. Analysis of primary stakeholder power, vulnerability, and risk in the Lake Titicaca basin.

Stakeholder	Event	Power				Vulnerability				Risk			
		Formal Authority	Resources	Discursive Legitimacy	State Interest	Regional Development	Economic	Education	Political	Ingestion (water)	Ingestion (food)	Dermal Contact	Livelihood Use
Inhabitants of large cities/ municipalities	1955-1957 Joint Ownership Agreement Signed	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	Medium (2)	High (3)	High (3)	Medium (2)	Low (1)	None (0)	None (0)
	1986 Ratification of the Agreement	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Low (1)	Medium (2)	Low (1)
	1996 Establishment of the ALT	Low (1)	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	1997-1998 Ratification of RAMSAR	Medium (2)	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	2009-2010 Withdrawal of Bolivian Support	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)
	2016 Bi-national Commitment and Current Status	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)
Rural communities (Fishing Based)	1955-1957 Joint Ownership Agreement Signed	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	Medium (2)	None (0)	None (0)
	1986 Ratification of the Agreement	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)
	1996 Establishment of the ALT	Low (1)	Medium (2)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)
	1997-1998 Ratification of RAMSAR	Medium (2)	Medium (2)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)
	2009-2010 Withdrawal of Bolivian Support	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)
	2016 Bi-national Commitment and Current Status	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)
Rural communities (Non-fishing Based)	1955-1957 Joint Ownership Agreement Signed	Medium (2)	Medium (2)	Medium (2)	Low (1)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Low (1)	None (0)	None (0)
	1986 Ratification of the Agreement	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Low (1)	Medium (2)	Low (1)
	1996 Establishment of the ALT	Low (1)	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	1997-1998 Ratification of RAMSAR	Medium (2)	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	2009-2010 Withdrawal of Bolivian Support	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Medium (2)
	2016 Bi-national Commitment and Current Status	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Medium (2)
Mining industry	1955-1957 Joint Ownership Agreement Signed	Low (1)	Low (1)	Low (1)	High (3)	High (3)	Medium (2)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	None (0)
	1986 Ratification of the Agreement	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Low (1)	Low (1)	None (0)
	1996 Establishment of the ALT	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	1997-1998 Ratification of RAMSAR	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	2009-2010 Withdrawal of Bolivian Support	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
	2016 Bi-national Commitment and Current Status	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)
Tourism industry	1955-1957 Joint Ownership Agreement Signed	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	Low (1)	High (3)	High (3)	Medium (2)	Low (1)	None (0)	None (0)
	1986 Ratification of the Agreement	Medium (2)	Low (1)	Medium (2)	Low (1)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Low (1)	High (3)	None (0)
	1996 Establishment of the ALT	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	None (0)
	1997-1998 Ratification of RAMSAR	Medium (2)	Low (1)	Low (1)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	None (0)
	2009-2010 Withdrawal of Bolivian Support	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)

Stakeholder	Event	Power				Vulnerability				Risk			
		Formal Authority	Resources	Discursive Legitimacy	State Interest	Regional Development	Economic	Education	Political	Ingestion (water)	Ingestion (food)	Dermal Contact	Livelihood Use
	2016 Bi-national Commitment and Current Status	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)

A quantitative summary of the relative stakeholder power, vulnerability, and risk leading up to the transboundary interactions in the Lake Titicaca basin can be seen in Table 12. The table presents the quantitative summation of the stakeholder analyses.

Table 12. Summary of stakeholder power, vulnerability, and risk over events in the Lake Titicaca basin.

Stakeholder	Event	Power	Vulnerability	Risk
Inhabitants of large cities/ municipalities	1955-1957 Joint Ownership Agreement Signed	4	11	3
	1986 Ratification of the Agreement	5	10	6
	1996 Establishment of the ALT	6	10	8
	1997-1998 Ratification of RAMSAR	7	10	8
	2009-2010 Withdrawal of Bolivian Support	10	9	9
	2016 Bi-national Commitment and Current Status	10	9	9
Rural communities (Fishing Based)	1955-1957 Joint Ownership Agreement Signed	9	12	5
	1986 Ratification of the Agreement	10	10	9
	1996 Establishment of the ALT	7	10	11
	1997-1998 Ratification of RAMSAR	8	10	11
	2009-2010 Withdrawal of Bolivian Support	10	9	12
	2016 Bi-national Commitment and Current Status	8	9	12
Rural communities (Non-fishing Based)	1955-1957 Joint Ownership Agreement Signed	7	12	3
	1986 Ratification of the Agreement	8	10	6
	1996 Establishment of the ALT	6	10	8
	1997-1998 Ratification of RAMSAR	7	10	8
	2009-2010 Withdrawal of Bolivian Support	10	9	10
	2016 Bi-national Commitment and Current Status	10	9	10
Mining industry	1955-1957 Joint Ownership Agreement Signed	6	11	5
	1986 Ratification of the Agreement	5	10	4
	1996 Establishment of the ALT	7	9	8
	1997-1998 Ratification of RAMSAR	8	9	8
	2009-2010 Withdrawal of Bolivian Support	8	8	8
	2016 Bi-national Commitment and Current Status	8	8	8
Tourism industry	1955-1957 Joint Ownership Agreement Signed	4	10	3
	1986 Ratification of the Agreement	6	10	6
	1996 Establishment of the ALT	5	9	8
	1997-1998 Ratification of RAMSAR	7	9	8
	2009-2010 Withdrawal of Bolivian Support	9	8	9
	2016 Bi-national Commitment and Current Status	9	8	9

Within the Lake Titicaca basin, the modified stakeholder analysis presents several general trends in the distribution of power, vulnerability, and risk. Although power varies between stakeholders, it generally increases with time. This increase is related to limited institutionalized participation in transboundary water governance, increase of discursive legitimacy as linked to political campaigns in the basin, and increasing state interest as a result of political campaigns and economic growth. In general, inhabitants of urban areas and rural agricultural communities have enjoyed higher levels of power in recent years which is largely related to political interest. Additionally, rural fishing communities represent a unique pattern of power. Between 1957 and 1986, fisheries received national attention through studies which increased their power relative to other stakeholders in the basin. However, over time, power in fisheries decreased, in part due to a decrease in resources given the lower volume of participating fishermen and a decrease in the importance of community managed environmental systems.

For all actors, vulnerability generally decreased with time and resulted in medium levels of risk after 1998. The decreasing risk was a result of increasing policies to protect against pollution and rights of water users, increasing regional development, and increasing education observed in literacy rates. Although vulnerability decreased over time, it exhibited an interesting pattern over the time period leading up to 1986. During this period, economic vulnerability was high. This economic vulnerability was related to an economic downturn in both states and damages incurred by natural disasters in the 1980s.

For all actors, risk generally increased with time. This increase in risk is related to the constant loading of heavy metals and domestic and industrial effluents on the lake. The presence of duckweed, which resulted from the high nutrient loading in the waterbody, also contributed to an increase in risk. Risk is generally highest in fishing and agricultural rural communities and is often related to livelihood use risk as water contamination harmed fisheries and has been fatal to livestock in the region. Risk for fishing communities is higher than all other stakeholders over almost every time point.

Outliers in distributions are operationally considered as actors that are adversely 2 or more points from the average power, risk, or vulnerability at a given time point (i.e., decreased power or increased risk or vulnerability). There are several outliers within the Lake Titicaca basin. Both inhabitants of large cities and the tourism industry had lower power prior to 1955. This decreased power is related to a lack of community resource management (such as the management observed in rural areas) as well as a lack of state interest. Urban areas and the region as a whole were largely ignored by the state prior to the 1950s, and the tourism industry was not very developed during this time period thus decreasing state interest. Between 1957 and 2020, fishermen have also been an outlier in the distribution of risk. This increased stakeholder risk is related to their occupational dermal contact with water, consumption patterns, and livelihood use. It is assumed that fishing communities frequently consumed fish from the lake as part of their diets. Given that heavy metals can bioaccumulate and present a human health risk, this impact can directly affect communities that regularly rely on fish protein. In addition, the water quality has a higher impact on livelihood use as water quality can directly affect the volume, quality, and distribution of fish in the lake.

4.1.3 Connection to Transboundary Interactions

The modified stakeholder analysis can be seen mapped against the intensity of conflict and cooperation in Figure 4. Within the basin five shifts in conflict or cooperation intensity occurred which were aligned with varying average stakeholder power, risk, and vulnerability.

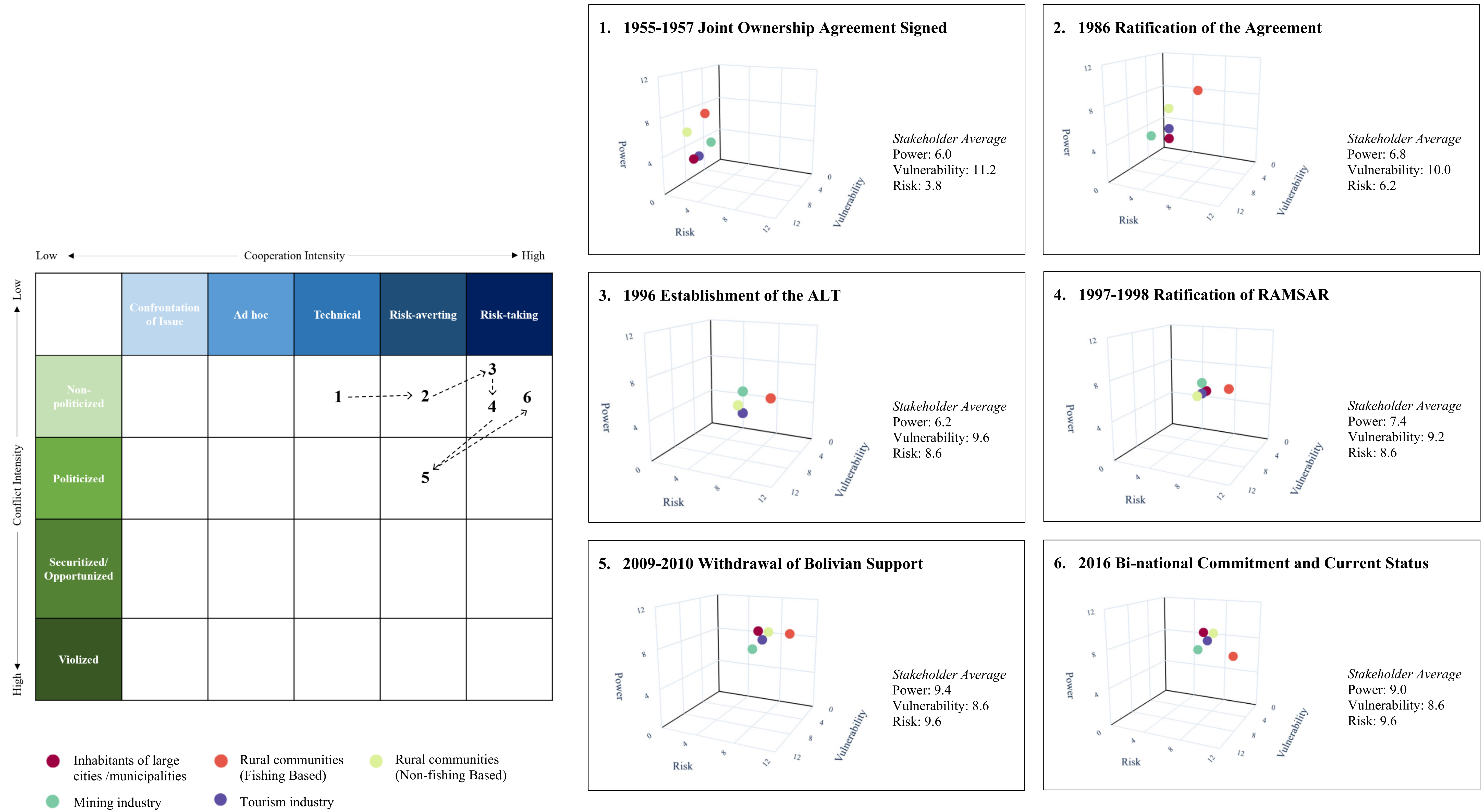

Figure 4. History of transboundary state interactions and modified stakeholder analyses in the Lake Titicaca basin.

4.2 Lake Victoria

Lake Victoria is one of the African Great Lakes and is shared between Kenya, Tanzania, and Uganda with Rwanda and Burundi within its watershed. With a volume of 2,760 km^3, the lake resides within a basin that houses 47 million people (The World Bank, 2018a; UNEP, 2006). The lake has experienced strong anthropogenic pressure with heavy loadings of phosphorous, nitrogen, biological oxygen demand (BOD), and pathogens in the lake as a result of untreated or poorly treated domestic and industrial wastewater. Agricultural practices have also led to increased sedimentation in the lake (Odada 2003; Verschuren et al., 2002). The growing pollutant load has led to eutrophication, enabled the domination of Nile perch and subsequent decimation of endemic cichlid species, and supported widespread growth of the water hyacinth (Zilov, 2013). Although water quality impacts are primarily related to organic pollutants, there are growing concerns of pesticides and metal pollutants related to agriculture, illegal fishing, and mining activities within the region (UNEP, 2006). These conditions have put a strain on much of the basin population.

Five stakeholders were selected that are closely tied to Lake Victoria. The stakeholder groups are separated based on their spatial distribution (i.e., urban versus rural) and occupations. The selected groups include inhabitants of urban areas, traditional fishing communities, rural agriculture communities, the mining industry, and the hydropower industry. Although there is some overlap in stakeholder groups, the spatial and occupational distinction is expected to capture a variety of differences in power, vulnerability, and risk.

4.2.1 Primary Transboundary Interactions

A range of transboundary water interactions have occurred between Kenya, Tanzania, and Uganda. A limited chronology of transboundary water interactions, water quality degradation, and conditions in the basin are presented in Figure 5. The primary transboundary water interactions, their conflictive and cooperative classification, and justification are included in Table 13.

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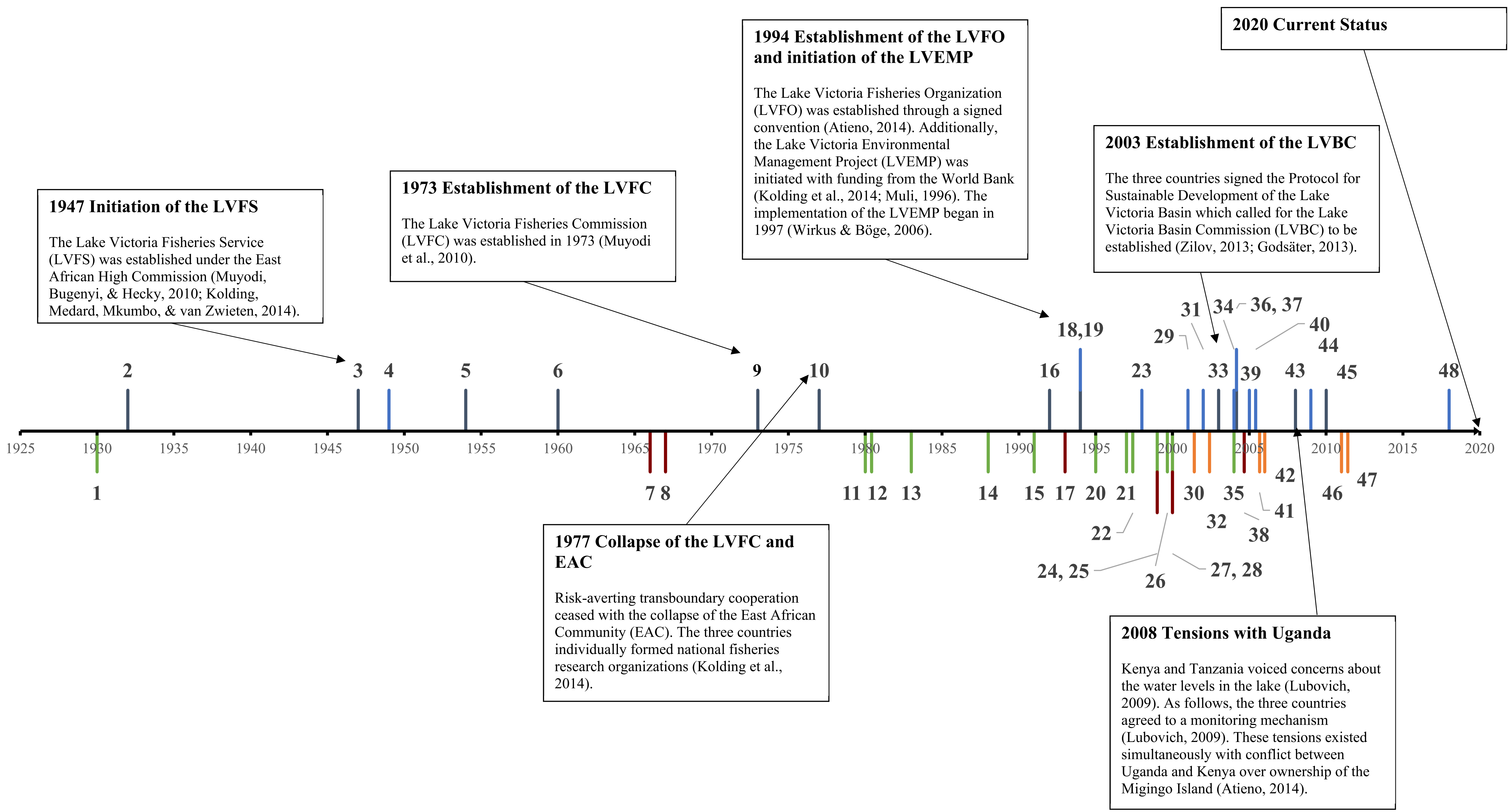

Figure 5. Timeline of state interactions, joint actions and programs, biophysical trends, international and state actions, and stakeholder actions in the Lake Victoria basin.

Transboundary State Interactions (**Dark Blue**)

Event	Description
2	The states begin to discuss potential collaboration over lake fisheries (Muyodi et al., 2010).
3	The LVFS was established under the East African High Commission (Muyodi et al., 2010; Kolding et al., 2014).
5	The Owens Fall Dam was constructed, and Uganda and Kenya sign the "Agreed Curve" for dam operation (Lubovich, 2009).
6	The role of LVFS was taken over by the three governments (Kolding et al., 2014).
9	The LVFC was established in 1973 (Muyodi et al., 2010).
10	Transboundary cooperation stopped with the collapse of the EAC and the three countries formed separate national fisheries research organizations (Kolding et al., 2014).
16	The three governments began discussions about transboundary water management following the Rio Earth Summit (Muyodi et al., 2010). They submitted a biodiversity grant to the Global Environment Facility (Ntiba, Kudoja, & Mukasa, 2001).
19	The LVFO was established through a signed convention (Atieno, 2014).
33	The three countries signed the Protocol for Sustainable Development of the Lake Victoria Basin which called for the LVBC to be established (Zilov, 2013; Godsäter, 2013).
36	Uganda laid claim to the Migingo Island, fostering tensions with Kenya (Atieno, 2014).
43	Kenya and Tanzania voiced concerns about the water levels in the lake (Lubovich, 2009). As follows, the three countries agreed to a monitoring mechanism (Lubovich, 2009).
45	Uganda and the LBVC did not meet "effectiveness conditions" causing a delay in implementation of LVEMP II (The World Bank, 2018a, p. 52). Uganda spending also led to a 10 month suspension by the World Bank (The World Bank, 2018a).

e.

Joint Actions and Programs (**Blue**)

Event	Description
4	The LVFS established the East African Fisheries Research Organization (EAFFRO; Kolding et al., 2014).
18	The LVEMP was initiated with funding from the World Bank (Kolding et al., 2014; Muli, 1996). The work began in 1997 (Wirkus & Böge, 2006).
23	The LVFO held a stakeholder workshop to establish a vision statement for 1999 to 2015 (Wirkus & Böge, 2006).
29	The Lake Victoria Development Program was initiated in the EAC in 2001 (Muyodi et al., 2010).
31	The LVEMP I was extended to 2004 (Jansen, Abila, & Owino, 1999).
34	The LVEMP I was extended to 2005 (Jansen et al., 1999).
37	A Regional Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (RPOA-IUU) was established (Wirkus & Böge, 2006).
39	The LVEMP I was completed (Lubovich, 2009).
40	The LVBC became operational (Lubovich, 2009).
44	LVEMP II was initiated to last until 2017 (The World Bank, 2018a).
48	The plans for LVEMP III were initiated (The World Bank, 2018b).

Biophysical Trends (**Green**)

Event	Description
1	Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006).
11	Nile fish were introduced to the lake and altered the lake regime (Jansen et al., 1999).
12	Algal blooms and low dissolved were observed in the lake (Muyodi et al., 2010).
13	A long drought began that lasted until 1984 (Mwiturubani & van Wyk, 2010).
14	The water hyacinth was introduced into the lake (Ntiba et al., 2001).
15	A long drought began that lasted until 1992 (Mwiturubani & van Wyk, 2010).
20	A long drought began that lasted until 1996 (Mwiturubani & van Wyk, 2010).
21	A large hyacinth outbreak occured (Muyodi et al., 2010).
22	A cholera outbreak occurred in communities along the shore of the lake (Shapiro et al., 1999).
25	Several fatalities occurred due to illegal fishing practices (fish poisoning; Muyodi et al., 2010).
26	A drought related to La Nina occured until 2001 (Mwiturubani & van Wyk, 2010).
28	Uganda began to discharge more water than agreed upon under the Agreed Curve (Lubovich, 2009).
35	A long drought began that lasted until 2005 (Mwiturubani & van Wyk, 2010).

International and State Actions (**Red**)

Event	Description
7	The United Nations (UN) and Food and Agriculture Organization (FAO) initiated studies on the lake (Muyodi et al., 2010).
8	The EAC was formed (Kolding et al., 2014).
17	The Treaty for East African Cooperation was signed by the three countries (Muyodi et al., 2010).
24	The European Union placed a temporary ban on fish from the lake (The World Bank, 1996).
27	The EAC was re-established and declared the basin an “economic growth zone" (Zilov, 2013; Wirkus & Böge, 2006). The LVFO became an EAC institution (Wirkus & Böge, 2006).
38	Rwanda and Burundi applied for membership to the EAC (Wirkus & Böge, 2006).

Stakeholder Actions (**Orange**)

Event	Description
30	An increase in conflict between fishermen and law enforcement was observed (UNEP, 2006).
32	The Lake Victoria Research Initiative (VicRes) was initiated and was coordinated by the Inter-University Council for East Africa (IUCEA; Lubovich, 2009).
41	Conflict escalated between Kenyan and Ugandan fishermen over territorial fishing rights leading to some fatalities (Wirkus & Böge, 2006).
42	Lake Victoria Advocacy Network-East Africa (LAVNET-EA), a fishermen organization, protested for fishermen’s rights and as a result, was alienated by the LVBC (Godsäter, 2013).
46	An internal document was leaked suggesting that the LVBC should remain government driven with limited influence of civil society (Godsäter, 2013).
47	Local protests in Tanzania pushed back against mining operations (Newenham-Kahindi, 2011).

Table 13. Conflict and cooperation intensity of major transboundary interactions in the Lake Victoria basin.

Event	Conflict Intensity	Cooperation Intensity
1947 Initiation of the LVFS	Non-Politicized	Risk-averting
	• The Lake Victoria Fisheries Service (LVFS) and East African Fisheries Research Organization (EAFRO) functioned based on voluntary action. • From 1962-1967, the Kenya had little to no data reporting which challenged the functioning of the organization (Food and Agriculture Organization [FAO], 1989). The organization was also weak due to a lack of staffing (FAO, 1989). • Because there was no clear link between the lack of reporting and potential conflict within the basin, the conflict intensity is considered non-politicized.	• The LFVS was a regional management institution established to collect data and manage administration of fisheries (Kolding et al., 2014). • During the same time period, the EAFRO was established in 1949 under the East African High Commission (Kolding et al., 2014). • The LVFS was dissolved in 1960 with the responsibilities overtaken by the national governments (Kolding et al., 2014). This process enabled for more minimal data collection that could be coordinated by the EAFRO (FAO, 1989). However, due to the continued existence of EAFRO, the intensity of cooperation was maintained. • Through the LFVS and EAFRO, the states worked together with shared goals and joint action to collect fisheries data. However, because authority and funding of the organizations were limited, it is assumed that there was limited commitment to unforeseen costs or constraints. As a result, the creation of the LVFS and later EAFRO, is considered risk-averting.
1973 Establishment of the LVFC	Non-politicized	Risk-averting
	• The Lake Victoria Fisheries Commission (LVFC) functioned with few meetings and no politicized conflict (FAO, 1989). For this reason, the conflict intensity is considered non-politicized.	• The LVFC was established in 1973 to improve the standardization of fisheries data which was coordinated by EAFFRO (renamed from EAFRO in 1960; Muyodi et al., 2010; Kolding et al., 2014). • The continued shared goals, joint action, and lack of future commitment within the LVFC and EAFFRO is considered risk-averting.
1977 Collapse of the LVFC and EAC	Non-politicized	Technical
	• Although conflict was occurring between the countries, the conflict was not focused on the lake. Therefore, the conflict intensity is considered non-politicized.	• When the East African Community (EAC) collapsed, cooperation ceased through the LVFC and EAFFRO institutions (FAO, 1989). • Fisheries data began to be managed by each country's national research

Event	Conflict Intensity	Cooperation Intensity
		organization (FAO, 1989). Any coordination of the lake was managed by a FAO sub-committee which engaged with the three riparian states starting in 1982 (Muyodi et al., 2010; Lugo, Jordan, & Benson, 2014). • Given that the states maintained shared goals through the management of fisheries but were not participating in joint action, the cooperation intensity is considered to be technical.
1994 Establishment of the LVFO and initiation of the LVEMP	Non-politicized	Risk-taking
	• The three countries made a voluntary commitment to the joint management of fisheries and the environment in the lake basin. There was no public conflict observed at this time; therefore, the conflict intensity is considered non-politicized.	• The three governments formed the Lake Victoria Fisheries Organization (LVFO) in 1994 through the signing of a convention (Wirkus & Böge, 2006). The LVFO is a permanent organization that has legal status, its own budget, and dispute resolution mechanisms (Wirkus & Böge, 2006; Zilov, 2013). The countries are also obligated to legislatively implement decisions of the LVFO Steering Committee (Zilov, 2013). • There have been criticisms that there is little financial investment by states in the LVFO and that there has not been harmonization of regulations signaling lack of commitment to constraints and costs affiliated with the organization (Ntiba et al., 2001). • The Lake Victoria Environmental Management Project (LVEMP) was also agreed upon by the three riparian countries in 1994 to conduct research and address environmental management of the lake (Wirkus & Böge, 2006; Kolding et al., 2014). The LVEMP constituted a five year commitment that relied primarily on external donor funding to address water quality concerns (Wirkus & Böge, 2006). The first implementation of the LVEMP (LVEMP I) was credited with building understanding of pollution in the lake and developing processes to address the water hyacinth outbreak (The World Bank, 2018a). • The LVFO and LVEMP have shared goals and joint actions. The LVEMP has limited constraints and a fixed

Event	Conflict Intensity	Cooperation Intensity
		timeline, signaling a lack of commitment to unforeseen costs which is considered risk-averting. Although the states have not exhibited commitment to unforeseen costs in the LVFO, the structure of the organization suggests that these may be incurred in the future. Given that there some commitment to unforeseen constraints in the LVFO, the overall cooperation intensity is considered risk-taking.
2003 Establishment of the LVBC	Non-politicized	Risk-taking
	• Although there were likely some tensions due to the decreasing water level in the lake, these tensions were not yet in the public space or politicized (Lubovich, 2009). Given the absence of any overt tensions, the conflict intensity is considered to be non-politicized.	• The EAC Council of Ministers established the Lake Victoria Basin Commission (LVBC) based on the "Protocol for Sustainable Development of the Lake Victoria Basin" that was ratified by the three countries (Lugo et al., 2014). The LVBC was established as the lead institution on environmental governance in the lake, has binding dispute resolution with the East African Court of Justice, has a decision making body, and is an implementing agent (Wirkus & Böge, 2006). The three countries have also committed to funding of the LVBC with increasing annual contributions (Okurut & Othero, 2012). • In addition to the LVBC, the reestablishment of the EAC in 1999 strengthened the LFVO by making it an EAC institution (Wirkus & Böge, 2006). The EAC also enables improved joint management of the watershed and highlighted the importance of Lake Victoria with establishment of the Lake Victoria Development Program which was a precursor to the LVBC (Wirkus & Böge, 2006). • The LVBC, EAC, and LVFO represent a continuation of shared goals and joint action. Furthermore, the formation of the EAC and LVBC were perceived to have "cemented the regional linkages" (The World Bank, 2006, p. 11). Given the commitment to dispute resolution, implementation, and financial contributions, the

Event	Conflict Intensity	Cooperation Intensity
		countries were exhibiting risk-taking cooperation.
2008 Tensions with Uganda	Opportunized/Securitized	Risk-taking
	• It was reported that there were "indications that competing interests and a lack of transparency are hampering cooperative efforts" (Lubovich, 2009, p. 2). • In 2008, Kenyan and Tanzanian officials publicly commented on Uganda's increased discharge of Lake Victoria water (above the Agreed Curve) and withholding of information (Lubovich, 2009). • Uganda and Kenya were experiencing tension around this time related to the Migingo Island. Uganda had laid claim to the island in 2004 although Kenya had considered the island within its territory (Atieno, 2014). International discussions over the island did not occur until 2009 and were not resolved at that point (Atieno, 2014). • Delays in the "effectiveness conditions" and "fiduciary noncompliance" with Uganda stalled the implementation of the second phase of the LVEMP (LVEMP II) by approximately a year in 2008 (The World Bank, 2018a, p. 52). • These actions designate conflict that was in the public space, and in the case of Migingo Island, led to actions that are outside of the norms of political processes. Therefore, interactions within the basin are considered securitized/opportunized.	• The LVBC and LVFO continued to function throughout this time period. • Although the first phase of the LVEMP concluded by 2005, there was interest in continuing its work through subsequent phases (The World Bank, 2018b). • Given that the institutions maintained their shared goals, joint actions, and commitment to future constraints, the interactions are considered risk-taking.
2020 Current Status	Non-politicized	Risk-taking
	• The EAC Council of Ministers agreed to establish a Water Release and Abstraction Policy that can monitor water releases from the lake (Lubovich, 2009). The mechanism was to be incorporated into the framework of the LVEMP II (EAC, 2008 as cited in Lubovich, 2009). • Given the continuation of the LVBC, initiation of LVEMP III, and the absence of tension within the public	• The LVBC and LVFO continued to function, and the second phase of the LVEMP (LVEMP II) was implemented from 2009-2017 which addressed environmental pollution and cooperation in the basin (The World Bank, 2018b). • The states were reported to have exhibited a high commitment to addressing water quality degradation in the basin (The World Bank, 2018b).

Event	Conflict Intensity	Cooperation Intensity
	space, the interactions are considered non-politicized.	• Given the continued functioning of risk-taking institutions, the interactions are considered to be risk-taking.

4.2.2 Power, Vulnerability, and Risk Classification

A summary of the categorized distribution of power, vulnerability, and risk is presented in Table 14. The full justification for each classification is provided in Appendix B. The detailed analysis of power, vulnerability, and risk are included in Table 22, Table 23, and Table 24 of Appendix B, respectively.

Table 14. Analysis of primary stakeholder power, vulnerability, and risk in the Lake Victoria basin.

Stakeholder	Event	Power				Vulnerability				Risk			
		Formal Authority	Resources	Discursive Legitimacy	State Interest	Regional Development	Economic	Education	Political	Ingestion (water)	Ingestion (food)	Dermal Contact	Livelihood Use
Inhabitants of Urban Areas	1947 Initiation of the LVFS	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1973 Establishment of the LVFC	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Low (1)
	1977 Collapse of the LVFC and EAC	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Low (1)
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	High (3)	High (3)	High (3)	Medium (2)
	2003 Establishment of the LVBC	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)
	2008 Tensions with Uganda	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)
	2020 Current Status	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)
Traditional fishing communities	1947 Initiation of the LVFS	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1973 Establishment of the LVFC	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Medium (2)
	1977 Collapse of the LVFC and EAC	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Medium (2)
	1994 Establishment of the LVFO and initiation of the LVEMP	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	Low (1)
	2003 Establishment of the LVBC	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)
	2008 Tensions with Uganda	High (3)	High (3)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	High (3)
	2020 Current Status	High (3)	High (3)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	High (3)
Rural agriculture communities	1947 Initiation of the LVFS	Low (1)	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1973 Establishment of the LVFC	Low (1)	Medium (2)	Low (1)	High (3)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Low (1)	Low (1)	None (0)
	1977 Collapse of the LVFC and EAC	Low (1)	Medium (2)	Low (1)	High (3)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Low (1)	Low (1)	None (0)
	1994 Establishment of the LVFO and initiation of the LVEMP	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)
	2003 Establishment of the LVBC	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Low (1)
	2008 Tensions with Uganda	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Low (1)
	2020 Current Status	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Low (1)
Mining industry	1947 Initiation of the LVFS	Low (1)	Low (1)	Low (1)	Medium (2)	High (3)	Medium (2)	High (3)	High (3)	None (0)	None (0)	Medium (2)	None (0)
	1973 Establishment of the LVFC	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	None (0)
	1977 Collapse of the LVFC and EAC	Low (1)	Low (1)	Low (1)	High (3)	High (3)	High (3)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	None (0)
	1994 Establishment of the LVFO and initiation of the LVEMP	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	High (3)	Medium (2)	High (3)	Medium (2)	Low (1)
	2003 Establishment of the LVBC	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	Low (1)
	2008 Tensions with Uganda	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	None (0)
	2020 Current Status	Medium (2)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	None (0)
Hydropower industry	1947 Initiation of the LVFS	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	Low (1)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1973 Establishment of the LVFC	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Low (1)
	1977 Collapse of the LVFC and EAC	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	High (3)	High (3)	Low (1)	Medium (2)	Low (1)
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)	Medium (2)
	2003 Establishment of the LVBC	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	High (3)
	2008 Tensions with Uganda	Medium (2)	Low (1)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	High (3)	Medium (2)
	2020 Current Status	Medium (2)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Medium (2)	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)

A quantitate summary of the relative stakeholder power, vulnerability, and risk leading up to the transboundary interactions of the Lake Victoria basin is presented in Table 15.

Table 15. Summary of stakeholder power, vulnerability, and risk over events in the Lake Victoria basin.

Stakeholder	Event	Power	Vulnerability	Risk
Inhabitants of Urban Areas	1947 Initiation of the LVFS	5	12	0
	1973 Establishment of the LVFC	5	12	7
	1977 Collapse of the LVFC and EAC	5	12	7
	1994 Establishment of the LVFO and initiation of the LVEMP	8	10	11
	2003 Establishment of the LVBC	8	9	12
	2008 Tensions with Uganda	8	10	11
	2020 Current Status	8	8	9
Traditional fishing communities	1947 Initiation of the LVFS	8	12	0
	1973 Establishment of the LVFC	8	12	8
	1977 Collapse of the LVFC and EAC	8	12	8
	1994 Establishment of the LVFO and initiation of the LVEMP	8	10	10
	2003 Establishment of the LVBC	10	10	12
	2008 Tensions with Uganda	11	10	11
	2020 Current Status	11	9	11
Rural agriculture communities	1947 Initiation of the LVFS	6	12	0
	1973 Establishment of the LVFC	7	12	4
	1977 Collapse of the LVFC and EAC	7	12	4
	1994 Establishment of the LVFO and initiation of the LVEMP	8	11	7
	2003 Establishment of the LVBC	9	10	8
	2008 Tensions with Uganda	9	10	8
	2020 Current Status	9	10	8
Mining industry	1947 Initiation of the LVFS	5	11	2
	1973 Establishment of the LVFC	4	12	5
	1977 Collapse of the LVFC and EAC	6	12	5
	1994 Establishment of the LVFO and initiation of the LVEMP	7	11	8
	2003 Establishment of the LVBC	8	9	8
	2008 Tensions with Uganda	8	9	7
	2020 Current Status	8	9	7
Hydropower industry	1947 Initiation of the LVFS	4	10	0
	1973 Establishment of the LVFC	7	11	7
	1977 Collapse of the LVFC and EAC	7	11	7
	1994 Establishment of the LVFO and initiation of the LVEMP	8	9	11
	2003 Establishment of the LVBC	8	8	12
	2008 Tensions with Uganda	7	10	11
	2020 Current Status	8	8	9

Within the Lake Victoria basin, there are several general trends that can be observed in the modified stakeholder analysis. Although power varies between stakeholders, it generally increases with time. These increases are related to greater institutionalization of stakeholders in transboundary water management as well as increases in discursive legitimacy. Although most stakeholders have a medium amount of power, traditional fishing communities often experienced higher power as a result of institutionalized participation in projects of the LVFO (through beach management units) and discursive legitimacy derived from fisheries role in addressing the food insecurity of the basin.

Additionally, vulnerability of stakeholders generally decreases with time. This decrease is related to the establishment of regulations and improved regional development with the distribution of greater water treatment in urban areas. Economic vulnerability has also decreased with time in recent years. Although there is a universal trend of decreasing vulnerability, for most stakeholders, vulnerability is consistently high (>9) and there are no outliers.

Within the risk axis, risk generally increased until the establishment of the LVBC in 2003, and then remains high or slightly decreases. For most actors, risk increases between 2-4 points between 1977 and 1994 when the LVFO and LVEMP were initiated. This increase is related to the advent of eutrophic conditions and the native fisheries collapse in the 1980s. The peak of risk between 1994 and 2003 represents the widest spread of water hyacinth spread which caused widespread damage in the basin. In general, inhabitants of urban areas, traditional fishing communities, and the hydropower industry experience higher risk from water quality than rural agricultural communities and the mining industry. This increase in risk is largely related to dermal contact due to proximity to the lake as well as occupational contact with the waterbody and risks to livelihoods.

Within the Lake Victoria basin, there are two points when outliers exist. Within the power categorization, there is an outlier of the mining industry between 1973 and 1977 which designates a decrease in power. This power is related to the national policies of Tanzania at the time. Because the gold mining industry is primarily concentrated in Tanzania and the country began to prioritize agriculture between 1973 and 1977, there was a decrease in state interest during this time period. The other outlier in the basin is the risk of traditional fishing communities in the current time period. This risk is primarily attributed to the livelihood use risk as there is a continued decrease in fish stock as a result of water quality impacts and overfishing (The World Bank, 2018a).

4.2.3 Connection to Transboundary Interactions

The modified stakeholder analysis can be seen mapped against the intensity of conflict and cooperation in Figure 6. Five major shifts occur in the intensity of cooperation and conflict which correspond with varying stakeholder average power, risk, and vulnerability.

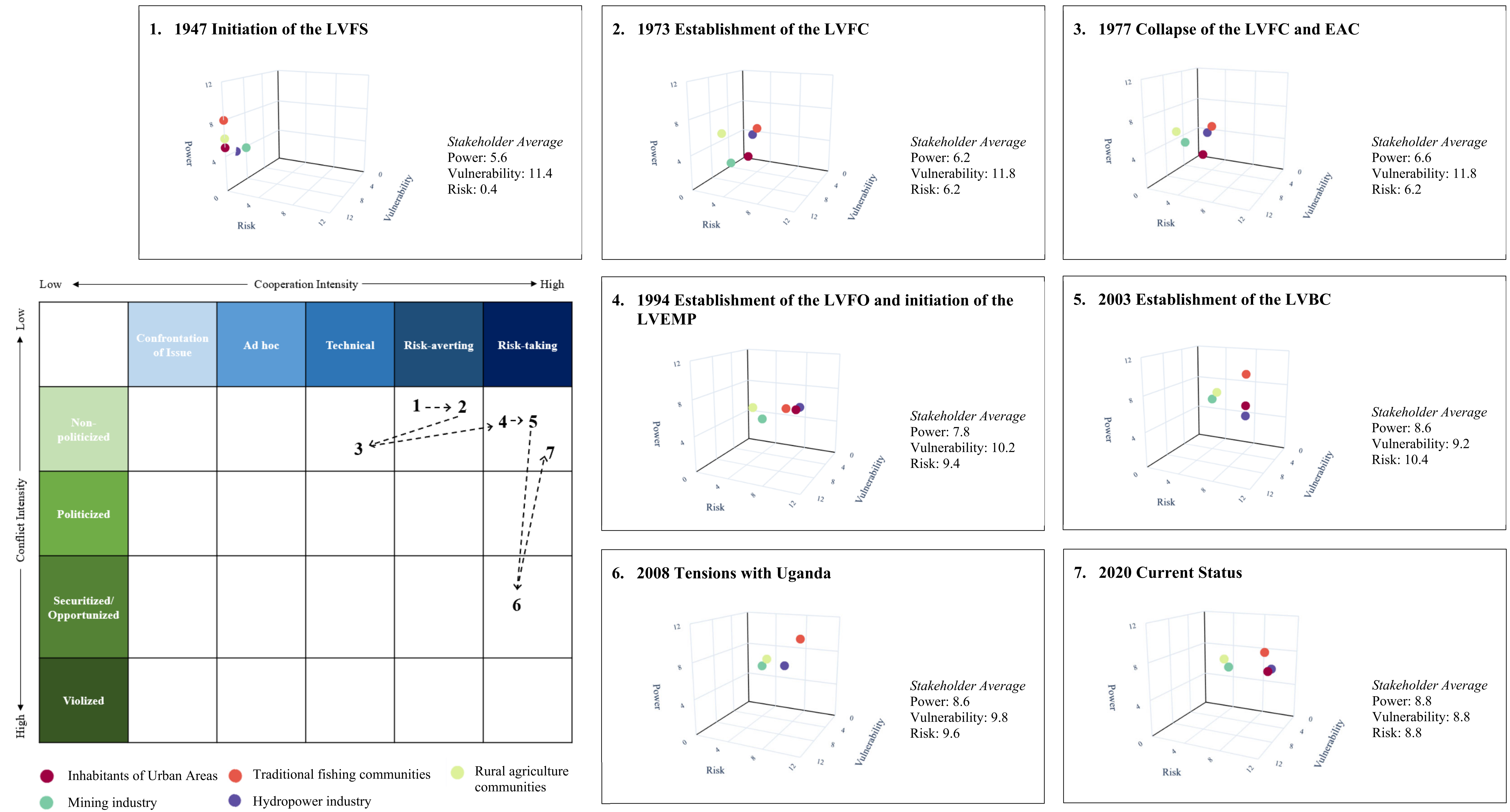

Figure 6. History of transboundary state interactions and modified stakeholder analyses in the Lake Victoria basin.

4.3 Lake Constance

Lake Constance, or Bodensee, is situated between Germany, Switzerland, and Austria and includes Liechtenstein within its basin. With a basin population of approximately 1.5 million, the lake receives disproportionate anthropogenic pressure related to industry and a high influx of annual tourism (ILEC, 2020; Hammerl & Gattenloehner, 2005). High nutrient loading from domestic wastes, industrial wastes, and agriculture within the region caused eutrophication and altered lake fisheries (Ostendorp et al., 2004; Hammerl & Gattenloehner, 2005). However, as a result of transboundary cooperation and policies, the nutrient load has been decreasing, and the lake returned to oligotrophic conditions at the beginning of the century (Bresciani, Stroppiana, Odermatt, Morabito, & Giardino, 2011). While the lake currently boasts high water quality, there are concerns that trace heavy metals, endocrine disruptors, and pesticides are present within the waterbody (Gerner, Rybár, Engel, & Domaracká, 2009; Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006).

Five stakeholders were selected that are closely tied to Lake Constance water quality. The stakeholder groups are separated based on their spatial distribution (i.e., urban versus rural), occupations, and hobbies. The selected groups include inhabitants of large cities/municipalities, fishermen, environmentalists, recreational boaters, and the tourism industry. Some overlap may exist within the stakeholder groups, but the spatial, occupational, and hobby distinction is made to create an effective separation. In particular, recreational boaters and the tourism industry are separated because the boaters represent locals and tourists engaging in a particular activity that is relevant to basin interactions. The tourism industry considers a broader group of providers and participants that exist in the region.

4.3.1 Primary Transboundary Interactions

Within the Lake Constance basin, there is a long history of transboundary interaction that has largely been cooperative. A limited chronology of transboundary water interactions, water quality degradation, and conditions in the basin is presented in Figure 7. The primary transboundary water interactions, their conflictive and cooperative classification, and justification are included in Table 16.

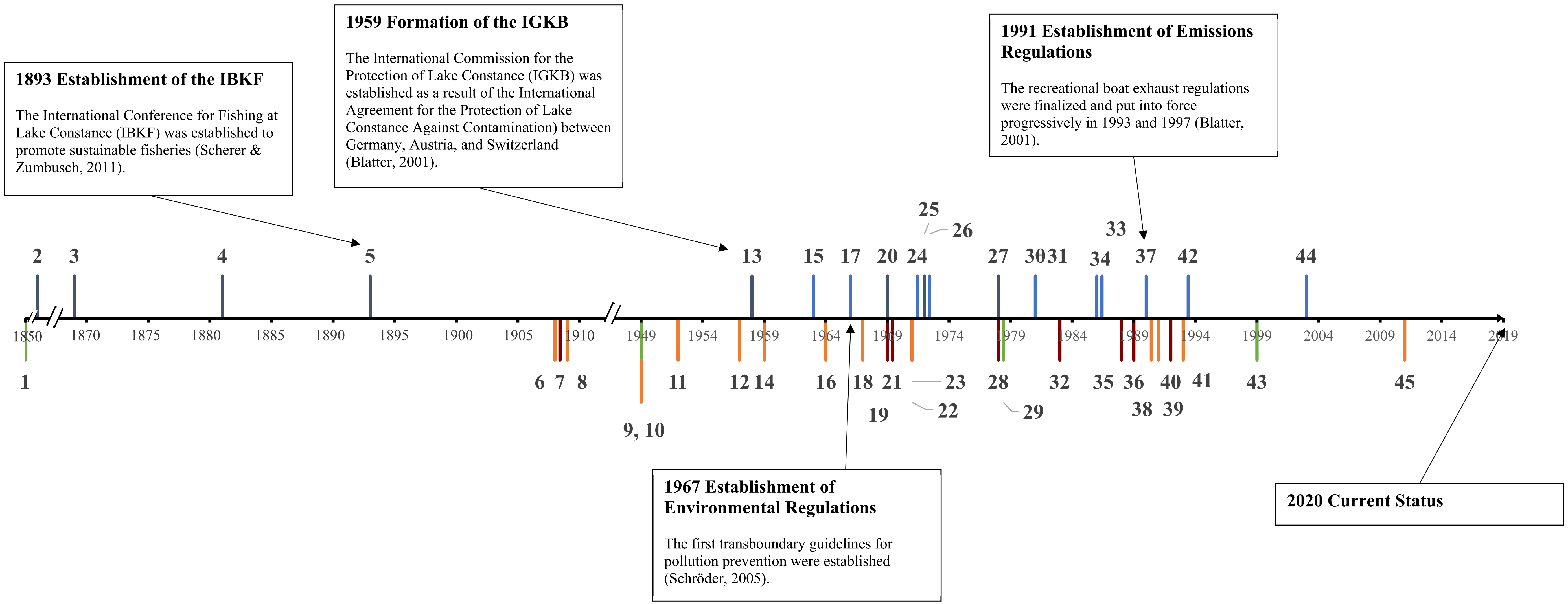

Figure 7. Timeline of state interactions, joint actions and programs, biophysical trends, international and state actions, and stakeholder actions in the Lake Constance basin.

Transboundary State Interactions (**Dark Blue**)

Event	Description
2	A treaty was signed between Germany, Austria, and Switzerland to regulate the lake outflow (Scherer & Zumbusch, 2011).
3	The first transboundary attempts to regulate fishing failed due to the political situation in the basin (Schröder, 2005).
4	The "Lindau Decision" was made which demonstrated an international commitment to standardizing national regulations over the lake (Schröder, 2005).
5	The IBKF was established to promote sustainable fisheries (Scherer & Zumbusch, 2011).
13	The IGKB was established as a result of an international agreement (the International Agreement for the Protection of Lake Constance Against Contamination) between Germany, Austria, and Switzerland (Blatter, 2001).
20	The European Conference of the Ministers of Spatial Planning was established.
25	The International Navigation Commission for Lake Constance (IKSB) was formed (Schröder, 2005).
27	Lake Constance becomes a RAMSAR site (Global Nature Fund, n.d.a).

Joint Actions and Programs (**Blue**)

Event	Description
15	The IGKB initiated a wastewater treatment program (Petri, 2006).
17	The first guidelines for pollution prevention were established (Schröder, 2005).
24	The pollution standards were revised (Schröder, 2005).
26	The first regulations for motorboats, including recreational boats, were established (Blatter, 2001).
30	An IGKB report on the water problems caused by boats was published and circulated with support of the AWBR (Blatter, 2001).
31	A Swiss canton vetoed motorboat emissions restrictions (Blatter, 2001).
33	The IGKB expanded its mandate to cover ecosystem protections (Schröder, 2005).
34	The pollution standards were revised (Schröder, 2005).
37	The motorboat exhaust regulations were finalized and put into force progressively in 1993 and 1997 (Blatter, 2001).
42	The IGKB began to publish annual brochures (Schröder, 2005).
44	The IGKB launched a program to rehabilitate shorelines (Bloesch & Schröder, 2008).

Biophysical Trends (**Green**)

Event	Description
1	Overfishing occurred as a result of impoverishment in the region (Schröder, 2005).
9	Eutrophication in the lake affected fisheries and gained public attention (Schröder, 2005)
29	Phosphorous concentrations peaked in the lake (Petri, 2006).
43	The lake returned to its oligotrophic state (Bresciani et al., 2011).

International and State Actions (**Red**)

Event	Description
7	The International Lake Constance Association (IBV) was established to promote tourism (Blatter, 2001).
19	The idea of the "Euroregion" came to the Lake Constance area (Blatter, 2001, p. 111).
21	1970 was declared the "European Year of Nature Protection" (Blatter, 2001).
23	The Lake Constance Conference of Government Leaders (IBK) was established without a formal treaty (Blatter, 2001).
28	The IBK began to focus on environmental and water protection (Scherer & Zumbusch, 2011).
32	The IBK established a subcommittee on motorboat regulations (Blatter, 2001).
35	The European Community supported cross-border collaboration with INTTERG grants (Blatter, 2001).
36	The IBK obtained a formal statue and budget (Blatter, 2001).
40	The European Union was formed.

Stakeholder Actions (**Orange**)

Event	Description
6	"Lake Constance Week" was established (Blatter, 2001).
8	The International Fishermen's Association of Lake Constance (IBF) was established and represented within the IBKF starting in 1912 (Schröder, 2005)
10	The IBF established a wastewater commission (Schröder, 2005).
11	The German State of Baden-Württemberg called for joint action to address environmental degradation in Lake Constance (Schröder, 2005).
12	The Lake Constance Ornithological Working Group was founded (Hammerl & Gattenloehner, 2005).
14	Environmental organizations started to highlight the damage caused by motorboats in the lake (Blatter, 2001).
16	The International Lake Constance Motorboat Union was formed (Blatter, 2001).
18	The Syndicate of the Waterworks in the Lake Constance-Rhine Region (AWBR) was established (Blatter, 2001).
22	The Working Committing Natural Protection Lake Constance (ANB) was established (Scherer & Zumbusch, 2011).
38	The Lake Constance Council was established as the "voice of the people" (Blatter, 2001, p. 112).
39	The Study Group on Tourism and Nature (ARGE FUN), a watersport lobby, was formed (Blatter, 2001).
41	The Lake Constance Foundation and Environmental Council of Lake Constance were formed by environmental organizations (Schröder, 2005).
45	The volume of fishermen decreased in the lake due to decreasing fish stocks which has led to local tension (DPA, 2013).

Table 16. Conflict and cooperation intensity of major transboundary interactions in the Lake Constance basin.

Event	Conflict Intensity	Cooperation Intensity
1893 Establishment of the IBKF	Non-politicized	Risk-taking
	• The International Conference for Fishing at Lake Constance (IBKF) operates by consensus (Schröder, 2005). Given the voluntary creation of the IBKF and opportunities for equal voice in decision making processes, the interaction is assumed to be non-politicized.	• The IBKF was established based on the signed "Agreement of Bregenz" in 1893 to sustainably develop the lake's fisheries (Schröder, 2005; Blatter, 2001). The IBKF is an annual conference that is engaged management decisions. The three countries are obligated to transform IBKF decisions into their national law although the decisions of the IBKF are not binding based on international law (Schröder, 2005). • The IBKF demonstrates shared goals, joint action, and some commitment to unforeseen constraints through the national law obligations. As a result of these conditions, the interaction is considered risk-taking.
1959 Formation of the IGKB	Non-politicized	Risk-taking
	• The International Commission for the Protection of Lake Constance (IGKB) operates by unanimity (Scroder, 2005). Given the voluntary creation of the IGKB and opportunities for equal voice in decision making processes, the interaction is assumed to be non-politicized.	• The IGKB was formed by an international agreement in 1959 to protect the lake from contamination (Schröder, 2005). The IGKB is a "consultant agency," and can make recommendations for environmental regulations (Schröder, 2005, p. 31). The three countries are obligated to transform IGKB recommendations into their national law through the agreement (Schröder, 2005). The IGKB is considered to be the "central authority" for the lake (Blatter, 2001, p. 103). • The IBKF remained active throughout this time period and was engaged in addressing pollution in the lake (Schröder, 2005). • Given the joint action, shared goals, and some commitment to unforeseen constraints through the national law obligations in the IGKB and the IBKF, the interaction is considered risk-taking.
1967 Establishment of Environmental Regulations	Non-politicized	Risk-taking
	• Given the absence of public tensions, it is assumed that the interaction was non-politicized.	• The IGKB published pollution guidelines in 1967 (Schröder, 2005). This action represents the functioning of the IGKB institution and continued

Event	Conflict Intensity	Cooperation Intensity
		commitment by the states to joint action. • Given the continued functioning of the IGKB and IBKF, the interaction is considered risk-taking.
1991 Establishment of Emissions Regulations	Politicized	Risk-taking
	• There was resistance to the emission regulations in Switzerland because of greater interests in recreational boats, decreased dependence on water quality in the lake, and concern of national regulations due to treaty requirements (Scherer & Zumbush, 2011). Initial consensus on the rules was halted by a veto by a Swiss canton in 1984 (Blatter, 2001). • Although there was support for the emissions rules, interventions were required to reach consensus on the emissions regulation (Blatter, 2001). • Given the contention in Switzerland prior to consensus being reached, the interaction is considered politicized.	• In 1991, the three countries agreed on emissions rules that were to come into effect in 1993 and 1997 (Blatter, 1997). Although the International Shipping Association of Lake Constance (ISKB) was initially mandated to determine the regulations, the International Association of the Lake Constance's Harbor Facility managed the regulations to shift implementation to regional government bodies (Scherer & Zumbusch, 2011). • Additional cross-border institutions including the ISKB and the Lake Constance Conference of Government Leaders (IBK) were established in 1972 (Blatter, 2001). These organizations played important roles in the negotiation and mediation over the establishment of regulations (Blatter, 2001). • The commitment to strict regulations, further institutionalization of transboundary governance, and continued functioning of the IGKB, IBKF, and ISKB indicate that the interaction was risk-taking.
2020 Current Status	Non-politicized	Risk-taking
	• The IGKB is described as amicable and increasingly informal due to high levels of trust (Blatter, 2001). The IGKB has further been described as "the most beautiful international commission there is" (Interview Subject as cited in Blatter, 2001, p. 118). • The institutions have been criticized for avoiding contentious topics (Scherer & Zumbusch, 2011). • Given the positive perception of the state relationships in the international institutions, the interactions are assumed to be non-politicized.	• The transboundary institutions are still functioning per their established structures and commitments. Therefore, the interactions are considered risk-taking.

4.3.2 Power, Vulnerability, and Risk Classification

A summary of the categorized distribution of power, vulnerability, and risk is presented in Table 17. The full justification for each classification is provided in Appendix C. The detailed analysis of power, vulnerability, and risk are listed included in Table 25, Table 26, and Table 27 of Appendix C, respectively.

Table 17. Analysis of primary stakeholder power, vulnerability, and risk in the Lake Constance basin.

Stakeholder	**Event**	**Power**				**Vulnerability**				**Risk**			
		Formal Authority	Resources	Discursive Legitimacy	State Interest	Regional Development	Economic	Education	Political	Ingestion (water)	Ingestion (food)	Dermal Contact	Livelihood Use
Inhabitants of large cities/ municipalities	1893 Establishment of the IBKF	Low (1)	Low (1)	Low (1)	Low (1)	Medium	Medium (2)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1959 Formation of the IGKB	Low (1)	Medium (2)	Medium (2)	High (3)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Low (1)	Low (1)
	1967 Establishment of Environmental Regulations	Medium (2)	Medium (2)	Medium (2)	High (3)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Medium (2)	Medium (2)
	1991 Establishment of Emissions Regulations	High (3)	High (3)	High (3)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	None (0)	Medium (2)	Medium (2)
	2020 Current Status	High (3)	High (3)	High (3)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	None (0)	Low (1)	None (0)	None (0)
Fishermen	1893 Establishment of the IBKF	Low (1)	Low (1)	Low (1)	High (3)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1959 Formation of the IGKB	High (3)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	None (0)	Medium (2)	None (0)
	1967 Establishment of Environmental Regulations	High (3)	High (3)	Medium (2)	High (3)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	High (3)	Low (1)
	1991 Establishment of Emissions Regulations	High (3)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	None (0)	High (3)	None (0)
	2020 Current Status	High (3)	High (3)	Medium (2)	Low (1)	Low (1)	Medium (2)	Low (1)	Low (1)	None (0)	Medium (2)	None (0)	High (3)
Environmentalists	1893 Establishment of the IBKF	Low (1)	Low (1)	Low (1)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1959 Formation of the IGKB	Low (1)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Low (1)	None (0)
	1967 Establishment of Environmental Regulations	Medium (2)	High (3)	High (3)	Medium (2)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Medium (2)	None (0)
	1991 Establishment of Emissions Regulations	Medium (2)	High (3)	High (3)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	None (0)	Medium (2)	None (0)
	2020 Current Status	Medium (2)	High (3)	High (3)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	None (0)	Low (1)	None (0)	None (0)
Recreational boaters	1893 Establishment of the IBKF	Low (1)	Low (1)	Low (1)	Low (1)	Medium (2)	Low (1)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1959 Formation of the IGKB	Low (1)	Medium (2)	Medium (2)	Medium (2)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Medium (2)	None (0)
	1967 Establishment of Environmental Regulations	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	High (3)	None (0)
	1991 Establishment of Emissions Regulations	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	None (0)	High (3)	None (0)
	2020 Current Status	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Low (1)	Low (1)	Low (1)	None (0)	Low (1)	None (0)	Low (1)
Tourism industry	1893 Establishment of the IBKF	Low (1)	Low (1)	Low (1)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	None (0)	None (0)	None (0)
	1959 Formation of the IGKB	Low (1)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (2)	Medium (2)	High (3)	High (3)	None (0)	Medium (2)	None (0)
	1967 Establishment of Environmental Regulations	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Low (1)	Medium (2)	High (3)	High (3)	None (0)	High (3)	None (0)
	1991 Establishment of Emissions Regulations	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	High (3)	None (0)	High (3)	None (0)
	2020 Current Status	Medium (2)	High (3)	Medium (2)	High (3)	Low (1)	Low (1)	Low (1)	Low (1)	None (0)	Medium (2)	None (0)	None (0)

The quantitative summation of the relative stakeholder power, vulnerability, and risk leading up to the transboundary interactions in the Lake Constance basin is presented Table 18.

Table 18. Summary of stakeholder power, vulnerability, and risk over events in the Lake Constance basin.

Stakeholder	Event	Power	Vulnerability	Risk
Inhabitants of large cities/ municipalities	1893 Establishment of the IBKF	4	10	0
	1959 Formation of the IGKB	8	8	5
	1967 Establishment of Environmental Regulations	9	8	7
	1991 Establishment of Emissions Regulations	12	4	7
	2020 Current Status	12	4	1
Fishermen	1893 Establishment of the IBKF	6	10	0
	1959 Formation of the IGKB	11	7	5
	1967 Establishment of Environmental Regulations	11	8	7
	1991 Establishment of Emissions Regulations	11	4	6
	2020 Current Status	9	5	5
Environmentalists	1893 Establishment of the IBKF	4	10	0
	1959 Formation of the IGKB	9	8	4
	1967 Establishment of Environmental Regulations	10	8	5
	1991 Establishment of Emissions Regulations	11	4	5
	2020 Current Status	11	4	1
Recreational boaters	1893 Establishment of the IBKF	4	9	0
	1959 Formation of the IGKB	7	8	5
	1967 Establishment of Environmental Regulations	9	8	6
	1991 Establishment of Emissions Regulations	10	4	6
	2020 Current Status	9	4	2
Tourism industry	1893 Establishment of the IBKF	4	10	0
	1959 Formation of the IGKB	8	8	5
	1967 Establishment of Environmental Regulations	9	7	6
	1991 Establishment of Emissions Regulations	10	4	6
	2020 Current Status	10	4	2

Within the Lake Constance basin, several general trends can be observed. For almost all actors, power increases with time. This power is derived from greater institutionalization of participation in transboundary processes through limited access to the IGKB and stakeholder participation in the non-binding IBK. Between 1967 and 1991, all actors obtained high levels of power (>9). While all other actors continue to increase in power, fishermen and recreational boaters present slightly different pattern. Both fishermen and recreational boaters decrease in power between 1991 and 2020. This decrease is related to state interest which appears to have shifted towards prioritizing environmental conservation and away from fishing and boating needs. Additionally, from 1967 on, municipalities were considered very powerful. This power is related to the formal authority, resources, and discursive legitimacy of the AWBR, a stakeholder organization that represents 77 municipalities in the Lake Constance area. The AWBR was given formal participation in the IGKB, conducts research, and regularly releases studies to the general public.

For all stakeholders, vulnerability generally decreases with time. Between 1967 and 1991, vulnerability became low for all actors as related to economic and educational vulnerability in the region as wells as the establishment of joint regulations to address water quality as per the recommendation of the IGKB in 1967. Vulnerability in the basin only increases over one time point for one actor. Vulnerability increases for fishermen between 1991 and 2020 and is related to the decline in fish in the region which has drastically impacted the industry and reduced economic opportunity for the stakeholder group.

The risk for all stakeholders is generally low (<7). The risk within the lake peaks between 1969 and 1967, is maintained through 1991, and decreases by the current time period. This risk is related to the eutrophication in the lake. The eutrophication began to build until 1989 at which point the nutrient loading in the lake began to decrease. The presence of eutrophication primarily threatened the drinking water and dermal contact exposure pathways. The return to oligotrophic conditions in the early 2000s decreased these exposure pathways for most stakeholders. Notably, the increase in eutrophication did not have a high livelihood risk impact on fishing communities. The absence of this risk was related to increased productivity in the lake. The increase in nutrients increased the fish biomass which was determined to have a net impact that did not adversely impact fisheries.

Only one outlier existed in the basin with a deviation greater than 2 points from the average. The outlier occurs for the risk of fishermen between 1991 and 2020. This risk increase is related to the livelihood use risk of fishermen in the current time period. The return to oligotrophic conditions has reduced the fish stock in the lake leading to a direct decrease in livelihoods and subsequent impact on livelihood use exposure.

4.3.3 Connection to Transboundary Interactions

The modified stakeholder analysis can be seen mapped against the intensity of conflict and cooperation in Figure 8. Three major shifts occur in the intensity of conflict and cooperation related to the initiation of cooperation and an increase and decrease in conflict intensity. These shifts were related to variations in the stakeholder average power, vulnerability, and risk.

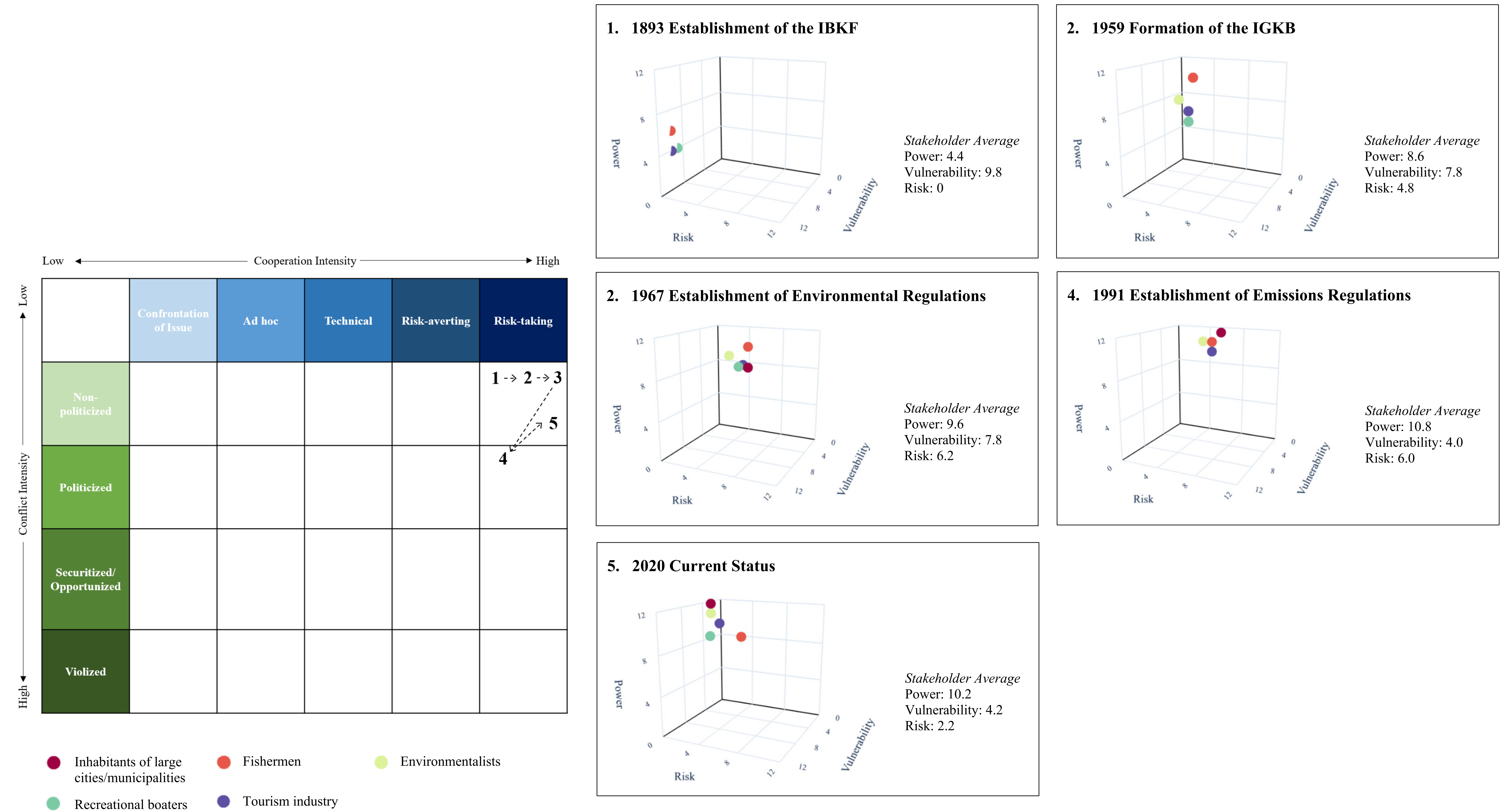

Figure 8. History of transboundary state interactions and modified stakeholder analyses in the Lake Constance basin.

4.4 Transboundary Water Interactions

4.4.1 State Interactions

Within the three basins, the intensity of cooperation varied from technical to risk-taking. In all basins, risk-taking cooperation represents the current intensity of interactions, and the majority of actions were highly cooperative. Of the analyzed transboundary water interactions, approximately 67% of interactions were risk-taking, 22% were risk-averting, and 11% were technical in intensity of cooperation.

The intensity of transboundary state water conflict ranged from non-politicized to securitized/opportunized. Within each basin, conflict intensity existed for only one interaction and was resolved by the next studied interaction. Of the analyzed transboundary water interactions, approximately 83% of interactions were non-politicized, 11% were politicized and 6% were securitized/opportunized. Although not every interaction was directly related to water quality, these patterns of interactions suggest that states primarily cooperate over management of water quality of transboundary lakes.

The modified stakeholder analysis shows a greater variation in power, vulnerability, and risk. Stakeholder power ranged between 4 and 12 with an average power of 7.8 throughout all basins, stakeholders, and interactions. Stakeholder vulnerability ranged from 4 to 12 with an average vulnerability of 9.1 throughout all basins, stakeholders, and interactions, and stakeholder risk ranged from 0 to 12 with an average risk of 6.5 throughout all basins, stakeholders, and interactions. When comparing the modified stakeholder analysis between basins, there is some variation. The average stakeholder power over all interactions in the Lake Titicaca, Lake Victoria, and Lake Constance basins is 7.5, 7.5, and 8.7, respectively. The average stakeholder vulnerability during all interactions in the Lake Titicaca, Lake Victoria, and Lake Constance basins is 9.6, 10.4, and 6.7, respectively. Finally, the average stakeholder risk throughout all interactions in the Lake Titicaca, Lake Victoria, and Lake Constance basins is 7.7, 7.3, and 3.8, respectively.

4.4.2 Alternate Water Interactions

While completing the data analysis, interactions were also observed at other levels of scale. Although a comprehensive literature review was not conducted to assess conflict or cooperation at other scales, as this was outside the scope of research, several conflicts related to water quality were noted. These conflicts are included in the following list which is not comprehensive and may be further limited by freedom of the press in two of the basins.

Lake Titicaca

- In rural fishing and agricultural communities of Peru, stakeholders exerted their rights to local management of resources (Orlove, 2002). These conflicts, which occurred during the 1970s and 1980s sometimes led to violent confrontations between stakeholders and the state (Orlove, 2002).
- In 2006, rural farmers in Bolivia initiated protests to call out eutrophication in the lake (Mancilla García, 2013). Additionally, fishermen in the Cohana area of Bolivia shut down roads to highlight the impacts of eutrophication on their communities (Mancilla García, 2013).
- In 2006, communities in Peru shut down highways to protest unregulated gold mining (Williams, 2015).
- Tension existed between stakeholders and the ALT as civil society and local governments expressed distrust and criticism of the organization and its projects (Mancilla García, 2013). On the Bolivian side of the lake, these tensions were expressed in contention over a compost project, and on the Peruvian side of the lake, the ALT was criticized for perpetuating presidential power (Mancilla García, 2013).
- Power struggles also existed between local organizations and the ALT over the duties of the binational organization (Mancilla García, 2013).
- Protests were observed in the Puno region of Peru related to the impacts of water contamination on the lake (van Eerten, 2016).
- Conflicts were reported between mining and agricultural land and water users (Calizaya, Meixner, Bengtsson, & Berndtsson, 2010).
- In 2011, indigenous communities in Peru protested mining within the basin at airports, the capital, and check points at the border (Williams, 2015). Several of these protests became violent (Williams, 2015).
- In 2016, residents of El Alto, Bolivia temporarily took a water distribution company hostage as a result of water shortages (Reuters, 2016). Although there was an ongoing

drought in the region which was likely the dominant factor in the water shortage, water quality may have contributed to this tension by decreasing alternate water sources, as a reservoir for El Alto had previously been reported as contaminated (Agramont et al., 2018).

Lake Victoria

- Starting in 2001, there was an increase in conflict between fishermen and enforcement authorities on the lake (UNEP, 2006).
- In the 2000s, there were reports of conflict between fishermen of Kenya and Uganda related to territorial fishing areas (Atieno, 2014). These conflicts caused several fatalities and were exacerbated by the dual state claims to Migingo Island which had led fishermen from both states to exert control of the region (Atieno, 2014).
- In 2006, fishermen protested to demand recognition of their rights (Godsäter, 2013).
- There were large protests that involved violent confrontation regarding the Barrick Gold Mine in Tanzania (Ewald, Nilsson, Närman, & Såtlgren, 2004). Although protests initially addressed the company's management, the greater community joined the protests in 2008 to address a variety of issues including environmental degradation in the basin (Newenham-Kahindi, 2011).

Lake Constance

- Throughout the 1900s there was sectoral conflict between international stakeholder organizations that had competing interests (Blatter, 2001). This conflict primarily pitted municipalities, environmentalists, and fishermen against recreational boaters and the sport boat industry (Blatter, 2001).
- Organizations competed for mandates to address environmental degradation (Blatter, 2001). These power struggles existed between various levels of government including state and federal governments in the riparian countries (Blatter, 2001).
- For instance, in the 1970s, two transboundary state organizations (the IGKB and ISKB) were in regular conflict that was characterized by distrust (Blatter, 2001). Any proposed rules were perceived poorly by the other organization (Blatter, 2001).

- Additionally, in 1991, the IBK and the ISKB engaged in a power struggle over the ownership of emissions regulations in a public meeting (Blatter, 2001). This act created conflict between the regional, sub-national government (IBK) and the federal organization (Blatter, 2001).
- At the present there is tension between fishermen and the state as fishermen express that efforts to clean the lake were excessive and without consideration of fishermen's needs (Scheven, 2014).

SECTION 5: Analysis and Discussion

5.1 Stakeholder Influence on Transboundary Water Interactions

In all three basins, high intensity cooperation was frequently observed in spite of the varying distributions of stakeholder power, vulnerability, and risk. Therefore, there is no universal correlation between the stakeholder power, vulnerability, risk, and transboundary interactions. Given the consistent intensities of cooperation, limited conflict, and absence of a universal pattern, it is likely that stakeholders were not the only factor that shaped state interactions. This finding is consistent with literature that suggests that stakeholders impact the state but do not solely dictate its actions (Warner & Zawahri, 2012).

Although there was not a universal pattern, stakeholders were observed to influence the state. The basins exhibited patterns of behavior that, in addition to the discourse framing by the state, indicate that stakeholders' power, vulnerability, and risk affected the states' decisions. These patterns relate to influence by individual stakeholder groups and the stakeholder group as a whole, with varying influence from vulnerability, risk, and power.

5.1.1 Vulnerability Driven Interactions

The initiation of transboundary cooperation occurred with similar stakeholder trends in all three basins. Prior to the initiation of cooperation, average stakeholder risk in each basin was low or non-existent, power was low, and vulnerability was high. Furthermore, there was limited variability in the vulnerability of basin stakeholder groups. This trend would suggest that if stakeholders play a role in the initiation of cooperation, vulnerability is the point of entry.

Within the Lake Titicaca and Lake Victoria basins, average stakeholder vulnerability was especially high at the initiation of cooperation (11.2 in Lake Titicaca and 11.4 in Lake Victoria). Similarly, in both basins, development was expressed as a driver of cooperation between states. In the Lake Titicaca basin, the transboundary desire to develop the basin led to a limited joint studies on fisheries and other regional development prior to the establishment of the joint ownership agreement which aimed to develop the economic uses of water (Orlove, 2002; Mancilla García, 2013; Priscoli & Wolf, 2010). This push for development directly addressed economic vulnerability of the primarily subsistent basin population, although the discursive connection was not explicitly made (WWAP, 2003). In the Lake Victoria basin, poverty and food insecurity were cited as a major concern in by the basin by the colonial governments (Lugo et al., 2014). As a result, the states began to engage in fisheries data management in order to support understanding and possible development of the fisheries resources (Muyodi et al., 2010). This narrative of cooperation in the Lake Victoria basin directly ties state action to the economic vulnerability of stakeholders. Therefore, within the Lake Titicaca and Lake Victoria basins, the high average stakeholder vulnerability encouraged the initiation of transboundary cooperation to address development. The government narratives both explicitly and implicitly connected their actions to the local population.

In the Lake Constance basin, vulnerability also shaped cooperation but through a slightly different manner. Similar to the other basins, average stakeholder vulnerability was high (9.8) during the initiation of cooperation (i.e. establishment of the IBKF) in 1893. It has been suggested that the desire to jointly manage fisheries came from overfishing and the economic impacts to fishermen in the seventh century (Schröder, 2005). Although the initiation of cooperation does not represent a concern for the vulnerability of all stakeholders, it does directly respond to vulnerability of fishing communities. As a result, a singular stakeholder group's vulnerability can also support the initiation of cooperation between states.

Stakeholder vulnerability was also is relevant in increasing cooperation intensity. In the Lake Titicaca basin, initial cooperation between Bolivia and Peru was technical due to limited commitments in 1957. However, commitment to cooperation was reinforced in 1986 when Bolivia ratified the joint ownership agreement and thus, initiated joint action (i.e., risk-averting cooperation). Prior to Bolivia's act of ratification, economic vulnerability of all actors was high. This vulnerability was related to a regional depression and damage from natural disasters. It has been suggested that Bolivia ratified the agreement as a result of the financial losses from drought and flooding in the region (Priscoli & Wolf, 2010). In essence, this reasoning connects state action to the economic vulnerability of actors. Through this pathway, widespread economic vulnerability in the region can motivate the state to increase its intensity of cooperation and engage in joint action.

In the Lake Victoria basin, vulnerability remained high throughout the duration of the study period. In particular, average stakeholder vulnerability was high (10.2) prior to the reestablishment of joint action in 1994. The development of the LVFO and LVEMP were fostered following the Rio Earth Summit in 1992 and were based on the idea that transboundary environmental management could address social concerns in the basin (Muyodi et al., 2010;

Lubovich, 2009). In this case, the broad stakeholder vulnerability helped to motivate the re-establishment of joint action and similarly, increase the cooperation intensity between the states.

Based on stakeholder patterns and the narrative of the states, stakeholder vulnerability likely motivates the initial cooperation between states and fosters joint action which can increase the cooperation intensity between states.

5.1.2 Risk Driven Interactions

General patterns of risk are more complicated to correlate with actions of the state. With water quality risks, there is often a gap between the actual risk and the perception of risk. As this analysis was completed after most events, risk could be determined in hindsight even if that risk was not recognized by stakeholders or the state at the time of the transboundary interaction. Within the basins, this gap frequently occurred when water quality impacts were not visible or did surpass a threshold where they were physically manifested (e.g., via sight or odor). Analysis of risk is further complicated because there is often a lag in reduction of risk. Because the three lakes have long residence times, even if impacts were to stop immediately, the lake would still present impacts for years. Therefore, even if the state were to interact in a way that responds to stakeholder risk, there is a lag time before that risk is reduced. These factors complicate a direct correlation between events and stakeholder risk in the basins. However, with consideration of these complicating factors, clear trends are present.

Within the three basins, increasing average stakeholder risk often led to increasing institutionalization of high intensity cooperation over water quality. In the Lake Titicaca basin, the initiation of risk-taking cooperation, through the establishment of the ALT, coincided with a large increase (greater than two points) in average stakeholder risk. Although the mandate of the ALT did not initially focus on water quality, as it was geared towards development and water level management, the states quickly followed this event by institutionalizing commitment to environmental protection through the RAMSAR Convention (Martínez Gonzales & Zuleta Roncal, 2007; Mancilla García, 2013). Therefore, an increase in cooperation intensity was not directly related to the increase in water quality, but the increasing level of risk was followed by a rapid institutionalization of cooperation over water quality. An additional large increase in average risk (greater than two points) occurred prior to the 1986 ratification of the joint agreement. Given that the agreement was not focused on water quality, it is assumed that this increase in cooperation intensity was not related to water quality risk and was based on stakeholder vulnerability as discussed in Section 5.1.1. However, the lack of response to the water quality risk is likely related to the perception of risk, as algal blooms were infrequent in the 1980s, and the states and stakeholders likely did not recognize the growing contaminant pressure on the lake.

In the Lake Victoria basin, average stakeholder risk experienced a large increase (greater than two points) leading up to the re-initiation of joint action in 1994. Although the highest intensity cooperation that occurred during that time period was focused on fisheries with the LVFO, risk-averting cooperation was initiated through the LVEMP to address water quality in the lake. Additionally, as stakeholder risk continued to increase, the states institutionalized risk-taking cooperation to address water quality through the LVBC. Therefore, within Lake Victoria, increasing water quality risk yielded increasing intensity of cooperation to address water quality issues. Notably, there was a large increase in stakeholder risk earlier in the basin (prior to 1974), however this risk was not widely recognized until the 1980s when algal blooms occurred in the lake and the endemic fish stock declined. Similar to Lake Titicaca, this gap in risk perception resulted in limited impact on action.

In the Lake Constance basin, high intensity cooperation began at the initiation of cooperation between the states (i.e., the establishment of the IBKF) when there was no water quality-related risk in the basin. However, the first increase in risk corresponded with additional risk-taking cooperation over water quality through the establishment of the IGKB. As risk continued to increase through the 1980s, the IGKB expanded its mandate to address ecosystem protection which demonstrates a direct response to increasing risk in the basin (Scherer & Zumbusch, 2011). Within Lake Constance, the increase in risk aligned with perceived risk of the lake. Therefore, the basin most clearly indicates the relationship between high-intensity cooperation and average stakeholder risk. Overall, this institutionalization of high intensity cooperation was consistent throughout all basins but did not clearly alter the pattern of interactions because other related interactions were occurring concurrently.

Risk is also perceived to play a role in the initiation of transboundary conflict. Within the Lake Titicaca basin there was an increase in average stakeholder risk prior to the 2010 conflict. In the Lake Constance and Lake Victoria basins, peak risk did not coexist with conflict, but risk remained near its peak value immediately prior to both events. Stakeholder risk is believed to contribute to conflict as discussed in Section 5.1.3.

5.1.3 Power Driven Interactions

Within the three basins, power generally increases with time; however, peaks of average stakeholder power are also perceived to correlate with increases in transboundary conflict intensity. The operational definition of stakeholder power considers the formal authority, resources, discursive legitimacy, and state interest of actors in the basin. When average stakeholder power increases, this represents that there are multiple actors that have the capacity to influence the state during that time period. This potential for broad influence can have varied implications for potential conflict between states.

In the Lake Constance basin, the conflict intensity between states increased as a result of clash of sectoral interests. Switzerland had incentive to prevent strict recreational boat emissions and Germany had higher incentive to protect drinking water as a result of their respective stakeholder water uses (Scherer & Zumbusch, 2011). Prior to the conflict over emissions, all stakeholder groups had a high level of power and thus, a high capacity to influence the state. The concern over recreational boats was primarily initiated by environmentalists and perpetuated by the AWBR, a stakeholder group that represented drinking water municipalities in the basin (Blatter, 2001). The AWBR was a powerful group which enabled their concerns of chemical contamination from boats to be a dominant narrative in the region although there was not clear evidence that boats were a source of pollution (Blatter, 2001). Along with environmentalists and fishermen, the AWBR was able to set a transboundary agenda about a contentious topic. However, recreational boaters also had strong power in the region and their own access to lobby the state (Blatter, 2001). Given the relative power of all stakeholders in the basin, this sectoral conflict was elevated to a transboundary level and able to play out between states, thereby enabling stakeholder power to initiate transboundary conflict.

In the Lake Titicaca basin, conflict intensity was related to a lack of distrust between Bolivia and Peru in the functioning of the ALT. Although multiple factors led to this source of contention, it has been suggested that stakeholders also played a role in the conflict. Around the time of Bolivia's withholding of funds, multiple stakeholders engaged in protest against the state and its transboundary actions. In Peru, rural and indigenous communities were protesting mining activities in the basin (Williams, 2015). Simultaneously, in Bolivia, rural communities were protesting to highlight pollution in the lake (Mancilla García, 2013). These protests exerted pressure on the state, and in the case of the Peruvian protests, led to tensions between the two countries (AQ Editors, 2010). The ALT began to address some of these concerns by initiating a program to remove and reuse duckweed to creating compost in a Bolivian bay (Mancilla García, 2016). This program was met by resistance of Bolivian non-governmental organizations (NGOs) and local governments who criticized the validity of the science and the potential spread of risk to agricultural communities (Mancilla García, 2013). It was suggested that this tension was emblematic of lack of transparency and participation in the institution which ultimately encouraged the unilateral move by the Bolivian government to limit funding to the ALT (Mancilla García, 2013). Therefore, within the context of Lake Titicaca, increases in stakeholder power enabled stakeholders to protest the actions of the state, which then fueled tensions between the state governments, especially given the political, environmentally focused, platform of Bolivia.

The Lake Victoria basin presents an alternate perspective on power. Within the Lake Victoria region, average power was consistent with previous years and had not yet peaked. However, leading up to the conflict, there were several powerful actors including fishing communities who, relatively, were the most powerful in the basin at that time period. Simultaneously, fishing communities were experiencing high vulnerability and high risk. Some members of the fishing community had attempted to exert influence by protesting, but this action had discredited the actors in the perspective of the LVBC (Godsäter, 2013). Other fishermen had demonstrated the impacts of water quality degradation through violent confrontation over fishing territory (UNEP, 2006). When Uganda laid claim to Migingo Island, a securitized/opportunized act which increased conflict intensity in the basin, the state essentially expanded its territory for fishing (Atieno, 2014). The capacity to control the territory was one theory for why Uganda chose this behavior (Atieno, 2014). Given that the fishing community was powerful, at high risk, and high vulnerability, it is possible that Uganda opportunized the island to address the concerns of this stakeholders group. As a result, the power of a singular stakeholder groups can also influence conflictive transboundary interactions.

In all of the examples, the high levels of stakeholder power enabled their interest to be elevated to the transboundary discourse which contributed to conflict within the basin. However, it must be noted that power alone is not sufficient motivation for stakeholder actions. In Lake Constance, Lake Titicaca, and Lake Victoria, average stakeholder risk was at or near its peak value in each basin. Therefore, it is likely that risk is required to motivate stakeholders to directly and indirectly exert their power in transboundary processes.

It is also necessary to consider that high stakeholder power does not necessitate that transboundary conflict will occur. Within Lake Constance and Lake Titicaca, the average stakeholder power remained high following its peak at the time of conflict. However, in the following interactions, the states returned to non-politicized conflict intensity. This pattern can suggest that stakeholders help to shape the state to initiate conflict to address their needs, and the resolution of conflict enables more sustained cooperation in the basin. Furthermore, in Lake Titicaca, stakeholders have continued to exert high average power through protests. While this exertion of power has not led to increasing intensity of conflict, the states have committed greater financial resources to address contamination in the lake (teleSUR/lgc-TP, 2016). Thus, it is possible that the continued exertion of power did not impact interactions, but instead, pressured states to address the efficacy of the high intensity cooperation that was occurring.

5.1.4 Influence of Narrative

In addition to influencing the interactions between states, stakeholders were also observed to shape and be affected by the narrative of the water quality problems. These narratives influenced state actions and led to a cascade of impacts in the basins.

In the Lake Titicaca basin, rural fishermen had high power, vulnerability, and risk between 1998 and 2010. Around 2006, rural fishermen protested in Cohana Bay about the impacts of duckweed and eutrophication on the lake (Mancilla García, 2013). Based on political interest in these stakeholders by the Bolivian government, and their high power, it was believed that this action set the dominant narrative for efforts in the lake (Mancilla García, 2013). As a result, binational efforts primarily addressed eutrophication and duckweed in the bays and ignored the prevalent heavy metal contamination in the lake (Mancilla García, 2016). Notably, there were protests in Peru about mining near tributaries to the lake that occurred around the same time. These protests presented an additional narrative which was believed to have contributed to tensions between Bolivia and Peru prior to the initiation of basin conflict as discussed in Section 5.1.3. Therefore, in the Lake Titicaca basin, the shaping of narratives likely affected the actions taken by the transboundary cooperating agencies as well as the conflictive interactions between the states.

In the Lake Constance basin, stakeholders similarly presented a dominant narrative. Water municipalities and environmentalists were perceived to drive the narrative that recreational boat emissions contributed to water quality degradation (Blatter, 2001). These stakeholder groups held strong power at the time and were able to dictate a narrative that the transboundary institutions addressed, independent of risk and vulnerability. Therefore, within the Lake Constance basin, this narrative shaped the conflictive interactions and joint regulations as discussed in Section 5.1.3.

Finally, even when not produced by stakeholders, the influence of narrative can also shape stakeholder and state actions. Although overfishing has substantially contributed to the decrease in fish stock of Lake Victoria, it was not the sole contributor to this decline. Degrading water quality enabled the dominance of predatory Nile perch and continues to be a hazard for fish. However, in spite of water quality's contribution to the problem, it is often mentioned as a side note when discussing the lake's fisheries. Instead, overfishing is the dominant narrative for lake's problems and was the primary focus of the LVFO (Ntiba et al., 2001). These concerns of overfishing led to territorial conflict between fishermen in order to defend their fishing grounds and may have shaped the state interactions over the lake (UNEP, 2006). By claiming Migingo Island, Uganda can gain greater control of territory for fishing. By framing overfishing as the dominant concern for fishermen, this state territory claim would address the concerns of domestic stakeholders. However, if the stakeholders and state were to focus on water quality as the lake's dominant problem, the state's choice of solution may have been addressed differently.

5.2 Alternate Influences on Transboundary Interactions

Although stakeholder power, vulnerability, and risk have shaped state interactions, these distributions are likely not the only factors that influence interactions between the states. Therefore, other dominant theories of interactions must be considered concurrently to understand their potential for influence and exchange with stakeholder distributions.

5.2.1 The Institutional Capacity Theory

Wolf et al. posit that the existence of institutional capacity (i.e., management organizations or transboundary agreements) and historical relationships can absorb changes in the system to foster transboundary cooperation (2003). Within this theory, conflict occurs when there is a shock to the system that overcomes the institutional capacity or influence of historic relationships to address the shock (Wolf et al., 2003). As a result of this theory, two factors, institutional capacity and historic relationships, must be assessed.

The institutional capacity of each basin can be considered against the five to seven analyzed events presented in each case study. Because these primary interactions address the establishment of water cooperation (independent of water quality impacts), it is assumed that this theory can be accurately assessed.

Within the Lake Constance and Lake Titicaca basins, some institutional capacity existed prior to the recognition of water quality impacts. Within the Lake Constance basin, the states were participating in risk-taking cooperation over the lake's fisheries. As water quality started to degrade, the IBKF expanded its focus through creation of a wastewater subgroup and began to address water quality in the lake until the IGKB was established by international treaty in 1959 (Schröder, 2005). Although there was not an existing institutional body that explicitly dealt with water quality in the lake as it began to deteriorate, transboundary institutions existed and could begin to address the issue until new institutions were created.

In the Lake Titicaca basin, some institutionalization had also occurred prior to observation of impacts. Water quality impacts were not observed in Lake Titicaca until the 1980s and became more prevalent in the following decades. Prior to the 1980s, both countries had signed an agreement on joint ownership of the lake and had made limited commitments until the treaty was ratified by all parties in 1986. The groups engaged in joint studies and focused on economic development and water level management prior to the institutionalization of a binational authority in 1996 (Martínez Gonzales & Zuleta Roncal, 2007). Although protection of ecology was loosely addressed within these studies and ALT Master Plan, mandates on water quality were not explicitly addressed by this time period (WWAP, 2003). However, as water quality continued to degrade, the ALT took on this problem and began to address it through the existing institution. Therefore, some institutional capacity existed prior to water quality impacts although a delay occurred before this existing capacity began to address impacts.

While both the Lake Constance and Lake Titicaca basins align with the institutional capacity theory to an extent, Lake Victoria presents an alternate perspective. In the Lake Victoria basin, there was limited institutional capacity prior the manifestation of water quality impacts. Although pollutant loading on the lake had been ongoing for decades, the advent of perceived impacts was rapid leading to dominance of the Nile perch and lake eutrophication occurring concurrently in the 1980s (Muyodi et al., 2010). The water quality impacts in the lake presented a greater shock to the system because they were not "creeping" as generally presumed (Wolf et al., 2003, p. 43). However, during the 1980s, there were limited relationships between the countries following the collapse of the EAC in 1977. During this time period, no joint action was occurring and existing institutions had been dissolved, with only limited fisheries coordination occurring through the FAO (Muyodi et al., 2010). Institutional capacity was not initiated in the basin until 1992 following the Rio Earth Summit. This establishment of capacity led to risk-averting institutionalization of a program to address water quality and risk-taking institutionalization of a program to address fisheries. The activities on Lake Victoria serve as a counterpoint to the institutional capacity theory, as cooperation occurred in spite of an absence of institutional capacity and the fact that the water quality impact was a relative shock to the system. However, future water quality impacts, such as the water hyacinth outbreak in 1997, did benefit from the institutional capacity that was established by the states in 1994.

The institutional capacity theory also suggests that positive historic relationships are able to promote cooperation in the advent of water quality impacts (Wolf et al., 2003). Historic relationships can both establish trust and a pattern of cooperation and can be built off of a shared identity between states. These historic relationships can also be considered in the context of the three basins.

Within the Lake Constance basin, the countries have a shared history and similar languages (Scherer & Zumbusch, 2011). Since 1648, the states have considered the lake as a "condominium," i.e. without borders, which demonstrates a perceived trust and history of cooperation (Blatter, 2001, p. 91). Acts by regional representatives and a history of cooperation during industrialization of the region furthered the building of positive relationships (Scherer & Zumbusch, 2011). Therefore, within the Lake Constance basin, it is likely that historic relationships shaped the high-intensity cooperation that characterized all transboundary water interactions.

In the Lake Titicaca basin, there was also a close historic relationship between Bolivia and Peru. The two countries were allies during the War of the Pacific, had shared identities due to ethic groups that spanned across the border, and are regularly described as a "brotherhood" (Sierra, 2018; Martínez Gonzales & Zuleta Roncal, 2007; Mamani-Salinas, 2013). Additionally, when initiating cooperation over the lake, the states chose to sign an agreement recognizing "indivisible and exclusive joint ownership" (Rieckermann et al., 2006). This agreement indicates a trust between the states which was likely built upon their positive historic relationship. As a result, this relationship may have contributed to the continued cooperation and low-intensity conflict that was observed. Additionally, the joint ownership of the lake was further credited for minimizing potential high intensity conflict through its prevention of unilateral action in the present and future (Martínez Gonzales & Zuleta Roncal, 2007).

Finally, within the Lake Victoria basin, there was a mixed historic relationship between states. The countries initially cooperated over the lake under the colonial pressure of Britain (Lugo et al., 2014). Additionally, there was a similar culture shared by stakeholders throughout the basin which can help to build shared identity and a pattern of cooperation (Ogutu-Ohwayo, 2008 as cited in Lugo et al., 2014). However, at the same time, the countries experienced conflictive relationships during the study period. Following the collapse of the EAC, there were military tensions between Kenya and Uganda and a war between Uganda and Tanzania (Rule, 1987; Roberts, 2014). Hydro-diplomacy ceased during this time period with the exception of some coordination through the FAO (FAO, 1989). The states did not resume hydro-diplomacy until the institutionalization of cooperation in 1994. Therefore, while the states did have previous experience working together, which may have enabled smoother institutionalization once hydro-diplomacy resumed, there was a conflictive relationship that can challenge interactions on the lake. As a result, historic relationships likely are not a sole explanation for the intensity of cooperation that was observed.

Within the three lakes, it is interesting to note that identity is an important component to the historic relationship between states. However, this identity is built off of the culture, language, and ethnicity of stakeholder groups near the border. Therefore, although historic relationships can be used to explain state interactions, this theory cannot be divorced from the influence of stakeholders on these processes.

5.2.2 Critical Transboundary Analysis

Critical transboundary analysis considers the role of a dominant power within the basin that can exert pressure to cooperate or conflict. This analysis traditionally considers a state as a hydro-hegemon but acknowledges that non-state actors can also play a role in exerting power to direct interactions in the basin (Warner et al., 2017).

In all three basins, there is no clear hydro-hegemon who dictates processes. The countries have similar levels of economic development and similar capacity to exert influence. Additionally, throughout the study period, there are few instances when the state acted against its self-interest and the interest of its stakeholders. It may be argued that in the establishment of emissions regulations at Lake Constance, Switzerland engaged in cooperation to the detriment of its domestic population. However, the state still exerted influence in the process which shifted the level of governance for regulation (Scherer & Zumbush, 2011). Additionally, the institutional bodies of Lake Constance act on consensus, and therefore, it is unlikely that one state can be coerced into action by a hegemon. Although international actors can also be hydro-hegemons, this was not observed in the three basins (Warner et al., 2017). Therefore, critical transboundary analysis was not observed to impact most interaction in the studied basins.

5.2.3 Cost Benefit Analysis

Sadoff and Grey suggest that states are motivated to cooperate because of the various benefits that can be gained and the fact that these benefits can outweigh the cost of cooperation (2002). They propose that these benefits can be to, from, because of, and beyond the ‘river,’ or in these case studies, the lake (Sadoff & Grey, 2002). In all three of the basins, it is possible that the benefits outweigh the cost of cooperation. By cooperating to address water quality, the states can create benefits to the river and its ecology through removing environmental stressors. This action can increase benefits from the river by reducing the risk to all stakeholders who use the waterbody for ingestion, food sources, domestic and occupational exposure, and livelihood use. These actions can also yield benefits because of the river by strengthening relationships in the basin, such as through the reestablishment of joint action in the Lake Victoria basin in 1994. Finally, cooperation to address water quality can yield benefits beyond the river, such as by enabling joint development and economic zones as was observed in Lake Titicaca and Lake Victoria. Sadoff & Grey’s categorization of benefits easily applies to the basins, in part because they are lakes (2002). These lakes have limited to no upstream and downstream dynamics, and therefore, any intensity of cooperation (e.g. shared goals or joint action) will likely benefit the state as well as its neighbors. Therefore, a cost benefit analysis may also play a role in the interactions between states.

Interestingly, fisheries were the inroads to cooperation on all of the studied lakes. Within the Lake Victoria and Lake Constance basins, fisheries institutions were the first to be established. In the Lake Titicaca basin, fisheries studies were part of the communication that preceded the joint agreement and were considered in studies leading up to the establishment of the ALT. In each basin, fisheries were perceived as a valuable resource, and there was concern that fisheries needed to be managed to prevent overfishing. Therefore, in all of the lakes, fisheries were perceived as a common good resource may be exploited without joint action or shared goals. Based on Sadoff & Grey's framework, this action designates that multiple benefits could be derived from fisheries (2002). However, throughout the duration of study, fisheries appeared to be the "canary in the coal mine" or indication of impacts to come. While fisheries received a lot of attention and joint action at the initiation of cooperation between states, fish stocks have declined in each basin, leaving fishermen at risk. As water quality impacts increased, there appears to be a diversion of resources and attention from fisheries to address perceived benefits elsewhere.

5.2.4 International Actors

Various international actors and ideologies are also capable of influencing the transboundary conflict and cooperation observed in the basins (Petersen-Perlman et al., 2017; Xie et al., 2017; Furlong, 2006). These international influences were observed in varying degrees between the case studies. For instance, in the Lake Titicaca basin, international actors helped to establish the Master Plan. Experts from Europe were integral in developing the plan which directed the actions taken by the cooperative institution (Martínez Gonzales & Zuleta Roncal, 2007). This origin of ideas may dominate actions within the plan which can impact how the states enact their efforts, and, at times, conflict over these efforts. Although there may be some influence of international actors within the Lake Titicaca basin, this influence is unlikely to dominate the interactions between states.

Within the Lake Victoria basin, the most recent phase of institutionalization was initiated following state participation in the Rio Earth Summit. The summit itself presented a global ideology of sustainable development which was integrated into the LVEMP program and subsequent institutions of the EAC and LVBC (UN, 2020; Godsäter, 2013). The idea of sustainable development was perceived to dominate the transboundary institutions and participation of actors (Godsäter, 2013). It also likely influenced the establishment of the LVFO and LVEMP, thus addressing stakeholder vulnerability in the basin. Therefore, the global ideology of sustainable development could serve as a powerful presence in state interactions and continued institutionalization. In addition, multiple international actors were involved in the management of the lake. The FAO engaged in fisheries management during the collapse of the EAC in 1977 (FAO, 1989). Ongoing projects including the LVEMP and LVFO are funded by multiple international donors including the World Bank, Global Environment Fund, the European Union, and the FAO (Wirkus & Böge, 2006). This donor presence can influence transboundary interactions by pushing for cooperation, which was part of the mission of the FAO and UNDP (Lugo et al., 2014). The World Bank also fostered this effort through the LVEMP and reports that the program "strengthened regional cooperation for an improved and collaborative management" (The World Bank, 2018a, p. 42). As a result, the presence of international donors has likely pressured greater transboundary cooperation in the basin. The presence of donors also may have shaped the formal authority of stakeholders by encouraging participation and altering their channels of communication with the state (Wirkus & Böge, 2006).

Finally, in Lake Constance, the idea of the "Euroregion" was credited for much of the institution building in the basin (Blatter, 2001). Blatter discusses that the effort to build a cohesive European region led to a race to institutionalize governance in the basin and to competition over mandates and authorities of these institutions (2001). Because environmental issues are an easy way to exert power, he suggests that in a desire to establish themselves within the "Euroregion," transboundary organizations actively sought to address environmental concerns including the regulations of recreational boats (Blatter, 2001). By participating in discussions of these regulations, the states not only increased the power of stakeholders but also altered intensity of conflict. Therefore, it is likely that the international idea of European cooperation was an influential actor in the Lake Constance basin and encouraged the states to continue to institutionalize risk-taking cooperation and take on a contentious issue that would temporarily escalate conflict intensity.

The international pressures of actors and ideologies likely influenced the interactions and actions in the basins. However, the presence of this international influence also likely affected the distribution of power, vulnerability, and risk amongst stakeholders through its pressure on the state.

5.3 Transboundary Water Interactions and Water Quality Influence on Stakeholders

While stakeholders played a role in state interactions, they were also impacted by these interactions and the water quality in the lake. In order to better understand the distributions that affect state actions, the creation of these distributions and their impact on stakeholders must be assessed.

5.3.1 Interactions of Axes

When considering patterns of power, vulnerability, and risk in stakeholders, some general trends can be recognized. In the three basins, there is a weak negative correlation between power and vulnerability (R^2 of 0.37). This trend indicates that generally, populations that are vulnerable also experience lower levels of power to influence transboundary water management which is emphasized in the consideration of social power (Bakker & Morinville, 2013). This trend can both explain vulnerability, as it is difficult to address social concerns without pathways to influence governance, and can provide evidence of structural violence by the state. However, this universal trend may also be primarily representing a comparison between the basins and not stakeholder trends. Correlation between power and vulnerability is weak in the Lake Titicaca and Lake Victoria basin, and the opposite correlation exists in Lake Constance, where greater vulnerability is often affiliated with greater power.

In all three basins, there is an additional weak correlation between power and risk (R^2 of 0.42, 0.42, and 0.39 in Lake Titicaca, Lake Victoria, and Lake Constance, respectively) where, as risk increases, power increases. This pattern may indicate a flaw in the conceptual framework where power incorporates state interest which could be a response to risk. Additionally, as states build transboundary institutions in response to risk, these organizations have created spaces for stakeholder participation which increases formal authority. However, at the same time, the pattern can also indicate stakeholder action. As stakeholders experience greater risk, they may actively seek to obtain greater power, such as through creation of groups, coalitions, and discursive legitimacy. Therefore, although interest and influence are intended to be separated within this analysis, they may interact temporally which is captured by the history of transboundary interactions and stakeholder analyses. This trend not only informs stakeholders' agency but also demonstrates a clear desire to influence the state.

These trends of influence are also observed throughout actions in each basin. The studied stakeholders have not been passive recipients of water quality impacts. Throughout the analysis, stakeholders have engaged in governance, communication with the state, and protests to exert influence on water quality. Within the Lake Titicaca and Lake Victoria basin, rural communities and fishermen have been active in distribution of voice. Many of these communities have engaged in protests, participated with institutionalized management, and distributed information to highlight the impacts from contamination. Given that these stakeholders have experienced high risk and vulnerability, there is motivation to be engaged in transboundary processes. Within Lake Constance, almost all stakeholders became engaged in transboundary management through establishment of transboundary organizations that directly participate in governance, lobby government actors, or produce and distribute information. Risk and vulnerability are lower in the Lake Constance basin with fairly even distributions between stakeholders. Although risk and vulnerability were lower than other basins, stakeholder groups were largely defined by interests in the Lake Constance basin. These interest groups are related to water and thus, are likely self-selecting to engage in the topic. As a result, this interest provides motivation to basin stakeholders.

5.3.2 Displacement of Conflict

As discussed in Section 4.4.2, various instances of conflict occurred at different levels of scale in the three basins. These conflicts ranged in intensity from politicized to violized and, in some cases, resulted in fatalities. The alternate conflicts in the basin can be broadly grouped in two categories. Some of the conflicts addressed water quality management and some were a result of water quality impacts.

Conflicts over the management of water quality further can be segregated into two groups. First, there was conflict over how water quality was managed. This included conflict to contest power and instigate water quality management. In many of the Lake Titicaca examples, “spectacle” such as road closures were used to highlight the water quality problems in the basin (McFarlane & Silver, 2017, p. 125). This conflict both brought attention to the region and to the specific stakeholders needs. These protests were often effective in forcing the state to engage with and address the issue. Second, conflict represented a power struggle over who would address water quality management. Multiple organizations in the Lake Constance region competed across sectors and levels of government for the authority to address water quality concerns. Similarly, NGOs and local governments contested the role of the ALT in the Lake Titicaca basin. Power struggles also occurred with stakeholder groups, as rural communities conflicted with Peruvian authorities over community resource management. While some of these conflicts utilized “auditing” and spaces in existing political process, some of the power struggles engaged in violence to access authority (McFarlane & Silver, 2017, p. 125).

Other conflicts existed as a result of water quality impacts. Conflicts represented a clash of interest between sectors, including the tension that percolated through the Lake Constance region where interest group cohesion was reported to be stronger than national boundaries (Blatter, 2001). Conflicts were also created by water quality impacts such as in Lake Victoria. The conflict between fishermen over territory is a clear result of environmental pressures that came from water quality. The decrease in fish stock put stress on the fishing industry which elevated the intensity of conflict for actors.

Although patterns in the purpose of conflict were consistent throughout the basins, patterns between the actors of conflict varied between the basins. These interactions include conflicts between stakeholders and the state, in governance within the state (at similar and different levels of scale), and between stakeholder groups. In the Lake Titicaca basin, conflict often existed between actors and the state and was primarily expressed through protests. In the Lake Constance basin, conflict existed between sectors (e.g., transboundary stakeholder groups) and within governance structures. This pattern may be related to the idea of the “Euroregion” which helped to promote connections between transboundary stakeholders and create access to the political system (Blatter, 2001). In Lake Victoria, although conflict existed between the stakeholders and the state, it also included conflict within stakeholder groups. The conflict between fishing communities is one of the few identified instances in the case studies where there was stakeholder conflict that was related to state identity. To some extent, this conflict could be related to a trickle down of state actions and tensions. Within recent history there were military tensions between Kenya and Uganda (Rule, 1987). Furthermore, the state conflict of the Migingo Island led fishing communities to defend their territories along state lines (Atieno, 2014). Therefore, the existence of tensions and poor relations in recent history may have contributed to the feelings of state-based conflicts on the lake; however, this influence of the state requires further evaluation. Additionally, this conflict may also be more closely linked to a lack of economic opportunities within the region as discussed in Section 5.3.3.

5.3.3 Structural Violence

Based on the definition by Galtung, structural violence is considered to occur when a community or specific actors within the community are kept from access to a safe environment (1969). The state can enact this structural violence when it is responsible for processes that enable these exposures to occur. The modified stakeholder analysis provided an opportunity to address questions of inequities, specifically, in the analysis of outliers.

Various outliers existed in the three lake basins as related to risk and power. When analyzing risk, fishing communities and fishermen were the only actors that were an outlier of risk. In the Lake Titicaca basin, fishing communities have been a risk outlier since 1957. In the Lake Victoria and Lake Constance basins, fishing communities and fishermen are an outlier of risk in the current time period. To some extent, the high risk for fishermen is innately tied to occupation. Fishermen have high dermal exposure to water and have livelihoods that are directly impacted by water quality in lakes, as water quality can affect the volume, quality, and distribution of fish. Other routes of exposure were higher for fishermen because in most cases, it was assumed that their catches contributed to their diets. Additionally, fishermen tend to reside in close proximity of the lake which can have implications for drinking water sources in their communities. Based solely on an analysis of risk distribution, this can suggest that structural violence against fishermen is occurring in each basin.

It could be argued that although fishermen are at higher risk, this is not the fault of the state. In all basins, the state has directed resources and initiated cooperative efforts over fisheries. In spite of these efforts, interventions have not been successful. In both Lake Titicaca and Lake Victoria, fish stocks decreased, in part, because of the lake's water quality. Fisheries studies and protection measures have not yielded successful results in providing opportunities to fishing communities. Many criticisms have occurred over these basin states' efforts to address concerns of fisheries. In Lake Titicaca, the ALT has been criticized for using questionable technical justification for their studies (Mancilla García, 2013). Compounded with implementation challenges in local communities, few active actions have been taken to address water quality on the lake (Mancilla García, 2013). In Lake Victoria, the states have been hesitant to standardize regulations and the LVFO was criticized for focusing on overfishing and ignoring the problems of water quality impacts (Njiru, Kazungu, Ngugi, Gichuki, & Muhoozi, 2008). In both lakes it could be argued that the governments have not diverted sufficient resources to address pollution on the lake which has thus led to a structural violence against fishing communities.

Furthermore, in Lake Victoria, the strain on fishing communities is high because of a reported lack of alternate livelihoods in the basin (Atieno, 2014). The economic situation has led to increasing growth of the fishing community with decreased catch per fishermen thus creating a negative feedback loop and greater impacts to fishermen (UNEP, 2006; Jansen et al., 1999). Although fishermen are not an outlier for vulnerability, the high widespread vulnerability in the Lake Victoria basin has created this trend of the growing fishing community and lack of alternate livelihoods. Combined with the presence of external actors and exploitation of the Nile fisheries, this has created conditions that prevent fishermen from meeting their basic needs, and could constitute a structural violence by the state.

In the Lake Constance basin, fish stocks have decreased to a level consistent with an oligotrophic lake which is a result of the decreased anthropogenic impact on water quality. Although this improvement of water quality has benefited most stakeholders in the basin, it has come at the expense of fishermen's livelihoods. This cooperative decision demonstrates a prioritization by the state that does not address all of the needs of fishermen. Therefore, this action can also constitute a structural violence, but is also an issue that can be addressed through opportunities for alternate livelihoods in the basin.

Outliers were also related to power of actors over a given time period. Inhabitants of large cities/municipalities, the tourism industry, and the mining industries have been outliers of leading up to one interaction in the Lake Titicaca and Lake Victoria basins. These power discrepancies were related to a lack of state attention, a low state of development of the sector, and a preference towards other economic development, respectively. While a decrease of state interest is a form of structural violence by the state, because this violence was applied over only a limited time period and is not currently ongoing, it is not determined to be a current concern within the basins.

Finally, structural violence can impact the basin as a whole when processes prevent actors from meeting their basic needs. Water quality impacts have affected all stakeholders in the three basins, and at times, have put a strain on meeting basic needs. Although the states have acted in a largely reactive manner, thus only increasing efforts once impacts were observed, the fact that the states have attempted to address water quality may suggest that structural violence is not occurring. However, the efficacy of the state efforts can also be considered.

As mentioned previously, efforts to address water quality have been limited on Lake Titicaca and Lake Victoria for various reasons. In Lake Titicaca, a failure to address mining effluents presents a constant, high level of risk in the basin (Mancilla García, 2016). Furthermore, the lack of stakeholder involvement in Lake Titicaca has been proposed as a reason why binational efforts are not successful (Priscoli & Wolf, 2010). These efforts, however, are further complicated by a lack of implementation at other levels of scale (Mancilla García, 2013). Given that the state is directly related to the establishment of environmental protections and participation of stakeholders, these actions can be seen as a structural violence that puts the community at high risk (average stakeholder risk of 9.6 in the current time period). Within the Lake Victoria basin, the governments have not yet standardized regulations and are still building understanding of pollutants. While the states reacted quickly and cooperated over concerns of the water hyacinth, they have been slow to respond to other sources of pollution in the basin (Lubovich, 2009). Although the current average risk is medium (8.6), it could be argued that the consistently high average vulnerability suggests that the state is not making enough effort to address vulnerability in the region, thus also constituting a structural violence. In Lake Constance basin, the governments quickly addressed and implemented phosphorous regulations which addressed concerns in the lake. In part, these governments had sufficient resources to establish and implement regulations to address the needs of the population. While a greater structural violence was not observed, other environmental policies came at the expense of two stakeholder groups, including recreational boaters who were not clearly linked to pollution. Therefore, the basin may have engaged in structural violence in its haste to create regulations.

Finally, the displacement of conflict must be acknowledged. The non-state conflict within the lake basins has required resources of stakeholders to exert influence. The advent of conflict requires time and effort, and has had high burdens including fatalities. These stakeholder burdens are highest in securitized/opportunized and violized intensities of conflict which require more resources to maintain. As discussed in Section 5.3.2, this conflict occurred as a means to address the governance of water quality and as a symptom of water quality. When there are few pathways for stakeholders to contest the state or for stakeholders to formally work through competition of interest, high intensity conflicts were initiated. These high intensity conflicts then challenged the capacity of stakeholders to meet their needs and participate in livelihood activities. Therefore, the absence of stakeholder participation mechanisms in the basins can also be considered a structural violence by the state.

5.4 Drivers of State Interactions

As observed in the three basins, the stakeholder distributions of power, risk, and vulnerably both influence transboundary conflict and cooperation. Through direct stakeholder engagement and indirect basin conditions, stakeholders have driven the narrative, responses, and institutionalization of transboundary interactions within the state. Although the level of influence varies, stakeholders as a whole and as individual stakeholder groups are capable of shaping the actions of the state. However, given the similar patterns of cooperation that were observed between the basins in spite of variations in the modified stakeholder analysis, other factors also influence state interactions.

Based on a limited analysis, multiple other state processes are capable of shaping interactions. Within the three basins evaluated, institutional capacity, historic relationships, and the benefits of cooperation may all have shaped the patterns of conflict and cooperation. Additionally, a third level of scale was also observed to influence interactions, thereby creating a space for international actors and ideologies to pressure states to coalesce or address the needs of actors. As a result, these three levels of scale simultaneously exert pressure on the states to shape the highly cooperative interactions and limited conflict in response to water quality risks.

However, based on the analysis, the three levels of scale do not exert influence within a vacuum. Stakeholder power, vulnerability, and risk can support institutionalization which provides capacity, the stakeholders themselves can contribute to a shared identity and exchange that promotes positive historic relationships, and shared benefits may be elected because they benefit the basin community and address concerns of risk and vulnerability. Furthermore, the power, vulnerability, and risk of actors can engage international actors through a justification of ideology or interest in addressing specific concerns. Simultaneously, these states and international actors contribute to the distributions between stakeholders and can establish the structural violence that motivates actions or can empower stakeholders to exert influence. Together these levels of scales have a fluidity that pushes states to cooperate and conflict.

5.5 Limitations

There are several limitations that were identified in the analysis. The first limitation is related to access to data. All analysis is based on secondary data which limits the extent and resolution of data that can be obtained. For instance, in the vulnerability analysis, available lines of evidence included country specific data. Although categories of vulnerability likely varied between stakeholders, a finer resolution of data could not be located to further inform the analysis. Additionally, for several categories, temporal data could not be located and assumptions needed to be made. This lack of data may limit accuracy in the determination of power, vulnerability, and risk although the broad analysis of high, medium, and accounts for some of the uncertainty in stakeholder analyses. Finally, secondary data relies on narratives, conflict, and cooperation that are in the public space. In two of the basins there are current limitations on the freedom of the press that may prevent information from being accessed. Although this limitation presented challenges, multiple lines of evidence were used to attempt to overcome press restrictions.

An additional limitation includes the evaluation of stakeholders. To simplify the analysis, only five stakeholder groups were selected per basin. Because the study attempted to select stakeholders that were most represented in literature, this selection can bias analysis to more powerful actors and can contribute to limiting other critical voices that influence action. Exclusion of stakeholders or use of stakeholder groups that are too broad may also limit analysis of actors that held influence. For instance, in the analysis of the mining industry there is a difference between local miners who work in the industry and the transnational company. Although this study tried to address actors within the basin, it misses analysis of these large transnational companies which may also impact state actions.

Future studies could improve the conceptual framework to overcome other limitations. In an effort to distinguish axes, the power axis relied on levels of evidence that to some degree, incorporate exertion of power. Although power exertion can be a source of greater power, based on how power is produced, this can also bias the analyses. Furthermore, in the absence of chemical data, the risk axis includes a binary "yes" or "no" of if impacts are occurring. While the existence of impact is a helpful metric, it may be useful to have a greater resolution in the severity of impact. The framework can be adapted to account for the relative toxicity and health risks of chemicals to more accurately inform the risk axis. The analysis could also incorporate the perception of risk as to enable a greater potential correlation between risk and interactions.

Changes to data collection could also improve the connection between stakeholder analyses and transboundary actions. Correlation is not causation, and although patterns exist, the narrative of government action is needed to support that stakeholders shape conflict and cooperation. Even when a narrative is given, it is not inherently representative of the state's motivation as the public face of the state does not always represent its private intentions. Additionally, governance processes are not always transparent, and therefore, the motivation for action has to be guessed at or rely on the analysis and interpretation of other authors. These issues could be addressed by conducting qualitative and quantitative primary data collection that more directly engages with stakeholders.

Finally, the state interactions could be further assessed. Additional future studies would also address the efficacy of the conflict or cooperation on the basin. Although the TWINS framework provides a designation for the type and intensity of interaction occurring, it does not look at the amount of effort expended for cooperation or identify that cooperation is in name only. Therefore, although state interactions may be responding to stakeholder power, vulnerability, or risk, the TWINS framework does not capture the magnitude of that response.

SECTION 6: Conclusion

Transboundary lakes provide a unique opportunity to study the influence between stakeholders and state interactions. The water quality degradation of lakes is felt by domestic stakeholders and states who share the impacts of anthropogenic influences on the waterbody. While many actors and levels of scale are affected by pollutants, the impacts and capacity to address water quality are not shared evenly. Among local stakeholders, variations in power, vulnerability, and risk shape how water quality is experienced and how actors choose to react.

These local distributions also directly and indirectly shaped how states interact over the transboundary lakes. High vulnerability within the basin helped to drive joint development narratives at the initiation of cooperation over lakes. This cooperation often sought to redress concerns of economic vulnerability within the basins and was often initiated through the management of fisheries. High stakeholder vulnerability also led to increased intensity of cooperation over time, thus requiring greater state involvement to address community concerns. Risk was also observed to lead to high-intensity cooperation. Although the response to risk was often latent due to lags in risk perception, high stakeholder risk often led to institutionalized transboundary cooperation that directly addresses water quality and thus, addresses risk. Additionally, risk provided motivation for actors to exert power which enabled stakeholders concerns to play out with in the transboundary discourse. This process often initiated an increase in conflict intensity that was quickly resolved to present a potential sustainable cooperation over the waterbody. Through analysis of the three basins, vulnerability, risk, and power were further connected within the timeline of these processes. In general, vulnerability drove joint development, which led to increased anthropogenic impacts on lakes, and thus risk, which in turn improved institutionalization of transboundary management that can empower stakeholders, and at each step of the process, shape the interactions of the state.

The pathways of influence for power, vulnerability, and risk directed the narratives of the state which then impacted the distributions in negative and positive feedback loops. The distributions also impacted the actors themselves who were observed to participate in conflict both to contest how water quality was managed and as symptom of water quality impacts. Together, these processes aligned with other influences on the state including existing institutional capacity, historic relationships, the motivation of joint benefits, and pressure from international actors and ideologies. Stakeholders both influenced and were influenced by these levels of scale, creating a mixing of direct and indirect interactions that ultimately yielded high intensity cooperation over water quality in lakes. Therefore, similar to the lakes themselves, the stratified temperatures intermixed and overcame the "hypolimnion," or in essence, overcame the bound perception of scale.

This understanding of the role of stakeholders fills a critical gap in analyses of transboundary interactions. Through understanding the complex interactions that stakeholders have with various levels of scale, policies can be improved to not only address water quality in lakes but to foster effective, high-intensity cooperation between states. While the findings of this research successfully highlighted the role of stakeholders, the analysis brought up several ideas that merit further evaluation. First, although high-intensity cooperation was occurring, it was not always observed to be efficient. The advent of cooperation did not inherently decrease risk and vulnerability within basins, and thus factors which improve efficacy of cooperation should be considered in future studies. Second, the displacement of conflict to other levels of scale not only highlights the transboundary exchanges between non-state actors, but suggests patterns of structural violence that can derive from the state. Greater analysis is needed to understand the cooperative and conflictive transboundary processes that exist at other levels of scale to address structural violence and harness stakeholders influence to improve transboundary management. Third, the study addressed three transboundary lakes that had notable and perceived water quality impacts. However, given the ongoing global degradation of water quality and general lack of data, it is likely that several lakes have water quality degradation that has not yet been addressed and played out between the states. Therefore, there is potential for states to identify water quality issues and react more proactively to minimize the duration of risk. Future studies could identify these water bodies and study the development of state interactions in the absence of pervasive, visible impacts. Finally, the conceptual framework was only applied to transboundary lakes. Although the modified stakeholder analysis was tailored to lakes, further studies could apply the framework on transboundary rivers and aquifers to illustrate patterns of behavior and ground the findings. Additionally, an alteration of criteria can expand the analysis to consider other pertinent hazards, including climate impacts, on waterbodies in transboundary and domestic settings. Future application of the framework would make the framework more robust and can provide a broader range of predictive behaviors to support transboundary management and identification of stakeholders' needs.

Overall, this research not only informs state interactions by interrogating the role of stakeholders, but it also highlights the mechanisms in which water quality impacts stakeholders. By understanding the vulnerability and risk derived from water quality impacts, as well as the patterns of development, states can act more proactively to empower and address the needs of stakeholders within their basins. This information can be harnessed to establish sustained, high-intensity cooperation over transboundary lakes that ultimately benefits the states and their domestic populations.

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APPENDIX A: Lake Titicaca

Table 19. Comprehensive analysis of primary stakeholder power in the Lake Titicaca basin.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
Inhabitants of large cities/ municipalities	1955-1957 Joint Ownership Agreement Signed	Low	Low	Low	Low
		• Prior to 1955, there was very limited joint action with no capacity to participate in transboundary management; therefore, formal authority is assumed to be low.	• Given the population distribution in the 1970s, it is assumed that a majority of the population lived in rural areas and thus the urban fraction of the population was low (Martínez Gonzales & Zuleta Roncal, 2007). • Given that no organized group was identified and city residents were assumed to be a minority fraction of the basin, resources power was low.	• Within the basin, a large percentage of community members have indigenous heritage. By 2020, approximately 62% of the population of Bolivia is indigenous with slightly lower percentages in cities (Draper, 2010; Martínez Gonzales & Zuleta Roncal, 2007). There are reports that indigenous people have historically felt excluded from political processes (Draper, 2010; Martínez Gonzales & Zuleta Roncal, 2007; van Eerten, 2016). These feelings of exclusion and lack of focus on urban areas were mobilized in the Bolivian presidential campaign of 2006 (Mancilla García, 2013). Given the strong response to this campaign and a historic perception of exclusion, it is implied that urban residents experienced a lower discursive legitimacy. • Additionally, no expression of voice was identified within this time period. As a result of the perceived lack of prioritization and limited exertion of voice, discursive legitimacy is assumed to be low.	• There was little national attention given to the lake region until the 1930s when both countries began to explore opportunities to develop the basin (Mancilla García, 2013). • In the 1950s, Peru began to design development projects in the basin, but it did not fund the projects (Mancilla García, 2013). • Although the states expressed some interest in development of the basin, little action was taken prior to 1955. Additionally, this interest was not directly linked to urban areas. Therefore, state interest is considered low.
	1986 Ratification of the Agreement	Low	Low	Low	Medium
		• Although limited transboundary projects were conducted during this time period, stakeholders were not engaged (Martínez Gonzales & Zuleta Roncal, 2007). Given the exclusion in transboundary processes, the formal authority is low.	• In 1976 and 1980, a majority of the economically active populations were involved in agriculture (Martínez Gonzales & Zuleta Roncal, 2007). Although some urban residents participated in farming, it is assumed that most of the agricultural population lived in rural areas. As a result, it is assumed that urban residents are a minority fraction in the basin. • Given that no organized group was identified and city residents were assumed to be a minority fraction of the basin, resources power was low.	• Discursive legitimacy is assumed to be consistent with previous years.	• The wording of the 1957 agreement demonstrated a state interest in the watershed and not solely the waterbody (World Water Assessment Programme [WWAP], 2003). The agreement also expressed a plan for economic development without altering the navigation or fishing on the lake (Priscoli & Wolf, 2010). • The states continued to engage in basin during this time period and focused on transportation, trade, the lake's water budget, and fisheries (Martínez Gonzales & Zuleta Roncal, 2007). • Large natural disasters including flooding pressured the Bolivian government to ratify the joint ownership agreement (Priscoli & Wolf, 2010). This flooding threatened the city of Oruro (Martínez Gonzales & Zuleta Roncal, 2007). • The state engagement in the region was not specific to members of the urban community and represented limited investment in the

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
					basin. However, given the expression of interest and limited joint action, the state interest is considered medium.
	1996 Establishment of the ALT	Low	Medium	Low	Medium
		• Joint actions occurred prior to the establishment of the ALT. These actions included the creation of the Master Plan for the basin. Although most of the work was completed between the state governments and European experts, national experts and technicians were engaged in the process (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, the public was able to comment on technical elements of the plan towards the end of its execution (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that some of the experts and technicians may have come from urban areas; however, given the limited capacity for input and likely few technicians involved, formal authority is low.	• In the 1980s and early 1990s various factors caused a large rural to urban migration with approximately with 40% of rural populations migrating to urban areas by 2015 (Williams, 2015). • In 1988, approximately 7.09% of the Bolivian population and 10.6% of the Peruvian population were involved in commerce (Revollo, Liberman Cruz, & Lescano Rivero, 2005). Additionally, approximately 3.4% of the Bolivian and 7.8% of the Peruvian population were involved in industry, and 2.42% of the Peruvian population was involved in construction (Revollo et al., 2005). It is assumed that these sectors were concentrated in urban areas. • Given the increasing population distribution in urban areas, it is assumed that city residents constituted a majority fraction in the basin and thus, resources power was medium.	• Discursive legitimacy is assumed to be consistent with previous years.	• In 1987, a study was funded by the Inter-American Development Bank to assess the capacity for cross-border exchange of transport, energy, tourism, fishery, agriculture, industry, and commercial border exchange (Martínez Gonzales & Zuleta Roncal, 2007). Although externally funded, this study supports and international interest in the relevant urban sectors that could inform both governments. • Additionally, the state was engaging in ongoing studies to prepare the Master Plan for the region. • Given the demonstrated state interest in the region with a limited focus on urban areas, state interest is considered medium.
	1997-1998 Ratification of RAMSAR	Medium	Medium	Low	Medium
		• The Autonomous Binational Authority of Lake Titicaca (ALT) is based on the principles of Integrated Water Resources Management (IWRM); however, this strategy had not been implemented as of 2009 (WWAP, 2003: Calizaya, 2009). • The ALT was reported to regularly hold workshops and seminars to inform civil society about the Master Plan and encourage public participation (Martínez Gonzales & Zuleta Roncal, 2007). This participation involves a variety of stakeholders and levels of government (Zilov, 2013). However, the workshops are considered "insufficient" due to a lack of finances (Martínez Gonzales & Zuleta Roncal, 2007, p. 82). • It was further reported that stakeholder participation was absent or minimal due to "social and economic instability" and weak institutions (WWAP, 2003, p. 477). This lack of participation was observed to impair the efficacy of the ALT (Priscoli & Wolf, 2010).	• The ALT's workshops sought to create greater transboundary connections between municipalities (Martínez Gonzales & Zuleta Roncal, 2007). This relationship building can improve transboundary coalitions. • Although relationship building was occurring to a small degree, given the consistent population distribution, it is assumed that resources power is consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• The state interest is assumed to be consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Any existing participation has been reported to be primarily "information sharing and sensitizing" (Avramoski, 2004, p. 6). • Although public participation was weak with low levels of influence in decision making, due to the institutionalization of this participation, formal authority was medium.			
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	High	High
		• In 2008 in Peru, concerned citizens were invited to participate in round table discussions with the government about mine management (Mancilla García, 2013). A broad group of stakeholders were included. • The ALT has been criticized as a non-transparent organization that makes obtaining data difficult for civil society and has some financial discrepancies (Mancilla García, 2013). • Although public participation was weak with low levels of influence in decision making, due to the national and transboundary institutionalization of this participation, formal authority was medium.	• In 2001, approximately 22.43% of the Peruvian population and 60.2% of the Bolivian population lived in urban areas (Martínez Gonzales & Zuleta Roncal, 2007). • Non-governmental organizations (NGOs) have been working to increase awareness and data collection on the lake, including the Suma Quta Project that was initiated in 2009 (Williams, 2015). These NGOs have sought to work with a broad group of stakeholders within the basin. • In 2005, approximately 59% of the basin population lived in urban areas (Revollo et al., 2005). The population was primarily concentrated in Puno, Juliaca, El Alto, and Oruro (Martínez Gonzales & Zuleta Roncal, 2007). • In 2003, approximately 3% of the Bolivian basin population and 14% of the Peruvian basin population were engaged in the services sector (WWAP, 2003). It is assumed that the services industry is primarily in urban locations and rural locations with tourism. Additionally, the economically active population that was engaged in trade had increased substantially since the 1980s (Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that members of the trade sector were urban residents. • Although a representative organization could not be located, because city residents constitute a majority fraction of the population, resource power is medium.	• There were violent protests in 2002 and 2005 in Cochabamba and El Alto, respectively, regarding water access (Mancilla García, 2016). These protests demanded a response by the government and yielded a restructuring of water governance once Evo Morales was elected (Mancilla García, 2013). • Protests in El Alto also dictated the development of a landfill in the region (Mancilla García, 2013). • Given that city residents expressed their voice publicly and the state reacted, discursive legitimacy is high.	• The urban protests were perceived as integral to Evo Morales's presidential campaign in Bolivia which focused on social movements, urban areas, and indigenous rights (Mancilla García, 2016). • Industry within the region is 8.7% of the gross domestic product (GDP) within the basin with a focus in Juliaca (Revollo et al., 2005). This economic contribution is not considered high. • Given the focus of the Morales campaign, it is assumed that urban residents hold a political interest to the Bolivian government. As a result of this interest, state interest is high.
	2016 Bi-national Commitment and Current Status	Medium	Medium	High	High
		• Formal authority is assumed to be consistent with previous years given the ongoing functioning of the ALT.	• By 2013, approximately 25% of the Bolivian population lived in El Alto and La Paz (Gonzales Iwanciw, Zalles, & Cabrera, 2013). • In 2015, large cities such as El Alto, Juliaca, and Puno continued to grow with populations of 800,000 and greater than 250,000 people, respectively (Williams, 2015).	• In 2016, water scarcity led to a protest in El Alto, where protesters briefly held a water distribution company hostage to demand a response from the government (Reuters, 2016). • In 2019, the freedom of the press index in Bolivia and Peru was 35.38 and 30.22, respectively (Reporters Without Borders [RSF], 2020). These rankings are classified by	• In 2013, providing water to El Alto was seen to be a political priority in Bolivia (Gonzales Iwanciw et al., 2013). • Additionally, water was reported to be a "priority" to the Bolivian government with the recognition of human rights of water (Gonzales Iwanciw et al., 2013, p. 11). This recognition

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			• Although a representative organization could not be located, because urban residents continued to constitute a majority fraction of the population, resource power is medium.	RSF as "bad" and "problematic," respectively (RSF, 2020). • It is assumed that the 2016 protests resulted in similar response from the government, therefore, discursive legitimacy is assumed to be high.	was cemented in the Bolivian constitution (Gonzales Iwanciw et al., 2013). • Given the continued Presidency of Morales in 2016, there was assumed to be a continued political interest in urban areas. Therefore, state interest is considered high.
Rural communities (Fishing Based)	1955-1957 Joint Ownership Agreement Signed	Medium	Medium	Medium	High
		• Communities in the basin were perceived to self-regulate environmental systems, including fishing along the lake (Orlove, 2002). • Given the recognition of local governance and high influence in decision making, formal authority was medium.	• It is assumed that communities had the capacity to organize, even if this organization was not reported prior to the 1970s (Orlove, 2002). • Given the capacity for ad hoc organization, resource power is assumed to be medium.	• Given the capacity for community organization and management, it is assumed that rural communities were capable of expressing voice and being perceived as representative. Therefore, discursive legitimacy is assumed to be medium.	• There was little national attention given to the lake region until the 1930s when both countries began to explore opportunities to develop the basin (Mancilla García, 2013). • In the 1950s, Peru began to design development projects in the basin, but it did not fund the projects (Mancilla García, 2013). • Both governments expressed interest in the development of fisheries and supported a study in 1935 (Orlove, 2002). The increase in trout during the 1950s also led to a joint agreement for fisheries development (Mancilla García, 2013). Given the expressed and demonstrated state interest in fisheries, state interest was high.
	1986 Ratification of the Agreement	Medium	Medium	High	High
		• Similar to previous years, communities in the basin were still been perceived to self-regulate environmental systems, including fishing in the lake (Orlove, 2002). These communities negotiated authority with the Peruvian government in the 1970s and 1980s (Orlove, 2002). Additionally, neoliberal policies led to protests in the 1980s in Bolivia, asserting some influence on state management (Seeman, 2016). • Although limited transboundary projects were conducted during this time period, stakeholders were not engaged (Martínez Gonzales & Zuleta Roncal, 2007). • Given the recognized community management but exclusion in transboundary processes, the formal authority was medium.	• In the 1970s, rural communities were able to contest and negotiate with the government of Peru concerning reeds in the Natural Reserve of Lake Titicaca (Orlove, 2002). Additionally, in the 1980s, fishing communities in Peru exerted their sovereignty by initiating sometimes violent conflict with the Peruvian military (Orlove, 2002). These actions demonstrate the capacity of communities to organize. • In 1976, approximately 74.1% of the economically active population in Bolivia were engaged in agriculture (Martínez Gonzales & Zuleta Roncal, 2007). In 1980, approximately 65.1% of the economically active population in Peru were engaged in agriculture (Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that agriculture encompasses fishing activity. • Additionally, in 1981, approximately 68.2% of the Peruvian community in the basin lived in rural areas (Martínez Gonzales & Zuleta Roncal, 2007). However, it is not assumed that all agricultural residents are in fishing activities.	• Local communities exerted their perspectives through active protests, violent confrontation, and regular communication with the state (Orlove, 2002). These actions resulted in responses from the state. As a result of this expression of voice and state response, discursive legitimacy was high.	• The 1950s and 1960s increase in trout density led to a joint state agreement concerning fisheries (Mancilla García, 2013). • The wording of the agreement in 1957 demonstrates an interest in the watershed and not solely the waterbody (WWAP, 2003). The agreement also expressed a plan for economic development without altering the navigation or fishing on the lake (Priscoli & Wolf, 2010). • The states continued to engage in research of the basin throughout this time period and focused on transportation, trade, the lake's water budget, and fisheries (Martínez Gonzales & Zuleta Roncal, 2007). • Large natural disasters including flooding pressured the Bolivian government to ratify the agreement (Priscoli & Wolf, 2010). This flooding threatened riparian areas around the lake and likely most of the fishing communities (Martínez Gonzales & Zuleta Roncal, 2007). • The state engagement in the region specifically addresses fisheries in the joint agreement, research, and commitment to lake management. As a result, state interest is considered high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			• Given the majority fraction of rural residents, the capacity for ad hoc organization, and the lack of international alliances, the resources power was medium.		
	1996 Establishment of the ALT	Low	Medium	Low	High
		• Various factors including migration to urban areas and greater government involvement, led to a decrease of community management of natural resources in the 1990s (Williams, 2015). • Joint actions occurred prior to the establishment of the ALT. These actions included the creation of the Master Plan for the basin. Although most of the work was completed between the state governments and European experts, national experts and technicians were engaged in the process (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, the public was able to comment on technical elements of the plan towards the end of its execution (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that most of the experts and technicians did not come from rural fishing communities, and given the limited capacity for input and decrease in local decision making, formal authority was low.	• In 1988, approximately 72.2% of the economically active population in Bolivia was engaged in agriculture (Martínez Gonzales & Zuleta Roncal, 2007). Within the basin, 72.8% of the Bolivian population participated in agriculture (Revollo et al., 2005). In 1989, approximately 59.8% of the Peruvian basin population participated in agriculture, (Revollo et al., 2005). It is assumed that fishing was encompassed within agricultural activity. • In 1993, approximately 60.87% of the Peruvian population and 42.7% of the Bolivian population lived in rural areas (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that the fishing community was a smaller fraction of the agricultural community. Additionally, although community governance was weakening in the 1990s, it is assumed that the fishing community maintained an ad hoc capacity to organize. Given the capacity for ad hoc organization, resource power is assumed to be medium.	• Within the basin, the majority of the population has indigenous heritage (Martínez Gonzales & Zuleta Roncal, 2007). There are reports that indigenous communities historically felt excluded from political processes, especially in rural areas (Draper, 2010; Martínez Gonzales & Zuleta Roncal, 2007; van Eerten, 2016). These feelings of exclusion were mobilized in the Bolivian presidential campaign of 2006 and may represent a lower discursive legitimacy (Mancilla García, 2013). As a result, discursive legitimacy is assumed to be low.	• In 1987, a study was funded by the Inter-American Development Bank to assess the capacity for cross-border exchange of transport, energy, tourism, fishery, agriculture, industry, and commercial border exchange (Martínez Gonzales & Zuleta Roncal, 2007). Although externally funded, this study demonstrated an international interest in the fishing sector that could inform both governments. • Through the Joint Sub-commission for the Development of the Integrated Region of Lake Titicaca (SUBCOMILAGO), both countries participated in fisheries projects in 1987 (Martínez Gonzales & Zuleta Roncal, 2007). • Given the joint participation in fisheries specific projects, state interest was high.
	1997-1998 Ratification of RAMSAR	Medium	Medium	Low	High
		• The ALT is based on the principles of Integrated Water Resources Management (IWRM); however, this strategy had not been implemented as of 2009 (WWAP, 2003: Calizaya, 2009). • The ALT was reported to regularly hold workshops and seminars to inform civil society about the Master Plan and encourage public participation (Martínez Gonzales & Zuleta Roncal, 2007). This participation involves a variety of stakeholders and levels of government (Zilov, 2013). However, the workshops are considered “insufficient” due to a lack of finances (Martínez Gonzales & Zuleta Roncal, 2007, p. 82). • It was further reported that stakeholder participation was absent or minimal due to “social and economic instability” and weak institutions (WWAP, 2003, p. 477). This lack	• The ALT’s workshops have sought to create greater transboundary connections between fishermen and municipalities (Martínez Gonzales & Zuleta Roncal, 2007). • The distribution of fishermen in the country is assumed to be consistent with previous years. • As a result of collaboration across countries and an assumed continued capacity for ad hoc organization, resources power is assumed to be medium.	• The discursive legitimacy is assumed to be consistent with previous years.	• The state interest is assumed to be consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		of participation was observed to impair the efficacy of the ALT (Priscoli & Wolf, 2010). • Any existing participation has been reported to be primarily "information sharing and sensitizing" (Avramoski, 2004, p. 6). • Although public participation was weak and limited to low levels of influence in decision making, due to the institutionalization of this participation, formal authority was medium.			
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	High	High
		• In 2008 in Peru, concerned citizens were invited to participate in round table discussions with the government about mine management (Mancilla García, 2013). A broad group of stakeholders were included. • The ALT has been criticized as a non-transparent organization that makes obtaining data difficult for civil society and has some financial discrepancies (Mancilla García, 2013). • Although public participation was weak with low levels of influence in decision making, due to the national and transboundary institutionalization of this participation, formal authority was medium.	• In 2003, approximately 73% of the Bolivian basin population and 59% of the Peruvian basin population were engaged in agricultural activity (WWAP, 2003). It is assumed that fishing activity was encompassed within agricultural activity. • Agriculture was also a facet of economic activity within the basin. In 2001, approximately 33.07% and 59.8% of the economically active population in Bolivia and Peru, respectively, were engaged in agriculture (Gonzlaes & Roncal, 2007). This is a decrease from previous years indicating a decrease in economic opportunity from agriculture and fishing. • There were localized decreases in the fishing community as a result of falling fish stocks and water quality impacts (Mancilla García, 2013). • NGOs have been working to increase awareness and data collection on the lake, including the Suma Quta Project that was initiated in 2009 (Williams, 2015). These NGOs have sought to work with a broad group of stakeholders within the basin. • In 2001, approximately 57.57% of the Peruvian population and 39.8% of the Bolivian population lived in rural areas (Martínez Gonzales & Zuleta Roncal, 2007). • In 2005, approximately 41% of the basin population lived in rural areas (Revollo et al., 2005). • Localized fishermen protests demonstrate a capacity for organization although a relevant stakeholder group could not be located. Given this ad hoc organization, resources power is assumed to be medium.	• Fishermen in Cohana closed down roadways in 2006 to protest eutrophication in the area (Mancilla García, 2013). These protests obtained press coverage and garnered World Bank attention resulting in a grant for development in the region (Mancilla García, 2013). The framing of eutrophication as a problem was also seen to dictate the narrative of water quality in the ALT and occurred as a result of these protests (Mancilla García, 2013; Mancilla García, 2016). • During the 2006 presidential campaign in Bolivia, "'fishermen,' i.e., rural people... was a particularly strong discursive tool" (Mancilla García, 2013, p. 224). • Given that the stakeholder's position was prioritized and dominated the narrative, discursive legitimacy was high.	• The importance of rural rights in Evo Morales' presidential campaign in Bolivia demonstrated a political interest in rural, fishing communities (Mancilla García, 2013). • Given the focus of the Morales campaign, it is assumed that fishing communities held political interest to the Bolivian government, and thus, state interest was high.
		Medium	Low	Medium	High

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	2016 Bi-national Commitment and Current Status	• Formal authority is assumed to be consistent with previous years given the ongoing functioning of the ALT.	• It is assumed that there was a continued decrease in local fishermen related to the ongoing water quality degradation (Mancilla García, 2013). • Given the decrease in fishing communities, it is assumed that there was a relative decrease in resources. Therefore, resources power is assumed to be low.	• The fishing community does not appear to have been active in public spaces in recent years. However, it is assumed that they are still perceived with credibility and some public support. • In 2019, the freedom of the press index in Bolivia and Peru were 35.38 and 30.22, respectively (RSF, 2020). These rankings are classified by RSF as "bad" and "problematic," respectively (RSF, 2020). • Given the assumption of perceived credibility and support, discursive legitimacy is assumed to be medium.	• Water was reported to be a "priority" to the Bolivian government with the recognition of human rights of water (Gonzales Iwanciw et al., 2013, p. 11). This recognition was cemented within the Bolivian constitution (Gonzales Iwanciw et al., 2013). • Given the continued Presidency of Morales in 2016, there was assumed to be a continued political interest in fishing communities. Therefore, state interest is considered high.
Rural communities (Non-fishing Based)	1955-1957 Joint Ownership Agreement Signed	Medium	Medium	Medium	Low
		• Communities along the basin were perceived to self-regulate environmental systems (Orlove, 2002). Rural communities also had their own local institutions to manage agriculture (Mancilla García, 2013). • Given the recognized community management but exclusion in transboundary processes, formal authority was medium.	• In 1976, 74.1% of the Bolivian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). In 1980, 65.1% of the Peruvian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that the distribution of the population engaged in agriculture was the majority fraction of the basin as consistent with the 1976 and 1980s trends (Martínez Gonzales & Zuleta Roncal, 2007). It is also assumed that communities had the capacity to organize, even if this organization was not reported prior to the 1970s (Orlove, 2002). • Given the capacity for ad hoc organization and majority fraction in the basin, resources power is assumed to be medium.	• Given the capacity for community organization, it is assumed that rural communities were capable of expressing their voices and being perceived as representative. However, the frequency of expression in public spaces could not be located and is assumed to be low. Therefore, discursive legitimacy is assumed to be medium.	• There was little national attention given to the lake region until the 1930s when both countries began to explore opportunities to develop the basin (Mancilla García, 2013). • In the 1950s, Peru began to design development projects in the basin, but it did not fund the projects (Mancilla García, 2013). • Although the states expressed some interest in development of the basin, little action was taken prior to 1955. This interest was also not directly linked to agricultural communities. As a result of the broad but undemonstrated interest, state interest was considered low.
	1986 Ratification of the Agreement	Medium	Medium	Medium	Medium
		• In the 1960s, the states required that the local institutions become agricultural unions (Van Cott, 2005). • Similar to previous years, communities in the basin were perceived to self-regulate environmental systems, including the use of resources from the lake (Orlove, 2002). These communities negotiated authority with the Peruvian government in the 1970s (Orlove, 2002). Additionally, neoliberal policies led to protests in the 1980s in Bolivia, asserting some influence on state management (Seeman, 2016). • Although limited transboundary projects were conducted during this time period, stakeholders	• In the 1970s, rural communities were able to contest and negotiate with the government of Peru concerning reeds in the Natural Reserve of Lake Titicaca (Orlove, 2002). • In 1976, 74.1% of the Bolivian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). In 1980, 65.1% of the Peruvian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, in 1981, approximately 68.2% of the Peruvian community in the basin lived in rural areas (Martínez Gonzales & Zuleta Roncal, 2007).	• The existence of agricultural unions was perceived to provide legitimacy to local representation (Mancilla García, 2013). However, the frequency of expression in public spaces could not be located and is assumed to be low. • Given the perceived legitimacy of actors and lack of clear expressions of voice, discursive legitimacy is assumed to be medium.	• The wording of the agreement in 1957 demonstrates an interest in the watershed and not solely the waterbody (WWAP, 2003). The agreement also expressed a plan for economic development without altering the navigation or fishing on the lake (Priscoli & Wolf, 2010). • The states continued to engage in research of the basin throughout this time period and focused on transportation, trade, the lake's water budget, and fisheries (Martínez Gonzales & Zuleta Roncal, 2007). • Large natural disasters including flooding pressured the Bolivian government to ratify the agreement (Priscoli & Wolf, 2010). This flooding threatened riparian areas and caused

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		were not engaged (Martínez Gonzales & Zuleta Roncal, 2007). • Given the recognized community management but exclusion in transboundary processes, the formal authority was medium.	• Given the capacity for ad hoc organization and the fraction of rural residents that were participating in agriculture, resources power was medium.		huge economic losses in the agricultural community (Martínez Gonzales & Zuleta Roncal, 2007; Priscoli & Wolf, 2010). • Although the general engagement in the region was not specific to the agricultural community, because the community was largely impacted by the floods that motivated the Bolivian agreement ratification, there was demonstration of state interest in the basin. Therefore, state interest is considered medium.
	1996 Establishment of the ALT	Low	Medium	Low	Medium
		• Various factors including migration to urban areas and greater government involvement, led to the decrease in community management of natural resources in the 1990s (Williams, 2015). • Joint actions occurred prior to the establishment of the ALT. These actions included the creation of the Master Plan for the basin. Although most of the work was completed between the state governments and European experts, national experts and technicians were engaged in the process (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, the public was able to comment on technical elements of the plan towards the end of its execution (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that most of the experts and technicians did not come from rural agricultural communities, and given the limited capacity for input, formal authority was low.	• In 1988, approximately 72.2% of the economically active population in Bolivia was engaged in agriculture (Martínez Gonzales & Zuleta Roncal, 2007). Within the basin, 72.8% of the Bolivian population participated in agriculture (Revollo et al., 2005). In 1989, approximately 59.8% of the Peruvian basin population participated in agriculture, (Revollo et al., 2005). It is assumed that the fishing community was a smaller fraction of the agricultural groups and that these percentages largely represent the non-fishing based communities. • In 1993, approximately 60.87% of the Peruvian population and 42.7% of the Bolivian population lived in rural areas (Martínez Gonzales & Zuleta Roncal, 2007). • Although a representative group could not be determined, because agriculture is a majority fraction in the basin and residences in rural areas are approximately equal to urban areas, rural agricultural communities are assumed to be a majority fraction of the basin population. As a result of this designation, resources power was medium.	• Within the basin, the majority of the population has indigenous heritage (Martínez Gonzales & Zuleta Roncal, 2007). There are reports that indigenous communities historically felt excluded from political processes, especially in rural areas (Draper, 2010; Martínez Gonzales & Zuleta Roncal, 2007; van Eerten, 2016). These feelings of exclusion were mobilized in the Bolivian presidential campaign of 2006 and may represent a lower discursive legitimacy (Mancilla García, 2013). As a result, discursive legitimacy is assumed to be low.	• In 1987, a study was funded by the Inter-American Development Bank to assess the capacity for cross-border exchange of transport, energy, tourism, fishery, agriculture, industry, and commercial border exchange (Martínez Gonzales & Zuleta Roncal, 2007). Although externally funded, this study demonstrated an international interest in the agriculture that could inform both governments. • The Special Binational Project of Lake Titicaca (PELT) began to initiate irrigation projects in the basin in the early 1990s (Mancilla García, 2013). • Given the expression of some state interest through irrigation projects without a complete demonstration of this interest, state interest is assumed to be medium.
	1997-1998 Ratification of RAMSAR	Medium	Medium	Low	Medium
		• The ALT is based on the principles of Integrated Water Resources Management (IWRM); however, this strategy had not been implemented as of 2009 (WWAP, 2003: Calizaya, 2009). • The ALT was reported to regularly hold workshops and seminars to inform civil society about the Master Plan and encourage public participation (Martínez Gonzales & Zuleta Roncal, 2007). This participation involves a variety of stakeholders and levels of	• Resource power is assumed to be consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• State interest is assumed to be consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		government (Zilov, 2013). However, the workshops are considered "insufficient" due to a lack of finances (Martínez Gonzales & Zuleta Roncal, 2007, p. 82). • It was further reported that stakeholder participation was absent or minimal due to "social and economic instability" and weak institutions (WWAP, 2003, p. 477). This lack of participation was observed to impair the efficacy of the ALT (Priscoli & Wolf, 2010). • Any existing participation has been reported to be primarily "information sharing and sensitizing" (Avramoski, 2004, p. 6). • Although public participation was weak and limited to low levels of influence in decision making, due to the institutionalization of this participation, formal authority was medium.			
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	High	High
		• In 2008 in Peru, concerned citizens were invited to participate in round table discussions with the government about mine management (Mancilla García, 2013). A broad group of stakeholders were included. • The ALT has been criticized as a non-transparent organization that makes obtaining data difficult for civil society and has some financial discrepancies (Mancilla García, 2013). • Although public participation was weak with low levels of influence in decision making, due to the national and transboundary institutionalization of this participation, formal authority was medium.	• By 2004, there were many local efforts in the Puno region to address pollution; however, these were not successful (Revollar, 2004 as cited in Rieckermann et al., 2006). These efforts represent an ad hoc capacity to organize. • In 2003, approximately 73% of the Bolivian basin population and 59% of the Peruvian basin population were engaged in agricultural activity (WWAP, 2003). • NGOs have been working to increase awareness and data collection on the lake, including the Suma Quta Project that was initiated in 2009 (Williams, 2015). These NGOs have sought to work with a broad group of stakeholders within the basin. • Approximately 48% of land in the basin is used for agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007; WWAP, 2003). • By 2010, there were 8 rural communities in Cohana Bay that were closely linked to contamination (Mancilla García, 2013). • Given the ad hoc capacity to organize and status as majority fraction in the basin, stakeholder power is assumed to be medium.	• Farmers protested in the Cohana region to bring attention to environmental issues in 2006 (Mancilla García, 2013). • In 2006 and 2007, rural community members in Peru shut down highways to protest unregulated gold mining (Williams, 2015). However, there was some contention over the motivation of protest leaders (Williams, 2015). • Farmers in Cohana reached out to the United States Agency for International Development (USAID) and the ALT requesting support, suggesting an open channel of communication to the state (Mancilla García, 2013). • During the 2006 presidential campaign in Bolivia, "'fishermen,' i.e., rural people... was a particularly strong discursive tool" (Mancilla García, 2013, p. 224). This represents a strong interest in rural communities at the time. • Given the public exertion of voice, communication channels to the state, and perception of prioritization within the presidential campaign, discursive legitimacy is assumed to be high.	• The importance of rural rights in Evo Morales' presidential campaign in Bolivia demonstrated a political interest in rural, agricultural communities (Mancilla García, 2013). • Given the focus of the Morales campaign, it is assumed that agricultural communities held political interest to the Bolivian government, and thus, state interest was high.
	2016 Bi-national Commitment and Current Status	Medium	Medium	High	High
		• Formal authority is assumed to be consistent with previous years given the ongoing functioning of the ALT.	• The fraction of the population and ad hoc capacity to organize are assumed to be consistent with previous years. Given these	• In 2011, thousands of indigenous community members protested at check points, the airport, and the regions capital about various aspects of	• Water was reported to be a "priority" to the Bolivian government with the recognition of human rights of water (Gonzales Iwanciw et

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			assumptions, resources power is assumed to be low.	mining in Peru (Williams, 2015). Some of the protests were violent and widely covered by the media (Williams, 2015). These protests elicited a response from the Bolivian state. • Local communities in Puno have been reported to protest contamination intermittently (van Eerten, 2016). • In 2012, a Peruvian environmental organization protested to raise awareness for environmental issues on the lake (Global Nature Fund, n.d.b). • In 2019, the freedom of the press index in Bolivia and Peru were 35.38 and 30.22, respectively (RSF, 2020). These rankings are classified by RSF as “bad” and “problematic,” respectively (RSF, 2020). • Given the expression of voice in public spaces and a national response to that expression, discursive legitimacy is considered high.	al., 2013, p. 11). This recognition was cemented within the Bolivian constitution (Gonzales Iwanciw et al., 2013). • Given the continued Presidency of Morales in 2016, there was assumed to be a continued political interest in agricultural communities. • Additionally, because the newly elected President of Peru was from the Puno area, there was a belief that the rural areas in the region would become a priority to the state government (van Eerten, 2016). • As a result of political interest in both countries, state interest is considered high.
Mining industry	1955-1957 Joint Ownership Agreement Signed	Low	Low	Low	High
		• Prior to 1955, there was very limited joint action with no capacity to participate in transboundary management; therefore, formal authority is assumed to be low.	• In 1956, there were 36,000 people employed by the state mining corporation in Bolivia (Troeng & Riera, 1997 as cited in Garcia, Persson, Bengtsson, & Berndtsson, 2005). • Given the low fraction of the population and lack of identified organized group, resources power is assumed to be low.	• No expression of voice was identified during this time period. As a result, discursive legitimacy is assumed to be low.	• There was a long history of mining in Bolivia and Peru (Garcia et al., 2005). In Bolivia, a state run corporation (COMIBOL) was created in 1952 (Garcia et al., 2005). All large mines were state owned leaving medium and small mines to be privately owned (Garcia et al., 2005). • The mining industry was perceived to “dominate” Bolivia’s economy until 1985 (Hudson & Hanratty, 1991, p. 133). In 1955, mining contributed 10% to the Bolivian GDP and was approximately 90% of Bolivian exports (Gomez, 1976). • Given the economic contribution to the Bolivian economy and the state participation in management, state interest in mining is assumed to be high.
	1986 Ratification of the Agreement	Low	Low	Low	Medium
		• Although limited transboundary projects were conducted during this time period, stakeholders were not engaged (Martínez Gonzales & Zuleta Roncal, 2007). Given the exclusion in transboundary processes, the formal authority is low.	• This mining sector grew in Bolivia the 1970s with a focus on tin (Garcia et al., 2005). In 1985, the Bolivian government policy changed and 75% of employees were laid off, decreasing the resources of Bolivian miners (Garcia et al. 2005). The crash in the market caused a migration of hundreds of thousands of people from mining communities to urban areas (Williams, 2015). It is assumed that a similar economic crash affected Peru.	• Discursive legitimacy is assumed to be consistent with previous years.	• A change in Bolivian government structure from 1964-1982 may have diverted some attention from mining the region (Garcia et al., 2005). • In 1967, the Bolivian constitution was updated and claimed state ownership for exploitable elements in the ground (Martínez Gonzales & Zuleta Roncal, 2007),

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			• Given the decrease in the mining industry, it is assumed that fewer members of the population were employed. Given the lack of clear organization and low participating fraction of the population, resources power was low.		• In 1985, the Bolivian government reduced state involvement in the mining industry (Garcia et al., 2005). • The wording of the 1957 agreement demonstrated a state interest in the watershed and not solely the waterbody (WWAP, 2003). The agreement also expressed a plan for economic development without altering the navigation or fishing on the lake (Priscoli & Wolf, 2010). • As a result of the mixed state engagement in the mining industry, state interest is assumed to be medium.
	1996 Establishment of the ALT	Low	Low	Medium	High
		• Joint actions occurred prior to the establishment of the ALT. These actions included the creation of the Master Plan for the basin. Although most of the work was completed between the state governments and European experts, national experts and technicians were engaged in the process (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, the public was able to comment on technical elements of the plan towards the end of its execution (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that most of the experts and technicians did not come from the mining community, and given the limited capacity for input, formal authority was low.	• In 1989, approximately 2.47% of the Peruvian population and 3.4% of the economically active Bolivian population participated in mining (Revollo et al., 2005). • There was not a clear organized group or evidence of ad hoc organization. As a result of the low fraction of the basin that participates in mining, resources power is assumed to be low.	• The mining industry was promoting regional economic growth with its increased activity in the 1990s (de la Flor, 2014). Given the reported polarization of public opinion in 2010, it is assumed that there is some support for mining in the region, and therefore, discursive legitimacy is assumed to be medium.	• In 1987, the Bolivian government restructured, and its metals export increased by 10% in one year (Garcia et al., 2005). • By the early 1990s, metals production had significantly increased in Bolivia, and by 1992, mining was considered an important economic sector in the country (Garcia et al., 2005; Mancilla García, 2013). • In the 1990s, the Peruvian government invested in mining and incorporated neo-liberal policies towards development (Williams, 2015; Bury, 2005). In 1996, a new mining policy was implemented that enabled greater competition and foreign investment in mining (Bury, 2005). Additionally, the Peruvian constitution of 1993 claimed state ownership for the nation's resources (Martínez Gonzales & Zuleta Roncal, 2007), • Mining was perceived to be critical to economic growth in Peru since the 1990s (de la Flor, 2014). In 1996, mining and petroleum was approximately 7% of the Peruvian GDP; however, the mining industry attracts foreign investment and is important to exports (Bury, 2005). • In 1987, a study was funded by the Inter-American Development Bank to assess the capacity for transport, energy, tourism, fishery, agriculture, industry, and commercial border exchange projects between the two countries (Martínez Gonzales & Zuleta Roncal, 2007). Although externally funded, this study supports and international interest in the relevant urban sectors that could inform both governments. Because this study did not specifically address

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
					mining, it is not assumed to have prioritized mining. • Given both countries' investment and profit from the mining industry, state interest is assumed to high.
	1997-1998 Ratification of RAMSAR	Medium	Low	Medium	High
		• The ALT is based on the principles of Integrated Water Resources Management (IWRM); however, this strategy had not been implemented as of 2009 (WWAP, 2003: Calizaya, 2009). • The ALT was reported to regularly hold workshops and seminars to inform civil society about the Master Plan and encourage public participation (Martínez Gonzales & Zuleta Roncal, 2007). This participation involves a variety of stakeholders and levels of government (Zilov, 2013). However, the workshops are considered "insufficient" due to a lack of finances (Martínez Gonzales & Zuleta Roncal, 2007, p. 82). • It was further reported that stakeholder participation was absent or minimal due to "social and economic instability" and weak institutions (WWAP, 2003, p. 477). This lack of participation was observed to impair the efficacy of the ALT (Priscoli & Wolf, 2010). • Any existing participation has been reported to be primarily "information sharing and sensitizing" (Avramoski, 2004, p. 6). • Although public participation was weak with low levels of influence in decision making, due to the institutionalization of this participation, formal authority was medium.	• Resources power is assumed to be consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• State interest in mining is assumed to be consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Medium	Low	Medium	High
		• In 2008 in Peru, concerned citizens were invited to participate in round table discussions with the government about mine management (Mancilla García, 2013). A broad group of stakeholders were included. • The ALT has been criticized as a non-transparent organization that makes obtaining data difficult for civil society and has some financial discrepancies (Mancilla García, 2013). • Although public participation was weak with low levels of influence in decision making, due to the national and transboundary	• In 2000, the mining sector employed approximately 0.4% of the population in Peru (International Monetary Fund, 2001). • In 2003, approximately 4% of the Bolivian basin population and 3% of the Peruvian basin population were engaged in mining activity (WWAP, 2003). • There was not a clear organized group or evidence of ad hoc organization. As a result of the low fraction of the basin that participates in mining, resources power is assumed to be low.	• Public opinion on mining in Peru was reported to be polarized due to the potential for economic growth and the residual pollution (Mancilla García, 2013). As a result of some favorable public opinion, discursive legitimacy is assumed to be medium.	• In 2000, mining was approximately 7% of the Peruvian GDP; however, mining was important to the economy by attracting foreign investment and contributing to exports (Bury, 2005). • In 2005, mining contributions to the Bolivian GDP had been declining (Revollo et al., 2005). Additionally, mining contributed to approximately 8.7% of the sub-regional GDP in Peru (Revollo et al., 2005). • From 2009-2013, the mining sector contributed to approximately 58% of Peru's exports

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		institutionalization of this participation, formal authority was medium.			(Banco Central de Reserva del Peru, 2014 as cited in Mancilla García, 2013). • Additionally, 15% of Peruvian government taxes came from mining, and half of these proceeds were reinvested into the local governments of the basin (de la Flor, 2014). • The mining sector has been perceived to be prioritized when assigning water rights in the basin (Calizaya et al., 2010). Within Peru, the state has also been accused of enabling illegal mining to occur (Williams, 2015). • Tensions have also existed between the heads of state due to Peru's mining policies (AQ Editors, 2010). • Given the economic contribution to the Peruvian economy, the perceived prioritization, and the willingness to invest in mining areas, state interest in mining is assumed to be high.
	2016 Bi-national Commitment and Current Status	Medium	Low	Medium	High
		• Formal authority is assumed to be consistent with previous years given the ongoing functioning of the ALT.	• Although mining is an important industry in the region, it is assumed that employment patterns were consistent with previous years. Due to a lack of organized groups, resources power is low.	• In 2019, the freedom of the press index in Bolivia and Peru were 35.38 and 30.22, respectively (RSF, 2020). These rankings are classified by RSF as "bad" and "problematic," respectively (RSF, 2020). • Discursive legitimacy is assumed to be consistent with previous years.	• By 2014, mining was approximately 14% of Peru's GDP and was approximately 60% of exports (de la Flor, 2014). • It was reported that small mineral cleaning companies have political power because of their role as Morales' electoral base (Do Alto 2011 in Mancilla García, 2016). • Given the increased economic contribution and perceived prioritization, it is assumed that the state interest is high.
Tourism industry	1955-1957 Joint Ownership Agreement Signed	Low	Low	Low	Low
		• Tourism did not become common in the region until the 1970s (Ypeij & Zorn, 2007). Therefore, formal authority is assumed to be low.	• Tourism did not become common in the region until the 1970s (Ypeij & Zorn, 2007). Therefore, resource power is assumed to be low.	• Tourism did become common in the region until the 1970s (Ypeij & Zorn, 2007). Therefore, discursive legitimacy is assumed to be low.	• Although there was interest in developing the region; tourism did not become common in the region until the 1970s (Mancilla García, 2013; Ypeij & Zorn, 2007). Therefore, state interest in tourism is assumed to be low.
	1986 Ratification of the Agreement	Medium	Low	Medium	Low
		• Within Taquile, a frequently studied island, tourism began in the 1976 (Ypejj & Zorn, 2007). The island was celebrated for its community managed tourism (Mitchell, 2008; Ypejj & Zorn, 2007). However, in the 1980s, additional actors entered the tourism industry and communities lost some management control (Ypejj & Zorn, 2007). • It is assumed that many tourist locations along the lake followed a similar pattern to Taquile.	• Tourists often traveled between large cities in Bolivia and Peru, thus enabling some shared transboundary benefits throughout the basin (Mitchell, 2008). • The tourism industry collapsed in the 1980s in Peru (Mitchell, 2008). It is assumed that similar tourism patterns occurred in Bolivia. • Given the low activity of the tourism industry by 1986, it is assumed that the fraction of the population participating in the industry was not a majority fraction. Additionally, no organized	• Given the community directed tourism that began in the 1970s and 1980s and the studies of the region, it is assumed that the tourism industry had a platform to express their voice and control the message. As a result, discursive legitimacy is considered medium.	• Although tourism was occurring in the 1980s, it was not a major industry due to conditions in the region (Mitchell, 2008). As a result of the low contribution to GDP and lack of transboundary actions, state interest is assumed to be low.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Given some extent of local tourism and resource management in the basin, the formal authority is assumed to be medium.	group was identified. Therefore, resources power was low.		
	1996 Establishment of the ALT	Low	Low	Low	Medium
		• Joint actions occurred prior to the establishment of the ALT. These actions included the creation of the Master Plan for the basin. Although most of the work was completed between the state governments and European experts, national experts and technicians were engaged in the process (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, the public was able to comment on technical elements of the plan towards the end of its execution (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that most of the experts and technicians did not come from tourism regions, and given the limited capacity for input, formal authority is considered low.	• There were 317,000 international tourists in Peru in 1990 (Mitchell, 2008). • Given that the industry was only starting to grow in the 1990s, it is assumed that tourism was not a major sector for employment. Additionally, a representative organization was not located. • As a result of the low participating population and lack of organization, resources power is assumed to be low.	• The entrance of different actors shifted the voice of the tourism industry. Additionally, many participants in tourism are from rural and urban areas. • Within the basin, there was a large percentage of indigenous communities in rural and urban areas (Martínez Gonzales & Zuleta Roncal, 2007). By 2020, approximately 62% of the population of Bolivia is indigenous (Draper, 2010). There are reports that indigenous communities historically felt excluded from political processes (Draper, 2010; Martínez Gonzales & Zuleta Roncal, 2007; van Eerten, 2016). These feelings of exclusion were mobilized in the Bolivian presidential campaign of 2006 and may represent a lower discursive legitimacy (Mancilla García, 2013). • Additionally, no expression of voice was identified within this time period. As a result of the perception of exclusion and limited expression of voice, discursive legitimacy is assumed to be low.	• In 1993, within Bolivia, the bAIN GNP per capita was estimated to be 35% the national GNP per capita (WWAP, 2003). • In 1996, travel and tourism were 4.9% of the GDP in Bolivia and 6.9% of the GDP in Peru (World Travel and Tourism Council, 2019). • In 1987, a study was funded by the Inter-American Development Bank to assess the capacity for cross-border exchange of transport, energy, tourism, fishery, agriculture, industry, and commercial border exchange (Martínez Gonzales & Zuleta Roncal, 2007). Although externally funded, this study demonstrated an international interest in the tourism sector that could inform both governments. • Given the contribution to the GDP, expression of international interest in tourism, and lack of transboundary actions related to tourism, state interest was medium.
	1997-1998 Ratification of RAMSAR	Medium	Low	Low	High
		• The ALT is based on the principles of Integrated Water Resources Management (IWRM); however, this strategy had not been implemented as of 2009 (WWAP, 2003: Calizaya, 2009). • The ALT was reported to regularly hold workshops and seminars to inform civil society about the Master Plan and encourage public participation (Martínez Gonzales & Zuleta Roncal, 2007). This participation involves a variety of stakeholders and levels of government (Zilov, 2013). However, the workshops are considered "insufficient" due to a lack of finances (Martínez Gonzales & Zuleta Roncal, 2007, p. 82). • It was further reported that stakeholder participation was absent or minimal due to "social and economic instability" and weak institutions (WWAP, 2003, p. 477). This lack of participation was observed to impair the efficacy of the ALT (Priscoli & Wolf, 2010).	• Resources power is assumed to be consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• As part of the Environmental Management Plan, the ALT, Organization of American States, and the United Nations Environment Programme (UNEP) researched the promotion of tourism in the basin (Martínez Gonzales & Zuleta Roncal, 2007). • In the 1990s, the Peruvian government invested in tourism (Williams, 2015). • In 1997, travel and tourism were 6.3% of the GDP in Bolivia and 7.9% of the GDP in Peru (World Travel and Tourism Council, 2019). • Given the international and state engagement in tourism, it is assumed that state interest in tourism was high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Any existing participation has been reported to be primarily "information sharing and sensitizing" (Avramoski, 2004, p. 6). • Although public participation was weak and limited to low levels of influence in decision making, due to the institutionalization of this participation, formal authority was medium.			
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	Medium	High
		• In 2008 in Peru, concerned citizens were invited to participate in round table discussions with the government about mine management (Mancilla García, 2013). A broad group of stakeholders were included. • The ALT has been criticized as a non-transparent organization that makes obtaining data difficult for civil society and has some financial discrepancies (Mancilla García, 2013). • Although public participation was weak with low levels of influence in decision making, due to the national and transboundary institutionalization of this participation, formal authority was medium.	• In 2003, approximately 3% of the Bolivian basin population and 14% of the Peruvian basin population were engaged in the services sector (WWAP, 2003). It is assumed that tourism is encompassed within the services industry. • In the mid-1990s, tourism rapidly expanded along the lake in Peru (Mitchell, 2008). • By 2005, there were approximately 1.2 million international tourists in Peru representing a growth rate of 10.8% since 1995 (UNWTO, 2005 as cited in Mitchell, 2008). However, tourism in the basin was reported to be poorly developed (Revollo et al., 2005). • By 2011, approximately 63.2% of the city of Puno were engaged in tourism as their sole source of employment (Mancilla García, 2013). A large portion of the Copacabana community were also engaged in tourism (Mancilla García, 2013). • Given the growing level of engagement in tourism and absence of a recognized representative organization, the resources power is assumed to be medium.	• It is assumed that there is mixed public opinion related to tourism. The growth of the tourism industry presented economic opportunity for many residents in the basin, and therefore, was likely favorably perceived. However, at the same time, tourism increased strains on resources. • As a result of mixed public opinion, discursive legitimacy is assumed to be medium.	• The lake is considered an important destination for international and local tourism (Mancilla García, 2013). • In 2010, travel and tourism were 6.2% of the GDP in Bolivia and 9.6% of the GDP in Peru (World Travel and Tourism Council, 2019). During the time period leading up to 2010, Bolivian tourism had peaked at approximately 10% of the GDP in Bolivia (World Travel and Tourism Council, 2019). • The World Bank designated funds through the Bolivian Ministry of Tourism to construct water treatment infrastructure and landfills (The World Bank et al., 2009 as cited in Mancilla García, 2013). The grant also had a "'tourism development component,' which was identified as the main economic potential of the region" (Mancilla García, 2013, p. 278). • Given the contribution to the GDP and growing capacity of the tourism sector, state interest is assumed to be high.
	2016 Bi-national Commitment and Current Status	Medium	Medium	Medium	High
		• Formal authority is assumed to be consistent with previous years given the ongoing functioning of the ALT.	• In the lake region, up to 700,000 tourists visit the Bolivia annually (Collyns, 2017). • The fraction of participating community members in the tourism industry is assumed to be consistent with previous years. As a result, resources power is assumed to be medium.	• It is assumed that there is still mixed perception on the tourism industry as the tourist influx has caused a strain on resources, including a large fish kill in Cohana Bay during the holiday season (Achá et al., 2018). • In 2019, the freedom of the press index in Bolivia and Peru were 35.38 and 30.22, respectively (RSF, 2020). These rankings are classified by RSF as "bad" and "problematic," respectively (RSF, 2020). • As a result of some positive public opinion, the discursive legitimacy is assumed to be medium.	• In 2016 and 2018, travel and tourism were 7% and 6.9% of the GDP in Bolivia and 9.8% and 9.5% of the GDP in Peru (World Travel and Tourism Council, 2019). • There are perceptions that tourism prospers while local people "suffer" (Collyns, 2017). • It is assumed that state interest is consistent with previous years.

Table 20. Comprehensive analysis of primary stakeholder vulnerability in the Lake Titicaca basin.

Stakeholder	Event	Regional Development	Economic	Education	Political
Inhabitants of large cities/ municipalities	1955-1957 Joint Ownership Agreement Signed	High	Medium	High	High
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of people had access to drinking water treatment (WWAP, 2003). • El Alto had access to alternate water sources that are located outside of the basin since its connection to the La Paz water supply in the 1950s (Agramont et al., 2018). As a result, approximately 80% of the city's water came from alternate basins and glaciers (Gonzales Iwanciw et al., 2013). However, the other urban areas in the basin are assumed to rely on lake-related freshwater given the urban dependence on surface water resources and the proximity of urban areas to the lake (Martínez Gonzales & Zuleta Roncal, 2007). • Groundwater is available in the region but is more expensive based on the need to install wells and operate pumps. As of 2005, few areas used groundwater (Revollo et al., 2005). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• Employment in cities offered some opportunity for diversification. Employment opportunities included the commercial industry, manufacturing, service industry, academia, transportation, trade, and mining (Mancilla García, 2013; Food and Agriculture Organization [FAO], 2015; Martínez Gonzales & Zuleta Roncal, 2007) Although several of the employment opportunities were full time, urban residents often maintained access to rural land which enabled access to agriculture (Mancilla García, 2013). Not all employment opportunities required a high rate of water usage. • Bolivia adjusted income: 0.485 (1955; Prados de la Escosura, 2019). • Peru adjusted income: 0.587 (1955; Prados de la Escosura, 2019). • Based on the former United Nations Development Programme (UNDP) human development thresholds, the countries are considered low and medium development based on the income parameter (<0.5 and <0.8, respectively; UNDP, 2009). • Given the potential for financial income, diversity of production in cities, intermediate dependence on water resources, and low and medium adjusted incomes, the economic vulnerability is considered medium.	• Bolivia average years of schooling: 2.08, literacy: 0.105 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Peru average years of schooling: 2.7, literacy: 0.178 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • As a result of the low literacy, educational vulnerability is considered high.	• The Water Law was established in Bolivia in 1906 which focused on water use and ownership (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • A decree on land reform and the water regime and a law on excess water use was established in Bolivia in 1953 and 1945, respectively (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • Although water laws existed, the laws only applied to one riparian country and did not focus on pollution controls. As a result, political vulnerability is considered high.
	1986 Ratification of the Agreement	High	High	Medium	Medium
		• An economic depression of the 1980s increased rural migration to urban areas (WWAP, 2003). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment, minimal use of alternate water resources, and quick rate of urbanization that may have exceed the capacity of existing infrastructure, regional development vulnerability is considered high.	• The 1982-1983 drought caused "hundreds of millions of dollars" of damage in the agricultural industry (Priscoli & Wolf, 2010, p. 214). This event was followed by flooding that started in 1986 and also caused significant economic damage to the agricultural sector (Priscoli & Wolf, 2010). These weather events impacted city residents that maintained agricultural plots. • In the 1980s, the mining industry collapsed causing massive layoffs in the Bolivian state-run mining corporation (Garcia et al., 2005). This event may have impacted urban residents who were involved in mining, extractive trade, and processing (Garcia et al., 2005).	• Bolivia average years of schooling: 5.36, literacy: 0.281, 63.2% (1985 and 1976; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 5.83, literacy: 0.373, 81.9% (1985 and 1981; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively).	• The Bolivian Civil Code was established in 1975 (WWAP, 2003). Bolivian decrees on regulation of industrial waste and solid waste were established in 1985 and 1977, respectively (Martínez Gonzales & Zuleta Roncal, 2007). • The General Water Law was established in Peru in 1969 to regulate water use and conservation (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). Additionally, a 'sanitation code' was established in Peru in the same year to address environmental health (Martínez Gonzales & Zuleta Roncal, 2007).

Stakeholder	Event	Regional Development	Economic	Education	Political
			• Bolivia gross national income (GNI) per capita: $740, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $840, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds from 1987, both countries were lower-middle income (>$481 and <$1941; 2019). • Although there was diversity of production and the GNI per capita is considered medium, the economic downturn and environmental conditions strongly impacted the lake basin. As a result, the economic vulnerability is considered high.	• As a result of the medium and high literacy and low average years of schooling, educational vulnerability is considered medium.	• Because water laws existed in both countries with a limited focus on pollution controls, the political vulnerability is considered medium.
	1996 Establishment of the ALT	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" between 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22) • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is considered high.	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $900, adjusted income: 0.519 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2150, adjusted income: 0.580 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3116; 2019). • Although there is diversity of production and the GNI per capita is considered medium, given the assumption of high poverty rates, the economic vulnerability is considered high.	• Bolivia average years of schooling: 7.1, expected years of schooling: 12.1, literacy: 0.373, 80.0% (1995 and 1992; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 7.3, expected years of schooling 12.2, literacy: 0.457, 87.2% (1995 and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is considered low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • As a result of the high literacy and low average years of schooling, the educational vulnerability is medium.	• The Environment Law was established in Bolivia in 1992 which enables pollution regulation (WWAP, 2003; Mancilla García, 2013). • The Environment and Natural Resources Code was established in Peru in 1992 which makes a federal ministry responsible for quality of consumable water (WWAP, 2003). • The corruption perception index for Bolivia was 3.4/10 in 1996 (Transparency International, 2020). • Bolivia moved to decentralize water management in the 1990s (Mancilla García, 2013). • As both countries have environmental regulations that address regulation of pollution, local regulations were established in one country, and the corruption perception index is medium (>33% and <66%), the political vulnerability is considered medium.
	1997-1998 Ratification of RAMSAR	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 79.4, percent of urban	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $950, adjusted income: 0.519 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019).	• Bolivia average years of schooling: 7.2, expected years of schooling: 12, literacy: 0.373, 80.0% (1997, 1995, and 1992; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Peru average years of schooling: 7.5, expected years of schooling 12.2, literacy: 0.457, 87.2% (1997, 1995, and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020).	• The establishment of the ALT provided an autonomous organization to manage the lake and enable water quality protection (Martínez Gonzales & Zuleta Roncal, 2006). With a technical organization in each country (PELT in Peru and Operative Unit of Bolivia [UOB] in Bolivia), the organization was also connected to the governance in each state (Priscoli & Wolf, 2010).

Stakeholder	Event	Regional Development	Economic	Education	Political
		population: 95.1 (2000; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 80.7/45.1, percent of urban population: 91.5/56.5 (2000; The World Bank, 2020). • As a result of the low access to water treatment in the basin and minimal use of alternate water resources, regional development vulnerability is considered high.	• Peru GNI per capita: $2280, adjusted income: 0.580 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3126; 2019). • Although there is diversity of production and the GNI per capita is considered medium, given the assumption of high poverty rates, the economic vulnerability is considered high.	• Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • Given the high literacy and low average years of schooling, educational vulnerability is medium.	• The corruption perception index for Bolivia was 2.05/10 in 1997 (Transparency International, 2020). • As both countries have environmental regulations that address the regulation of pollution, and the corruption perception index is high for one country (<33%), the political vulnerability is medium.
	2009-2010 Withdrawal of Bolivian Support	Medium	High	Medium	Medium
		• In 2003, approximately 19% and 24% of the basin population had access to drinking water treatment in Peru and Bolivia, respectively (WWAP, 2003). However, these rates varied in large cities, and in smaller urban cities, communities managed their own drinking water systems (WWAP, 2003). • By 2009, approximately 50% of the basin population had access to improved sources of water (Calizaya, 2009). • Lack of opportunity led to the urban migration of young men looking for work (Gonzales Iwanciw et al., 2013). This migration led to crowding and housing deterioration in cities (Martínez Gonzales & Zuleta Roncal, 2007). Additionally, urban migration led to unplanned city sprawl that challenged access to drinking and wastewater treatment (Williams, 2015). • Medical facilities were poorly equipped and predominantly located in urban areas (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 87.9, percent of urban population: 97.7 (2010; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 87.2/48.5, percent of urban population: 93.9/57.9 (2010; The World Bank, 2020). • Given the increasing trend of drinking water access in 2009 which met the threshold of 50%, regional development vulnerability is medium.	• In 2003, 73.5% of the basin population in Peru and 69.8% of the basin population in Bolivia lived in poverty (WWAP, 2003). • Bolivia GNI per capita: $1780, adjusted income: 0.569, gap at national poverty line: 24.6, urban gap at national poverty line: 17 (2010 and 2009; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $4410, adjusted income: 0.664, gap at national poverty line: 9, urban gap at national poverty line: 4.5 (2010; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country was lower-middle income and one country was upper-middle income (>$1006 and >$3976, respectively; 2019). • Given the high rate of poverty in the region (>50%), in spite of diversity of production in cities and medium GNI per capita, economic vulnerability is high.	• By 2010, there was a general public awareness that waste management and population growth contributed to water quality degradation (Mancilla García, 2013). Within cities, stakeholders believed that cities were the cause of pollution (Mancilla García, 2013). There was also concern that other actors continued to dispose of waste directly into the lake (Mancilla García, 2013). • PELT and the USAID sought to increase public awareness through distribution of flyers and "awareness" programs (Mancilla García, 2013, p. 151). • Although the ALT supported some implementation of monitoring programs, general monitoring data was limited (Rieckermann et al., 2006). In 2006, only Inner Puno Bay was monitored on a monthly basis, and several wastewater operators were uncertain about the quality of their effluents (Rieckermann et al., 2006). NGOs and government organizations collected data periodically throughout other parts of the lake; however, the organization did not share all collected data (Mancilla García, 2013). • In 2010, officials were concerned that there was insufficient monitoring data to manage the lake (Mancilla García, 2013). • In 2003, the illiteracy rate in the basin was 22%, with lower rates of literacy in cities (WWAP, 2003). These illiteracy rates indicated that the education in the basin was "remarkably low" (Revollo et al., 2005, p. 381). • Bolivia average years of schooling: 7.8, expected years of schooling: 13.8, literacy: 0.540, 92.2%, 91.2% (2010, 2011, and 2009; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020).	• The establishment of the ALT created a framework for regulation but does not have a mechanism to address differences in the countries' water management (WWAP, 2003). The structure of water governance institutions also varied between the two countries (Mancilla García, 2013). • The Bolivian water legislation was considered "fragmentary and outdated" in 2007 (Martínez Gonzales & Zuleta Roncal, 2007, p. 26). Additionally, existing laws were perceived to not provide equitable access to indigenous communities (Draper, 2010). • Most waste and sanitation were managed by municipalities, coordinated at a regional level, and supervised at a national level (Mancilla García, 2013). There was criticism that a lack of local support in this process led to insufficient treatment (Mancilla García, 2013). • The Basic Sanitation and Drinking Water Law was established in Bolivia in 1999 (WWAP, 2003). This law promoted privatization of water resources (Draper, 2010). • In response to protests, the Interinstitutional Water Council (CONAIG) was created in 2002 to revise Bolivia water laws with consideration of stakeholders (WWAP, 2003). • In 2004, the Bolivian government passed a law that recognizes the right to water and guarantees water access for indigenous and agricultural communities (Draper, 2010). • The Peruvian government began to decentralize authority in water management in the 2000s (Mancilla García, 2013). The decentralization in Peru lead to the creation of regional government structures in 2003 (Guevara-Pérez, 2018).

Stakeholder	Event	Regional Development	Economic	Education	Political
				• Peru average years of schooling: 8.4, expected years of schooling 13.4, literacy: 0.491, 87.9%, 89.59% (2010, 2005, and 2007; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low in one country and medium in another based on the education parameter (<8.25 years and <10.47 years, respectively), and the literacy calculation is considered low in one country and medium in the other (<0.5 and <0.8, respectively; UNDP, 2009). The countries' literacy percentage is high and the basin specific literacy percentage is medium (>80% and <80%, respectively; UNDP, 2009). • Given that there is some risk awareness and access to data and literacy is medium, educational vulnerability is medium.	• In 2010, the corruption perception index was 2.8/10 in Bolivia and 3.5/10 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
	2016 Bi-national Commitment and Current Status	Medium	High	Medium	Medium
		• The growth rate of El Alto was relatively high at approximately 4.95% in 2013 (Gonzales Iwanciw et al., 2013). It was projected that El Alto would be unable to meet water demands by 2018 due to population growth (Gonzales Iwanciw et al., 2013). • Additionally, water quality and overfishing are increasing the rates of rural-urban migration with former fishermen to moving to urban areas (Shahriari, 2012). • Within El Alto, access to drinking water treatment was 70% in 2013 and a "high level of informality" was observed in the city (Gonzales Iwanciw et al., 2013; Mancilla García, 2013). • It is assumed that water treatment within the basin is less than the national averages as per the 2009 trends. In spite of increasing rates of urbanization, it is assumed that the rates of water access have not decreased since 2009. Therefore, it is assumed that at least 50% of the basin has access to improved water sources. • Bolivia percent of people using at least basic drinking water services: 92.8, percent of urban population: 99.4 (2017; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 91.1/50.4, percent of	• In 2011, approximately 81.4% of the population in the basin was below the poverty line (PNUMA, 2011 as cited in Mancilla García, 2013). • Certain large cities have a high incidence of poverty, including 70% of the population in El Alto, Bolivia (Gonzales Iwanciw et al., 2013). • Bolivia GNI per capita: \$3040/\$3370 (2016/2018), adjusted income: 0.593, gap at national poverty line: 16.9, urban gap at national poverty line: 10.5 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru GNI per capita: \$6110/\$6470 (2016/2-18), adjusted income: 0.684, gap at national poverty line: 5.8, urban gap at national poverty line: 3.3 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the World Bank income thresholds, one country is lower-middle income, and one country is upper-middle income (<\$1006/\$996 and <\$3956/\$3896, respectively; 2019). • Although there is diversity of production and medium GNI per capita, given the high rate of poverty in the region, economic vulnerability is high.	• There is a high level of public awareness that pollution is occurring, and this awareness is affiliated with an understanding of some of the risks of pollution (Williams, 2015; Shahriari, 2012; van Eerten, 2016). However, administrative communication about water quality has been lacking (Williams, 2015). • Bolivia average years of schooling: 9.0, expected years of schooling: 14, literacy: 0.657, 92.5%, 92.5% (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 9.2, expected years of schooling 13.8, literacy: 0.625, 94.2%, 94.4% (2018, 2015, and 2017; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 years and <10.49 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%; UNDP, 2009). • Given that there is some risk awareness, information is not easily accessible, and literacy is high, educational vulnerability is considered medium.	• The Law of the Rights of Mother Earth and the Framework Law of Mother Earth and Integral Development for Living Well were passed in Bolivia in 2010 and 2012, respectively, and provide the right to water and freedom from contamination (Gonzales Iwanciw et al., 2013). • In 2013, Bolivia was debating a new Water Law with approximately 20 versions in circulation (Gonzales Iwanciw et al., 2013). It is not apparent that a new water law has been passed. • Non-compliance with regulation has been reported in the mining sector (Mancilla García, 2016). • City officials, including El Alto's mayor, have reported difficulty in enforcing water regulations due to the potential for local unrest and protest (Shahriari, 2012). • In 2019, the corruption perception index was 31/100 in Bolivia and 36/100 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, enforcement is inconsistent, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
		urban population: 95.6/58.8 (2010; The World Bank, 2020). • Given the assumption that drinking water treatment meets the 50% threshold, regional development is medium.			
Rural communities (Fishing Based)	1955-1957 Joint Ownership Agreement Signed	High	High	High	High
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Groundwater is available in the region but is more expensive based on the need to install wells and operate pumps. As of 2005, few areas used groundwater (Revollo et al., 2005). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• Rural livelihoods were primarily subsistent in the basin (Martínez Gonzales & Zuleta Roncal, 2007). Although fishing communities diversified by growing crops and maintaining livestock, they were highly dependent on water resources for fishing and agriculture (Orlove, 2002; Mancilla García, 2013). Several rural residents gained income through part-time involvement in urban commercial activities (Mancilla García, 2013). • The introduction of non-native trout caused a boom in lake fisheries in the 1950s (Mancilla García, 2013). • Bolivia adjusted income: 0.485 (1955; Prados de la Escosura, 2019). • Peru adjusted income: 0.587 (1955; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low and medium development based on the income parameter (<0.5 and <0.8, respectively; UNDP, 2009). • Although there was some diversity of livelihood in rural fishing based communities, livelihoods were primarily subsistent and had a high dependence on water resources. Therefore, economic vulnerability is high.	• Bolivia average years of schooling: 2.08, literacy: 0.105 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Peru average years of schooling: 2.7, literacy: 0.178 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • As a result of the low literacy, educational vulnerability is considered high.	• The Water Law was established in Bolivia in 1906 which focused on water use and ownership (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • A decree on land reform and the water regime and a law on excess water use was established in Bolivia in 1953 and 1945, respectively (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • Although water laws existed, the laws only applied to one riparian country and did not focus on pollution controls. As a result, political vulnerability is considered high.
	1986 Ratification of the Agreement	High	High	Medium	Medium
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• The 1982-1983 drought caused "hundreds of millions of dollars" of damage in the agricultural industry (Priscoli & Wolf, 2010, p. 214). This event was followed by flooding that started in 1986 and also caused significant economic damage to the agricultural sector (Priscoli & Wolf, 2010). As fishing communities are riparian, it is assumed that these communities were strongly impacted by flooding. • In addition to subsistence fishing, the management of the non-native trout species provided an additional source of income for riparian communities in Peru, following the	• Bolivia average years of schooling: 5.36, literacy: 0.281, 63.2% (1985 and 1976; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 5.83, literacy: 0.373, 81.9% (1985 and 1981; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The	• The Bolivian Civil Code was established in 1975 (WWAP, 2003). Bolivian decrees on regulation of industrial waste and solid waste were established in 1985 and 1977, respectively (Martínez Gonzales & Zuleta Roncal, 2007). • The General Water Law was established in Peru in 1969 to regulate water use and conservation (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). Additionally, a 'sanitation code' was established in Peru in the same year to address environmental health (Martínez Gonzales & Zuleta Roncal, 2007).

Stakeholder	Event	Regional Development	Economic	Education	Political
			recognition of environmental impacts in the 1970s (Mancilla García, 2013). • Bolivia GNI per capita: $740, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $840, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds from 1987, both countries were lower-middle income (>$481 and <$1941; 2019). • Given the primarily subsistent nature of fishing communities and the economic impacts of flooding, economic vulnerability is high.	literacy percentage is middle to high (>50% and >80%, respectively). • As a result of the medium and high literacy and low average years of schooling, educational vulnerability is considered medium.	• Because water laws existed in both countries with a limited focus on pollution controls, the political vulnerability is considered medium.
	1996 Establishment of the ALT	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is considered high.	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $900, adjusted income: 0.519 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2150, adjusted income: 0.580 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3116; 2019). • Although the GNI per capita is considered medium, it is assumed that economic vulnerability is high as based on the rates of poverty and primarily subsistent livelihoods in fishing communities.	• Bolivia average years of schooling: 7.1, expected years of schooling: 12.1, literacy: 0.373, 80.0% (1995 and 1992; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 7.3, expected years of schooling 12.2, literacy: 0.457, 87.2% (1995 and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is considered low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • As a result of the high literacy and low average years of schooling, the educational vulnerability is medium.	• The Environment Law was established in Bolivia in 1992 which enables pollution regulation (WWAP, 2003; Mancilla García, 2013). • The Environment and Natural Resources Code was established in Peru in 1992 which makes a federal ministry responsible for quality of consumable water (WWAP, 2003). • The corruption perception index for Bolivia was 3.4/10 in 1996 (Transparency International, 2020). • Bolivia moved to decentralize water management in the 1990s (Mancilla García, 2013). • As both countries have environmental regulations that address regulation of pollution, local regulations were established in one country, and the corruption perception index is medium (>33% and <66%), the political vulnerability is considered medium.
	1997-1998 Ratification of RAMSAR	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that is not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 79.4, percent of rural population: 54.2 (2000; The World Bank, 2020).	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $950, adjusted income: 0.519 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2280, adjusted income: 0.580 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019).	• Bolivia average years of schooling: 7.2, expected years of schooling: 12, literacy: 0.373, 80.0% (1997, 1995, and 1992; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Peru average years of schooling: 7.5, expected years of schooling 12.2, literacy: 0.457, 87.2% (1997, 1995, and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education	• The establishment of the ALT provided an autonomous organization to manage the lake and enable water quality protection (Martínez Gonzales & Zuleta Roncal, 2006). With a technical organization in each country (PELT in Peru and UOB in Bolivia), the organization was also connected to the governance in each state (Priscoli & Wolf, 2010). • The corruption perception index for Bolivia was 2.05/10 in 1997 (Transparency International, 2020).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Peru percent of people using at least basic/safe drinking water services: 80.7/45.1, percent of rural population: 51.3/14.0 (2000; The World Bank, 2020). • As a result of the low access to water treatment in the basin and minimal use of alternate water resources, regional development vulnerability is considered high.	• Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3126; 2019). • Although the GNI per capita is considered medium, it is assumed that economic vulnerability is high as based on the rates of poverty and primarily subsistent livelihoods in fishing communities.	parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • Given the high literacy and low average years of schooling, educational vulnerability is medium.	• As both countries have environmental regulations that address the regulation of pollution, and the corruption perception index is high for one country (<33%), the political vulnerability is medium.
	2009-2010 Withdrawal of Bolivian Support	Medium	High	Medium	Medium
		• In 2003, approximately 19% and 24% of the basin population had access to drinking water treatment in Peru and Bolivia, respectively (WWAP, 2003). • By 2009, approximately 50% of the basin population had access to improved sources of water (Calizaya, 2009). • Medical facilities were poor equipped and predominantly located in urban areas (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 87.9, percent of rural population: 68.6 (2010; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 87.2/48.5, percent of rural population: 65.6/18.0 (2010; The World Bank, 2020). • Given the increasing trend of drinking water access in 2009 which met the threshold of 50%, regional development vulnerability is medium.	• In 2007, the primary employment in the region was non-salaried work where families focus on the same activity (Martínez Gonzales & Zuleta Roncal, 2007). This employment continues the pattern of subsistent livelihoods. • Water quality impacts to boat access and fish quantity caused some fishermen to abandon their employment and raise cattle (Mancilla García, 2013). These impacts also caused the migration of some fishermen to urban areas to find employment (Shahriari, 2012). • In 2003, 73.5% of the basin population in Peru and 69.8% of the basin population in Bolivia lived in poverty (WWAP, 2003). • Bolivia GNI per capita: $1780, adjusted income: 0.569, gap at national poverty line: 24.6, rural gap at national poverty line: 39.3 (2010 and 2009; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $4410, adjusted income: 0.664, gap at national poverty line: 9, rural gap at national poverty line: 21.3 (2010; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country was lower-middle income and one country was upper-middle income (>$1006 and >$3976, respectively; 2019). • Given the high rate of poverty in the region, subsistent livelihoods, and dependence on water resources, economic vulnerability is high.	• By 2010, there was a general public awareness that waste management and population growth contributed to water quality degradation (Mancilla García, 2013). Farmers (and it is assumed that fishing communities) attributed sources of pollution to farther away cities, demonstrating an awareness of the greater hydrologic system (Mancilla García, 2013). • PELT and the USAID sought to increase public awareness through distribution of flyers and "awareness" programs (Mancilla García, 2013, p. 151). • Although the ALT supported some implementation of monitoring programs, general monitoring data was limited (Rieckermann et al., 2006). In 2006, only Inner Puno Bay was monitored on a monthly basis, and several wastewater operators were uncertain about the quality of their effluents (Rieckermann et al., 2006). NGOs and government organizations collected data periodically throughout other parts of the lake; however, the organization did not share all collected data (Mancilla García, 2013). • In 2010, officials were concerned that there was insufficient monitoring data to manage the lake (Mancilla García, 2013). • In 2003, the illiteracy rate in the basin was 22% (WWAP, 2003). These illiteracy rates indicated that the education in the basin was "remarkably low" (Revollo et al., 2005, p. 381). • Bolivia average years of schooling: 7.8, expected years of schooling: 13.8, literacy: 0.540, 92.2%, 91.2% (2010, 2011, and 2009; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 8.4, expected years of schooling 13.4, literacy: 0.491, 87.9%, 89.59% (2010, 2005, and 2007; UNDP, 2020;	• The establishment of the ALT created a framework for regulation but does not have a mechanism to address differences in the countries' water management (WWAP, 2003). The structure of water governance institutions also varied between the two countries (Mancilla García, 2013). • The Bolivian water legislation was considered "fragmentary and outdated" in 2007 (Martínez Gonzales & Zuleta Roncal, 2007, p. 26). Additionally, existing laws were perceived to not provide equitable access to indigenous communities (Draper, 2010). • Most waste and sanitation were managed by municipalities, coordinated at a regional level, and supervised at a national level (Mancilla García, 2013). There was criticism that a lack of local support in this process led to insufficient treatment (Mancilla García, 2013). • The Basic Sanitation and Drinking Water Law was established in Bolivia in 1999 (WWAP, 2003). This law promoted privatization of water resources (Draper, 2010). • In response to protests, the Interinstitutional Water Council (CONAIG) was created in 2002 to revise Bolivia water laws with consideration of stakeholders (WWAP, 2003). • In 2004, the Bolivian government passed a law that recognizes the right to water and guarantees water access for indigenous and agricultural communities (Draper, 2010). • The Peruvian government began to decentralize authority in water management in the 2000s (Mancilla García, 2013). The decentralization in Peru lead to the creation of regional government structures in 2003 (Guevara-Pérez, 2018). • In 2010, the corruption perception index was 2.8/10 in Bolivia and 3.5/10 in Peru (Transparency International, 2020).

Stakeholder	Event	Regional Development	Economic	Education	Political
				Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low in one country and medium in another based on the education parameter (<8.25 years and <10.47 years, respectively), and the literacy calculation is considered low in one country and medium in the other (<0.5 and <0.8, respectively; UNDP, 2009). The countries' literacy percentage is high and the basin specific literacy percentage is medium (>80% and <80%, respectively; UNDP, 2009). • Given that there is some risk awareness and access to data and literacy is medium, educational vulnerability is medium.	• Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
	2016 Bi-national Commitment and Current Status	Medium	High	Medium	Medium
		• It is assumed that water treatment in the basin is less than the national average as per the 2009 trends. Based on the 2009 values, it is assumed that at least 50% of the basin has access to improved water sources. • Bolivia percent of people using at least basic drinking water services: 92.8, percent of rural population: 78.1 (2017; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 91.1/50.4, percent of rural population: 75.6/20.8 (2010; The World Bank, 2020). • Given the assumption that drinking water treatment meets the 50% threshold, regional development is medium.	• In 2011, approximately 81.4% of the population in the basin was below the poverty line (PNUMA, 2011 as cited in Mancilla García, 2013). • Lack of opportunity has led rural community members to migrate to urban areas to look for work (Gonzales Iwanciw et al., 2013). • Bolivia GNI per capita: \$3040/\$3370 (2016/2018), adjusted income: 0.593, gap at national poverty line: 16.9, rural gap at national poverty line: 30.5 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru GNI per capita: \$6110/\$6470 (2016/2-18), adjusted income: 0.684, gap at national poverty line: 5.8, rural gap at national poverty line: 13.7 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (<\$1006/\$996 and <\$3956/\$3896, respectively; 2019). • Although the GNI per capita is medium, given the high rate of poverty in the region (>50%), economic vulnerability is high.	• There is a high level of public awareness that pollution is occurring, and this awareness is affiliated with an understanding of some of the risks of pollution (Williams, 2015; Shahriari, 2012; van Eerten, 2016). However, administrative communication about water quality has been lacking (Williams, 2015). • Bolivia average years of schooling: 9.0, expected years of schooling: 14, literacy: 0.657, 92.5%, 92.5% (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 9.2, expected years of schooling 13.8, literacy: 0.625, 94.2%, 94.4% (2018, 2015, and 2017; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 years and <10.49 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%; UNDP, 2009). • Given that there is some risk awareness, information is not easily accessible, and literacy is high, educational vulnerability is considered medium.	• The Law of the Rights of Mother Earth and the Framework Law of Mother Earth and Integral Development for Living Well were passed in Bolivia in 2010 and 2012, respectively, and provide the right to water and freedom from contamination (Gonzales Iwanciw et al., 2013). • In 2013, Bolivia was debating a new Water Law with approximately 20 versions in circulation (Gonzales Iwanciw et al., 2013). It is not apparent that a new water law has been passed. • Non-compliance with regulation has been reported in the mining sector and enforcement is inconsistent in cities (Mancilla García, 2016; Shahriari, 2012). • In 2019, the corruption perception index was 31/100 in Bolivia and 36/100 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, enforcement is inconsistent, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
		High	High	High	High

Stakeholder	Event	Regional Development	Economic	Education	Political
Rural communities (Non-fishing Based)	1955-1957 Joint Ownership Agreement Signed	• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Groundwater is available in the region but is more expensive based on the need to install wells and operate pumps. As of 2005, few areas used groundwater (Revollo et al., 2005). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• Rural livelihoods were primarily subsistent in the basin (Martínez Gonzales & Zuleta Roncal, 2007). Several predominantly agricultural areas were riparian and used resources from the lake without fishing (Orlove, 2002). Subsistence agriculture was dependent on water resources, with surface water commonly used for irrigation and livestock rearing (Martínez Gonzales & Zuleta Roncal, 2007). However, many farms within the basin are not irrigated and therefore water reliance is closely linked to climate conditions (WWAP, 2003 Martínez Gonzales & Zuleta Roncal, 2007). Several rural residents gained income through part-time involvement in urban commercial activities (Mancilla García, 2013). • Bolivia adjusted income: 0.485 (1955; Prados de la Escosura, 2019). • Peru adjusted income: 0.587 (1955; Prados de la Escosura, 2019). • Based on the former UNDP human development classification, the countries are considered low and medium development based on the income parameter (<0.5 and <0.8, respectively; UNDP, 2009). • Although there is some diversity of livelihood within agricultural communities, livelihoods were primarily subsistent and dependent on water resources. Therefore, economic vulnerability is high.	• Bolivia average years of schooling: 2.08, literacy: 0.105 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Peru average years of schooling: 2.7, literacy: 0.178 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • As a result of the low literacy, educational vulnerability is considered high.	• The Water Law was established in Bolivia in 1906 which focused on water use and ownership (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • A decree on land reform and the water regime and a law on excess water use was established in Bolivia in 1953 and 1945, respectively (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • Although water laws existed, the laws only applied to one riparian country and did not focus on pollution controls. As a result, political vulnerability is considered high.
	1986 Ratification of the Agreement	High	High	Medium	Medium
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• In 1976, 72.8% of the Bolivian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). In 1980, 65.1% of the Peruvian economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). Although agricultural livelihoods were predominantly subsistent, these percentages imply that some community members gained an economic income from agriculture. • The 1982-1983 drought caused "hundreds of millions of dollars" of damage in the agricultural industry (Priscoli & Wolf, 2010, p. 214). This event was followed by flooding that started in 1986 and also caused significant economic damage to the agricultural sector (Priscoli & Wolf, 2010).	• Bolivia average years of schooling: 5.36, literacy: 0.281, 63.2% (1985 and 1976; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 5.83, literacy: 0.373, 81,9% (1985 and 1981; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • As a result of the medium and high literacy and low average years of schooling, educational vulnerability is considered medium.	• The Bolivian Civil Code was established in 1975 (WWAP, 2003). Bolivian decrees on regulation of industrial waste and solid waste were established in 1985 and 1977, respectively (Martínez Gonzales & Zuleta Roncal, 2007). • The General Water Law was established in Peru in 1969 to regulate water use and conservation (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). Additionally, a 'sanitation code' was established in Peru in the same year to address environmental health (Martínez Gonzales & Zuleta Roncal, 2007). • Because water laws existed in both countries with a limited focus on pollution controls, the political vulnerability is considered medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
			• Bolivia GNI per capita: $740, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $840, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds from 1987, both countries were lower-middle income (>$481 and <$1941; 2019). • Given the high fraction of subsistence livelihoods in agricultural communities and the economic losses to commercial agriculture, economic vulnerability is high.		
	1996 Establishment of the ALT	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment, continued minimal utilization of alternate water resources, and unmet basic needs, vulnerability from regional development is considered high.	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $900, adjusted income: 0.519 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2150, adjusted income: 0.580 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3116; 2019). • Although the GNI per capita is considered medium, it is assumed that economic vulnerability is high as based on the rates of poverty and primarily subsistent livelihoods in agricultural communities.	• Bolivia average years of schooling: 7.1, expected years of schooling: 12.1, literacy: 0.373, 80.0% (1995 and 1992; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 7.3, expected years of schooling 12.2, literacy: 0.457, 87.2% (1995 and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is considered low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • As a result of the high literacy and low average years of schooling, the educational vulnerability is medium.	• The Environment Law was established in Bolivia in 1992 which enables pollution regulation (WWAP, 2003; Mancilla García, 2013). • The Environment and Natural Resources Code was established in Peru in 1992 which makes a federal ministry responsible for quality of consumable water (WWAP, 2003). • The corruption perception index for Bolivia was 3.4/10 in 1996 (Transparency International, 2020). • Bolivia moved to decentralize water management in the 1990s (Mancilla García, 2013). • As both countries have environmental regulations that address regulation of pollution, local regulations were established in one country, and the corruption perception index is medium (>33% and <66%), the political vulnerability is considered medium.
	1997-1998 Ratification of RAMSAR	High	High	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 79.4, percent of rural population: 54.2 (2000; The World Bank, 2020).	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $950, adjusted income: 0.519 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2280, adjusted income: 0.580 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019).	• Bolivia average years of schooling: 7.2, expected years of schooling: 12, literacy: 0.373, 80.0% (1997, 1995, and 1992; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Peru average years of schooling: 7.5, expected years of schooling 12.2, literacy: 0.457, 87.2% (1997, 1995, and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy	• The establishment of the ALT provided an autonomous organization to manage the lake and enable water quality protection (Martínez Gonzales & Zuleta Roncal, 2006). With a technical organization in each country (PELT in Peru and UOB in Bolivia), the organization was also connected to the governance in each state (Priscoli & Wolf, 2010). • The corruption perception index for Bolivia was 2.05/10 in 1997 (Transparency International, 2020). • As both countries have environmental regulations that address the regulation of

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Peru percent of people using at least basic/safe drinking water services: 80.7/45.1, percent of rural population: 51.3/14.0 (2000; The World Bank, 2020). • As a result of the low access to water treatment in the basin and minimal use of alternate water resources, regional development vulnerability is considered high.	• Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3126; 2019). • Although the GNI per capita is considered medium, it is assumed that economic vulnerability is high as based on the rates of poverty and primarily subsistent livelihoods in agricultural communities.	calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • Given the high literacy and low average years of schooling, educational vulnerability is medium.	pollution, and the corruption perception index is high for one country (<33%), the political vulnerability is medium.
	2009-2010 Withdrawal of Bolivian Support	Medium	High	Medium	Medium
		• In 2003, approximately 19% and 24% of the basin population had access to drinking water treatment in Peru and Bolivia, respectively (WWAP, 2003). • By 2009, approximately 50% of the basin population had access to improved sources of water (Calizaya, 2009). • Medical facilities were poor equipped and predominantly located in urban areas (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 87.9, percent of rural population: 68.6 (2010; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 87.2/48.5, percent of rural population: 65.6/18.0 (2010; The World Bank, 2020). • Given the increasing trend of drinking water access in 2009 which met the threshold of 50%, regional development vulnerability is medium.	• In 2001, between 33.1% to 46.5% of the economically active population were engaged in agriculture and livestock (Martínez Gonzales & Zuleta Roncal, 2007). The economically active population represented between 35.7% and 49.1% of the population within the basin (Martínez Gonzales & Zuleta Roncal, 2007). • In spite of the commercial farming activity, in 2007, the primary employment in the region was non-salaried work where families focus on the same activity (Martínez Gonzales & Zuleta Roncal, 2007). This agricultural pattern is partially linked to land fragmentation and Bolivian land ownership practices which supported a continuation of subsistence agriculture and contributed to poverty (WWAP, 2003; Revollo et al., 2005). • In 2003, 73.5% of the basin population in Peru and 69.8% of the basin population in Bolivia lived in poverty (WWAP, 2003). • Bolivia GNI per capita: $1780, adjusted income: 0.569, gap at national poverty line: 24.6, rural gap at national poverty line: 39.3 (2010 and 2009; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $4410, adjusted income: 0.664, gap at national poverty line: 9, rural gap at national poverty line: 21.3 (2010; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country was lower-middle income and one country was upper-middle income (>$1006 and >$3976, respectively; 2019). Given the high rate of poverty in the region, subsistent livelihoods, and dependence on water resources, economic vulnerability is high.	• By 2010, there was a general public awareness that waste management and population growth contributed to water quality degradation (Mancilla García, 2013). Farmers attributed sources of pollution to farther away cities, demonstrating an awareness of the greater hydrologic system (Mancilla García, 2013). • PELT and the USAID sought to increase public awareness through distribution of flyers and "awareness" programs (Mancilla García, 2013, p. 151). • Although the ALT supported some implementation of monitoring programs, general monitoring data was limited (Rieckermann et al., 2006). In 2006, only Inner Puno Bay was monitored on a monthly basis, and several wastewater operators were uncertain about the quality of their effluents (Rieckermann et al., 2006). NGOs and government organizations collected data periodically throughout other parts of the lake; however, the organization did not share all collected data (Mancilla García, 2013). • In 2010, officials were concerned that there was insufficient monitoring data to manage the lake (Mancilla García, 2013). • In 2003, the illiteracy rate in the basin was 22% (WWAP, 2003). These illiteracy rates indicated that the education in the basin was "remarkably low" (Revollo et al., 2005, p. 381). • Bolivia average years of schooling: 7.8, expected years of schooling: 13.8, literacy: 0.540, 92.2%, 91.2% (2010, 2011, and 2009; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 8.4, expected years of schooling 13.4, literacy: 0.491, 87.9%, 89.59% (2010, 2005, and 2007; UNDP, 2020;	• The establishment of the ALT created a framework for regulation but does not have a mechanism to address differences in the countries' water management (WWAP, 2003). The structure of water governance institutions also varied between the two countries (Mancilla García, 2013). • The Bolivian water legislation was considered "fragmentary and outdated" in 2007 (Martínez Gonzales & Zuleta Roncal, 2007, p. 26). Additionally, existing laws were perceived to not provide equitable access to indigenous communities (Draper, 2010). • Most waste and sanitation were managed by municipalities, coordinated at a regional level, and supervised at a national level (Mancilla García, 2013). There was criticism that a lack of local support in this process led to insufficient treatment (Mancilla García, 2013). • The Basic Sanitation and Drinking Water Law was established in Bolivia in 1999 (WWAP, 2003). This law promoted privatization of water resources (Draper, 2010). • In response to protests, the Interinstitutional Water Council (CONAIG) was created in 2002 to revise Bolivia water laws with consideration of stakeholders (WWAP, 2003). • In 2004, the Bolivian government passed a law that recognizes the right to water and guarantees water access for indigenous and agricultural communities (Draper, 2010). • The Peruvian government began to decentralize authority in water management in the 2000s (Mancilla García, 2013). The decentralization in Peru lead to the creation of regional government structures in 2003 (Guevara-Pérez, 2018). • In 2010, the corruption perception index was 2.8/10 in Bolivia and 3.5/10 in Peru (Transparency International, 2020).

Stakeholder	Event	Regional Development	Economic	Education	Political
				Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low in one country and medium in another based on the education parameter (<8.25 years and <10.47 years, respectively), and the literacy calculation is considered low in one country and medium in the other (<0.5 and <0.8, respectively; UNDP, 2009). The countries' literacy percentage is high and the basin specific literacy percentage is medium (>80% and <80%, respectively; UNDP, 2009). • Given that there is some risk awareness and access to data and literacy is medium, educational vulnerability is medium.	• Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
	2016 Bi-national Commitment and Current Status	Medium	High	Medium	Medium
		• It is assumed that water treatment in the basin is less than the national average as per the 2009 trends. Based on the 2009 values, it is assumed that at least 50% of the basin has access to improved water sources. • Bolivia percent of people using at least basic drinking water services: 92.8, percent of rural population: 78.1 (2017; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 91.1/50.4, percent of rural population: 75.6/20.8 (2010; The World Bank, 2020). • Given the assumption that drinking water treatment meets the 50% threshold, regional development is medium.	• In 2011, approximately 81.4% of the population in the basin was below the poverty line (PNUMA, 2011 as cited in Mancilla García, 2013). • Lack of opportunity has led rural community members to migrate to urban areas to look for work (Gonzales Iwanciw et al., 2013). • Bolivia GNI per capita: $3040/$3370 (2016/2018), adjusted income: 0.593, gap at national poverty line: 16.9, rural gap at national poverty line: 30.5 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru GNI per capita: $6110/$6470 (2016/2-18), adjusted income: 0.684, gap at national poverty line: 5.8, rural gap at national poverty line: 13.7 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (<$1006/$996 and <$3956/$3896, respectively; 2019). • Although the GNI per capita is medium, given the high rate of poverty in the region (>50%), economic vulnerability is high.	• There is a high level of public awareness that pollution is occurring, and this awareness is affiliated with an understanding of some of the risks of pollution (Williams, 2015; Shahriari, 2012; van Eerten, 2016). However, administrative communication about water quality has been lacking (Williams, 2015). • Bolivia average years of schooling: 9.0, expected years of schooling: 14, literacy: 0.657, 92.5%, 92.5% (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 9.2, expected years of schooling 13.8, literacy: 0.625, 94.2%, 94.4% (2018, 2015, and 2017; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 years and <10.49 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%; UNDP, 2009). • Given that there is some risk awareness, information is not easily accessible, and literacy is high, educational vulnerability is considered medium.	• The Law of the Rights of Mother Earth and the Framework Law of Mother Earth and Integral Development for Living Well were passed in Bolivia in 2010 and 2012, respectively, and provide the right to water and freedom from contamination (Gonzales Iwanciw et al., 2013). • In 2013, Bolivia was debating a new Water Law with approximately 20 versions in circulation (Gonzales Iwanciw et al., 2013). It is not apparent that a new water law has been passed. • Non-compliance with regulation has been reported in the mining sector and enforcement is inconsistent in cities (Mancilla García, 2016; Shahriari, 2012). • In 2019, the corruption perception index was 31/100 in Bolivia and 36/100 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, enforcement is inconsistent, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
Mining industry		High	Medium	High	High

Stakeholder	Event	Regional Development	Economic	Education	Political
	1955-1957 Joint Ownership Agreement Signed	• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Groundwater is available in the region but is more expensive based on the need to install wells and operate pumps. As of 2005, few areas used groundwater (Revollo et al., 2005). • Mining communities are assumed to exist in both urban and rural locations based on the distribution of mining sites in the basin (Mancilla García, 2013). Therefore, water access rates must consider both urban and rural access. • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• In Bolivia, there were high rates of employment in mining due a state-run corporation initiative in the 1950s (Garcia et al., 2005). In Peru, international mining corporations dominated large scale mines, although there was an active small and medium size mining sector (De Echave, 2005). • The mining industry required high volumes of water and thus had a high dependence of water resources (Mancilla García, 2013). • Bolivia adjusted income: 0.485 (1955; Prados de la Escosura, 2019). • Peru adjusted income: 0.587 (1955; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low and medium development based on the income parameter (<0.5 and <0.8, respectively; UNDP, 2009). • Given the potential lucrative income from the active mining industry, the high dependence on water resources, and the low and medium GNI per capita, the economic vulnerability is medium.	• Bolivia average years of schooling: 2.08, literacy: 0.105 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Peru average years of schooling: 2.7, literacy: 0.178 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • As a result of the low literacy, educational vulnerability is considered high.	• The Water Law was established in Bolivia in 1906 which focused on water use and ownership (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • A decree on land reform and the water regime and a law on excess water use was established in Bolivia in 1953 and 1945, respectively (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • Although water laws existed, the laws only applied to one riparian country and did not focus on pollution controls. As a result, political vulnerability is considered high.
	1986 Ratification of the Agreement	High	High	Medium	Medium
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Many citizens moved away from mining centers due to local instability in the 1980s (Williams, 2015). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• An economic depression caused a decrease in mining in the 1980s in both Bolivia and Peru (WWAP, 2003). • Bolivia GNI per capita: $740, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $840, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds from 1987, both countries were lower-middle income (>$481 and <$1941; 2019). • Given the strong economic impacts on the mining industry, the economic vulnerability is considered to be high.	• Bolivia average years of schooling: 5.36, literacy: 0.281, 63.2% (1985 and 1976; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 5.83, literacy: 0.373, 81,9% (1985 and 1981; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • As a result of the medium and high literacy and low average years of schooling, educational vulnerability is considered medium.	• The Bolivian Civil Code was established in 1975 (WWAP, 2003). Bolivian decrees on regulation of industrial waste and solid waste were established in 1985 and 1977, respectively (Martínez Gonzales & Zuleta Roncal, 2007). • The General Water Law was established in Peru in 1969 to regulate water use and conservation (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). Additionally, a 'sanitation code' was established in Peru in the same year to address environmental health (Martínez Gonzales & Zuleta Roncal, 2007). • Because water laws existed in both countries with a limited focus on pollution controls, the political vulnerability is considered medium.
	1996 Establishment of the ALT	High	Medium	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22).	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the	• Bolivia average years of schooling: 7.1, expected years of schooling: 12.1, literacy: 0.373, 80.0% (1995 and 1992; UNDP, 2020;	• The Environment Law was established in Bolivia in 1992 which enables pollution regulation (WWAP, 2003; Mancilla García, 2013).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is considered high.	population had limited economic means and was likely in poverty. • The mining industry began to rebound in 1990s in both Bolivia and Peru (Garcia et al., 2005; De Echave, 2005). The growth of the industry in Peru was a result of changing national policies (De Echave, 2005). • Bolivia GNI per capita: $900, adjusted income: 0.519 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2150, adjusted income: 0.580 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3116; 2019). • Although poverty was widespread in the basin, it is assumed that the boom in the mining sector positively influenced the income of mining participants relative to other members of the community. Based on the financial income and growth of the industry, the economic vulnerability is considered to be medium.	Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 7.3, expected years of schooling 12.2, literacy: 0.457, 87.2% (1995 and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is considered low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • As a result of the high literacy and low average years of schooling, the educational vulnerability is medium.	• The Environment and Natural Resources Code was established in Peru in 1992 which makes a federal ministry responsible for quality of consumable water (WWAP, 2003). • The corruption perception index for Bolivia was 3.4/10 in 1996 (Transparency International, 2020). • Bolivia moved to decentralize water management in the 1990s (Mancilla García, 2013). • As both countries have environmental regulations that address regulation of pollution, local regulations were established in one country, and the corruption perception index is medium (>33% and <66%), the political vulnerability is considered medium.
	1997-1998 Ratification of RAMSAR	High	Medium	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 79.4, percent of rural population: 54.2, percent of urban population: 95.1 (2000; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 80.7/45.1, percent of rural population: 51.3/14.0, percent of urban population: 91.5/56.5 (2000; The World Bank, 2020). • As a result of the low access to water treatment in the basin and minimal use of alternate water resources, regional development vulnerability is considered high.	• Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • The mining industry continued to rebound throughout the 1990s (Garcia et al., 2005; De Echave, 2005). • Bolivia GNI per capita: $950, adjusted income: 0.519 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2280, adjusted income: 0.580 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3126; 2019). • Although there is a high dependence on water resources and poverty within the basin, it is assumed that mining communities have a greater income relative to other members of the basin. Based on the financial income and	• Bolivia average years of schooling: 7.2, expected years of schooling: 12, literacy: 0.373, 80.0% (1997, 1995, and 1992; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Peru average years of schooling: 7.5, expected years of schooling 12.2, literacy: 0.457, 87.2% (1997, 1995, and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • Given the high literacy and low average years of schooling, educational vulnerability is medium.	• The establishment of the ALT provided an autonomous organization to manage the lake and enable water quality protection (Martínez Gonzales & Zuleta Roncal, 2006). With a technical organization in each country (PELT in Peru and UOB in Bolivia), the organization was also connected to the governance in each state (Priscoli & Wolf, 2010). • The corruption perception index for Bolivia was 2.05/10 in 1997 (Transparency International, 2020). • As both countries have environmental regulations that address the regulation of pollution, and the corruption perception index is high for one country (<33%), the political vulnerability is medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
			growth of the industry, the economic vulnerability is considered to be medium.		
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	Medium	Medium
		• In 2003, approximately 19% and 24% of the basin population had access to drinking water treatment in Peru and Bolivia, respectively (WWAP, 2003). However, these rates varied in large cities (WWAP, 2003). • By 2009, approximately 50% of the basin population had access to improved sources of water (Calizaya, 2009). • Medical facilities were poorly equipped and predominantly located in urban areas (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 87.9, percent of rural population: 68.6, percent of urban population: 97.7 (2010; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 87.2/48.5, percent of rural population: 65.6/18.0, percent of urban population: 93.9/57.9 (2010; The World Bank, 2020). • Given the increasing trend of drinking water access in 2009 which met the threshold of 50%, regional development vulnerability is medium.	• The mining industry continued to expand and strengthen in the 2000s in Peru (de la Flor, 2014). Additionally, the global market for the extractive industry was strong, causing a proliferation of artisanal mines to occur in the basin and attempt to take advantage of profits (Williams, 2015). • In 2003, 73.5% of the basin population in Peru and 69.8% of the basin population in Bolivia lived in poverty (WWAP, 2003). • Bolivia GNI per capita: $1780, adjusted income: 0.569, gap at national poverty line: 24.6, urban gap at national poverty line: 17, rural gap at national poverty line: 39.3 (2010 and 2009; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $4410, adjusted income: 0.664, gap at national poverty line: 9, urban gap at national poverty line: 4.5, rural gap at national poverty line: 21.3 (2010; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (>$1006 and >$3976, respectively; 2019). • Given the financial success of the mining industry, it is assumed that participants in the mining sectors have greater incomes than other populations in the basin. Based on the financial income and continued growth of the industry, the economic vulnerability is considered to be medium.	• By 2010, there was a general public awareness that waste management and population growth contributed to water quality degradation (Mancilla García, 2013). • PELT and the USAID sought to increase public awareness through distribution of flyers and "awareness" programs (Mancilla García, 2013, p. 151). • Although the ALT supported some implementation of monitoring programs, general monitoring data was limited (Rieckermann et al., 2006). In 2006, only Inner Puno Bay was monitored on a monthly basis, and several wastewater operators were uncertain about the quality of their effluents (Rieckermann et al., 2006). NGOs and government organizations collected data periodically throughout other parts of the lake; however, the organization did not share all collected data (Mancilla García, 2013). • In 2010, officials were concerned that there was insufficient monitoring data to manage the lake (Mancilla García, 2013). • In 2003, the illiteracy rate in the basin was 22%, with lower rates of literacy in cities (WWAP, 2003). These illiteracy rates indicated that the education in the basin was "remarkably low" (Revollo et al., 2005, p. 381). • Bolivia average years of schooling: 7.8, expected years of schooling: 13.8, literacy: 0.540, 92.2%, 91.2% (2010, 2011, and 2009; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 8.4, expected years of schooling 13.4, literacy: 0.491, 87.9%, 89.59% (2010, 2005, and 2007; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low in one country and medium in another based on the education parameter (<8.25 years and <10.47 years, respectively), and the literacy calculation is considered low in one country and medium in the other (<0.5 and <0.8, respectively; UNDP, 2009). The	• The establishment of the ALT created a framework for regulation but does not have a mechanism to address differences in the countries' water management (WWAP, 2003). The structure of water governance institutions also varied between the two countries (Mancilla García, 2013). • The Bolivian water legislation was considered "fragmentary and outdated" in 2007 (Martínez Gonzales & Zuleta Roncal, 2007, p. 26). Additionally, existing laws were perceived to not provide equitable access to indigenous communities (Draper, 2010). • Most waste and sanitation were managed by municipalities, coordinated at a regional level, and supervised at a national level (Mancilla García, 2013). There was criticism that a lack of local support in this process led to insufficient treatment (Mancilla García, 2013). • The Basic Sanitation and Drinking Water Law was established in Bolivia in 1999 (WWAP, 2003). This law promoted privatization of water resources (Draper, 2010). • In response to protests, CONAIG was created in 2002 to revise Bolivia water laws with consideration of stakeholders (WWAP, 2003). • In 2004, the Bolivian government passed a law that recognizes the right to water and guarantees water access for indigenous and agricultural communities (Draper, 2010). • The Peruvian government began to decentralize authority in water management in the 2000s (Mancilla García, 2013). The decentralization in Peru lead to the creation of regional government structures in 2003 (Guevara-Pérez, 2018). • In 2010, the corruption perception index was 2.8/10 in Bolivia and 3.5/10 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
				countries' literacy percentage is high and the basin specific literacy percentage is medium (>80% and <80%, respectively; UNDP, 2009). • Given that there is some risk awareness and access to data and literacy is medium, educational vulnerability is medium.	
	2016 Bi-national Commitment and Current Status	Medium	Medium	Medium	Medium
		• It is assumed that water treatment within the basin is less than the national averages as per the 2009 trends. In spite of increasing rates of urbanization, it is assumed that the rates of water access have not decreased since 2009. Therefore, it is assumed that at least 50% of the basin has access to improved water sources. • Bolivia percent of people using at least basic drinking water services: 92.8, percent of rural population: 78.1, percent of urban population: 99.4 (2017; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 91.1/50.4, percent of rural population: 75.6/20.8, percent of urban population: 95.6/58.8 (2010; The World Bank, 2020). • Given the assumption that drinking water treatment meets the 50% threshold, regional development is medium.	• It is assumed that the extractive industry continues to maintain economic success in both countries in spite of its high water usage. • In 2011, approximately 81.4% of the population in the basin was below the poverty line (PNUMA, 2011 as cited in Mancilla García, 2013). • Bolivia GNI per capita: \$3040/\$3370 (2016/2018), adjusted income: 0.593, gap at national poverty line: 16.9, urban gap at national poverty line: 10.5, rural gap at national poverty line: 30.5 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru GNI per capita: \$6110/\$6470 (2016/2-18), adjusted income: 0.684, gap at national poverty line: 5.8, urban gap at national poverty line: 3.3, rural gap at national poverty line: 13.7 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (<\$1006/\$996 and <\$3956/\$3896, respectively; 2019). • Given the financial success of the mining industry, it is assumed that participants in the mining sectors have greater incomes than other populations in the basin. Based on the financial income and continued growth of the industry, the economic vulnerability is considered to be medium.	• There is a high level of public awareness that pollution is occurring, and this awareness is affiliated with an understanding of some of the risks of pollution (Williams, 2015; Shahriari, 2012; van Eerten, 2016). However, administrative communication about water quality has been lacking (Williams, 2015). • Bolivia average years of schooling: 9.0, expected years of schooling: 14, literacy: 0.657, 92.5%, 92.5% (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 9.2, expected years of schooling 13.8, literacy: 0.625, 94.2%, 94.4% (2018, 2015, and 2017; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 years and <10.49 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%; UNDP, 2009). • Given that there is some risk awareness, information is not easily accessible, and literacy is high, educational vulnerability is considered medium.	• The Law of the Rights of Mother Earth and the Framework Law of Mother Earth and Integral Development for Living Well were passed in Bolivia in 2010 and 2012, respectively, and provide the right to water and freedom from contamination (Gonzales Iwanciw et al., 2013). • In 2013, Bolivia was debating a new Water Law with approximately 20 versions in circulation (Gonzales Iwanciw et al., 2013). It is not apparent that a new water law has been passed. • Non-compliance with regulation has been reported in the mining sector (Mancilla García, 2016). • City officials, including El Alto's mayor, have reported difficulty in enforcing water regulations due to the potential for local unrest and protest (Shahriari, 2012). • In 2019, the corruption perception index was 31/100 in Bolivia and 36/100 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, enforcement is inconsistent, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.
Tourism industry	1955-1957 Joint Ownership Agreement Signed	High	Low	High	High
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Groundwater is available in the region but is more expensive based on the need to install wells and operate pumps. As of 2005, few areas used groundwater (Revollo et al., 2005).	• Tourism was not common in the Lake Titicaca region and largely began in the 1970s in Taquile (Zorn, 2004). • Bolivia adjusted income: 0.485 (1955; Prados de la Escosura, 2019). • Peru adjusted income: 0.587 (1955; Prados de la Escosura, 2019).	• Bolivia average years of schooling: 2.08, literacy: 0.105 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Peru average years of schooling: 2.7, literacy: 0.178 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of	• The Water Law was established in Bolivia in 1906 which focused on water use and ownership (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • A decree on land reform and the water regime and a law on excess water use was established in Bolivia in 1953 and 1945, respectively

Stakeholder	Event	Regional Development	Economic	Education	Political
		• The tourism industry is assumed to be distributed between urban and rural regions based on tourist sites in the basin (Mancilla García, 2013). Therefore, water access rates must consider both urban and rural access. • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• Based on the former UNDP human development thresholds, the countries are considered low and medium development based on the income parameter (<0.5 and <0.8, respectively; UNDP, 2009). • The absence of a tourism industry implies that economic vulnerability was low as the market had not yet been created.	schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • As a result of the low literacy, educational vulnerability is considered high.	(WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). • Although water laws existed, the laws only applied to one riparian country and did not focus on pollution controls. As a result, political vulnerability is considered high.
	1986 Ratification of the Agreement	High	High	Medium	Medium
		• Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is high.	• Economic and political instability strongly impacted the growing tourism industry of Peru in the late 1980s (Mitchell, 2008). Given that similar conditions were occurring in Bolivia, it is assumed that tourism was also halted at this period. • The tourism industry is moderately dependent on water resources, as the cultural significance of the area is tied to the lake (Mancilla García, 2013). • Bolivia GNI per capita: $740, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $840, adjusted income: 0.502 (1986 and 1985; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds from 1987, both countries were lower-middle income (>$481 and <$1941; 2019). • Given the direct economic impacts on the tourism industry, economic vulnerability is high.	• Bolivia average years of schooling: 5.36, literacy: 0.281, 63.2% (1985 and 1976; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 5.83, literacy: 0.373, 81,9% (1985 and 1981; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • As a result of the medium and high literacy and low average years of schooling, educational vulnerability is considered medium.	• The Bolivian Civil Code was established in 1975 (WWAP, 2003). Bolivian decrees on regulation of industrial waste and solid waste were established in 1985 and 1977, respectively (Martínez Gonzales & Zuleta Roncal, 2007). • The General Water Law was established in Peru in 1969 to regulate water use and conservation (WWAP, 2003; Martínez Gonzales & Zuleta Roncal, 2007). Additionally, a 'sanitation code' was established in Peru in the same year to address environmental health (Martínez Gonzales & Zuleta Roncal, 2007). • Because water laws existed in both countries with a limited focus on pollution controls, the political vulnerability is considered medium.
	1996 Establishment of the ALT	High	Medium	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • As a result of the low access to water treatment and minimal use of alternate water resources, regional development vulnerability is considered high.	• The tourism industry became a fast-growing industry in Peru in the late 1990s (Boza, 1997 as cited in Mitchell, 2008). The growth of the industry impacted both urban and rural spaces with growth of hotels and services in cities and along the islands of the lake (Mitchell, 2008; Mancilla García, 2013). Patterns of employment were also altered in this time, with members of the community moving into the tourism industry (Mancilla García, 2013). • Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty.	• Bolivia average years of schooling: 7.1, expected years of schooling: 12.1, literacy: 0.373, 80.0% (1995 and 1992; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 7.3, expected years of schooling 12.2, literacy: 0.457, 87.2% (1995 and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years) and literacy calculation is considered low (<0.5; UNDP, 2009). The literacy percentage is high (>80%).	• The Environment Law was established in Bolivia in 1992 which enables pollution regulation (WWAP, 2003; Mancilla García, 2013). • The Environment and Natural Resources Code was established in Peru in 1992 which makes a federal ministry responsible for quality of consumable water (WWAP, 2003). • The corruption perception index for Bolivia was 3.4/10 in 1996 (Transparency International, 2020). • Bolivia moved to decentralize water management in the 1990s (Mancilla García, 2013). • As both countries have environmental regulations that address regulation of pollution,

Stakeholder	Event	Regional Development	Economic	Education	Political
			• Bolivia GNI per capita: $900, adjusted income: 0.519 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2150, adjusted income: 0.580 (1996 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3116; 2019). • Although poverty was widespread in the basin, it is assumed that the boom in the tourism sector positively influenced the income of participants relative to other members of the community. Based on the financial income and growth of the industry, the economic vulnerability is considered to be medium.	• With a consideration of both literacy and average years of schooling, the educational vulnerability is considered medium.	local regulations were established in one country, and the corruption perception index is medium (>33% and <66%), the political vulnerability is considered medium.
	1997-1998 Ratification of RAMSAR	High	Medium	Medium	Medium
		• Within the region, approximately 73.5% of the population had "one basic need that [was]… not met" throughout 1990 and 2001 (Martínez Gonzales & Zuleta Roncal, 2007, p. 22). • Given the 2003 status of water treatment in the basin, it is assumed that less than 19-24% of the population had access to drinking water treatment (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 79.4, percent of rural population: 54.2, percent of urban population: 95.1 (2000; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 80.7/45.1, percent of rural population: 51.3/14.0, percent of urban population: 91.5/56.5 (2000; The World Bank, 2020). • As a result of the low access to water treatment in the basin and minimal use of alternate water resources, regional development vulnerability is considered high.	• The tourism sector continued to grow through the 1990s (Mitchell, 2008). • Given the high percentage of population without a basic need met in the 1990s (73.5%; Martínez Gonzales & Zuleta Roncal, 2007), it is assumed that a substantial fraction of the population had limited economic means and was likely in poverty. • Bolivia GNI per capita: $950, adjusted income: 0.519 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $2280, adjusted income: 0.580 (1997 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, both countries were lower-middle income (>$786 and <$3126; 2019). • Although there is a high dependence on water resources and poverty within the basin, it is assumed that tourism participants have a greater income relative to other members of the basin. Based on the financial income and continued growth of the industry, the economic vulnerability is considered to be medium.	• Bolivia average years of schooling: 7.2, expected years of schooling: 12, literacy: 0.373, 80.0% (1997, 1995, and 1992; UNDP, 2020; Prados de la Escosura, 2019, The World Bank, 2020). • Peru average years of schooling: 7.5, expected years of schooling 12.2, literacy: 0.457, 87.2% (1997, 1995, and 1993; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%). • Given the high literacy and low average years of schooling, educational vulnerability is medium.	• The establishment of the ALT provided an autonomous organization to manage the lake and enable water quality protection (Martínez Gonzales & Zuleta Roncal, 2006). With a technical organization in each country (PELT in Peru and UOB in Bolivia), the organization was also connected to the governance in each state (Priscoli & Wolf, 2010). • The corruption perception index for Bolivia was 2.05/10 in 1997 (Transparency International, 2020). • As both countries have environmental regulations that address the regulation of pollution, and the corruption perception index is high for one country (<33%), the political vulnerability is medium.
	2009-2010 Withdrawal of Bolivian Support	Medium	Medium	Medium	Medium
		• In 2003, approximately 19% and 24% of the basin population had access to drinking water treatment in Peru and Bolivia, respectively (WWAP, 2003). However, these rates varied in large cities (WWAP, 2003).	• The tourism industry continued to grow and tourism was considered "an important and stable source of income," in relevant cities (Mancilla García, 2013, p. 211). Urban families were reported to have mixed occupations with some family members participating in tourism	• By 2010, there was a general public awareness that waste management and population growth contributed to water quality degradation (Mancilla García, 2013). Farmers (and it is assumed that fishing communities) attributed sources of pollution to farther away cities,	• The establishment of the ALT created a framework for regulation but does not have a mechanism to address differences in the countries' water management (WWAP, 2003). The structure of water governance institutions

Stakeholder	Event	Regional Development	Economic	Education	Political
		• By 2009, approximately 50% of the basin population had access to improved sources of water (Calizaya, 2009). • Medical facilities are poor and predominantly located away from rural areas (WWAP, 2003). • Bolivia percent of people using at least basic drinking water services: 87.9, percent of rural population: 68.6, percent of urban population: 97.7 (2010; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 87.2/48.5, percent of rural population: 65.6/18.0, percent of urban population: 93.9/57.9 (2010; The World Bank, 2020). • Given the increasing trend of drinking water access in 2009 which met the threshold of 50%, regional development vulnerability is medium.	while others maintained a rural agricultural plot (Mancilla García, 2013). • In 2003, 73.5% of the basin population in Peru and 69.8% of the basin population in Bolivia lived in poverty (WWAP, 2003). • Bolivia GNI per capita: $1780, adjusted income: 0.569, gap at national poverty line: 24.6, urban gap at national poverty line: 17, rural gap at national poverty line: 39.3 (2010 and 2009; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Peru GNI per capita: $4410, adjusted income: 0.664, gap at national poverty line: 9, urban gap at national poverty line: 4.5, rural gap at national poverty line: 21.3 (2010; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (>$1006 and >$3976, respectively; 2019). Given the financial success of the tourism industry, it is assumed that participants in the tourism sector have greater incomes than other populations in the basin. Based on the financial income and continued growth of the industry, the economic vulnerability is considered to be medium.	demonstrating an awareness of the greater hydrologic system (Mancilla García, 2013). • PELT and the USAID sought to increase public awareness through distribution of flyers and "awareness" programs (Mancilla García, 2013, p. 151). • Although the ALT supported some implementation of monitoring programs, general monitoring data was limited (Rieckermann et al., 2006). In 2006, only Inner Puno Bay was monitored on a monthly basis, and several wastewater operators were uncertain about the quality of their effluents (Rieckermann et al., 2006). NGOs and government organizations collected data periodically throughout other parts of the lake; however, the organization did not share all collected data (Mancilla García, 2013). • In 2010, officials were concerned that there was insufficient monitoring data to manage the lake (Mancilla García, 2013). • In 2003, the illiteracy rate in the basin was 22% (WWAP, 2003). These illiteracy rates indicated that the education in the basin was "remarkably low" (Revollo et al., 2005, p. 381). • Bolivia average years of schooling: 7.8, expected years of schooling: 13.8, literacy: 0.540, 92.2%, 91.2% (2010, 2011, and 2009; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 8.4, expected years of schooling 13.4, literacy: 0.491, 87.9%, 89.59% (2010, 2005, and 2007; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low in one country and medium in another based on the education parameter (<8.25 years and <10.47 years, respectively), and the literacy calculation is considered low in one country and medium in the other (<0.5 and <0.8, respectively; UNDP, 2009). The countries' literacy percentage is high and the basin specific literacy percentage is medium (>80% and <80%, respectively; UNDP, 2009).	also varied between the two countries (Mancilla García, 2013). • The Bolivian water legislation was considered "fragmentary and outdated" in 2007 (Martínez Gonzales & Zuleta Roncal, 2007, p. 26). Additionally, existing laws were perceived to not provide equitable access to indigenous communities (Draper, 2010). • Most waste and sanitation were managed by municipalities, coordinated at a regional level, and supervised at a national level (Mancilla García, 2013). There was criticism that a lack of local support in this process led to insufficient treatment (Mancilla García, 2013). • The Basic Sanitation and Drinking Water Law was established in Bolivia in 1999 (WWAP, 2003). This law promoted privatization of water resources (Draper, 2010). • In response to protests, CONAIG was created in 2002 to revise Bolivia water laws with consideration of stakeholders (WWAP, 2003). • In 2004, the Bolivian government passed a law that recognizes the right to water and guarantees water access for indigenous and agricultural communities (Draper, 2010). • The Peruvian government began to decentralize authority in water management in the 2000s (Mancilla García, 2013). The decentralization in Peru lead to the creation of regional government structures in 2003 (Guevara-Pérez, 2018). • In 2010, the corruption perception index was 2.8/10 in Bolivia and 3.5/10 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
				• Given that there is some risk awareness and access to data and literacy is medium, educational vulnerability is medium.	
	2016 Bi-national Commitment and Current Status	Medium	Medium	Tourism	Medium
		• It is assumed that water treatment within the basin is less than the national averages as per the 2009 trends. In spite of increasing rates of urbanization, it is assumed that the rates of water access have not decreased since 2009. Therefore, it is assumed that at least 50% of the basin has access to improved water sources. • Bolivia percent of people using at least basic drinking water services: 92.8, percent of rural population: 78.1, percent of urban population: 99.4 (2017; The World Bank, 2020). • Peru percent of people using at least basic/safe drinking water services: 91.1/50.4, percent of rural population: 75.6/20.8, percent of urban population: 95.6/58.8 (2010; The World Bank, 2020). • Given the assumption that drinking water treatment meets the 50% threshold, regional development is medium.	• In 2011, approximately 81.4% of the population in the basin was below the poverty line (PNUMA, 2011 as cited in Mancilla García, 2013). • Bolivia GNI per capita: $3040/$3370 (2016/2018), adjusted income: 0.593, gap at national poverty line: 16.9, urban gap at national poverty line: 10.5, rural gap at national poverty line: 30.5 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru GNI per capita: $6110/$6470 (2016/2-18), adjusted income: 0.684, gap at national poverty line: 5.8, urban gap at national poverty line: 3.3, rural gap at national poverty line: 13.7 (2018, 2015, and 2014; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the World Bank income thresholds, one country is lower-middle income and one country is upper-middle income (<$1006/$996 and <$3956/$3896, respectively; 2019). • Given the financial success of the tourism industry, it is assumed that participants in the tourism sector have greater incomes than other populations in the basin. Based on the financial income and continued success of the industry, the economic vulnerability is considered to be medium.	• There is a high level of public awareness that pollution is occurring, and this awareness is affiliated with an understanding of some of the risks of pollution (Williams, 2015; Shahriari, 2012; van Eerten, 2016). However, administrative communication about water quality has been lacking (Williams, 2015). • Bolivia average years of schooling: 9.0, expected years of schooling: 14, literacy: 0.657, 92.5%, 92.5% (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Peru average years of schooling: 9.2, expected years of schooling 13.8, literacy: 0.625, 94.2%, 94.4% (2018, 2015, and 2017; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 years and <10.49 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is high (>80%; UNDP, 2009). • Given that there is some risk awareness, information is not easily accessible, and literacy is high, educational vulnerability is considered medium.	• The Law of the Rights of Mother Earth and the Framework Law of Mother Earth and Integral Development for Living Well were passed in Bolivia in 2010 and 2012, respectively, and provide the right to water and freedom from contamination (Gonzales Iwanciw et al., 2013). • In 2013, Bolivia was debating a new Water Law with approximately 20 versions in circulation (Gonzales Iwanciw et al., 2013). It is not apparent that a new water law has been passed. • Non-compliance with regulation has been reported in the mining sector (Mancilla García, 2016). • City officials, including El Alto's mayor, have reported difficulty in enforcing water regulations due to the potential for local unrest and protest (Shahriari, 2012). • In 2019, the corruption perception In 2019, the corruption perception index was 31/100 in Bolivia and 36/100 in Peru (Transparency International, 2020). • Because both countries have environmental regulations that address regulation of pollution, the ALT enables joint management efforts, enforcement is inconsistent, and the corruption index is high in one country and medium in another (<33% and <66%, respectively), political vulnerability is medium.

Table 21. Comprehensive analysis of primary stakeholder risk in the Lake Titicaca basin.

Stakeholder	**Event**	**Ingestion (water)**		**Ingestion (aquatic biota, irrigated crops, and/or livestock)**		**Dermal Contact (domestic and/or recreational)**		**Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)**	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
Inhabitants of large cities/ municipalities	1955-1957 Joint Ownership Agreement Signed	Yes	Medium	Yes	Low	No	Medium	No	Low
		• There is a long history of mining in the basin that has historically contributed to mining waste (i.e., heavy metals) loading in the lake (Garcia et al., 2005; Martínez Gonzales & Zuleta Roncal, 2007). These pollutant loads flow into the lake through tributaries, causing trace metal pollutants to concentrate in sediments along the shoreline (Mancilla García, 2013; Monroy et al., 2014). • Heavy metal pollution also affects the tributaries and other surface waters in the basin (Caliyza et al., 2010). • It is likely that metal concentrations were trace in the majority of the lake's surface water, and thus, there was likely a water consumption impact.	• By 2007, approximately 80% of Peruvian urban areas and 22% of Bolivian urban areas of relied on surface water sources (basin average of 48%; Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that historically, the reliance on surface water was consistent or greater due to the ease of access. • Many of the large cities are in close proximity to the lake. It is assumed that these cities use adjacent reservoirs, including the lake, as a surface water source. • However, not all large cities are adjacent to the lakeshore (e.g., El Alto), and some have been identified to also use water from outside of the basin (Agramont et al., 2018). • As a result of mixed water sources, the water ingestion exposure is medium.	• Heavy metals can bioaccumulate in crops, biota, and livestock which can increase their concentrations through biomagnification. Therefore, the presence of trace heavy metals can present a health risk through ingestion. • Additionally, fish were likely caught in close proximity to the shoreline based on the traditional means of fishing (Orlove, 2002). Given that mining impacts are concentrated along the shoreline, fish from these areas may have increased exposure to heavy metals.	• Given the size of cities and their relative productivity in the 1950s, it is assumed that most food sources were local from the lake basin. • A majority of crops within the basin were grown within close proximity to the lake, and irrigated plots use surface water irrigation (Williams, 2015; WWAP, 2003). Given that tributaries were often the conduits for metals contamination, it is likely that irrigation water from the streams and lake were impacted by metals. However, a majority of agriculture is not irrigated (WWAP, 2003). • Any protein from the lake was likely also impacted by trace metals. • Livestock also likely drank from tributaries and lake and may have consumed fodder from the lake which has the capacity to bioaccumulate	• Heavy metals can be a source of risk through dermal exposure. However, given the likely trace concentrations in the lake during the pre-1955 time period, dermal exposure is not considered to have an impact.	• It is assumed that dermal contact is highest in communities in close proximity to the waterbody due to ease of contact and access. • The large cities within the basin are in varying degrees of proximity to the lake. Therefore, exposure is considered medium.	• Although metals concentrations can lead to some exposure through various industries, it is unlikely that trace concentrations of mercury impacted the functioning of sectors within urban areas.	• Various industries within major cities, including mining, required the use of water. However, not all sectors are heavily water dependent or dependent on quality water. Therefore, exposure is considered low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
					metals (WWAP, 2003). • Therefore, some of food sources may have been impacted by heavy metals. However, because metals had not yet been identified to bioaccumulate in fish (as mercury bioaccumulation was first observed in the 2000s only mercury), it is assumed that bioaccumulation in each of the food sources was low (Martínez Gonzales & Zuleta Roncal, 2007). Therefore, the exposure is considered low.				
	1986 Ratification of the Agreement	Yes	Medium	Yes	Low	Yes	Medium	Yes	Low
		• In the 1980s, pollution was observed in Puno Bay as a result of urban and industrial effluents (i.e., untreated and poorly treated wastewater; NorthCote, Morales, Zea, & Vazquez, 1989 as cited in Archundia et al., 2017; Mancilla García, 2013). • These effluents came from communities and increased the loading of nutrients, biological oxygen	• It is assumed that the drinking water exposure is consistent with previous years.	• The increase of biological loading on the lake is capable of harming biota such as fish through an increase of pathogens and parasites (WWAP, 2003). These impacts likely contributed to the decrease of fish stock that was observed in the 1970s and accompanied the introduction of trout into the system (Mancilla García, 2013).	• Given that heavy metals bioaccumulation in lake fish was not observed until the 2000s, and aquatic biota have greater exposure to contaminants, it is still assumed that ingestion exposure is low.	• The presence of biologic waste also contributes to dermal exposure, as contact with untreated or poorly treated wastewater can increase the spread of gastrointestinal diseases. • In combination with the trace heavy metal loading on the lake, there is an impact of the lake's pollutants on the dermal exposure pathway.	• It is assumed that dermal exposure is consistent with previous years.	• The introduction of urban wastes can impact industrial and commercial use of water due to clogging of water intakes and residue following water use. Therefore, the water quality is assumed to impact livelihoods in urban areas.	• It is assumed that livelihood use exposure is consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		demand (BOD), and pathogens in the lake (Mancilla García, 2013). • Improperly closed mines in 1985 and 1987 increased the loading of heavy metals on the lake through the Suches River (The World Bank et al., 2009 as cited in Mancilla García, 2013). • Mining wastes continued to increase heavy metals loading on the lake although the mining sector was not very active in the region during the 1980s (Garcia et al., 2005). • As a result of these sources of contamination, there is a continued water consumption impact.		• The increased algal growth can also endanger livestock that drink from the lake given the presence of pathogens. • Additionally, the continued legacy and loading of heavy metals is capable of adversely affecting biota. • As a result of these sources of contamination, there is a food ingestion impact.					
	1996 Establishment of the ALT	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Eutrophic water quality impacts and duckweed were observed in Puno Bay in 1992 as a result of untreated wastewater in the region (Martínez Gonzales & Zuleta Roncal, 2007). • In the 1990s, water quality impacts were also identified in the in the El Alto	• The contamination of alternate water resources in the basin increases the exposure to drinking water contamination in cities. El Alto, is an exception to this exposure as not all of the water used in El Alto is from the lake basin (Agramont et al., 2018).	• The continued organic and heavy metal loading continued to serve as a source of potential risk to all food sources in the basin.	• With the increase in pollution, it is assumed that there is a greater impact to ingestion exposure. As a result, the ingestion exposure is assumed to be medium. It is also assumed that urban communities also have access to food sources from outside of the basin	• The continued organic and heavy metal loading continued to serve as a source of potential risk to dermal contact in the basin.	• The dermal contact exposure was considered consistent with previous years.	• The continued organic and heavy metal loading continued to serve as a source of potential risk to industrial and commercial use of water in the basin.	• The livelihood use of water exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		watershed which drains to Cohana Bay (Chiqui, 2001 in as cited in Archundia et al., 2017). • The high nutrient load from wastewater enabled the spread of duckweed in both bays (Martínez Gonzales & Zuleta Roncal, 2007). • Due to the large size of the lakes, the greatest organic impacts were concentrated in bays (Cohana and Puno) and near the mouth of the Coata River (Martínez Gonzales & Zuleta Roncal, 2007). It is likely that most of the other shoreline areas were impacted, but limited data was collected (Rieckermann et al., 2006; WWAP, 2003). At this point, authorities did not consider the impact of water quality to be widespread (Revollar, 2004 as cited in Rieckermann et al., 2006). • Pollutant loadings continued to impact tributaries which drained wastewater and mining influents	• Given the expansion of pollution in most water sources, drinking water ingestion exposure is considered high.		as a result of regular transit and trade.				

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		into the lake. It is likely that these impacts began to compromise alternate drinking water sources (including groundwater; Mancilla García, 2013). • Eutrophic conditions, pathogens, and heavy metals all created health risk for communities that drink lake water or utilize alternate water sources in proximity of the lake. Therefore, there is a continued water ingestion impact.							
	1997-1998 Ratification of RAMSAR	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Wastewater effluents and mining wastes continued to be discharged into the lake. Therefore, the impact is assumed to be consistent with previous years.	• It is assumed that the drinking water exposure is consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that ingestion exposure is consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that the dermal exposure is consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that the livelihood exposure is consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• The impact of wastewater discharge on the lake continued to increase which enabled the spread of duckweed. By 2008, duckweed covered 42 square kilometers of	• By 2007, approximately 48% of urban areas in the basin relied on surface water sources, and it was reported that groundwater aquifers were not frequently used	• Wild fisheries collapsed in the early 2000s, and fish biomass decreased by approximately 45% since the 1980s (Williams, 2015; Monroy et al., 2014). These	• In El Alto, low rates of animal protein consumption were reported (FAO, 2015). Therefore, there was likely little exposure to contaminants through fish and limited exposure	• The presence of cyanobacteria increased dermal risk as it can release toxins that can be harmful based on contact. Along with existing organic and heavy metal pollution, there was	• Although not all cities are in direct proximity of the lake, the contamination of major tributaries that run adjacent to cities increased the frequency of dermal	• The impact is assumed to be consistent with previous years.	• It is assumed that the livelihood exposure is consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		Cohana Bay and 12 square kilometers of Puno Bay (The World Bank et al., 2009 as cited in Mancilla García, 2013). Cohana Bay was also considered eutrophic (Fontúrbel Rada, 2005). • Algal growth in the lake existed at depths of up to 100 meters, and some cyanobacteria was present (WWAP, 2003). Cyanobacteria is capable of releasing toxins that are harmful if ingested. • High concentrations of tin were observed throughout the lake (Martínez Gonzales & Zuleta Roncal, 2007), and physical waste and odors were also observed in the lake and its tributaries (Mancilla García, 2013). • During this time period, other localized pollution continued to increase. Heavy metals contamination was identified in Copacabana Bay and rivers that pass near and downstream of El Alto (Rieckermann et al., 2006; Duwig et al., 2014).	(Martínez Gonzales & Zuleta Roncal, 2007; Revollo et al., 2005). • Given the contamination of the lake and alternate water sources, water ingestion exposure is high.	decreases were likely linked to pollution including the presence of duckweed which caused anoxic conditions and altered fish reproduction due to its blocking of sunlight (Williams, 2015; Mancilla García, 2013). Heavy metal toxicity also likely impacted the fish stock (Mancilla García, 2013). • Heavy metal concentrations were observed to be elevated at the mouth of rivers and to have bioaccumulated, leading to high mercury concentrations in certain species of fish in Puno Bay (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, fish were observed to have deformities related to heavy metal contamination in the National Reserve of Titicaca (Mancilla García, 2013). • This data suggests a strong impact of water quality on	through crops (as most crops were not irrigated as of 2003). • Given that some of the food sources are assumed to be from the basin, it is assumed that ingestion exposure remained medium.	a continued impact on dermal contact.	exposure to city residents. • Additionally, high rates of gastrointestinal illness reported throughout the basin suggested exposure of community members to untreated wastewater (Maydana Iturriaga et al., 2009 as cited in Mancilla García, 2013; PNUMA, 2011 as cited in Mancilla García, 2013).		

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		However, sediment sorption and bioremediation of reeds were observed to decrease the impact of some of these discharges on Cohana Bay (Duwig et al., 2014). • Both countries acknowledged that localized contamination was "severe" (Rieckermann et al., 2006, p. 507). In response to contamination, since 2006, the ALT and PELT have worked to remove duckweed and waste from Puno Bay (Mancilla García, 2013). • This deterioration of conditions suggests a continued impact to drinking water ingestion in the lake.		ingestion of biota from the lake.					
	2016 Bi-national Commitment and Current Status	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• By 2013, several major lake tributaries were confirmed to be polluted including the Ramis, Coata, Suches, and Katari Seco, Seque, and Pallina rivers (Mancilla García, 2013; The World Bank et al., 2009 as	• Urban areas continued to have a high reliance on surface waters in 2013 (Gonzales Iwanciw et al., 2013). • Additionally, reservoirs for El Alto and La Paz were impacted by mining contamination	• Metals concentrations in most fish and benthic species throughout the lake exceeded international thresholds (Monroy et al., 2014). Mercury was also found in high concentrations in lake sediments	• It is assumed that ingestion exposure is consistent with previous years.	• Given the increased concentrations of pollutants in the lake, the water quality has a dermal exposure impact.	• It is assumed that dermal exposure is consistent with previous years.	• Given the increased concentrations of pollutants on the lake, it is assumed that the water quality has an impact through livelihood use.	• It is assumed that the livelihood exposure is consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		cited in Mancilla García, 2013). • Lead concentrations near tributary discharges exceeded international thresholds (Monroy et al., 2014). • Conditions also worsened on Cohana Bay, with an algal bloom that covered 50% of the shallow part of the lake (Lake Huiñaimarca which includes Cohana Bay) in 2005 (Achá et al., 2018). This event enabled a greater release of toxic methylmercury Achá et al., 2018). • However, it was reported in 2012 that the majority of the lake was "still clean" (Shahriari, 2012). • Various interventions had been implemented, including a large treatment plant for El Alto discharges; however, the lake has a 1,000 year retention time, suggesting that cycling of contaminants will exist into the future (Mancilla García, 2013; Rieckermann et al., 2006).	(Agramont et al., 2018; Salvarredy-Aranguren, Probst, Roulet, & Isaure, 2008). • As a result of the high contamination in the lake, residents of Copacabana informally altered their drinking water sources to wells and springs (Collyns, 2017). • Although alternate water sources are being used, they are generally informal, and therefore, drinking water exposure is still considered high.	(PNUMA, 2011 as cited in Mancilla García, 2016). • The eutrophication event in Lake Huiñaimarca (which contains Cohana Bay) led to a 5 week long anoxic event that killed fish, frogs, and birds in 2015 (Archundia et al., 2017). • Finally, there are reports of cattle deformities related to drinking water from the tributaries to the lake (Shahriari, 2012). This has led agricultural workers to use alternate water sources including wells which may decrease impact on livestock (Shahriari, 2012). • The patterns of bioaccumulation and toxicity indicate a high impact of pollution on food sources within the basin.					

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• Based on contaminant impacts, there is a continued risk to water ingestion.							
Rural communities (Fishing Based)	1955-1957 Joint Ownership Agreement Signed	Yes	High	Yes	Medium	No	High	No	High
		• The legacy of mining in the basin suggests that there were trace heavy metal concentrations throughout the lake that are concentrated along the shoreline (Garcia et al., 2005; Monroy et al., 2014; Martínez Gonzales & Zuleta Roncal, 2007). • Trace heavy metal concentrations in surface water can impact health through water consumption.	• Rural areas were heavily dependent on surface water sources in 2007 (Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that historically, this pattern of surface water reliance was consistent or greater due to the ease of access.	• Heavy metals are capable of bioaccumulating in crops, aquatic biota, and livestock. • The fish caught for consumption were likely caught near the shore based on fishing practices (Orlove, 2002). Therefore, fish are more likely to have a heavy metal exposure. • Additionally, crops from the lake that are capable of bioaccumulation were used as cattle fodder (Mancilla García, 2013). These feeding patterns can increase metal uptake in livestock. As a result, there is an impact to ingestion.	• Riparian communities often use resources from the lake and maintain agricultural crops (Mancilla García, 2013). In particular, fishing communities also raised livestock and crops as a means of subsistence (Orlove, 2002). • Crop irrigation is primarily sourced from surface water, which, in riparian communities, is likely from the lake (WWAP, 2003). However, a majority of agriculture was not irrigated (WWAP, 2003). • As primarily subsistent communities, the diets of fishing communities' likely consisted of food from the basin including high quantities of fish. Therefore, fishing communities have high ingestion exposure.	• Heavy metals pose risk through dermal exposure. However, given that the concentrations were likely trace during this time period, dermal exposure was not considered to have an impact from heavy metals. • Rearing of livestock also presents a potential dermal risk as livestock defecation can impact nearby water sources. However, cattle densities were low in the 1950s (Mancilla García, 2013). Therefore, there was not sufficient risk from dermal contact.	• Fishing communities are often riparian which implies a greater dermal exposure through direct water use and recreational exposure while fishing (Revollo et al., 2005; Orlove, 2002). As a result, dermal exposure was high.	• Although bioaccumulation can affect fish, there was not a clear impact on fisheries in the 1950s.	• There was a spike in trout fishing in the 1950s as a result of stocking the lake (Mancilla García, 2013). This enabled a growth of the fishing industry at the time. • The fishing industry is innately tied to the quality of water in the lake; therefore, livelihood use exposure is high.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
					However, because metals were not identified in fish tissue until the 2000s, it is assumed that bioaccumulation in each food source was low (Martínez Gonzales & Zuleta Roncal, 2007). As a result, ingestion exposure was medium.				
	1986 Ratification of the Agreement	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• The lake began to display impacts of urban and industrial effluents as a result of continued loading of nutrients, BOD, and pathogens (NorthCote et al., 1989 as cited in Archundia et al., 2017; Mancilla García, 2013). • Mining wastes were simultaneously increased in the lake through improper closure of sites (The World Bank et al., 2009 as cited in Mancilla García, 2013). • Together, the organic and heavy metal effluents provide a risk to drinking water ingestion.	• The patterns of drinking water consumption are assumed to be consistent with previous years.	• The increase of biological loading on the lake is capable of harming biota through an increase of pathogens and parasites (WWAP, 2003). Along with toxicity from the continued sources of heavy metals, both fish and livestock can bioaccumulate contaminants and be adversely impacted. • As a result, there is an impact to ingestion	• The patterns of consumption are assumed to be consistent with previous years.	• The presence of biologic waste is also a risk to dermal exposure, as contact with untreated or poorly treated wastewater can increase the spread of gastrointestinal diseases. • In combination with increasing concentrations of trace heavy metals, there is an impact to dermal exposure..	• It is assumed that dermal exposure is consistent with previous years, with high exposure due to proximity and the nature of fishing.	• Trout species began to impact the local fish in the lake in the 1970s (Mancilla García, 2013). Trout were then captured and kept in cages to support a balanced ecosystem (Mancilla García, 2013). • The presence of organic contamination can decrease oxygen concentrations and introduce parasites to the lake which. Along with toxicity from heavy metals, these contaminants can lead to fish kills. • It is possible that water quality impacts began to affect fisheries in the 1970s which coincided with the impacts of trout. Therefore, there is a	• Although fishermen have a high dependence on the volume and quality of fish, because no clear impacts of water quality were observed in fisheries during the 1980s, the frequency of exposure is low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
								livelihood use impact.	
	1996 Establishment of the ALT	Yes	High	Yes	High	Yes	High	Yes	Medium
		• Eutrophic conditions began to manifest in bays and shorelines around the lake (Martínez Gonzales & Zuleta Roncal, 2007). These nutrient loadings enabled the spread of duckweed. • Alternate water sources also began to be impacted due to pollutant introduction and flow through tributaries (Mancilla García, 2013). • Eutrophic conditions, pathogens, and heavy metals all create health risk for communities that drink lake water or use alternate water sources in proximity of the lake.	• The patterns of drinking water consumption are assumed to be consistent with previous years.	• The continued contaminant load of organic pollutants and heavy metals continued to present risk to most food sources in the basin.	• Given the increasing heavy metal loading in the lake, potential for bioaccumulation, and likely fish-rich diet, ingestion exposure is assumed to be high.	• The continued organic and heavy metal loading continue to serve as sources of potential risk to dermal contact.	• It is assumed that dermal exposure is consistent with previous years, with high exposure due to the nature of fishing and proximity to the lake.	• The high loading of organic contaminants can cause anoxic conditions that leads to fish kills. Additionally, the high incidence of pathogens can cause parasites in fish (WWAP, 2003). • The volume of fish in the lake began to decrease in the 1980s (Monroy et al., 2014). Therefore, there was a continued livelihood use impact.	• Although there is a high dependence on fish stocks, because clear impacts of water quality were not observed in the 1980s, the frequency of exposure is medium.
	1997-1998 Ratification of RAMSAR	Yes	High	Yes	High	Yes	High	Yes	Medium
		• Wastewater effluents and mining wastes continued to be discharged into the lake. Therefore, it is assumed that there is a continued impact to water ingestion.	• It is assumed that the drinking water exposure is consistent with previous years.	• The ingestionimpact is assumed to be consistent with previous years.	• It is assumed that ingestion exposure is consistent with previous years.	• The dermal impact is assumed to be consistent with previous years.	• It is assumed that dermal exposure is consistent with previous years, with high exposure due to the nature of fishing and proximity to the lake.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Yes	High	Yes	High	Yes	High	Yes	High
		• The continued discharge of	• In 2007, rural areas were heavily	• Wild fisheries had collapsed in the	• It is assumed that fishing communities	• The presence of cyanobacteria	• Around this time period, interview	• Wild fisheries collapsed in the	• The decrease in fisheries directly

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		wastewater effluents led to eutrophic conditions and a broad distribution of duckweed (Fontúrbel Rada, 2005). Cyanobacteria, which releases toxins, was also present in the algal blooms (WWAP, 2003). • Increased loading of heavy metals continued in the lake, and elevated concentrations of tin were observed in lake water (Martínez Gonzales & Zuleta Roncal, 2007). • Physical waste and odors were also observed in surface waters (Mancilla García, 2013). • Both countries acknowledged that localized contamination was "severe" (Rieckermann et al., 2006, p. 507). • The deterioration of conditions suggests a continued impact to drinking water ingestion in the lake.	dependent on surface water sources (Martínez Gonzales & Zuleta Roncal, 2007). • It is assumed that drinking water exposure is consistent with previous years.	early 2000s, and fish biomass decreased by approximately 45% since the 1980s (Williams, 2015; Monroy et al., 2014). These decreases were likely linked to pollution including the presence of duckweed which caused anoxic conditions and altered fish reproduction due to its blocking of sunlight (Williams, 2015; Mancilla García, 2013). Heavy metal toxicity also likely impacted the fish stock (Monroy et al., 2014). • Heavy metal concentrations were observed to be elevated at the mouth of rivers and to have bioaccumulated, leading to high mercury concentrations in certain species of fish in Puno Bay (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, fish were observed to have deformities related to heavy metal contamination	continued to consume fish given the ease of access. Therefore, the ingestion exposure is consistent with previous years.	increased dermal risk as it can release toxins that can be harmful based on contact. Along with existing organic and heavy metal pollution, there was a continued impact on dermal contact. • Livestock defecation near surface waters also presented some risk to dermal exposure (Ribera Arismendi & Marco Octavio, 2008 as cited in Mancilla García, 2013).	participants reported that they could no longer bathe in the lake due to the increase of contamination (Mancilla García, 2013). • Although behaviors may have shifted due to the acknowledgement of contamination, it is assumed that fishermen still had high dermal exposure through their occupational tasks. • Additionally, high rates of gastrointestinal illness were reported throughout the basin, suggesting continued exposure with untreated wastewater (Maydana Iturriaga et al., 2009 as cited in Mancilla García, 2013; PNUMA, 2011 as cited in Mancilla García, 2013).	early 2000s, and the fish biomass continued to decrease by 45% until 2014 (Williams, 2015; Monroy et al., 2014). These decreases were likely linked to pollution including duckweed and heavy metals (Williams, 2015; Mancilla García, 2013; Monroy et al., 2014). • The spread of duckweed impacted access to fisheries and boats, especially in Cohana (Mancilla García, 2013). • As a result of decreasing access to fisheries, livestock increased in Cohana Bay, increasing the loading of defecation waste in the area while also potentially contaminating the drinking water sources for the livestock (Mancilla García, 2013). • Given the multiple impacts to fisheries, there is a livelihood use impact.	impacted fishing communities in the region. In Cohana Bay, most fishermen were forced to switch to livestock rearing for their livelihoods (Mancilla García, 2013). • Given the increased impact and the direct reliance on fisheries, livelihood use exposure is assumed to be high.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				in the National Reserve of Titicaca (Mancilla García, 2013). • This data suggests a strong impact of water quality on ingestion of biota from the lake.					
	2016 Bi-national Commitment and Current Status	Yes	High	Yes	High	Yes	High	Yes	High
		• By 2013, several major lake tributaries were confirmed as polluted including the Ramis, Coata, Suches, and Katari Seco, Seque, and Pallina rivers (Mancilla García, 2013; The World Bank et al., 2009 as cited in Mancilla García, 2013). • Pollution increased in Cohana Bay leading to a large fish kill in 2015, and increased heavy metals concentrations were found throughout the watershed (Achá et al., 2018; Monroy et al., 2014). • Given the high nutrient, pathogen, and heavy metal loads in the lake, the drinking water ingestion is likely impacted.	• Rural areas continued to have a high reliance on surface waters in 2013 (Gonzales Iwanciw et al., 2013). • The population of Cohana Bay was observed suffer health diseases related to water quality (UAC Batallas, 2010 as cited in Archundia et al., 2017). This response suggests a high exposure to contaminated surface water sources. • As a result of the high contamination in the lake, residents of Copacabana informally altered their drinking water sources to wells and springs (Collyns, 2017). It is assumed that rural, riparian communities similarly altered drinking water sources.	• Metals concentrations in most fish and benthic species throughout the lake exceeded international thresholds (Monroy et al., 2014). Mercury was also found in high concentrations in lake sediments (PNUMA, 2011 as cited in Mancilla García, 2016). • The eutrophication event in Lake Huiñaimarca (which contains Cohana Bay) led to a 5 week long anoxic event that killed fish, frogs, and birds in 2015 (Archundia et al., 2017). • Finally, there are reports of cattle deformities related to drinking water from the tributaries to the lake (Shahriari, 2012). This has led agricultural workers	• It is assumed that ingestion exposure is consistent with previous years	• Given the increased concentrations of pollutants in the lake, there is a continued impact to dermal exposure.	• It is assumed that dermal exposure is consistent with previous years, with high exposure due to the nature of fishing and proximity to the lake.	• Fish were observed to have deformities typical of metal contamination (Mancilla García, 2013). • There are also reports of cattle deformities following drinking water from the lake's tributaries (Shahriari, 2012) • Other water quality impacts are assumed to be consistent with previous years.	• The increase in makeshift cities has put a strain on rural communities who must travel further to access viable water and biota (Williams, 2015). • Additionally, water quality has altered the fish patterns and along with "over-fishing, has pushed many former fishermen to migrate to cities" (Shahriari, 2012). • Given the impact to both fisheries and alternative livelihoods of livestock rearing, it is assumed that there is a high impact to fishing communities.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			• Although alternate water sources are being used, they are generally informal, and therefore, drinking water exposure is still considered high.	to use alternate water sources including wells which may decrease impact on livestock (Shahriari, 2012). • The patterns of bioaccumulation and toxicity indicate a high impact of pollution on food sources within the basin.					
Rural communities (Non-fishing Based)	1955-1957 Joint Ownership Agreement Signed	Yes	Medium	Yes	Low	No	Medium	No	Low
		• The legacy of mining in the basin suggests that there were trace heavy metal concentrations throughout the lake that are concentrated along the shoreline (Garcia et al., 2005; Monroy et al., 2014; Martínez Gonzales & Zuleta Roncal, 2007). • Trace heavy metal concentrations in surface water can impact health through water consumption.	• Rural areas were heavily dependent on surface water sources in 2007 (Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that historically, this pattern of surface water reliance was consistent or greater due to the ease of access. • It is assumed that lake water was predominantly used by riparian communities and that non-riparian communities used alternate surface water sources. • It is assumed that agricultural, rural areas are distributed throughout the basin (i.e., riparian and non-riparian), and therefore, water ingestion exposure	• Heavy metals are capable of bioaccumulating in crops, aquatic biota, and livestock. • The fish caught for consumption were likely caught near the shore based on fishing practices (Orlove, 2002). Therefore, fish are more likely to have a heavy metal exposure. • Additionally, crops from the lake that are capable of bioaccumulation were used as cattle fodder (Mancilla García, 2013). These feeding patterns can increase metal uptake in livestock. As a result, there is an impact to ingestion.	• Several predominantly agricultural areas are riparian and use resources from the lake without fishing (Orlove, 2002). • A majority of crops within the basin are grown within close proximity to the lake, and irrigated plots use surface water irrigation (Williams, 2015; WWAP, 2003). Given that tributaries were often the conduits for metals contamination, it is likely that irrigation water from rivers and lake were impacted by metals. However, a majority of agriculture was not irrigated (WWAP, 2003). • Any protein from the lake was likely	• Heavy metals pose risk through dermal exposure. However, given that the concentrations were likely trace during this time period, dermal exposure was not considered to have an impact from heavy metals. • Rearing of livestock also presents a potential dermal risk as livestock defecation can impact nearby water sources. However, cattle densities were low in the 1950s (Mancilla García, 2013). Therefore, there was not sufficient risk from dermal contact.	• It is assumed that riparian communities are distributed between rural and urban areas. • It is also assumed that riparian communities have the highest rates of dermal exposure given the ease of access and use of the lake (Orlove, 2002). • Given that agricultural and livestock communities were both riparian and non-riparian, exposure is medium.	• Heavy metals are capable of bioaccumulating in crops and livestock which can impact agricultural areas. However, it is unlikely that bioaccumulation has impacted the growth of crops or livestock as surface water concentrations were trace. • Therefore, it is assumed that there was not a substantive livelihood use impact.	• Because most agriculture was not irrigated, livelihood use exposure is assumed to be low (WWAP, 2003). • Given the lack of reporting on bioaccumulation in the lake, livelihood use exposure related to livestock is also assumed to be low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			is assumed to be medium.		also impacted by trace metals. • Livestock likely drank from contaminated surface water sources and may have consumed fodder from the lake which has the capacity to bioaccumulate metals (WWAP, 2003). • It is assumed that rural communities primarily consumed food from the basin. • Therefore, some of the food sources may have been impacted by heavy metals. However, because metals were not identified in fish tissue until the 2000s, it is assumed that bioaccumulation in each food source was low (Martínez Gonzales & Zuleta Roncal, 2007). As a result, ingestion exposure was low.				
	1986 Ratification of the Agreement	Yes	Medium	Yes	Low	Yes	Medium	Yes	Low
		• The lake began to display impacts of urban and industrial effluents as a result of continued loading of nutrients, BOD, and pathogens (NorthCote et al., 1989 as cited in	• It is assumed that the drinking water exposure is consistent with previous years.	• The increase of biological loading on the lake is capable of harming biota through an increase of pathogens and parasites (WWAP, 2003). Along with	• The patterns of ingestion are assumed to be consistent with previous years.	• The presence of biologic waste is also a risk to dermal exposure, as contact with untreated or poorly treated wastewater can increase the spread	• It is assumed that dermal exposure is consistent with previous years.	• Heavy metals are capable of bioaccumulating in crops and livestock which can impact agricultural areas. However, it is unlikely that bioaccumulation has	• Because most agriculture was not irrigated and no livestock fatalities had been reported at this point, livelihood use exposure is assumed to be low (WWAP, 2003).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		Archundia et al., 2017; Mancilla García, 2013). • Mining wastes were simultaneously increased in the lake through improper closure of sites (The World Bank et al., 2009 as cited in Mancilla García, 2013). • Together, the organic and heavy metal effluents provide a risk to drinking water ingestion.		toxicity from the continued sources of heavy metals, both fish and livestock can bioaccumulate contaminants and be adversely impacted. • As a result, there is an impact to ingestion		of gastrointestinal diseases. • In combination with increasing concentrations of trace heavy metals, there is an impact to dermal exposure.		impacted the growth of crops or livestock as surface water concentrations were trace. • Given that algal growth can endanger livestock, it is assumed that there is impact to livelihood use.	
	1996 Establishment of the ALT	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Eutrophic conditions began to manifest in bays and shorelines around the lake (Martínez Gonzales & Zuleta Roncal, 2007). These nutrient loadings enabled the spread of duckweed. • Alternate water sources also began to be impacted due to pollutant introduction and flow through tributaries (Mancilla García, 2013). • Eutrophic conditions, pathogens, and heavy metals all create health risk for communities that drink lake water or use alternate water	• The contamination of alternate water resources increases the ingestion exposure to all rural areas. As a result, water ingestion exposure is high	• The continued contaminant load of organic pollutants and heavy metals continued to present risk to most food sources in the basin.	• The increase in pollution increases the exposure for agricultural communities who are assumed to consume food from within the basin. • Given that not all crops are irrigated, ingestion exposure is assumed to be medium.	• The continued contaminant load of organic pollutants and heavy metals continued to present risk to dermal contact in the basin.	• It is assumed that dermal exposure is consistent with previous years.	• The broader distribution of contamination affects livestock and irrigation that stem from tributaries. Therefore, there is a continued livelihood use impact.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		sources in proximity of the lake.							
	1997-1998 Ratification of RAMSAR	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Wastewater effluents and mining wastes continued to be discharged into the lake. Therefore, it is assumed that there is a continued impact to water ingestion.	• It is assumed that the drinking water exposure is consistent with previous years.	• The ingestion impact is assumed to be consistent with previous years.	• It is assumed that ingestion exposure is consistent with previous years.	• The dermal contact impact is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Yes	High	Yes	Medium	Yes	High	Yes	Medium
		• The continued discharge of wastewater effluents led to eutrophic conditions and a broad distribution of duckweed (Fontúrbel Rada, 2005). Cyanobacteria, which releases toxins, was also present in the algal blooms (WWAP, 2003). • Increased loading of heavy metals continued in the lake, and elevated concentrations of tin were observed in lake water (Martínez Gonzales & Zuleta Roncal, 2007). • Physical waste and odors were also observed in surface waters (Mancilla García, 2013). • Both countries acknowledged that	• In 2007, rural areas were heavily dependent on surface water sources (Martínez Gonzales & Zuleta Roncal, 2007). • This surface water dependence was demonstrated in Cohana Bay where the population had a high rate of health diseases related to water quality (UAC Batallas, 2010 as cited in Archundia et al., 2017). • It is assumed that drinking water exposure was high.	• Wild fisheries had collapsed in the early 2000s, and fish biomass decreased by approximately 45% since the 1980s (Williams, 2015; Monroy et al., 2014). These decreases were likely linked to pollution including the presence of duckweed which caused anoxic conditions and altered fish reproduction due to its blocking of sunlight (Williams, 2015; Mancilla García, 2013). Heavy metal toxicity also likely impacted the fish stock (Monroy et al., 2014). • Heavy metal concentrations were observed to be	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria increased dermal risk as it can release toxins that can be harmful based on contact. Along with existing organic and heavy metal pollution, there was a continued impact on dermal contact. • Livestock defecation near surface waters also presented some risk to dermal exposure (Ribera Arismendi & Marco Octavio, 2008 as cited in Mancilla García, 2013).	• Although not all rural communities are in direct proximity of the lake, the contamination of major tributaries that run adjacent to cities increase the frequency of dermal exposure to city residents. • Additionally, high rates of gastrointestinal illness reported throughout the basin suggest exposure with untreated wastewater (Maydana Iturriaga et al., 2009 as cited in Mancilla García, 2013; PNUMA, 2011 as cited in Mancilla García, 2013).	• The livelihood use impact is assumed to be consistent with previous years.	• Giving the increasing impact in a variety of tributaries, it is assumed that there was a greater livelihood use exposure for livestock. Therefore, livelihood use exposure is assumed to be medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		localized contamination was "severe" (Rieckermann et al., 2006, p. 507). • The deterioration of conditions suggests a continued impact to drinking water ingestion in the lake.		elevated at the mouth of rivers and to have bioaccumulated, leading to high mercury concentrations in certain species of fish in Puno Bay (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, fish were observed to have deformities related to heavy metal contamination in the National Reserve of Titicaca (Mancilla García, 2013). • This data suggests a strong impact of water quality on ingestion of biota from the lake.					
	2016 Bi-national Commitment and Current Status	Yes	High	Yes	Medium	Yes	High	Yes	Medium
		• By 2013, several major tributaries into the lake were confirmed to be polluted including the Ramis, Coata, Suches, and Katari Seco, Seque, and Pallina rivers (Mancilla García, 2013; The World Bank et al., 2009 as cited in Mancilla García, 2013). • Pollution increased in Cohana Bay leading to a large fish kill in 2015	• By 2013, many rural residents still relied on surface water sources (Gonzales Iwanciw et al., 2013). • Given the contamination of alternate water sources, it is assumed that drinking water exposure was high.	• Metals concentrations in most fish and benthic species throughout the lake exceeded international thresholds (Monroy et al., 2014). Mercury was also found in high concentrations in lake sediments (PNUMA, 2011 as cited in Mancilla García, 2016). • The eutrophication event in Lake	• It is assumed that ingestion exposure is consistent with previous years.	• Given the increased concentrations of pollutants on the lake, the water quality has an impact through dermal exposure.	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• It is assumed that livelihood use exposure is consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		increased heavy metals concentrations were observed throughout the watershed (Achá et al., 2018; Monroy et al., 2014). • Given the high nutrient, pathogen, and heavy metal loading in to the lake, the drinking water ingestion is likely impacted.		Huiñaimarca (which contains Cohana Bay) led to a 5 week long anoxic event that killed fish, frogs, and birds in 2015 (Archundia et al., 2017). • Finally, there are reports of cattle deformities following drinking from the tributaries of the lake (Shahriari, 2012). This has led agricultural works to use alternate water sources including wells which may decrease impact on livestock (Shahriari, 2012). • These occurrences indicate a high impact of pollution on food sources within the basin.					
Mining industry	1955-1957 Joint Ownership Agreement Signed	Yes	Medium	Yes	Low	Yes	Medium	No	Low
		• The legacy of history throughout the mining basin suggests that there are trace heavy metal concentrations throughout the lake that are concentrated along the shoreline (Garcia et al., 2005; Monroy et al., 2014; Martínez Gonzales & Zuleta Roncal, 2007).	• Based on the distribution of mining settlements, it is assumed that mines are located in both urban and rural areas, in the highlands surrounding the lake (Mancilla García, 2013). • It is assumed that there is a mixed dependence on lake water as rural areas were heavily	• The heavy metals present are capable of bioaccumulating in crops, aquatic biota, and livestock. • The fish caught for consumption were likely caught nearshore based on fishing practices (Orlove, 2002). Therefore, the fish are more likely to have a heavy metal exposure.	• It is assumed that urban and rural members of the mining industry primarily consumed food from the basin. • A majority of crops within the basin are grown within close proximity to the lake, and irrigated plots use surface water irrigation (Williams, 2015; WWAP, 2003). Given that	• Heavy metals can be a risk through dermal exposure. However, given the likely trace concentrations in the lake at this period, dermal exposure was not considered to have an impact from heavy metals. • However, the mining industry can incur heavy metal pollution in nearby	• Although most mines are not located in direct proximity of the lake, they are often located along or near the tributaries that their effluents drain into. Given this proximity, the dermal contact exposure to tributaries is considered to be medium.	• Although water quality impacts were occurring, they are not assumed to have a substantial impact on mining processes.	• Mining is a water intensive industry. However, it is likely that mines used alternate water sources (e.g., tributaries) to avoid fees from pumping. Therefore, livelihood use exposure to water quality is considered to be low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• It is likely that metal concentrations were trace within the majority of the surface water which can have a water consumption impact.	dependent on surface water sources in 2007, and approximately 80% of Peruvian urban areas and 22% of Bolivian urban areas of rely on surface water sources (basin average of 48%; Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that reliance on water from the lake is highest in riparian communities. • Given the mixed reliance on surface waters and the distribution of mines that span away from the lake, the drinking water exposure is considered to be medium.	• Additionally, crops from the lake that are capable of bioaccumulation have been used as cattle fodder which can increase uptake in livestock (Mancilla García, 2013).	tributaries were often the conduits for metals contamination, it is likely that irrigation water from the rivers and lake were impacted by metals. However, a majority of agriculture is not irrigated (WWAP, 2003). • Any protein from the lake was likely also impacted by trace metals. • Livestock also likely drank from tributaries and lake and may have consumed fodder from the lake which has the capacity to bioaccumulate metals (WWAP, 2003). • Therefore, some food sources may have been impacted by heavy metals. However, because metals had not yet been identified to bioaccumulate in fish (with only mercury bioaccumulation observed in the 2000s), it is assumed that bioaccumulation in each of the food sources was low (Martínez Gonzales & Zuleta Roncal, 2007). Therefore,	waterbodies such as tributaries that drain into the lake. Therefore, it is assumed that there was a dermal contact impact in nearby surface water.			

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
					the exposure is considered low.				
	1986 Ratification of the Agreement	Yes	Medium	Yes	Low	Yes	Low	No	Low
		• The lake began to display impacts of urban and industrial effluent loading of nutrients, BOD, and pathogens in the lake (NorthCote et al., 1989 as cited in Archundia et al., 2017; Mancilla García, 2013). • Mining wastes were increased in the lake through improper closure (The World Bank et al., 2009 as cited in Mancilla García, 2013). • Together, the organic and heavy metal effluents provide a risk to drinking water ingestion.	• The patterns of drinking water consumption are assumed to be consistent with previous years.	• The increase of biological loading on the lake is capable of harming biota such as fish through an increase of pathogens and parasites (WWAP, 2003). • The increased algal growth can also endanger livestock that drink from the lake given the pathogens in the water. • Additionally, the continued legacy and loading of heavy metals is capable of adversely affecting biota.	• The patterns of ingestion consumption are assumed to be consistent with previous years.	• The presence of biologic waste also contributes to dermal exposure, as contact with untreated or poorly treated wastewater can increase the spread of gastrointestinal diseases. • In combination with the trace heavy metal loading on the lake, there is an impact of the lake's pollutants on the dermal exposure pathway. • Additionally, mining effluents can increase heavy metal pollution in nearby surface water bodies. Therefore, it is assumed that there is a dermal contact impact in surface water.	• Although most mines are not located in direct proximity of the lake, they are often located along or near the tributaries that their effluents drain into. Given this proximity, there is dermal contact exposure in tributaries. • However, due to the low activity in the mining sector in the 1980s, it is assumed that there was minimal occupational exposure. Therefore, dermal contact exposure to tributaries is considered to be low.	• The livelihood use impact is assumed to be consistent with previous years.	• Given the likely alternate water sources and the low activity in the mining industry in the 1980s, livelihood use exposure is considered to be low.
	1996 Establishment of the ALT	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Eutrophic conditions began to be exhibited in bays and shorelines around the lake (Martínez Gonzales & Zuleta Roncal, 2007). These nutrient loadings enabled the spread of duckweed.	• The contamination of alternate water resources in the basin increases the exposure to drinking water contamination in cities. As a result of the likely surface water ingestion in both urban and rural areas, the drinking	• The continued organic and heavy metal loading continue to serve as sources of potential risk to all food sources within the basin.	• With the increase in pollution, it is assumed that there is an increase in exposure even though mining residents in urban communities may also have had access to food from outside of the basin as a	• The continued organic and heavy metal loading continue to serve as sources of potential risk to dermal contact within the basin. • Additionally, mining effluents can	• Although most mines are not located in direct proximity of the lake, they are often located along or near the tributaries that their effluents drain into. Given this proximity, the dermal contact	• Increased effluent loading may have altered the viable water use for the mining industry (including in tributaries). Therefore, it is assumed that there was a livelihood use impact.	• Given the likely small impact of eutrophic conditions and the alternate water sources, livelihood use exposure is considered low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• Alternate water sources also began to be impacted due to the distribution of contaminants in tributaries (Mancilla García, 2013). • Eutrophic conditions, pathogens, and heavy metals all create health risk for communities that drink lake water or utilize alternate water sources in proximity of the lake.	water exposure is considered high.		result of regular transit and trade. • As a result of the pollutant increase, ingestion exposure is assumed to be medium.	increase heavy metal pollution in nearby surface water bodies. Therefore, it is assumed that there is a dermal contact impact in surface water.	exposure to tributaries is considered to be medium.		
	1997-1998 Ratification of RAMSAR	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• Wastewater effluents and mining wastes continued to be discharged into the lake. Therefore, the impact is assumed to be consistent with previous years.	• The drinking water exposure is assumed to be consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that ingestion exposure is consistent with previous years.	• The dermal contact impact is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• The continued discharge of wastewater effluents led to eutrophic conditions and a broad distribution of duckweed (Fontúrbel Rada, 2005). Cyanobacteria, which releases a toxin, was also present within algal blooms (WWAP, 2003). • Increased loading of heavy metals was	• In 2007, rural communities and approximately 80% of Peruvian urban areas and 22% of Bolivian urban areas of rely on surface water sources (basin average of 48%; Martínez Gonzales & Zuleta Roncal, 2007). • The drinking water exposure is assumed	• Wild fisheries had collapsed in the early 2000s, and fish biomass decreased by approximately 45% since the 1980s (Williams, 2015; Monroy et al., 2014). These decreases are likely linked to pollution including the presence of duckweed which can cause anoxic	• Within El Alto, low rates of animal protein consumption were reported (FAO, 2015). Therefore, there is likely little exposure to contaminants through fish and limited exposure through crops (as most were not irrigated as of 2003).	• The presence of cyanobacteria increases dermal risk as it can release toxins that can be harmful based on contact. Along with existing organic and heavy metal pollution, there is an impact on dermal contact. • Additionally, mining effluents can increase heavy	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		noted in the lake with tin observed in waters throughout the lake (Martínez Gonzales & Zuleta Roncal, 2007). • Physical waste and odors were also observed in surface waters and the lake (Mancilla García, 2013). • Both countries acknowledged that localized contamination was "severe" (Rieckermann et al., 2006, p. 507). • This deterioration of conditions suggests continued impact to drinking water ingestion in the lake.	to be consistent with previous years.	conditions and alter fish reproduction due to its blocking of sunlight and heavy metals which can be toxic to fish (Williams, 2015; Mancilla García, 2013). • Heavy metal concentrations were observed to be elevated at the mouth of rivers and to bioaccumulate, leading to high mercury concentrations in certain species of fish in Puno Bay (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, fish were observed to have deformities related to heavy metal contamination in the National Reserve of Titicaca (Mancilla García, 2013). • This data suggests a strong impact of water quality on ingestion of biota from the lake.	• Given that some of the food sources are assumed to be from the basin, it is assumed that ingestion exposure remains medium.	metal pollution in nearby surface water bodies. Therefore, it is assumed that there is a dermal contact impact in surface water.			
	2016 Bi-national Commitment and Current Status	Yes	High	Yes	Medium	Yes	Medium	Yes	Low
		• By 2013, several major tributaries into the lake were confirmed to be polluted including the Ramis, Coata, Suches, and Katari	• By 2013, many rural and urban residents still relied on surface water sources (Gonzales Iwanciw et al., 2013).	• Metals concentrations in most fish and benthic species throughout the lake exceeded international	• It is assumed that ingestion exposure is consistent with previous years.	• Given the increased concentrations of pollutants on the lake, the water quality has an impact through dermal exposure.	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		Seco, Seque, and Pallina rivers (Mancilla García, 2013; The World Bank et al., 2009 as cited in Mancilla García, 2013). • Pollution increased in Cohana Bay leading to a large fish kill in 2015 increased heavy metals concentrations were observed throughout the watershed (Achá et al., 2018; Monroy et al., 2014). • Given the high nutrient, pathogen, and heavy metal loading in to the lake, the drinking water ingestion is likely impacted.	• Given the levels of contamination in the lake, it was suggested that residents of the city Copacabana were informally altering their drinking water sources to wells and springs (Collyns, 2017). • Although alternate water sources are being used, they are generally informal, and therefore, drinking water exposure is still considered high.	thresholds (Monroy et al., 2014). Mercury was also found in high concentrations in lake sediments (PNUMA, 2011 as cited in Mancilla García, 2016). • The eutrophication event in Lake Huiñaimarca (which contains Cohana Bay) led to a 5 week long anoxic event that killed fish, frogs, and birds in 2015 (Archundia et al., 2017). • Finally, there are reports of cattle deformities following drinking from the tributaries of the lake (Shahriari, 2012). This has led agricultural works to use alternate water sources including wells which may decrease impact on livestock (Shahriari, 2012). • These occurrences indicate a high impact of pollution on food sources within the basin.		• Additionally, mining effluents can increase heavy metal pollution in nearby surface water bodies. Therefore, it is assumed that there is a dermal contact impact in surface water.			
Tourism industry	1955-1957 Joint Ownership Agreement Signed	Yes	Medium	Yes	Low	No	High	No	Medium
		• The legacy of history throughout the mining basin suggests that there are trace heavy	• Based on the distribution of tourist areas, it is assumed that mines are located in both	• The heavy metals present are capable of bioaccumulating in crops, aquatic biota, and livestock.	• It is assumed that tourist groups primarily consumed food from the basin.	• Heavy metals can be a risk through dermal exposure. However, given the likely trace	• It is assumed that tourist activities are primarily concentrated near the lake; therefore,	• As no visible impacts were observed in the basin at this time, it is assumed that	• Because tourism is concentrated around the lake and the lake is a draw for tourism, it is

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		metal concentrations throughout the lake that are concentrated along the shoreline (Garcia et al., 2005; Monroy et al., 2014; Martínez Gonzales & Zuleta Roncal, 2007). • It is likely that metal concentrations were trace within the majority of the surface water which can have a water consumption impact.	urban and rural areas, in the highlands surrounding the lake (Mancilla García, 2013; Mitchell, 2008). • It is assumed that there is a mixed dependence on lake water as rural areas were heavily dependent on surface water sources in 2007, and approximately 80% of Peruvian urban areas and 22% of Bolivian urban areas of rely on surface water sources (basin average of 48%; Martínez Gonzales & Zuleta Roncal, 2007). It is assumed that reliance on water from the lake is highest in riparian communities. • Given the mixed reliance on surface waters, the drinking water exposure is considered to be medium.	• The fish caught for consumption were likely caught nearshore based on fishing practices (Orlove, 2002). Therefore, the fish are more likely to have a heavy metal exposure. • Additionally, crops from the lake that are capable of bioaccumulation have been used as cattle fodder which can increase uptake in livestock (Mancilla García, 2013).	• A majority of crops within the basin are grown within close proximity to the lake, and irrigated plots use surface water irrigation (Williams, 2015; WWAP, 2003). Given that tributaries were often the conduits for metals contamination, it is likely that irrigation water from the rivers and lake were impacted by metals. However, a majority of agriculture is not irrigated (WWAP, 2003). • Any protein from the lake was likely also impacted by trace metals. • Livestock also likely drank from tributaries and lake and may have consumed fodder from the lake which has the capacity to bioaccumulate metals (WWAP, 2003). • Therefore, some food sources may have been impacted by heavy metals. However, because metals had not yet been identified to bioaccumulate in fish (with only mercury	concentrations in the lake at this period, dermal exposure was not considered to have an impact from heavy metals. • There is some risk with the use of livestock, as livestock defecation can impact nearby water sources. However, livestock raising was not in high concentrations in the 1950s (Mancilla García, 2013). Therefore, there is not considered to be risk from dermal contact.	it is assumed that dermal exposure is high (Mancilla García, 2013: Mitchell, 2008).	there was not a livelihood use impact.	assumed that livelihood use exposure is medium (Mitchell, 2008; Mancilla García, 2013).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
					bioaccumulation observed in the 2000s), it is assumed that bioaccumulation in each of the food sources was low (Martínez Gonzales & Zuleta Roncal, 2007). Therefore, the exposure is considered low.				
	1986 Ratification of the Agreement	Yes	Medium	Yes	Low	Yes	High	No	Medium
		• The lake began to display impacts of urban and industrial effluent loading of nutrients, BOD, and pathogens in the lake (NorthCote et al., 1989 as cited in Archundia et al., 2017; Mancilla García, 2013). • Mining wastes were increased in the lake through improper closure (The World Bank et al., 2009 as cited in Mancilla García, 2013). • Together, the organic and heavy metal effluents provide a risk to drinking water ingestion.	• It is assumed that drinking water ingestion exposure was consistent with previous years.	• The increase of biological loading on the lake is capable of harming biota such as fish through an increase of pathogens and parasites (WWAP, 2003). • The increased algal growth can also endanger livestock that drink from the lake given the pathogens in the water. • Additionally, the continued legacy and loading of heavy metals is capable of adversely affecting biota.	• The patterns of ingestion consumption are assumed to be consistent with previous years.	• The presence of biologic waste also contributes to dermal exposure, as contact with untreated or poorly treated wastewater can increase the spread of gastrointestinal diseases. • In combination with the trace heavy metal loading on the lake, there is an impact of the lake's pollutants on the dermal exposure pathway.	• It is assumed that dermal exposure was consistent with previous years.	• It is assumed that livelihood use impact was consistent with previous years.	• It is assumed that livelihood use exposure was consistent with previous years.
	1996 Establishment of the ALT	Yes	High	Yes	Medium	Yes	High	No	Medium
		• Eutrophic conditions began to be exhibited in bays and shorelines around the lake (Martínez Gonzales & Zuleta Roncal,	• The contamination of alternate water resources in the basin increases the exposure to drinking water contamination in cities. As a result	• The continued organic and heavy metal loading continue to serve as sources of potential risk to all food	• Due to the increase in pollution, the ingestion exposure is assumed to be medium. It is also assumed that tourist locations have had	• The continued organic and heavy metal loading continue to serve as sources of potential risk to dermal	• It is assumed that dermal exposure was consistent with previous years.	• It is assumed that livelihood use impact was consistent with previous years.	• It is assumed that livelihood use exposure was consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		2007). These nutrient loadings enabled the spread of duckweed. • Alternate water sources also began to be impacted due to the distribution of contaminants in tributaries (Mancilla García, 2013). • Eutrophic conditions, pathogens, and heavy metals all create health risk for communities that drink lake water or utilize alternate water sources in proximity of the lake.	of the likely surface water ingestion in both urban and rural areas, the drinking water exposure is considered high.	sources within the basin.	access to food from outside of the basin as a result of regular transit and trade.	contact within the basin.			
	1997-1998 Ratification of RAMSAR	Yes	High	Yes	Medium	Yes	High	No	Medium
		• Wastewater effluents and mining wastes continued to be discharged into the lake. Therefore, the impact is assumed to be consistent with previous years.	• The drinking water exposure is assumed to be consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that ingestion exposure is consistent with previous years.	• The impact is assumed to be consistent with previous years.	• It is assumed that dermal exposure was consistent with previous years.	• Although the spread of duckweed may have decreased the appearance of the lake, it is assumed that there was not a tourism livelihood use impact.	• It is assumed that livelihood use exposure was consistent with previous years.
	2009-2010 Withdrawal of Bolivian Support	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• The continued discharge of wastewater effluents led to eutrophic conditions and a broad distribution of duckweed (Fontúrbel Rada, 2005). Cyanobacteria, which releases a toxin, was also	• In 2007, rural communities and approximately 80% of Peruvian urban areas and 22% of Bolivian urban areas of rely on surface water sources (basin average of 48%; Martínez Gonzales & Zuleta Roncal, 2007).	• Wild fisheries had collapsed in the early 2000s, and fish biomass decreased by approximately 45% since the 1980s (Williams, 2015; Monroy et al., 2014). These decreases are likely linked to pollution	• Within El Alto, low rates of animal protein consumption were reported (FAO, 2015). Therefore, there is likely little exposure to contaminants through fish and limited exposure through crops (as most were not	• The presence of cyanobacteria increases dermal risk as it can release toxins that can be harmful based on contact. Along with existing organic and heavy metal pollution, there is an impact on dermal contact.	• It is assumed that dermal exposure was consistent with previous years.	• Participants in the tourism industry in Copacabana and Puno were concerned that the lake's appearance, odor, and accumulation of waste would detract from the tourism industry (Mancilla García, 2013).	• Given that tourism was still growing in the region, it is assumed that livelihood use exposure was low (Mancilla García, 2013).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		present within algal blooms (WWAP, 2003). • Increased loading of heavy metals was noted in the lake with tin observed in waters throughout the lake (Martínez Gonzales & Zuleta Roncal, 2007). • Physical waste and odors were also observed in surface waters and the lake (Mancilla García, 2013). • Both countries acknowledged that localized contamination was “severe” (Rieckermann et al., 2006, p. 507). • This deterioration of conditions suggests continued impact to drinking water ingestion in the lake.	• The drinking water exposure is assumed to be consistent with previous years.	including the presence of duckweed which can cause anoxic conditions and alter fish reproduction due to its blocking of sunlight and heavy metals which can be toxic to fish (Williams, 2015; Mancilla García, 2013). • Heavy metal concentrations were observed to be elevated at the mouth of rivers and to bioaccumulate, leading to high mercury concentrations in certain species of fish in Puno Bay (Martínez Gonzales & Zuleta Roncal, 2007). • Additionally, fish were observed to have deformities related to heavy metal contamination in the National Reserve of Titicaca (Mancilla García, 2013). • This data suggests a strong impact of water quality on ingestion of biota from the lake.	irrigated as of 2003). • Given that some of the food sources are assumed to be from the basin, it is assumed that ingestion exposure remains medium.			• This concern also directly affects communities living on the floating islands (van Eerten, 2016). • Therefore, it is assumed that there is a livelihood use exposure.	
	2016 Bi-national Commitment and Current Status	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• By 2013, several major tributaries into the lake were	• By 2013, many rural and urban residents still relied on	• Metals concentrations in most fish and	• It is assumed that ingestion exposure	• Given the increased concentrations of pollutants on the	• It is assumed that dermal exposure	• It is assumed that livelihood use exposure is	• Local communities have reported suffering from water

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		confirmed to be polluted including the Ramis, Coata, Suches, and Katari Seco, Seque, and Pallina rivers (Mancilla García, 2013; The World Bank et al., 2009 as cited in Mancilla García, 2013). • Pollution increased in Cohana Bay leading to a large fish kill in 2015 increased heavy metals concentrations were observed throughout the watershed (Achá et al., 2018; Monroy et al., 2014). • Given the high nutrient, pathogen, and heavy metal loading in to the lake, the drinking water ingestion is likely impacted.	surface water sources (Gonzales Iwanciw et al., 2013). • Given the levels of contamination in the lake, it was suggested that residents of the city Copacabana were informally altering their drinking water sources to wells and springs (Collyns, 2017). • Although alternate water sources are being used, they are generally informal, and therefore, drinking water exposure is still considered high.	benthic species throughout the lake exceeded international thresholds (Monroy et al., 2014). Mercury was also found in high concentrations in lake sediments (PNUMA, 2011 as cited in Mancilla García, 2016). • The eutrophication event in Lake Huiñaimarca (which contains Cohana Bay) led to a 5 week long anoxic event that killed fish, frogs, and birds in 2015 (Archundia et al., 2017). • Finally, there are reports of cattle deformities following drinking from the tributaries of the lake (Shahriari, 2012). This has led agricultural works to use alternate water sources including wells which may decrease impact on livestock (Shahriari, 2012). • These occurrences indicate a high impact of pollution on food sources within the basin.	is consistent with previous years.	lake, the water quality has an impact through dermal exposure.	was consistent with previous years.	consistent with previous years.	quality in the lake, although "hotels and tourist operators prosper" (Collyns, 2017). • Giving the continued active tourism industry and perception of success, it is assumed that livelihood use exposure is low.

APPENDIX B: Lake Victoria

Table 22. Comprehensive analysis of primary stakeholder power in the Lake Victoria basin.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
Inhabitants of Urban Areas	1947 Initiation of the LVFS	Low • The Lake Victoria Fisheries Service (LVFS) was primarily a data collection organization that did appear to have any involvement of stakeholders (Kolding et al., 2014). • Additionally, the LVFS tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	Low • Given the high percentage of basin residents who participate in agriculture for their livelihoods (assumed to be approximately 80%), it is assumed that urban areas are not the majority fraction in the basin even though some urban actors participate in agriculture (Majaliwa et al., 2000 as cited in UNEP, 2006; Mwiturbani, 2010). • As no representative organization could be located and the stakeholder group is not the majority group in the basin, resources power is assumed to be low.	Low • No expression of voice was identified within this time period. As a result, discursive legitimacy is assumed to be low.	Medium • Historic policies prioritized unsustainable use of resources in the region over communities (Stein, 2008; Wiebe & Dodge, 1987 as cited in Okurut & Othero, 2012). However, there was an interest in socio-economic development in the basin starting in the early 1900s as linked to studies within the basin (Lugo et al., 2014; Muyodi et al., 2010). Poverty, economic development, and food self-sufficiency were identified as the major basin issues (FAO, 1996). The colonial government was interested in addressing this development through transboundary management (Lugo et al., 2014). • Although there is a demonstration of interest in development of the region, because the development is not specific to urban areas, state interest is medium.
	1973 Establishment of the LVFC	Low • The Lake Victoria Fisheries Commission (LVFC) was primarily a data collection organization that did appear to have any involvement of stakeholders (FAO, 1989). • Additionally, the LVFC tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority power was low.	Low • Resources power is assumed to be consistent with previous years.	Low • Discursive legitimacy is assumed to be consistent with previous years.	Medium • There was a continued interest in development in the basin. The East African Community (EAC; established in 1966) identified that poverty, economic development, and food independence were critical for the basin (FAO, 1996). However, state interventions yielded unsustainable practices that put a greater strain on resources (Lugo et al., 2014). • Given the general demonstrated interest in the basin that did not specifically target urban residents, state interest is considered medium.
	1977 Collapse of the LVFC and EAC	Low • During the collapse of the LVFC and EAC, management of fisheries was conducted by national governments (Muyodi et al., 2010). • It is assumed that there was not institutionalized participation of stakeholders as there was not a functioning transboundary organization. • Additionally, activities continued to focus on fisheries development, therefore it is assumed that if local processes engaged stakeholders, these were limited to members of the fisheries sector.	Low • Resources power is assumed to be consistent with previous years.	Low • Discursive legitimacy is assumed to be consistent with previous years.	Medium • It is assumed that state interest was consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• As a result of the lack of participation or influence, formal authority was low.			
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium	Medium	Medium	Medium
		• The Lake Victoria Environmental Management Project (LVEMP) addressed development of all stakeholders in the basin. The planning of the LVEMP was largely international and did not engage local stakeholders (Jansen et al., 1999). However, the final draft of the LVEMP engaged local representatives of the private sector, academia, and government (Jansen et al., 1999). • Although many local stakeholders were excluded in the LVEMP process, it is assumed that several members of the private sector and academia are related to urban areas in the basin. As a result of limited participation, formal authority is considered to be medium.	• OSIENALA was formed in 1992 to represent local communities who are dependent on the lake (Karani & Wekesa, 2008). OSIENALA primarily operates in Kenya but also represents citizens of the other two countries. Members of the organization include fishermen, farmers, cooperative societies, environmental clubs (Global Nature Fund, n.d.c). OSIENALA also implements projects within the lake area (Godsäter, 2013). • Growth rates were 6% in urban areas (Ntiba et al., 2001). Given the increasing growth of the urban population, it is assumed that urban areas are a growing fraction in the basin. • Given that there was a representative organization that was capable of implementing projects but was not specific to urban areas, the resource power is medium.	• There is criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). However, organizations such as OSIENALA were in the public space. • Given the expression of voice but perceived lack of credibility in representation, discursive legitimacy is medium.	• In 1992, following the Rio Summit, the three governments began discussions about joint management to address environmental and social concerns in the basin (Muyodi et al., 2010). • These discussions represented a continued interest in economic development and poverty eradication in the basin. It is assumed that the states individually maintained this interest during the period of time that transboundary management was not occurring. • Given the expressed interest in the region, demonstration of that impact through transboundary discussion, and lack of specific focus on urban areas, state interest is assumed to be medium.
	2003 Establishment of the LVBC	Medium	Medium	Medium	Medium
		• The EAC treaty committed to providing opportunities for civil actors to be engaged in governance (Godsäter, 2013). Within the basin region, this provided opportunities through the Lake Victoria Fisheries Organization (LVFO) and LVEMP. • The LVEMP was meant to involve all stakeholders based in part, on the involvement of the World Bank as a funding source (Njiru et al., 2008). Stakeholder workshops were held as part of LVEMP I (Wirkus & Böge, 2006). These workshops were considered not very successful with stakeholders in the lake's catchment area (Wirkus & Böge, 2006). The LVEMP also engaged National Task Forces in the planning of LVEMP II. Representatives from local governments, NGOs, the private sector, and academia participated in these national organizations and are comprised of approximately 15,000 stakeholders and 40 NGOs (Wirkus & Böge, 2006). Although multiple mechanisms for participation in the LVEMP exist, the extent of stakeholder involvement has been contested (Wirkus & Böge, 2006).	• ECOVIC was formed in 1995 with support from the international community (Lubaale & Omenya, 2007). ECOVIC is a network that represents urban and rural communities including approximately 30 NGOs, institutions, and fishermen (OSIENALA, 2004; Godsäter, 2013). ECOVIC implements various projects including a program that improves sanitation (Godsäter, 2013). • Programs to address the lake basin were being implemented by over 2000 civil society organizations, but cumulatively, these actions were not effective in obtaining "common goals" (EAC, 2003 as cited in Okurut & Othero, 2012, p. 353). • In 2000, there were approximately 21 million people living in urban areas (Scheren, Zanting, & Lemmens, 2000). • By 2000, there was also approximately 35 fish processing factories around the lake that are funded by aid agencies and international development banks (Jansen et al., 1999). These factories likely were located in cities. • Given that there were representative organization that was capable of implementing	• Discursive legitimacy is assumed to be consistent with previous years.	• The reestablished EAC is focused on economic development and harmonization of policies (Godsäter, 2013). With the establishment of the basin as an economic zone, the EAC signaled a strong interest in development of the region (Lubovich, 2009). • The EAC agenda has been interpreted as "market-oriented" with little space for social development and local communities (Jonyo, 2005 as cited in Godsäter, 2013, p. 74; Kimani, 2007 as cited in Godsäter, 2013). • Certain industries present potential for contribution to the GDP. For instance, water transportation in the basin is worth \$10 million per year (Okurut & Othero, 2012). • Although there is a demonstrated interest in development of the region, because the development is not specific to urban areas, state interest is medium.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Several NGOs had institutionalized participation in transboundary basin management. The organization, Organisation for Management of Lake Victoria resources (ECOVIC) has observer status on the EAC Council of Ministers which implements LVEMP II (Godsäter, 2013). Additionally, OSIENALA works closely with the Lake Victoria Basin Commission (LVBC) and LVFO to implement several projects (Godsäter, 2013). • EASWN attempts to serve as a citizen watchdog organization and motivate members of civil society to be engaged in monitoring, advocacy, and lobbying of transboundary institutions (Godsäter, 2013). • Although NGOs have been involved in multiple governance processes of the LVFO and LVEMP, there is criticism that involvement is not democratic and is biased to organizations that reinforce state objectives (Wirkus & Böge, 2006; Godsäter, 2013). • Given that institutionalized participation of the private sector and civil society occured in the LVEMP and LVFO, but participation was contingent on the preferences of the state, formal authority was medium.	projects but were not specific to urban areas, resource power is medium.		
	2008 Tensions with Uganda	Medium	Medium	Medium	Medium
		• In the basin water governance, state actors were perceived to dominate processes and only engage with civil society actors that supported the state agenda (Godsäter, 2013). As a result, stakeholder authority was limited and governance was considered as only "partly participatory" (Godsäter, 2013, p. 76). Additionally, the state was perceived to dictate the EAC, thus weakening its institutional power (Godsäter, 2013). • The LVBC was reported to work closely with representatives of the private sector and civil society whose interests were relevant to the LVBC's mandate (Okurt & Othero, 2016). The LVBC hosts an Annual Stakeholders' Forum which enables stakeholders to evaluate the extent to which the basin has become an economic growth zone (Okurut & Othero, 2012). However, the LVBC has been criticized for intentionally neglecting the opinions of	• Given the continued existence of ECOVIC and OSINELA, resources power is medium.	• EASWN and ECOVIC report that there are insufficient formal communication channels between civil society and the LVBC (Godsäter, 2013). • There was continued criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). In spite of the LVBC call to disclose funding sources, most organizations elected not to release funding information (Godsäter, 2013). • Given the expression of voice but perceived lack of credibility in representation, discursive legitimacy is medium.	• By 2006, the economic activity of all sectors in the basin provided approximately 33% of the GDP in each riparian country (UNEP, 2006). • In 2008, services (i.e., government, communications, transportation, and finance). that are assumed to be primarily based in urban areas, constituted 50.12%, 43.72%, and 46.23% of the GDP of Kenya, Tanzania, and Uganda, respectively (Plecher, 2020a,b,c). Given that a some of this contribution came from outside of the basin, the GDP contribution is not solely attributed to the urban stakeholders. • The LVEMP and LVBC have promoted poverty reduction which are reported to be priorities of the three governments (UNEP, 2006). These actions demonstrate a continued interest in the region. • However, at the same time, the LVBC was observed to be economically oriented with a focus on sustainable development (Godsäter, 2013). This mindset was perceived to be at the

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		certain stakeholders and wanting to engage primarily with governments (Godsäter, 2013). • The World Bank reports that approximately 50% of LVEMP II actions engaged community driven development by local institutions and communities (The World Bank, 2018a). This process included identification and capacity building of community organizations that implemented the projects (The World Bank, 2018a). However, it was also perceived that civil society had no influence in design and implementation of LVEMP II (Godsäter, 2013). • Given the institutionalized participation in the LVBC and LVEMP that is perceived to be contingent on the preferences of the state, formal authority was medium.			expense of local communities' needs (Godsäter, 2013). • Given that there are continued projects and institutions that focus on addressing communities within the basin, but these efforts are not solely focused on urban residents, state interest is medium.
	2020 Current Status	Medium	Medium	Medium	Medium
		• Formal authority is assumed to be consistent with previous years.	• Given that both stakeholder organizations still exist, it is assumed that resources power is consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years. • In 2019, the freedom of the press index in Kenya, Tanzania, and Uganda were 32.44, 36.28, and 16.06, respectively (RSF, 2020). These rankings are classified by RSF as "bad," "problematic," and "fairly good," respectively (RSF, 2020). • Given the assumption that the stakeholders express their voice publicly through representative organizations, but the state does not necessarily respond, discursive legitimacy is assumed to be medium.	• Services (i.e., government, communications, transportation, and finance) that are assumed to be based in urban areas, constitute 42.67%, 37.9%, and 47.59% of the GDP of Kenya, Tanzania, and Uganda, respectively (2018 and 2017; Plecher, 2020a,b,c). Given that a some of this contribution came from outside of the basin, the GDP contribution is not solely attributed to the urban stakeholders. • The World Bank reports that the states have exhibited a strong commitment to addressing environmental degradation and poverty in the basin through the implementation of LVEMP III (The World Bank, 2018b). • Given the continued demonstration of interest in the region without specific attention to urban residents, state interest is considered medium.
Traditional fishing communities	1947 Initiation of the LVFS	Low	Medium	Medium	High
		• The LVFS was primarily a data collection organization that did appear to have any involvement of stakeholders (Kolding et al., 2014). • Additionally, the LVFS tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	• In the 1970s, fisheries were primarily managed by local communities, suggesting organization and potential for mobilization (Jansen et al., 1999). It is assumed that community governance occurred as consistent with the 1970s (Jansen et al., 1999). • Given the capacity for ad hoc organization, resources power is medium.	• In the early 1900s, fishing patterns shifted to commercial fishing to meet the dietary needs of growing urban areas (Lugo et al., 2014). This action likely provided some public support for fishing communities. Given the high dependence of local communities on fisheries, discursive legitimacy is assumed to be medium.	• Historic policies prioritized unsustainable use of resources in the region over communities (Stein, 2008; Wiebe & Dodge, 1987 as cited in Okurut & Othero, 2012). However, there was an interest in socio-economic development in the basin starting in the early 1900s as linked to studies within the basin (Lugo et al., 2014; Muyodi et al., 2010). Poverty, economic development, and food self-sufficiency were identified as the major basin issues (FAO, 1996). Given the capacity of fisheries to

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
					address food security concerns, there was likely a state interest in fisheries. • Fisheries research was also conducted in the 1920s in response to decrease catches (Muyodi et al., 2010). This interest was further captured by the desire for better fisheries data collection which led to the establishment of the LVFS. • Given the demonstrated state interest in fisheries research, state interest was high.
	1973 Establishment of the LVFC	Low	Medium	Medium	High
		• The LVFC was primarily a data collection organization that did appear to have any involvement of stakeholders (FAO, 1989). • Additionally, the LVFC tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • In the 1960s and 1970s, most fisheries management was led by "colonial administrators," which limited access for public participation (Witte et al., 2000; Pringle, 2005; Lugo et al., 2014, p. 226). • As a result of the lack of participation and influence, formal authority was low.	• In the 1970s, there were approximately 50,000 fishermen operating in the basin (Jansen et al., 1999). • Fisheries were primarily managed by local communities, suggesting organization and potential for mobilization (Jansen et al., 1999). In some places, community governance had been institutionalized, although this coverage was not consistent throughout the lake (Jansen et al., 1999). • Given the capacity for ad hoc organization, the resources power is considered medium.	• Discursive legitimacy is assumed to be consistent with previous years.	• "Colonial administrators" had a high interest in the Nile perch and directed the stocking of the lake (Lugo et al., 2014, p. 226). Given the influence of colonial powers, this supported a state interest in the lake. • There was growing interest in starting a joint organization for fisheries data in 1963 (Muyodi et al., 2010). This yielded the establishment of the LVFC in 1973 following the establishment of the East African Fisheries Research Organization (EAFRO) in 1949 (Muyodi et al., 2010). The LVFS also demonstrated a joint interest in fisheries data. • External actors were also interested in fisheries causing the UNDP, FAO, and EU to implement studies in the 1960s and 1970s (Muyodi et al., 2010). The FAO furthered this interest by initiating a discussion of African fisheries at a UN conference in 1972 (Lugo et al., 2014). • Simultaneously, there was a continued interest in development of the region. The East African Commission (established in 1966) identified that poverty, economic development, and food independence were critical for the basin (FAO, 1996). However, state interventions yielded unsustainable practices that put a greater strain on resources (Lugo et al., 2014). • Given the expressed state interest and implemented programs related to fisheries, state interest is assumed to be high.
	1977 Collapse of the LVFC and EAC	Low	Medium	Medium	High
		• During the collapse of the LVFC and EAC, management of fisheries was completed by national governments (Muyodi et al., 2010). • It is assumed that there was not institutionalized participation of stakeholders as there was not a functioning transboundary organization.	• Fisheries continued to be managed by local communities, suggesting organization and potential for mobilization (Jansen et al., 1999). • In 1975, there were approximately 12,000 fishermen in Kenya (Jansen et al., 1999). • Given the capacity for ad hoc organization, the resources power was medium.	• Discursive legitimacy is assumed to be consistent with previous years.	• The establishment of the LVFC and participation in the organization indicatds a state interest in fisheries (FAO, 1989). As a result of the participation in the LVFC, state interest is considered high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• As a result of the lack of participation and influence, formal authority was low.			
	1994 Establishment of the LVFO and initiation of the LVEMP	Low	Medium	Medium	High
		• The LVEMP addressed development of all stakeholders in the basin. The planning of the LVEMP was largely international and did not engage local stakeholders (Jansen et al., 1999). However, the final draft of the LVEMP engaged local representatives of the private sector, academia, and government (Jansen et al., 1999). Notably, many local stakeholders were not included in this process. • It is assumed that fishermen were largely excluded from LVEMP and LVFO development. As a result of lack of participation, formal authority was low.	• OSIENALA was formed in 1992 to represent local communities who are dependent on the lake (Karani & Wekesa, 2008). OSIENALA primarily operates in Kenya but also represents citizens in the other two countries. Members of the organization include fishermen, farmers, cooperative societies, environmental clubs (Global Nature Fund, n.d.c). OSIENALA also implements projects within the lake area (Godsäter, 2013). • The Tanzania Association of Fisheries and Lake Victoria Environment Conservation (TAFLEC) was established in 1997 (OSIENALA, 2004). • In the 1980s, it was estimated that 180,000 jobs were directly and indirectly created by the shift to the Nile perch industry (Jansen et al., 1999). At this time period, international actors began to take over the industry which decreased the influence of local management (Jansen et al., 1999). • By 1995, there were approximately 24,000 fishermen in the Kenyan part of the lake which has doubled since 1975 (Jansen et al., 1999). • Given that there was a representative organization that was capable of implementing projects but was not specific to fishermen, resource power was medium.	• There is criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). • In the 1980s, it was estimated that 180,000 jobs were created by the shift to the Nile perch industry (Jansen et al., 1999). Additionally, the Nile perch was considered “the savior” by many fishermen (Reynolds & Greboval, 1988). These events likely bolstered public opinion towards the fishing community. • Given the likely public support, discursive legitimacy is assumed to be medium.	• The Nile perch boom in the 1980s increased national and international attention on the lake’s fisheries (Jansen et al., 1999). Export infrastructure was established in the 1980s in Kenya and Uganda and in the 1990s in Tanzania (Jansen et al., 1999). • Although joint action was not occurring in the years leading up to 1994, each country maintained its own fisheries organization (Muyodi et al., 2010). • Given the economic increase in the region, state interest is assumed to be high.
	2003 Establishment of the LVBC	High	Medium	Medium	High
		• The EAC treaty committed to providing opportunities for civil actors to be engaged in governance (Godsäter, 2013). Within the basin region, this provided opportunities through the LVFO and LVEMP. • Within the LVFO there are national committees who consult on issues handled by the organization. It is reported that the private sector, NGOs, and civil society are also part of these committees (Ntiba et al., 2001). • In addition to participation on committees, the Beach Management Units (BMUs) were established in 1998 and provided an opportunity for local communities to participate in the management of fisheries (Godsäter, 2013; Eggert & Lokina, 2010).	• ECOVIC was formed in 1995 with support from the international community (Lubaale & Omenya, 2007). ECOVIC is a network that represents urban and rural communities including approximately 30 NGOs, institutions, and fishermen (OSIENALA, 2004; Godsäter, 2013). ECOVIC implements various projects including a program that improves sanitation (Godsäter, 2013). • Programs to address the lake basin were being implemented by over 2000 civil society organizations, but cumulatively, these actions were not effective in obtaining “common goals” (EAC, 2003 as cited in Okurut & Othero, 2012, p. 353).	• According to Jansen et al., “tens of millions of people in East and Central Africa” consumed fish from the lake as critical source of animal protein (1999, p. 5). • In the early 2000s, fishermen received public attention for their increasing levels of conflict between countries and with authorities (UNEP, 2006; Atieno, 2014). • Given the likely public support and the public attention that did not necessarily yield state action, discursive legitimacy is assumed to be medium.	• In 1995, the three states had fisheries policies that were directed at increasing employment and improving conditions in the fishing industry while also enabling the local community to have greater access to the food source (Jansen et al., 1999). • The LVEMP I was described as paying substantial attention to fisheries (Lubovich, 2009). Additionally, the establishment of the LVFO demonstrates a transboundary interest in fisheries. • By 2001, fisheries were approximately 0.5% of the Kenyan economy and 3% of the Tanzanian and Ugandan economies (UNEP, 2006). • In 2003, fish catch was 13% of exports in Tanzania (Ewald, 2004).

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		However, this system has been questioned in its reinforcement of state authority (Godsäter, 2013). • Additionally, the Lake Victoria Management Project (through the LVFO) was intended to improve stakeholder involvement, in part, due to its funding source of the European Union (Njiru et al., 2008). • The LVEMP was meant to involve all stakeholders based in part, on the involvement of the World Bank as a funding source (Njiru et al., 2008). Stakeholder workshops were held as part of LVEMP I (Wirkus & Böge, 2006). These workshops were considered successful with fishing communities (Wirkus & Böge, 2006). The LVEMP also engaged National Task Forces in the planning of LVEMP II. Representatives from local governments, NGOs, the private sector, and academia participated in these national organizations and are comprised of approximately 15,000 stakeholders and 40 NGOs (Wirkus & Böge, 2006). Although multiple mechanisms for participation in the LVEMP exist, the extent of stakeholder involvement has been contested (Wirkus & Böge, 2006). • Several NGOs had institutionalized participation in transboundary basin management. The organization ECOVIC has observer status on the EAC Council of Ministers which implements LVEMP II (Godsäter, 2013). Additionally, OSIENALA works closely with the LVBC and LVFO to implement several projects (Godsäter, 2013). • EASWN attempts to serve as a citizen watchdog organization and motivate members of civil society to be engaged in monitoring, advocacy, and lobbying of transboundary institutions (Godsäter, 2013). • Although NGOs have been involved in multiple governance processes of the LVFO and LVEMP, there is criticism that involvement is not democratic and is biased to organizations that reinforce state objectives (Wirkus & Böge, 2006; Godsäter, 2013). • Given the institutionalized participation in the BMUs which have a higher influence on decision making, formal authority was high.	• Hundreds of thousands of people were involved in the processing and trade of the lake's fisheries in the late 1990s (Jansen et al., 1999). • The decrease of fish stock impacted approximately 30 million people that were supported by the lake (LVFO, 1999 as cited in Eggert & Lokina, 2010). • By 2000, there were also approximately 35 fish processing factories around the lake that were funded by aid agencies and international development banks (Jansen et al., 1999). • Given that there was a representative organization that was capable of implementing projects, the organization was not specific to fishermen, and the fishing community was not the majority fraction in the basin, resource power was medium.		• Funding from fisheries benefited national treasuries and was not reinvested in the regions (Ntiba et al., 2001). • Uganda removed a fishing ban in 2003 against technical recommendations in order to remain competitive within the fishing market (Owino, 2015). • Given the continued state participation in fisheries and the contribution to the GDP, state interest was assumed to be high.
		High	High	Medium	High

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	2008 Tensions with Uganda	• In the basin water governance, state actors were perceived to dominate processes and only engage with civil society actors that supported the state agenda (Godsäter, 2013). As a result, stakeholder authority was limited and governance was considered as only "partly participatory" (Godsäter, 2013, p. 76). Additionally, the state was perceived to dictate the EAC, thus weakening its institutional power (Godsäter, 2013). • The LVBC was reported to work closely with representatives of the private sector and civil society whose interests were relevant to the LVBC's mandate (Okurt & Othero, 2016). The LVBC hosts an Annual Stakeholders' Forum which enables stakeholders to evaluate the extent to which the basin has become an economic growth zone (Okurut & Othero, 2012). However, the LVBC has been criticized for intentionally neglecting the opinions of certain stakeholders and wanting to engage primarily with governments (Godsäter, 2013). • The World Bank reports that approximately 50% of LVEMP II actions engaged community driven development by local institutions and communities (The World Bank, 2018a). This process included identification and capacity building of community organizations that implemented the projects (The World Bank, 2018a). However, it was also perceived that civil society had no influence in design and implementation of LVEMP II (Godsäter, 2013). • Although participation in much of the LVBC and LVEMP were perceived to be contingent on the preferences of the states, because of the continued participation in the BMUS, formal authority was high.	• The Lake Victoria NGOs Advocacy Network-East Africa (LAVNET-EA), comprised of the Uganda Fisheries and Fish Conservation Association, Kenyan Indigenous Fishers Peoples Network, Tanzanian Kivulini Women's Rights Organization, and Tanzanian Kagera Development and Credit Revolving Trust fund, was established and advocated for fishing communities in the basin (Godsäter, 2013). It is assumed that LAVNET-EA was established between 2003 and 2008. • By 2006, fishing was considered "the most important economic activity" for riparian communities and supported the income and food security of 3 million people (UNEP, 2006, p. 6; EAC Secretariat, 2006). • In 2008, it was predicted that approximately 198,000 fishermen and 600,000 fish traders were employed in the fisheries industry (The World Bank, 2008). • Given the existence of a fisheries specific transboundary organization that had some capacity for implementation, the resources power was high.	• In 2006, lake fishermen protested to demand rights (Godsäter, 2013). This action alienated their involvement in the LVBC (Godsäter, 2013). • Programs related to fishing communities were reported to not address the actual needs of the communities (KADETFU, 2010 as cited in Godsäter, 2013). • EASWN and ECOVIC reported that there were insufficient formal communication channels between civil society and the LVBC (Godsäter, 2013). • There was continued criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). In spite of the LVBC call to disclose funding sources, most organizations elected not to release funding information (Godsäter, 2013). • Given the expression of voice, perceived lack of credibility, and absence of state response, discursive legitimacy was medium.	• The LVBC decision making body is made up of several ministers including the ministry of fisheries (Wirkus & Böge, 2006). In addition to the existence of the LVFO, this organization suggested a prioritization of fisheries. • However, at the same time, existing institutions including the LVFO and LVBC were observed to be economically oriented with a focus on sustainable development (Godsäter, 2013). This mindset was perceived to be at the expense of local communities' needs (Godsäter, 2013). In particular, state management was criticized for focusing on fishing methods and not water quality impacts (Kolding & van Zwieten, 2006). This focus demonstrated a consideration of fisheries with a displacement of the perceived problem onto fishermen. Furthermore, the states were criticized for not committing many financial resources to fisheries (Njiru et al., 2008). • By 2006, the lake's fisheries were reported to be worth approximately $400 million annually (Okurut & Othero, 2012). • In 2008, it was reported that the annual income from the lake was $600 million (Njiru et al., 2008). Fishing was also considered necessary for the "economic health and livelihood security" of the basin (Lubovich, 2009, p. 5). • However, overall, the GDP of all sectors in the basin were considered "relatively low" ($3-4 billion; UNEP, 2006, p. 6). • The state demonstrated an interest in fisheries through its institutional structure and fisheries were a significant economic opportunity in the basin. As a result, state interest was high.
	2020 Current Status	High	High	Medium	High
		• Formal authority is assumed to be consistent with previous years.	• It is assumed that representative organizations are still functioning. • By 2018, approximately 800,000 people were employed by the lake's fishery with more than 200,000 fishermen directly relying on fishing for their livelihoods (The World Bank, 2018b). In addition, approximately 3 million people's livelihoods are supported by the fisheries (The World Bank, 2018b).	• Discursive legitimacy is assumed to be consistent with previous years. • In 2019, the freedom of the press index in Kenya, Tanzania, and Uganda were 32.44, 36.28, and 16.06, respectively (RSF, 2020). These rankings are classified by RSF as "bad," "problematic," and "fairly good" respectively (RSF, 2020). • Given the assumption that the fishing community express their voice publicly	• By 2018, the fisheries had an estimated annual income of approximately $500 million per year annually with $400 million in export revenues (The World Bank, 2018b). • In 2008, agriculture and livestock in the basin comprised of 30-40% of the GDP in the region (The World Bank, 2018b). In 2018, agriculture was 34.19% and 24.21% of the GPD in Kenya and Uganda (Plecher, 2020a,c). In 2017, agriculture was 28.74% of the GDP in

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			• Given the ongoing organized groups that are specific to fishermen and are transboundary, resources power is high.	through representative organizations, discursive legitimacy is assumed to be medium.	Tanzania (Plecher, 2020b). The agricultural sector encompasses fishing in the region. • The World Bank reports that the states have exhibited a strong commitment to addressing environmental degradation and poverty in the basin through the implementation of LVEMP III (The World Bank, 2018b). • Given the high income of fisheries for the three riparian countries, state interest is considered high.
Rural agriculture communities	1947 Initiation of the LVFS	Low	Medium	Low	Medium
		• The LVFS was primarily a data collection organization that did appear to have any involvement of stakeholders (Kolding et al., 2014). • Additionally, the LVFS tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	• Given the large percentage of the population that was involved in agriculture in 2000 (approximately 80%), it is assumed that agriculture was the majority fraction of the basin (Majaliwa et al., 2000 as cited in UNEP, 2006). Therefore, resources power is assumed to be medium.	• No expression of voice was identified within this time period. As a result, discursive legitimacy is assumed to be low.	• Historic policies prioritized unsustainable use of resources in the region over communities (Stein, 2008; Wiebe & Dodge, 1987 as cited in Okurut & Othero, 2012). However, there was an interest in socio-economic development in the basin starting in the early 1900s as linked to studies within the basin (Lugo et al., 2014; Muyodi et al., 2010). Poverty, economic development, and food self-sufficiency were identified as the major basin issues (FAO, 1996). Given the capacity of agriculture to address food security concerns, there was likely a state interest in agriculture. • Given the regional interest without a specific focus on agriculture, state interest is considered medium.
	1973 Establishment of the LVFC	Low	Medium	Low	High
		• The LVFC was primarily a data collection organization that did appear to have any involvement of stakeholders (FAO, 1989). • Additionally, the LVFC tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	• Given the large percentage of the population that was involved in agriculture in 2000 (approximately 80%), it is assumed that agriculture was the majority fraction of the basin (Majaliwa et al., 2000 as cited in UNEP, 2006). Therefore, resources power is assumed to be medium.	• No expression of voice was identified within this time period. As a result, discursive legitimacy is assumed to be low.	• There was a continued interest in development in the basin. The EAC (established in 1966) identified that poverty, economic development, and food independence were critical for the basin (FAO, 1996). However, state interventions yielded unsustainable practices that put a greater strain on resources (Lugo et al., 2014). • Additionally, in the 1960s Tanzania focused on agriculture as its economic growth opportunity. (Henckel, Poulsen, Sharp, & Spora, 2016). • Given the Tanzanian interest in agriculture, state interest was high.
	1977 Collapse of the LVFC and EAC	Low	Medium	Low	High
		• During the collapse of the LVFC and EAC, management of fisheries was completed by national governments (Muyodi et al., 2010). • It is assumed that there was not institutionalized participation of stakeholders	• Given the large percentage of the population that was involved in agriculture in 2000 (approximately 80%), it is assumed that agriculture was the majority fraction of the basin (Majaliwa et al., 2000 as cited in UNEP,	• No expression of voice was identified within this time period. As a result, discursive legitimacy is assumed to be low.	• It is assumed that state interest is consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		as there was not a functioning transboundary organization. • Additionally, activities continued to focus on fisheries development, therefore it is assumed that if local processes engaged stakeholders, these were limited to members of the fisheries sector. • As a result of the lack of participation and influence, formal authority was low.	2006). Therefore, resources power is assumed to be medium		
	1994 Establishment of the LVFO and initiation of the LVEMP	Low	Medium	Medium	High
		• The LVEMP addressed development of all stakeholders in the basin. The planning of the LVEMP was largely international and did not engage local stakeholders (Jansen et al., 1999). However, the final draft of the LVEMP engaged local representatives of the private sector, academia, and government (Jansen et al., 1999). Notably, many local stakeholders were not included in this process. • It is assumed that agricultural communities were largely excluded from LVEMP and LVFO development. As a result of lack of participation, formal authority was low.	• OSIENALA was formed in 1992 to represent local communities who are dependent on the lake (Karani & Wekesa, 2008). OSIENALA primarily operates in Kenya but also represents citizens in the other two countries. Members of the organization include fishermen, farmers, cooperative societies, environmental clubs (Global Nature Fund, n.d.c). OSIENALA also implements projects within the lake area (Godsäter, 2013). • Given that there was a representative organization that was capable of implementing projects but was not specific to agriculture, resource power was medium.	• Although organizations existed that could represent agricultural communities; there was criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). • Given the expression of voice but perceived lack of credibility in representation, discursive legitimacy was medium.	• In 1992, following the Rio Summit, the three governments began discussions about joint management to address environmental and social concerns in the basin (Muyodi et al., 2010). • These discussions represented a continued interest in economic development and poverty eradication in the basin. It is assumed that the states individually maintained this interest during the period of time that transboundary management was not occurring. • Based on agricultural exports in 2003, agriculture is assumed to be a major sector of the Tanzanian economy (Ewald et al., 2004). • Given the high economic importance of agriculture in Tanzania, state interest is assumed to be high.
	2003 Establishment of the LVBC	Medium	Medium	Medium	High
		• The EAC treaty committed to providing opportunities for civil actors to be engaged in governance (Godsäter, 2013). Within the basin region, this provided opportunities through the LVFO and LVEMP. • The LVEMP was meant to involve all stakeholders based in part, on the involvement of the World Bank as a funding source (Njiru et al., 2008). Stakeholder workshops were held as part of LVEMP I (Wirkus & Böge, 2006). These workshops were considered not very successful with stakeholders in the lake's catchment area (Wirkus & Böge, 2006). The LVEMP also engaged National Task Forces in the planning of LVEMP II. Representatives from local governments, NGOs, the private sector, and academia participated in these national organizations and are comprised of approximately 15,000 stakeholders and 40 NGOs (Wirkus & Böge, 2006). Although	• By 1996, agriculture supported approximately 21 million inhabitants of the basin (The World Bank, 1996). • By 2000, approximately 80% of the basin participated in agriculture for their livelihoods (Majaliwa et al., 2000 as cited in UNEP, 2006). • ECOVIC was formed in 1995 with support from the international community (Lubaale & Omenya, 2007). ECOVIC is a network that represents urban and rural communities including approximately 30 NGOs, institutions, and fishermen (OSIENALA, 2004; Godsäter, 2013). ECOVIC implements various projects including a program that improves sanitation (Godsäter, 2013). • Programs to address the lake basin were being implemented by over 2000 civil society organizations, but cumulatively, these actions were not effective in obtaining "common	• Discursive legitimacy is considered consistent with previous years.	• Since 2002, approximately 43.5% of the basin has been used for agriculture (Lubovich, 2009). • Prior to 2004, these agricultural products were 50% of Tanzania's exports (i.e., coffee and cotton; Ewald et al., 2004). • The reestablished EAC is focused on economic development and harmonization of policies (Godsäter, 2013). With the establishment of the basin as an economic zone, the EAC signaled a strong interest in development of the region (Lubovich, 2009). • The EAC agenda has been interpreted as "market-oriented" with little space for social development and local communities (Jonyo, 2005 as cited in Godsäter, 2013, p. 74; Kimani, 2007 as cited in Godsäter, 2013). • Given the high economic importance of agriculture to Tanzania, state interest is assumed to be high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		multiple mechanisms for participation in the LVEMP exist, the extent of stakeholder involvement has been contested (Wirkus & Böge, 2006). • Several NGOs had institutionalized participation in transboundary basin management. The organization ECOVIC has observer status on the EAC Council of Ministers which implements LVEMP II (Godsäter, 2013). Additionally, OSIENALA works closely with the LVBC and LVFO to implement several projects (Godsäter, 2013). • EASWN attempts to serve as a citizen watchdog organization and motivate members of civil society to be engaged in monitoring, advocacy, and lobbying of transboundary institutions (Godsäter, 2013). • Although NGOs have been involved in multiple governance processes of the LVFO and LVEMP, there is criticism that involvement is not democratic and is biased to organizations that reinforce state objectives (Wirkus & Böge, 2006; Godsäter, 2013). • Given the institutionalized participation occured within the LVEMP, but participation was contingent on the preferences of the state, formal authority was medium.	goals" (EAC, 2003 as cited in Okurut & Othero, 2012, p. 353). • Given that there was a representative organization that was capable of implementing projects but was not specific to agricultural communities, resource power was medium.		
	2008 Tensions with Uganda	Medium	Medium	Medium	High
		• In the basin water governance, state actors were perceived to dominate processes and only engage with civil society actors that supported the state agenda (Godsäter, 2013). As a result, stakeholder authority was limited and governance was considered as only "partly participatory" (Godsäter, 2013, p. 76). Additionally, the state was perceived to dictate the EAC, thus weakening its institutional power (Godsäter, 2013). • The LVBC was reported to work closely with representatives of the private sector and civil society whose interests were relevant to the LVBC's mandate (Okurt & Othero, 2016). The LVBC hosts an Annual Stakeholders' Forum which enables stakeholders to evaluate the extent to which the basin has become an economic growth zone (Okurut & Othero, 2012). However, the LVBC has been criticized for intentionally neglecting the opinions of	• Given the continued existence of ECOVIC and OSINELA, and an assumed high pattern of participation in agriculture, resources power was medium.	• EASWN and ECOVIC report that there are insufficient formal communication channels between civil society and the LVBC (Godsäter, 2013). • There was continued criticism that not all organizations are representative of the stakeholders and exist, in part, for profit (Godsäter, 2013). In spite of the LVBC call to disclose funding sources, most organizations elected not to release funding information (Godsäter, 2013). • Given the expression of voice but perceived lack of credibility in representation, discursive legitimacy was medium.	• By 2008, agriculture contributed approximately 22.2%, 24.77%, and 21.38% to the GDP of Kenya, Tanzania, and Uganda, respectively (Plecher, 2020a,b,c). • By 2006, the economic activity of all sectors in the basin provided approximately 33% of the GDP in each riparian country (UNEP, 2006). • The LVBC decision making body is made up of several ministers including the ministry of agriculture (Wirkus & Böge, 2006). The inclusion of the ministry of agriculture represents an interest in the sector. • Additionally, the LVEMP and LVBC have promoted poverty reduction which are reported to be priorities of the three governments (UNEP, 2006). These actions designate a continued interest in the region. • However, at the same time, the LVBC was observed to be economically oriented with a focus on sustainable development (Godsäter, 2013). This mindset was perceived to be at the

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		certain stakeholders and wanting to engage primarily with governments (Godsäter, 2013). • The World Bank reports that approximately 50% of LVEMP II actions engaged community driven development by local institutions and communities (The World Bank, 2018a). This process included identification and capacity building of community organizations that implemented the projects (The World Bank, 2018a). However, it was also perceived that civil society had no influence in design and implementation of LVEMP II (Godsäter, 2013). • Given the institutionalized participation in the LVBC and LVEMP that is perceived to be contingent on the preferences of the state, formal authority was medium.			expense of local communities' needs (Godsäter, 2013). • Given the contributions of agriculture to the national GDPs, state interest was high.
	2020 Current Status	Medium	Medium	Medium	High
		• Formal authority is assumed to be consistent with previous years.	• Approximately 80% of the basin population participate in agriculture and livestock for their livelihoods (The World Bank, 2018b). In 2011, agriculture employed approximately 90% of Tanzania (Newenham-Kahindi, 2007 as cited in Newenham-Kahindi, 2011). These percentages are consistent with reports from previous years. • Given the continued existence of ECOVIC and OSINELA and the high fraction of agricultural participants, resources power is medium.	• Discursive legitimacy is assumed to be consistent with previous years. • In 2019, the freedom of the press index in Kenya, Tanzania, and Uganda were 32.44, 36.28, and 16.06, respectively (RSF, 2020). These rankings are classified by RSF as "bad," "problematic," and "fairly good" respectively (RSF, 2020). • Given the assumption that the stakeholders express their voice publicly through representative organizations, but the state does not necessarily respond, discursive legitimacy is assumed to be medium.	• In 2010, agriculture in the basin comprised of 30-40% of the basin states' GDP (Mwiturubani, 2010). In 2018, agriculture and livestock in the basin comprised also of 30-40% of the regional GDP (The World Bank, 2018b). In 2018, agriculture was 34.19% and 24.21% of the GPD in Kenya and Uganda (Plecher, 2020a,c). In 2017, agriculture was 28.74% of the GDP in Tanzania (Plecher, 2020b). • In Tanzania in 2011, agriculture was approximately 50% of the country's GDP and contributed to the majority of exports in the region (Newenham-Kahindi, 2007 as cited in Newenham-Kahindi, 2011). Most of the industry in Tanzania was also related to agriculture (Newenham-Kahindi, 2011). • The World Bank reports that the states have exhibited a strong commitment to addressing environmental degradation and poverty in the basin through the implementation of LVEMP III (The World Bank, 2018b). • Given the contributions of agriculture to the region and the interest in general development of the region, state interest is high.
Mining industry	1947 Initiation of the LVFS	Low	Low	Low	Medium
		• The LVFS was primarily a data collection organization that did appear to have any involvement of stakeholders (Kolding et al., 2014).	• In 1995, there were approximately 550,000 miners that were active in all of Tanzania (Phillips et al., 2001). This is assumed to be a minor fraction of the basin.	• No expression of voice was identified within this time period. As a result, discursive legitimacy is assumed to be low.	• Gold mining began in the colonial period, 1894, and by 1938, the regional gold mining industry was dominated by British and South

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Additionally, the LVFS tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	• Given the patterns of employment in 1995 and lack of clear representative organization, resources power is assumed to be low (Phillips et al., 2001).		African companies (70%; Newenham-Kahindi, 2011; Henckel et al., 2016). • A majority of gold mining occurred in the Tanzania region and was a significant economic opportunity due to its high export value in the 1940s (Henckel et al., 2016). • Following the second world war, there was a downturn in the mining industry leading to the closure of many small mines in the region (Henckel et al., 2016). • Given that gold mining was important to the economy but was declining by 1947, state interest is considered medium.
	1973 Establishment of the LVFC	Low	Low	Low	Low
		• The LVFC was primarily a data collection organization that did appear to have any involvement of stakeholders (FAO, 1989). • Additionally, the LVFC tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation or influence, formal authority was low.	• Given the patterns of employment in 1995 and lack of clear stakeholder group, resources power is assumed to be low (Phillips et al., 2001).	• Discursive legitimacy is assumed to be consistent with previous years.	• Policies in Tanzania shifted away from mining in the 1960s to prefer agriculture (Henckel et al., 2016). • Additionally, commercial gold mining ended in 1972 after a decline of activity within the region (Henckel et al., 2016). Given the economic decline during this time period, state interest is considered to be low.
	1977 Collapse of the LVFC and EAC	Low	Low	Low	High
		• During the collapse of the LVFC and EAC, management of fisheries was completed by national governments (Muyodi et al., 2010). • It is assumed that there was not institutionalized participation of stakeholders as there was not a functioning transboundary organization. • Additionally, activities continued to focus on fisheries development, therefore it is assumed that if local processes engaged stakeholders, these were limited to members of the fisheries sector. • As a result of the lack of participation or influence, formal authority was low.	• Given the patterns of employment in 1995 and lack of clear stakeholder group, resources power is assumed to be low (Phillips et al., 2001).	• Discursive legitimacy is assumed to be consistent with previous years.	• A state mining corporation (STAMICO) was formed in Tanzania in 1974 to enable the country to capture profits from the industry (Henckel et al., 2016). This corporation also aimed to create local employment opportunities (Newenham-Kahindi, 2011). • The establishment of the corporation demonstrated a state investment by Tanzania and, as a result, state interest was high.
	1994 Establishment of the LVFO and initiation of the LVEMP	Low	Low	Medium	High
		• The LVEMP addressed development of all stakeholders in the basin. The planning of the LVEMP was largely international and did not engage local stakeholders (Jansen et al., 1999). However, the final draft of the LVEMP engaged local representatives of the private sector, academia, and government (Jansen et	• In 1995, there were approximately 550,000 miners that were active in Tanzania (Phillips et al., 2001). • The quantity of miners is considered to be low relative to the size of the basin, and no organization could be located; therefore, resources power is assumed to be low.	• For each mining job, three additional jobs were created in urban and rural areas in the 1990s, (Ewald et al., 2004). Additionally, the mining industry was reported to increase incomes from agriculture (Ewald et al., 2004). • The benefits derived from the mining industry may have improved public opinion. As a result	• In the 1990s, there was increased activity in the mining sector in Tanzania, in part, related to a shift in economic policy (Henckel et al. 2016). • Given the growth and continued Tanzanian state participation in the industry, state interest was high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		al., 1999). Notably, many local stakeholders were not included in this process. • Given the low engagement of mining in the region in the early 1990s, it is assumed that the mining industry was largely excluded from LVEMP and LVFO development. • As a result of the lack of participation or influence, formal authority was low.		of increasing public opinion, discursive legitimacy is assumed to be medium.	
	2003 Establishment of the LVBC	Medium	Low	Medium	High
		• The EAC treaty committed to providing opportunities for civil actors to be engaged in governance (Godsäter, 2013). Within the basin region, this provided opportunities through the LVFO and LVEMP. • The LVEMP was meant to involve all stakeholders based in part, on the involvement of the World Bank as a funding source (Njiru et al., 2008). Stakeholder workshops were held as part of LVEMP I (Wirkus & Böge, 2006). These workshops were considered less successful with stakeholders in the lake's catchment (Wirkus & Böge, 2006). The LVEMP also engaged National Task Forces in the planning of LVEMP II. Representatives from local governments, NGOs, the private sector, and academia participate in these national organizations with participation of approximately 15,000 stakeholders and 40 NGOs participated (Wirkus & Böge, 2006). There has been contested opinions on the involvement of stakeholders in LVEMP implementation (Wirkus & Böge, 2006). • Several NGOs had institutionalized participation in transboundary basin management. The organization ECOVIC has observer status on the EAC Council of Ministers which implements LVEMP II (Godsäter, 2013). Additionally, OSIENALA works closely with the LVBC and LVFO to implement several projects (Godsäter, 2013). • EASWN attempts to serve as a citizen watchdog organization and motivate members of civil society to be engaged in monitoring, advocacy, and lobbying of transboundary institutions (Godsäter, 2013). • Although NGOs have been involved in multiple governance processes of the LVFO and LVEMP, there is criticism that involvement is not democratic and is biased to	• The increase of international activity in the mining industry changed the patterns of employment. Many artisanal and small-scale miners left the industry, and due to the increase in technology, skilled staff, who often come from outside of the basin, were required (Ewald et al., 2004). • Given the decrease in local employment, resources power is assumed to be low.	• Large protests and violent conflict occurred in contention with the Barrick Gold Mine in Tanzania resulting in fatalities and potential human rights violations (Ewald et al., 2004). These protests were led by employees of the mine. • Although the protest was directed at a singular mine in a region where gold mining is one of the only growing industries, it is assumed that there was a low public opinion of the mining corporations that existed in the region. • Additionally, in 2000, a mine opened in Tanzania that led to fatalities of human and cattle who used a tributary that was contaminated with mining waste (MacDougall, 2001). The fatalities may have decreased public opinion of mining operations. • Because the active protests were conducted by the mining communities, it is assumed that there was public support for local communities. Therefore, public support is assumed to be medium.	• In 1998, Tanzania established the Mining Act, which enabled greater foreign investment in the industry (Henckel et al., 2016). The state also continued to be involved. In 2004, the Tanzanian military in joint venture with a private company, became a major gold trader in the basin (Ewald et al., 2004). Furthermore, the state benefits from foreign profits in the region as it is able to receive a 3% tax on gold profits (Ewald et al., 2004). The state belief was that economic growth through mining would improve development in the region (Ewald et al., 2004). • In 2003, minerals were 37% of exports in Tanzania (Ewald, 2004). The mineral sector was perceived to be prioritized in Tanzania because of its ability to provide hard currency and income from exports (Lubovich, 2009). This prioritization was also observed in the 2000s, when pollution from a mine caused fatalities, but the government did not implement restrictions (MacDougall, 2001). • The basin has been considered an attractive area for international mining companies since the early 2000s (Newenham-Kahindi, 2011). • Tanzania also sought to improve oversight of mining operations by joining an organization in the African Union (Newenham-Kahindi, 2011). • Given the expressed and perceived interest in mining and contributions to the economy of Tanzania, state interest is considered high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		organizations that reinforce state objectives (Wirkus & Böge, 2006; Godsäter, 2013). • Given that institutionalized participation of the private sector occurred in the LVEMP, but participation was contingent on the preferences of the state, formal authority was medium.			
	2008 Tensions with Uganda	Medium	Low	Medium	High
		• In the basin water governance, state actors were perceived to dominate processes and only engage with civil society actors that supported the state agenda (Godsäter, 2013). As a result, stakeholder authority was limited and governance was considered as only “partly participatory” (Godsäter, 2013, p. 76). Additionally, the state was perceived to dictate the EAC, thus weakening its institutional power (Godsäter, 2013). • The LVBC was reported to work closely with representatives of the private sector and civil society whose interests were relevant to the LVBC’s mandate (Okurt & Othero, 2016). The LVBC hosts an Annual Stakeholders’ Forum which enables stakeholders to evaluate the extent to which the basin has become an economic growth zone (Okurut & Othero, 2012). However, the LVBC has been criticized for intentionally neglecting the opinions of certain stakeholders and wanting to engage primarily with governments (Godsäter, 2013). • The World Bank reports that approximately 50% of LVEMP II actions engaged community driven development by local institutions and communities (The World Bank, 2018a). This process included identification and capacity building of community organizations that implemented the projects (The World Bank, 2018a). However, it was also perceived that civil society had no influence in design and implementation of LVEMP II (Godsäter, 2013). • Given the institutionalized participation in the LVBC and LVEMP that is perceived to be contingent on the preferences of the state, formal authority was medium.	• The patterns of employment were assumed to be consistent with previous years. • Tanzanian NGOs sought to improve relationships between stakeholders and corporations by informing stakeholders of the benefits of cooperation (Newenham-Kahindi, 2011). • Although these NGOs were present and identified, because they did not necessarily advocate for the rights of the mining communities, they are not considered representative of the stakeholder group. Therefore, resources power is considered low.	• In 2008, the local community in Tanzania protested against the Barrick gold mine (Newenham-Kahindi, 2011). This action signaled a continued decrease in public opinion of the mining operations. • However, protesters continued to support the local community members who had worked at the mine (Newenham-Kahindi, 2011). As a result of the support for mining community members but continued contention with mining corporations, discursive legitimacy is assumed to be medium.	• In 2008, the industry in Kenya, Tanzania, and Uganda constituted 18.58%, 23.74%, and 25.77% of the national GDP, respectively (Plecher, 2020a,b,c). Industry encompasses mining, and therefore, the mining industry is assumed to be a portion of this GDP contribution. • Given that gold mining is still operational in Tanzania and contributes to the GDP, state interest is assumed to be high.
	2020 Current Status	Medium	Low	Medium	High
		• Frmal authority is assumed to be consistent with previous years.	• The patterns of employment were assumed to be consistent with previous years and no stakeholder organization was identified.	• Discursive legitimacy is assumed to be consistent with previous years.	• Industry in Kenya, Tanzania, and Uganda constituted 16.49%, 25.1%, and 19.87% of the national GDP, respectively (2018 and 2017;

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
			Therefore, resources power is considered to be low.	• In 2019, the freedom of the press index in Kenya, Tanzania, and Uganda were 32.44, 36.28, and 16.06, respectively (RSF, 2020). These rankings are classified by RSF as "bad," "problematic," and "fairly good" respectively (RSF, 2020). • As a result of the mixed public opinion, discursive legitimacy is medium.	Plecher, 2020a,b,c). Industry encompasses mining, and therefore, the mining industry is assumed to be a portion of this GDP contribution. • Given that gold mining is still operational in Tanzania and contributes to the GDP, it is assumed that state interest is high.
Hydropower industry	1947 Initiation of the LVFS	Low	Low	Low	Low
		• Hydropower had not been expanded in the basin by 1947. Therefore, formal authority is considered low.	• Hydropower had not been expanded in the basin by 1947. Therefore, resource power is considered low.	• Hydropower had not been expanded in the basin by 1947. Therefore, discursive legitimacy is considered low.	• Hydropower had not been expanded in the basin by 1947. Therefore, state interest is considered low.
	1973 Establishment of the LVFC	Low	Low	Medium	High
		• The LVFC was primarily a data collection organization that did appear to have any involvement of stakeholders (FAO, 1989). • Additionally, the LVFC tracked fisheries development and was not concerned with the lake's water quality or water usage (Kolding et al., 2014). • As a result of the lack of participation and influence, formal authority was low.	• Hydropower in the basin is concentrated in Uganda and related to the Owens Falls dam. • It is assumed that the number of people employed in the hydropower industry is low based on the job creation analysis of an alternate hydropower dam in Uganda (i.e., Bugoye HydroPower Project) that would employ 1,079 people (Scott, Dark, Seth, & Rud, 2013). • No representative organization could be located. • Given the lack of an identified organization and majority fraction of the basin population, resources power is assumed to be low.	• Hydropower creates job opportunities for other actors as a result of improved power supply. Based on an analysis of an alternate hydropower dam in Uganda, it was estimated that approximately 191-199 jobs are indirectly be related to power operation and approximately 8,434-10.256 jobs are supported and created as a result of improved power supply (Scott et al., 2013). • Given the employment opportunities related to hydropower, it is assumed that there is some public support; therefore, discursive legitimacy is assumed to be medium.	• The Agreed Curve was established in 1949 and 1953 between Uganda and Kenya to regulate the lake's outflow (Lubovich, 2009). • As part of the Agreed Curve, the ambient levels of the lake must be maintained at the expense of hydropower generation (Lubovich, 2009). • Given Uganda's interest which motivated the state to participate in a transboundary agreement, state interest was high.
	1977 Collapse of the LVFC and EAC	Low	Low	Medium	High
		• During the collapse of the LVFC and EAC, management of fisheries was completed by national governments (Muyodi et al., 2010). • It is assumed that there was not institutionalized participation of stakeholders as there was not a functioning transboundary organization. • Additionally, activities continued to focus on fisheries development, therefore it is assumed that if local processes engaged stakeholders, these were limited to members of the fisheries sector. • As a result of the lack of participation and influence, formal authority was low.	• Resources power is assumed to be consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• State interest is assumed to be consistent with previous years.
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium	Low	Medium	High
		• The LVEMP addressed development of all stakeholders in the basin. The planning of the LVEMP was largely international and did not	• In 1993, construction began on the Owens Falls dam to increase its capacity (Kull, 2006).	• Discursive legitimacy is assumed to be consistent with previous years.	• The Agreed Curve was updated in 1991 between Uganda and Egypt (Kull, 2006).

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		engage local stakeholders (Jansen et al., 1999). However, the final draft of the LVEMP engaged local representatives of the private sector, academia, and government (Jansen et al., 1999). • Although many local stakeholders were excluded, it is assumed that the hydropower industry constituted as part of the involved private sector. As a result of limited participation, formal authority was medium.	• Resources power is assumed to be consistent with previous years.		• The dam was also expanded in 1993 to increase capacity. • Given Uganda's interest in hydropower which motivated participation in the transboundary agreement and support of dam expansion, state interest was high.
	2003 Establishment of the LVBC	Medium	Low	Medium	High
		• The EAC treaty committed to providing opportunities for civil actors to be engaged in governance (Godsäter, 2013). Within the basin region, this provided opportunities through the LVFO and LVEMP. • The LVEMP was meant to involve all stakeholders based in part, on the involvement of the World Bank as a funding source (Njiru et al., 2008). Stakeholder workshops were held as part of LVEMP I (Wirkus & Böge, 2006). These workshops were considered not very successful with stakeholders in the lake's catchment area (Wirkus & Böge, 2006). The LVEMP also engaged National Task Forces in the planning of LVEMP II. Representatives from local governments, NGOs, the private sector, and academia participated in these national organizations and are comprised of approximately 15,000 stakeholders and 40 NGOs (Wirkus & Böge, 2006). Although multiple mechanisms for participation in the LVEMP exist, the extent of stakeholder involvement has been contested (Wirkus & Böge, 2006). • Several NGOs had institutionalized participation in transboundary basin management. The organization ECOVIC has observer status on the EAC Council of Ministers which implements LVEMP II (Godsäter, 2013). Additionally, OSIENALA works closely with the LVBC and LVFO to implement several projects (Godsäter, 2013). • EASWN attempts to serve as a citizen watchdog organization and motivate members of civil society to be engaged in monitoring, advocacy, and lobbying of transboundary institutions (Godsäter, 2013).	• By 1999, the expansion of the Owens Falls dam was completed (Kull, 2006). • Even with the expansion, it was assumed that the number of people employed in the hydropower industry was low based on the job creation analysis (Scott et al., 2013). • Given the lack of organization and minority fraction of the basin, resources power was low.	• Although water levels on the lake were dropping, the governments had not yet denounced the impacts of hydropower in public spaces (Lubovich, 2009). Therefore, discursive legitimacy is assumed to be consistent with previous years.	• The state interest is assumed to be consistent with previous years. Therefore, the state interest power is assumed to be high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• Although NGOs have been involved in multiple governance processes of the LVFO and LVEMP, there is criticism that involvement is not democratic and is biased to organizations that reinforce state objectives (Wirkus & Böge, 2006; Godsäter, 2013). • Given that institutionalized participation of the private sector occurred in the LVEMP, but participation was contingent on the preferences of the state, formal authority was medium.			
	2008 Tensions with Uganda	Medium	Low	Low	High
		• In the basin water governance, state actors were perceived to dominate processes and only engage with civil society actors that supported the state agenda (Godsäter, 2013). As a result, stakeholder authority was limited and governance was considered as only "partly participatory" (Godsäter, 2013, p. 76). Additionally, the state was perceived to dictate the EAC, thus weakening its institutional power (Godsäter, 2013). • The LVBC was reported to work closely with representatives of the private sector and civil society whose interests were relevant to the LVBC's mandate (Okurt & Othero, 2016). The LVBC hosts an Annual Stakeholders' Forum which enables stakeholders to evaluate the extent to which the basin has become an economic growth zone (Okurut & Othero, 2012). However, the LVBC has been criticized for intentionally neglecting the opinions of certain stakeholders and wanting to engage primarily with governments (Godsäter, 2013). • The World Bank reports that approximately 50% of LVEMP II actions engaged community driven development by local institutions and communities (The World Bank, 2018a). This process included identification and capacity building of community organizations that implemented the projects (The World Bank, 2018a). However, it was also perceived that civil society had no influence in design and implementation of LVEMP II (Godsäter, 2013). • Given the institutionalized participation of the private sector in the LVBC and LVEMP that was perceived to be contingent on the preferences of the state, formal authority was medium.	• Resources power is assumed to be consistent with previous years.	• The public comments on Uganda's operation of the dam may have decreased public opinion of the facility (Lubovich, 2009). As a result of the public attention to violation of the agreement, discursive legitimacy is assumed to be low.	• By 2004, hydroelectricity was the main energy source in the basin, supplying up to 78% of regional power (Ewald et al., 2004). • Uganda continued to operate two dams and hoped to expand energy generation capacity (Government of Uganda, 2007 as cited in Lubovich, 2009). • In 2008, the industry in Kenya, Tanzania, and Uganda constituted 18.58%, 23.74%, and 25.77% of the national GDP, respectively (Plecher, 2020a,b,c). Industry encompasses energy consumption, and therefore, hydropower is assumed to be a portion of this GDP contribution. • Given the dominance of hydropower in Uganda, state interest is assumed to be high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	2020 Current Status	Medium	Low	Medium	High
		• Rormal authority is assumed to be consistent with previous years.	• Resources power is assumed to be consistent with previous years.	• As the water level concerns were addressed, it is assumed that public opinion became favorable due to employment generation. • In 2019, the freedom of the press index in Kenya, Tanzania, and Uganda were 32.44, 36.28, and 16.06, respectively (RSF, 2020). These rankings are classified by RSF as "bad," "problematic," and "fairly good" respectively (RSF, 2020). • Given the assumed public support, discursive legitimacy is medium.	• The lake provides 90% of Uganda's hydropower production (The World Bank, 2018b). • The industry in Kenya, Tanzania, and Uganda constituted 16.49%, 25.1%, and 19.87% of the national GDP, respectively (2018 and 2017; Plecher, 2020a,b,c). Industry encompasses energy consumption, and therefore, hydropower is assumed to be a portion of this GDP contribution. • Given the dominance of hydropower in Uganda, state interest is assumed to be high.

Table 23. Comprehensive analysis of primary stakeholder vulnerability in the Lake Victoria basin.

Stakeholder	Event	Regional Development	Economic	Education	Political
Inhabitants of Urban Areas	1947 Initiation of the LVFS	High	High	High	High
		• Development of rail transit to Kisumu and Kampala enabled greater migration to the lake basin in the early 1990s (Hecky. Mugidde, Ramlal, Talbot, & Kling, 2010). • Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• There is often a diversity of livelihoods in cities including industry, services, trade, commercial activities, and transportation. Not all of these sectors require a high water usage. It is assumed that this diversity existed in urban areas. • Kenya adjusted income: 0.304 (1950; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.235 (1950; Prados de la Escosura, 2019). • Uganda adjusted income: 0.313 (1950; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Although there was likely a diversity of production in urban areas, based on the income parameter, economic vulnerability was high.	• Kenya average years of schooling: 0.84, literacy: 0.055 (1945 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.35, literacy: 0.017 (1950; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 0.66, literacy: 0.068 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• Community governance of fisheries existed but was inconsistent in extent and enforcement throughout the lake (Jansen et al., 1999). • As a result of the absence of state environmental regulations and enforcement, the political vulnerability was high.
	1973 Establishment of the LVFC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Kenya GNI per capita: $200, adjusted income: 0.360 (1973 and 1970; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.282 (1970; Prados de la Escosura, 2019). • Uganda adjusted income: 0.351 (1970; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Although there was likely a diversity of production in urban areas, based on the income parameter, economic vulnerability was high.	• Kenya average years of schooling: 1.45, literacy: 0.113 (1970 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.79, literacy: 0.096 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.05, literacy: 0.098 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• In the 1970s there was limited government regulation of the lake's fisheries, and any regulations were poorly enforced (Jansen et al., 1999). In some places, community governance had supplemented regulation and been institutionalized; however, this coverage was not consistent throughout the lake (Jansen et al., 1999). • Given the absence of regulations and limited enforcement, political vulnerability was high.
	1977 Collapse of the LVFC and EAC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin.	• Kenya GNI per capita: $280, adjusted income: 0.365 (1977 and 1975; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.291 (1975; Prados de la Escosura, 2019). • Uganda adjusted income: 0.334 (1975; Prados de la Escosura, 2019).	• Kenya average years of schooling: 1.86, literacy: 0.137 (1975 and 1950; UNDP, 2020; Prados de la Escosura, 2019).; • Tanzania average years of schooling: 2.18, literacy: 0.114 (1975; UNDP, 2020; Prados de la Escosura, 2019).	• The Water Act was established in Kenya in 1974 to centralize management of drinking water and improve access (Ogendi & Ong'oa, 2009). • The Water Utilisation and Control Act was established in Tanzania in 1974 as a resource-exploitation statue (Pallangyo, 2007).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Although there was likely a diversity of production in urban areas, based on the income parameter, the economic vulnerability was high.	• Uganda average years of schooling: 1.43, literacy: 0.111 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• Given that there were not regulations in all three countries, the existing regulations did not focus on pollution control, and there was limited enforcement, political vulnerability was high.
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium	High	Medium	High
		• Kenya percent of people using at least basic/safe drinking water services: 47.3, percent of urban population: 88.0/62.1 (2000; The World Bank, 2020). • It is assumed that Tanzania and Uganda have less access to basic drinking water services based on trends from 2003 (The World Bank, 2020). Based on the 2003 data, it is assumed that access to drinking water service in urban areas is medium in two countries and high in one (>50% and >80%, respectively). • The growth rate in the basin was estimated to be 6% in urban areas (Ntiba et al., 2001). • Given the drinking water access and high growth rates that can exceed infrastructure, the regional development vulnerability is assumed to be medium.	• The Nile perch industry experienced rapid growth in the 1980s (Jansen et al., 1999). This event created employment opportunities in various sectors that could provide services to fishermen (Jansen et al., 1999). • Additionally, other actors joined the management of fisheries due to the potential for economic gains. The fishery enabled investments by urban residents (e.g., government officials, businessmen, and teachers) who were able to profit through "absentee ownership" (Jansen et al., 1999, p. 12). • In the 1980s, the poverty rate in Kisumu was reported to be 37% with a rising trend (Mireri, Atekyereza, Kyessi, & Mushi, 2007). • Kenya GNI per capita: $260, adjusted income: 0.379 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $160, adjusted income: 0.266 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $180, adjusted income: 0.307 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$725; 2019). • Although there was likely a diversity of production in urban areas and poverty is considered medium (>20% and <50%), it is assumed that incomes were similar to the average basin income. Therefore, based on GNI per capita, the economic vulnerability was high.	• Kenya average years of schooling: 4.4, expected years of schooling: 8.8, literacy: 0.319, 82.2% (1994, 1995, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4, expected years of schooling: 5.5, literacy: 0.255, 59.1% (1994 and 1995; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 3.3, expected years of schooling: 5.5, literacy: 0.209, 56.1% (1994, 1995, and 1991; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Based on the middle to high literacy and low average years of schooling, educational vulnerability was medium.	• The National Environment Management Council Act was established in Tanzania in 1983 to advise on environmental policies (Pallangyo, 2007). • The National Environmental Management Policy was established in Uganda in 1994 (Akello, 2007). • Fisheries compliance in Tanzania was reported to be low in 1993 (Wilson, 1993 as cited in Eggert & Lokina, 2010). • All three countries had environmental regulations although the regulations were not solely related to environmental pollution. Given that laws existed but did not have consistent compliance, political vulnerability is considered high.
		Medium	High	Medium	Medium

Stakeholder	Event	Regional Development	Economic	Education	Political
	2003 Establishment of the LVBC	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). These uses vary but can include untreated water for drinking. • In 1997 there was cholera outbreak which suggests that there was low coverage of water treatment and frequent consumption of raw lake water (Shapiro et al., 1999). • The basin's growth rate was approximately 3% in 2001 and was expected to put a greater strain on the lake resources (UNEP, 2006). • Kenya percent of people using at least basic/safe drinking water services: 49.5, percent of urban population: 87.4/62.0 (2003; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 31.6, percent of urban population: 67.8/3.9 (2003; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 30.3/5.2, percent of urban population: 71.2/24.0 (2003; The World Bank, 2020). • The urban access to basic drinking water services is medium in two countries and high in one (>50% and >80%, respectively). • Given the medium to high rate of drinking water access and high growth rate, regional development vulnerability was medium.	• Kenya GNI per capita: $400, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.381 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $430, gap at national poverty line: 6.7, urban gap at national poverty line: 3.9, adjusted income: 0.306 (2003, 2011, and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $250, gap at national poverty line: 8.7, urban gap at national poverty line: 3.5, adjusted income: 0.365 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$765; 2019). • On a per capita income basis, the three countries are in the lowest third of countries of the world (UNEP, 2006). • Although there was likely a diversity of production in urban areas, it is assumed that incomes were similar to the average basin income. Therefore, based on GNI per capita, the economic vulnerability was high.	• A low level of public awareness was reported in understanding how human activities cause degradation (Machiwa, 2003). • Kenya average years of schooling: 5.6, expected years of schooling: 8.9, literacy: 0.441, 82.2%, 82.2% (2003, 2005, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4.4, expected years of schooling: 7.1, literacy: 0.351, 67.8%, 69.4% (2003, 2005, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 4.3, expected years of schooling: 11.6, literacy: 0.273, 68.1%, 73.2% (2003, 2005, 2002, and 2010; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development threholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• Harmonization of policies was identified as a "long-term" goal of the LVEMP (Kolding et al., 2014, p. 2). The lack of immediate action to harmonize policies was predicted to challenge management of the lake (Lubovich, 2009). • Additionally, existing regulations at various levels of scale were considered weak leading to the influx of domestic and industrial waste (Ntiba et al., 2001). • In 1997, the Kenyan government moved to decentralize management to communities (Ogendi & Ong'oa, 2009). • In 1999, the National Water Policy was established in Kenya to address water sanitation and water resources management; these rules were revised in 2002 (Ogendi & Ong'oa, 2009). The Environmental Management and Coordination Act was also established in 1999 to address environmental management and conservation (Okurut & Othero, 2012). • A National Environmental Policy was established in 1997 in Tanzania to promote more sustainable management of resources (Pallangyo, 2007). • The Ugandan Water Policy, National Wetlands Management Policy, and Fisheries Policy were established between 1995 and 2000 (Akello, 2007). • The Uganda Water Act was established in 1997, and the National Environmental Act was established in 1995 (Uganda Legal Information Institute, n.d.; Akello, 2007). The act established the National Environment Management Authority to help to address pollution (Okurut & Othero, 2012). • Several factors limited implementation and enforcement of regulations. In Uganda, law enforcement professionals lacked sufficient legal resources, technical capacity, and political support (Akello, 2007). The other states also suffered from a lack of personnel and conservation initiatives (Lugo et al., 2014). Decentralization of fisheries management furthered patterns of insufficient staffing (Ntiba et al., 2001). • The lack of enforcement of water management and fishing regulations was credited for water quality degradation in the lake (Muli, 1996).

Stakeholder	Event	Regional Development	Economic	Education	Political
					• In 2003, the corruption perception index was 1.9/10 in Kenya, 2.5/10 in Tanzania, and 2.2/10 in Uganda (Transparency International, 2020). • Given that regulations were established in all countries that addressed pollution, but corruption was high (<33%) and enforcement was low, the political vulnerability is considered medium.
	2008 Tensions with Uganda	High	High	Medium	Medium
		• High rates of rural to urban migration were occurring in 2006, and the three countries had higher than average population densities within the basin which strained available resources (Wirkus & Böge, 2006; The World Bank, 2008). The high population growth rates (3-4%) and urbanization in the basin led to the expansion of unplanned urban settlements that do not have sufficient water services (UNEP, 2006; Lubovich, 2009). • There are few hospitals in close proximity to communities within the basin (UNEP, 2006). • Communities within the basin have high rates of diarrheal diseases compared to other parts of East Africa (UNEP, 2006). Along with other illnesses, this creates a health burden which can divert resources and further increase vulnerability. • Water supply was not ubiquitous in cities. In Kisumu, 40% of coverage existed in planned parts of the cities and most community members accessed alternate water sources (Mireri et al., 2007). No coverage existed in the wide-spread informal settlements which are common to urban areas of Kenya (Mireri et al., 2007). Although alternate water sources were used, many of these sources (e.g., shallow wells) were at risk of contamination due to the low levels of sanitation coverage in the city (Mireri et al., 2007). Additionally, the Kisumu municipality was reported to regularly have water shortages (Mireri et al., 2007). • Kenya percent of people using at least basic/safe drinking water services: 53.0, percent of urban population: 86.4/57.7 (2008; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 40.2,	• Urban residents participated in commercial activities, trading, provision of social services, car washing, sand scooping, and urban agriculture (UNEP, 2006; Mireri et al., 2007). • Communities in the basin were considered food insecure, suggesting a high dependence on environmental resources and a lack of financial means to adapt to purchase food (Njiru et al., 2008). • Urban agriculture was used for employment and as a way to address food insecurity. These practices take up 80% of the land cover within the extent of Kisumu (Mireri et al., 2007). • Degradation of wetlands has decreased alternate opportunities for livelihoods (UNEP, 2006). • High rates of poverty were observed in the basin. In 2004, the mean household poverty in the region was 46.4% (LBDA, 2004 as cited in UNEP, 2006; Lubovich, 2009). Additionally, 64.5% of Kenyans, 36% of Tanzanians, and 39% of Ugandans were below the poverty line (UNEP, 2006). • In 2006, approximately 70% of the basin population was reported to live in "abject poverty" (UNEP, 2006, p. 32). • Poverty was also observed in cities. In Kisumu, 60% of the population lived in informal settlements and 60% of the municipality lived in poverty (Mireri et al., 2007). Unemployment within the city is approximately 30%, and 52% of the working population participates in "informal" activities including trading and bicycle transport (Mireri et al., 2007, p. 378). • Several factors have increased the poverty within cities. The decrease in lake levels had a negative economic impact on transportation, trade, hydropower, and fishing on the lake (The World Bank, 2008). Further, closure and	• A low public understanding of sources of cyanobacteria was reported in 2008 (Bathwondi, 2008 as cited in Lugo et al., 2014). • In 2004, 18.3% of Kenyans, 23% of Tanzanians, and 33% of Ugandans did not have access to formal education (UNEP, 2006). • Kenya average years of schooling: 6, expected years of schooling: 10.2, literacy: 0.278, 72.2%, 82.2% (2008, 2007, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 5, expected years of schooling: 8.4, literacy: 0.286, 67.8%, 69.4% (2008, 2007, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 5.2, expected years of schooling: 10.9, literacy: 0.272, 68.1%, 71.3% (2008, 2007, 2010, and 2006; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• The LVBC was established with the goal to harmonize policies between the riparian countries; however, national coordination has been lacking (Song et al., 2018). • Additionally, although regulations existed in all three countries, enforcement was generally weak (UNEP, 2006). Therefore, the laws, implementation, enforcement, and penalties varied between the three countries (Njiru et al., 2008). • Local regulations exist but also differ, creating management challenges. The national authorities have not driven coordination of local municipalities (Wirkus & Böge, 2006). Additionally, a lack of coordination between districts has caused conflict and complicated implementation (UNEP, 2006; EAC, 2005 as cited in Lubovich, 2009). • The Environmental Management Act was established in Tanzania in 2004 to provide a framework that addresses issues such as pollution prevention, establish a regulatory body, and decentralize enforcement to local authorities (Pallangyo, 2007). However, local authorities often do not have the resources to enforce regulations (Pallangyo, 2007). • A significant percent of fishermen reported that they do not consistently comply with regulations (Eggert & Lokina, 2010). • In 2008, the corruption perception index was 2.1/10 in Kenya, 3.0/10 in Tanzania, and 2.6/10 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high (<33%) and enforcement is low, the political vulnerability is considered medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
		percent of urban population: 75.2/24.3 (2008; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 36.6/5.9, percent of urban population: 72.6/21.1 (2008; The World Bank, 2020). • Given the low coverage of drinking water access in Kisumu and rates of growth in the basin, it is assumed that other cities lack water access for at least 50% of their populations. Therefore, access to drinking water is considered low. • As a result of low assumed rates of access to water treatment, regional development vulnerability was high.	decrease of industry, such as several major factories in Kisumu, have altered employment patterns (Mireri et al., 2007). • Kenya GNI per capita: $820, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.391 (2008, 2005, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $600, gap at national poverty line: 6.7, urban gap at national poverty line: 3.9, adjusted income: 0.317 (2008, 2011, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $440, gap at national poverty line: 6.8, urban gap at national poverty line: 1.8, adjusted income: 0.378 (2008, 2009, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$975; 2019). • Based on the high levels of poverty which are also observed in cities (>50%), economic vulnerability was high.		
	2020 Current Status	Medium	Medium	Medium	Medium
		• Large rates of urbanization have occurred in cities along the lake including Mwanza, Kisumu, and Entebbe (The World Bank, 2018b). Industrial development has also rapidly increased within the region (The World Bank, 2018b). • Poor planning in municipalities has led to insufficient wastewater treatment (Atieno, 2014). • Within the city of Kisumu, approximately 65% of residents had an improved water source in 2010; alternate water sources include open wells, streams, ponds, and water purchased from vendors (Maoulidi, 2010). • It is assumed that water treatment trends in Kisumu are similar to other urban areas around the lake. Therefore, it is assumed that access to improved water sources in the lake is medium (>50% and <80%). • Kenya percent of people using at least basic/safe drinking water services: 58.9, percent of urban population: 84.6/50.0 (2017; The World Bank, 2020).	• Increased growth of industry has impacted Kampala, Entebbe, Mwanza, Bukoba, and Kisumu (Zilov, 2013). • However, poverty within the basin was considered “extremely high” in 2009 (Lubovich, 2009, p. 5). • Approximately one third of the basin lived on less than $1.25/day (i.e., in extreme poverty; The World Bank, 2016). In 2018, approximately 43.4% of Kenyans, 46.6% of Tanzanians, and 34.6% of Ugandans in the basin lived in poverty, and these rates were greater within the basin (The World Bank, 2018b). • Additionally, in 2016, The World Bank reported a high dependence of local communities on the lake (The World Bank, 2016). • Kenya GNI per capita: $1,620, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.420 (2018, 2005, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $1,020, gap at national poverty line: 6.7, urban gap at national	• Low levels of public awareness in understanding sources of pollution were reported in 2012 (Wang, 2012). • Kenya average years of schooling: 6.6, expected years of schooling: 11.1, literacy: 0.329, 78.7%, 81.5% (2018, 2015, 2014, and 2018; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 6, expected years of schooling: 8.0, literacy: 0.353, 77.9%, 69.4% (2018, 2015, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 6.1, expected years of schooling: 11.2, literacy: 0.291, 70.2%, 77.9% (2018, 2015, and 2012; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is medium in two countries	• The lack of coordination has been criticized for its impact that “hamper[s] development efforts” (Lubovich, 2009, p. 12). • The LVBC self-reported that it had weaknesses in financial sustainability, partnership framework, and inter-departmental coordination (2013). • Failure of regional bodies to implement projects has also impacted consistency within the region as part of LVEMP II (The World Bank, 2018a). This failure is largely affected by insufficient country funding of projects which includes monitoring of water quality and fisheries (The World Bank, 2018a). • It was reported that cities did not predict the growth of industries in the region; therefore, there are insufficient municipal regulations to manage discharges (Atieno, 2014). Additionally, existing regulations are not enforced and are regularly broken by industries (Atieno, 2014). • In 2019, the corruption perception index was 28/100 in Kenya, 37/100 in Tanzania, 28/100 in Uganda (Transparency International, 2020).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Tanzania percent of people using at least basic/safe drinking water services: 56.7, percent of urban population: 85.5/35.0 (2017; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 49.1/7.1, percent of urban population: 75.1/15.7 (2017; The World Bank, 2020). • As a result of medium assumed rates of improved water access, regional development vulnerability is medium.	poverty line: 3.9, adjusted income: 0.362 (2018, 2011, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $620, gap at national poverty line: 5.2, urban gap at national poverty line: 2.5, adjusted income: 0.416 (2018, 2012, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is considered low income (<$996) and two are considered lower-middle income (<$3,895; 2019). • Given that poverty throughout the basin was considered medium (>20% and <50%) and the GNI per capita was medium, the economic vulnerability is medium.	and high in one country (>50% and >80%, respectively). • Based on the low public awareness, medium to high literacy, and low average schooling, educational vulnerability is medium.	• Given that regulations were established for all three countries and relate to pollution, but corruption is high and medium (<33% and <66%, respectively) and enforcement is low, the political vulnerability is considered medium.
Traditional fishing communities	1947 Initiation of the LVFS	High	High	High	High
		• Development of rail transit to Kisumu and Kampala enabled greater migration to the lake basin in the early 1990s (Hecky et al., 2010). This action also enabled the commercialization of the lake fisheries enabling initial overfishing at the beginning of the century (Hecky et al., 2010). • It is assumed that fishing communities are predominantly in rural areas. Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Fisheries were led by small scale operators with an even distribution of profits that were evenly spread throughout the lake (Jansen et al., 1999). • Fishermen were directly reliant on the water resources without a limited diversity of income sources. Although fish were sold in local markets, fishing was largely a subsistence activity (UNEP, 2006). • Kenya adjusted income: 0.304 (1950; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.235 (1950; Prados de la Escosura, 2019). • Uganda adjusted income: 0.313 (1950; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the subsistence livelihoods, high dependence on water resources, and low income parameter, the economic vulnerability was high.	• Kenya average years of schooling: 0.84, literacy: 0.055 (1945 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.35, literacy: 0.017 (1950; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 0.66, literacy: 0.068 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• Community governance of fisheries existed but was inconsistent in extent and enforcement throughout the lake (Jansen et al., 1999). • As a result of the absence of state environmental regulations and enforcement, the political vulnerability was high.
	1973 Establishment of the LVFC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to	• Kenya adjusted income: 0.360 (1970; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.282 (1970; Prados de la Escosura, 2019). • Uganda adjusted income: 0.351 (1970; Prados de la Escosura, 2019).	• Kenya average years of schooling: 1.45, literacy: 0.113 (1970 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.79, literacy: 0.096 (1970; UNDP, 2020; Prados de la Escosura, 2019).	• In the 1970s there was limited government regulation of the lake's fisheries, and any regulations were poorly enforced (Jansen et al., 1999). In some places, community governance had supplemented regulation and been institutionalized; however, this coverage was

Stakeholder	Event	Regional Development	Economic	Education	Political
		drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Although profits were evenly spread, based on the largely subsistence lifestyle, high water resources dependence, and income parameter, the economic vulnerability was high.	• Uganda average years of schooling: 1.05, literacy: 0.098 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	not consistent throughout the lake (Jansen et al., 1999). • Given the absence of regulations and limited enforcement, political vulnerability was high.
	1977 Collapse of the LVFC and EAC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Kenya adjusted income: 0.365 (1975; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.291 (1975; Prados de la Escosura, 2019). • Uganda adjusted income: 0.334 (1975; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Although profits were evenly spread, based on the largely subsistence lifestyle, high water resources dependence, and income parameter, the economic vulnerability was high.	• Kenya average years of schooling: 1.86, literacy: 0.137 (1975 and 1950; UNDP, 2020; Prados de la Escosura, 2019).; • Tanzania average years of schooling: 2.18, literacy: 0.114 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.43, literacy: 0.111 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• The Water Act was established in Kenya in 1974 to centralize management of drinking water and improve access (Ogendi & Ong'oa, 2009). • The Water Utilisation and Control Act was established in Tanzania in 1974 as a resource-exploitation statue (Pallangyo, 2007). • Given that there were not regulations in all three countries, the existing regulations did not focus on pollution control, and there was limited enforcement, political vulnerability was high.
	1994 Establishment of the LVFO and initiation of the LVEMP	High	Medium	Medium	High
		• Kenya percent of people using at least basic drinking water services: 47.3, percent of rural population: 37.2 (2000; The World Bank, 2020). • It is assumed that Tanzania and Uganda have low access (<50%) to basic drinking water treatment based on the trends from 2003 (The World Bank, 2020). • The growth rate in the basin was estimated to be 3% in rural areas (Ntiba et al., 2001). Combined with the high population density of the region this implies a strain on water resources (Hecky et al., 2010). • The growth of the Nile perch fish market encouraged migration from nearby countries which can further contribute to insecurity for recently migrated fishermen (The World Bank, 2018b). • Given the drinking water access and high growth rates that likely exceed existing	• The introduction of Nile perch made fishing more lucrative livelihoods in the 1990s. The Nile perch increased income for fishing communities which led to a proliferation of commercial facilities where wealth could be spent (Jansen et al., 1999). This increase in income also enabled several fishermen to diversify and expand their efforts, thus providing new economic opportunities (Jansen et al., 1999). • Other actors joined the management of fisheries due to the potential for economic gains. The industry shifted from being solely owner-operated to include absentee ownership and employ fishermen who do not own gear and were previously unemployed (Jansen et al., 1999). • However, the catch from the fisheries was often required to be exported and thus, was no	• Kenya average years of schooling: 4.4, expected years of schooling: 8.8, literacy: 0.319, 82.2% (1994, 1995, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4, expected years of schooling: 5.5, literacy: 0.255, 59.1% (1994 and 1995; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 3.3, expected years of schooling: 5.5, literacy: 0.209, 56.1% (1994, 1995, and 1991; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The	• The National Environment Management Council Act was established in Tanzania in 1983 to advise on environmental policies (Pallangyo, 2007). • The National Environmental Management Policy was established in Uganda in 1994 (Akello, 2007). • Fisheries compliance in Tanzania was reported to be low in 1993 (Wilson, 1993 as cited in Eggert & Lokina, 2010). • All three countries had environmental regulations although the regulations were not solely related to environmental pollution. Given that laws existed but did not have consistent compliance, political vulnerability is considered high.

Stakeholder	Event	Regional Development	Economic	Education	Political
		infrastructure, the regional development vulnerability was high.	longer sold to the local community (Jansen et al., 1999). • Kenya GNI per capita: $260, adjusted income: 0.379 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $160, adjusted income: 0.266 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $180, adjusted income: 0.307 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$725; 2019). • Although there is a high dependence on water resources and low GNI per capita, as a result of the increase of economic opportunity in the fishing sector, economic vulnerability was medium.	literacy percentage is middle to high (>50% and >80%, respectively). • Based on the middle to high literacy and low average years of schooling, educational vulnerability was medium.	
	2003 Establishment of the LVBC	High	High	Medium	Medium
		• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). These uses vary but can include untreated water for drinking. • In 1997 there was cholera outbreak which suggests that there was low coverage of water treatment and frequent consumption of raw lake water (Shapiro et al., 1999). • The basin's growth rate was approximately 3% in 2001 which was expected to put a greater strain on the lake (UNEP, 2006). • It was suggested that fishermen frequently migrate (Jansen et al., 1999). This can decrease stable access to environmental resources and healthcare. • Kenya percent of people using at least basic/safe drinking water services: 49.5, percent of rural population: 39.4 (2003; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 31.6, percent of rural population: 20.4 (2003; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 30.3/5.2, percent of rural population: 22.5/1.6 (2003; The World Bank, 2020).	• Fishermen identified few alternative sources of cash income in the basin, suggesting limited regional opportunity (Geheb & Crean, 2003). However, this identification also highlighted the financial opportunities of fisheries (Geheb & Crean, 2003). • The fishery was impacted by a brief ban of exports to the European Union in 1999 (Zilov, 2013). There was also a decrease in catch per fishermen since the early 1990s with increasing numbers of fishermen involved in the industry (Muyodi et al., 2010). • The influx in fishermen was related to the lack of alternate means of income, leading to an increase of unskilled workers in the field (Geheb & Crean, 2003). • External actors began to take over the fish market thus decreasing the range of employment opportunities for local communities and altering the distribution of wealth (Njiru et al., 2008). This has further led to food insecurity of local communities who lost access to the local catch (UNEP, 2006). • Funds from the fishing industry were sent to the national treasury and not returned to the region which makes it challenging to promote better management within the region (Ntiba et al., 2001).	• A low level of public awareness was reported in understanding how human activities cause degradation (Machiwa, 2003). • Kenya average years of schooling: 5.6, expected years of schooling: 8.9, literacy: 0.441, 82.2%, 82.2% (2003, 2005, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4.4, expected years of schooling: 7.1, literacy: 0.351, 67.8%, 69.4% (2003, 2005, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 4.3, expected years of schooling: 11.6, literacy: 0.273, 68.1%, 73.2% (2003, 2005, 2002, and 2010; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development threholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• Harmonization of policies was identified as a "long-term" goal of the LVEMP (Kolding et al., 2014, p. 2). The lack of immediate action to harmonize policies was predicted to challenge management of the lake (Lubovich, 2009). • Additionally, existing regulations at various levels of scale were considered weak leading to the influx of domestic and industrial waste (Ntiba et al., 2001). • In 1997, the Kenyan government moved to decentralize management to communities (Ogendi & Ong'oa, 2009). • In 1999, the National Water Policy was established in Kenya to address water sanitation and water resources management; these rules were revised in 2002 (Ogendi & Ong'oa, 2009). The Environmental Management and Coordination Act was also established in 1999 to address environmental management and conservation (Okurut & Othero, 2012). • A National Environmental Policy was established in 1997 in Tanzania to promote more sustainable management of resources (Pallangyo, 2007). • The Ugandan Water Policy, National Wetlands Management Policy, and Fisheries Policy were established between 1995 and 2000 (Akello, 2007).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• The rural access to basic drinking water services is low in all countries (<50%). Given the low rate of drinking water access, regional development vulnerability was high.	• Kenya GNI per capita: $400, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.381 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $430, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.306 (2003, 2011, and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $250, gap at national poverty line: 8.7, rural gap at national poverty line: 9.7, adjusted income: 0.365 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$765; 2019). • On a per capita income basis, the three countries are in the lowest third of countries of the world (UNEP, 2006). • Although the fishing industry provided an economic opportunity to actors from all areas, given the decreasing catches, export of profits from the region, and low GNI per capita, the economic vulnerability was high.		• The Uganda Water Act was established in 1997, and the National Environmental Act was established in 1995 (Uganda Legal Information Institute, n.d.; Akello, 2007). The act established the National Environment Management Authority to help to address pollution (Okurut & Othero, 2012). • Several factors limited implementation and enforcement of regulations. In Uganda, law enforcement professionals lacked sufficient legal resources, technical capacity, and political support (Akello, 2007). The other states also suffered from a lack of personnel and conservation initiatives (Lugo et al., 2014). Decentralization of fisheries management furthered patterns of insufficient staffing (Ntiba et al., 2001). • The lack of enforcement of water management and fishing regulations was credited for water quality degradation in the lake (Muli, 1996). • In 2003, the corruption perception index was 1.9/10 in Kenya, 2.5/10 in Tanzania, and 2.2/10 in Uganda (Transparency International, 2020). • Given that regulations were established in all countries that addressed pollution, but corruption was high (<33%) and enforcement was low, the political vulnerability is considered medium.
	2008 Tensions with Uganda	High	High	Medium	Medium
		• High population growth rates (3-4%) led to the expansion of unplanned rural settlements that do not have sufficient water services (UNEP, 2006; Lubovich, 2009). Poorer rural residents frequently resided in "remote and ecologically fragile" areas (UNEP, 2006, p. 7). • Lakeside communities also had poor access to healthcare (Muyodi et al., 2010). • Communities within the basin have high rates of diarrheal diseases compared to other parts of East Africa (UNEP, 2006). Along with other illnesses, this creates a health burden which can divert resources and further increase vulnerability. • Kenya percent of people using at least basic/safe drinking water services: 53.0, percent of rural population: 43.1 (2008; The World Bank, 2020).	• The amount of fish caught decreased per fishermen since the early 1990s (7 kg to 3 kg), with an increase in participating fishermen since 1975 (35,000 to 165,000 fishermen; Muyodi et al., 2010). Changes in fishing technology and species diversity increased vulnerability of fishermen of small fish (UNEP, 2006). • Fishing was considered the "most important economic activity" for riparian communities (UNEP, 2006, p. 6). • Although the industry has become lucrative, few of the profits are reaped by basin inhabitants as exporting firms control profits and generally invest externally (UNEP, 2006). Additionally, the decrease in lake levels had a negative economic impact on fishing in the lake (The World Bank, 2008). • In 2004, the mean household poverty in the region was reported to be 46.4% (LBDA, 2004	• A low public understanding of sources of cyanobacteria was reported in 2008 (Bathwondi, 2008 as cited in Lugo et al., 2014). • In 2004, 18.3% of Kenyans, 23% of Tanzanians, and 33% of Ugandans did not have access to formal education (UNEP, 2006). • Kenya average years of schooling: 6, expected years of schooling: 10.2, literacy: 0.278, 72.2%, 82.2% (2008, 2007, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 5, expected years of schooling: 8.4, literacy: 0.286, 67.8%, 69.4% (2008, 2007, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 5.2, expected years of schooling: 10.9, literacy: 0.272, 68.1%, 71.3% (2008, 2007, 2010, and	• The LVBC was established with the goal to harmonize policies between the riparian countries; however, national coordination has been lacking (Song et al., 2018). • Additionally, although regulations existed in all three countries, enforcement was generally weak (UNEP, 2006). Therefore, the laws, implementation, enforcement, and penalties varied between the three countries (Njiru et al., 2008). • Local regulations exist but also differ, creating management challenges. The national authorities have not driven coordination of local municipalities (Wirkus & Böge, 2006). Additionally, a lack of coordination between districts and fisheries have caused conflict and complicated implementation (UNEP, 2006; EAC, 2005 as cited in Lubovich, 2009).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Tanzania percent of people using at least basic/safe drinking water services: 40.2, percent of rural population: 27.9 (2008; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 36.6/5.9, percent of rural population: 28.5/2.5 (2008; The World Bank, 2020). • Given the low coverage of drinking water access in rural areas (<50%) and incidence of gastrointestinal disease, regional development vulnerability was high.	as cited in UNEP, 2006; Lubovich, 2009). Additionally, 64.5% of Kenyans, 36% of Tanzanians, and 39% of Ugandans were below the poverty lines (UNEP, 2006). • In 2006, approximately 70% of the basin population was reported to live in "abject poverty" (UNEP, 2006, p. 32). • Degradation of wetlands has decreased alternate opportunities for livelihoods (UNEP, 2006). • Kenya GNI per capita: $820, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.391 (2008, 2005, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $600, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.317 (2008, 2011, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $440, gap at national poverty line: 6.8, rural gap at national poverty line: 7.6, adjusted income: 0.378 (2008, 2009, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$975; 2019). • Based on the strain in the fishing industry, the high levels of poverty in the basin, and the low GNI per capita, the economic vulnerability was high.	2006; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• The Environmental Management Act was established in Tanzania in 2004 to provide a framework that addresses issues such as pollution prevention, establish a regulatory body, and decentralize enforcement to local authorities (Pallangyo, 2007). However, local authorities often do not have the resources to enforce regulations (Pallangyo, 2007). • A significant percent of fishermen reported that they do not consistently comply with regulations (Eggert & Lokina, 2010). Further, there was a poor relationship between fishermen and enforcement institutions, causing a spike in conflict in 2001 (UNEP, 2006). These tensions are believed to further impede fisheries management (UNEP, 2006). • In 2008, the corruption perception index was 2.1/10 in Kenya, 3.0/10 in Tanzania, and 2.6/10 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high (<33%) and enforcement is low, the political vulnerability is considered medium.
	2020 Current Status	High	Medium	Medium	Medium
		• The basin has one of the highest rural population densities in the world (Lubovich, 2009). The growth of the fishing industry has increased the population density along the lake, straining resources (Atieno, 2014). • Within small, riparian communities, dependence on lake water can be high. Within the small Kenyan town of Usoma, 38% of survey respondents use water from the lake for cooking, 86% use water for other domestic uses, and 42% use water for open defecation (Bisung, Elliott, Schuster-Wallace, Karanja, & Bernard, 2014). • Kenya percent of people using at least basic/safe drinking water services: 58.9,	• NGOs and various community organizations have been attempting to increase alternative livelihoods for fishermen (Atieno, 2014). Within the basin, subsistence farming and fishing are considered "the primary livelihoods of those most in need" (The World Bank, 2018b, p. 5). • However, many fishermen entered the business without experience due to lack of alternate opportunities causing a high percentage of working fishermen to be underage (Atieno, 2014). The decrease in fish catch has created economic challenges for fishermen (Atieno, 2014).	• Low levels of public awareness in understanding sources of pollution were reported in 2012 (Wang, 2012). A lack of awareness related to hyacinth removal mechanisms was also reported amongst fishermen (Atieno, 2014). • Within the small community of Usoma, approximately 70% of survey respondents had a primary education, and 30% of respondents had education that exceeded primary education (Bisnug et al., 2014). • Kenya average years of schooling: 6.6, expected years of schooling: 11.1, literacy: 0.329, 78.7%, 81.5% (2018, 2015, 2014, and 2018; UNDP, 2020; Prados de la Escosura, 2019).	• The lack of coordination has been criticized for its impact that "hamper[s] development efforts" (Lubovich, 2009, p. 12). • The LVBC self-reported that it had weaknesses in financial sustainability, partnership framework, and inter-departmental coordination (2013). • Failure of regional bodies to implement projects has also impacted consistency within the region as part of LVEMP II (The World Bank, 2018a). This failure is largely affected by insufficient country funding of projects which includes monitoring of water quality and fisheries (The World Bank, 2018a). • It was reported that cities did not predict the growth of industries in the region; therefore,

Stakeholder	Event	Regional Development	Economic	Education	Political
		percent of rural population: 49.6 (2017; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 56.7, percent of rural population: 42.5 (2017; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 49.1/7.1, percent of rural population: 41.3/4.5 (2017; The World Bank, 2020). • As a result of low rates of improved water access (<50%), regional development vulnerability is high.	• Poverty within the basin was considered "extremely high" in 2009 (Lubovich, 2009, p. 5). • Approximately a third of the basin lives on less than $1.25/day (i.e., in extreme poverty; The World Bank, 2016). In 2018, approximately 43.4% of Kenyans, 46.6% of Tanzanians, and 34.6% of Ugandans in the basin lived in poverty with higher rates in the basin (The World Bank, 2018b). • Additionally, in 2016, The World Bank reported a high dependence of local communities on the lake (The World Bank, 2016). • Kenya GNI per capita: $1,620, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.420 (2018, 2005, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $1,020, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.362 (2018, 2011, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $620, gap at national poverty line: 5.2, rural gap at national poverty line: 5.9, adjusted income: 0.416 (2018, 2012, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is considered low income (<$996) and two are considered lower-middle income (<$3,895; 2019). • Given that poverty throughout the basin is considered medium (>20% and <50%) the GNI per capita is considered medium, and there is growing efforts to increase diversity of opportunity in fishing communities, economic vulnerability is medium.	• Tanzania average years of schooling: 6, expected years of schooling: 8.0, literacy: 0.353, 77.9%, 69.4% (2018, 2015, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 6.1, expected years of schooling: 11.2, literacy: 0.291, 70.2%, 77.9% (2018, 2015, and 2012; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is medium in two countries and high in one country (>50% and >80%, respectively). • Based on the low public awareness, medium to high literacy, and low average schooling, educational vulnerability is medium.	there are insufficient municipal regulations to manage discharges (Atieno, 2014). Additionally, existing regulations are not enforced and are regularly broken by industries (Atieno, 2014). • In 2019, the corruption perception index was 28/100 in Kenya, 37/100 in Tanzania, 28/100 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high and medium (<33% and <66%, respectively) and enforcement is low, the political vulnerability is considered medium.
Rural agriculture and livestock communities	1947 Initiation of the LVFS	High	High	High	High
		• Development of rail transit to Kisumu and Kampala enabled greater migration to the lake basin in the early 1990s (Hecky et al., 2010). • Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin.	• Agriculture and livestock communities are highly dependent on environmental resources, especially because most of the agriculture is rainfed (The World Bank, 2018b). It is implied that subsistence agriculture is common throughout the basin and that diversity of employment in rural areas is low (The World Bank, 2018b). • Kenya adjusted income: 0.304 (1950; Prados de la Escosura, 2019).	• Kenya average years of schooling: 0.84, literacy: 0.055 (1945 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.35, literacy: 0.017 (1950; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 0.66, literacy: 0.068 (1955; UNDP, 2020; Prados de la Escosura, 2019).	• Community governance of fisheries existed but was inconsistent in extent and enforcement throughout the lake (Jansen et al., 1999). • As a result of the absence of state environmental regulations and enforcement, the political vulnerability was high.

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Tanzania adjusted income: 0.235 (1950; Prados de la Escosura, 2019). • Uganda adjusted income: 0.313 (1950; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the primarily subsistence livelihoods and low income parameter, economic vulnerability was high	• Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	
	1973 Establishment of the LVFC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Kenya adjusted income: 0.360 (1970; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.282 (1970; Prados de la Escosura, 2019). • Uganda adjusted income: 0.351 (1970; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the largely subsistence lifestyle and income parameter, economic vulnerability was high.	• Kenya average years of schooling: 1.45, literacy: 0.113 (1970 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.79, literacy: 0.096 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.05, literacy: 0.098 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• In the 1970s there was limited government regulation of the lake's fisheries, and any regulations were poorly enforced (Jansen et al., 1999). In some places, community governance had supplemented regulation and been institutionalized; however, this coverage was not consistent throughout the lake (Jansen et al., 1999). • Given the absence of regulations and limited enforcement, political vulnerability was high.
	1977 Collapse of the LVFC and EAC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Kenya adjusted income: 0.365 (1975; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.291 (1975; Prados de la Escosura, 2019). • Uganda adjusted income: 0.334 (1975; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the largely subsistence lifestyle and income parameter, economic vulnerability was high.	• Kenya average years of schooling: 1.86, literacy: 0.137 (1975 and 1950; UNDP, 2020; Prados de la Escosura, 2019).; • Tanzania average years of schooling: 2.18, literacy: 0.114 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.43, literacy: 0.111 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• The Water Act was established in Kenya in 1974 to centralize management of drinking water and improve access (Ogendi & Ong'oa, 2009). • The Water Utilisation and Control Act was established in Tanzania in 1974 as a resource-exploitation statue (Pallangyo, 2007). • Given that there were not regulations in all three countries, the existing regulations did not focus on pollution control, and there was limited enforcement, political vulnerability was high.
		High	High	Medium	High

Stakeholder	Event	Regional Development	Economic	Education	Political
	1994 Establishment of the LVFO and initiation of the LVEMP	• Kenya percent of people using at least basic drinking water services: 47.3, percent of rural population: 37.2 (2000; The World Bank, 2020). • It is assumed that Tanzania and Uganda have low access (<50%) to basic drinking water treatment based on the trends from 2003 (The World Bank, 2020). • The growth rate in the basin was estimated to be 3% in rural areas (Ntiba et al., 2001). Combined with the high population density of the region this implies a strain on water resources (Hecky et al., 2010). • Given the drinking water access and high growth rates that likely exceed existing infrastructure, the regional development vulnerability was high.	• Kenya GNI per capita: $260, adjusted income: 0.379 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $160, adjusted income: 0.266 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $180, adjusted income: 0.307 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$725; 2019). • Given the largely subsistence lifestyle and low GNI per capita, the economic vulnerability was high.	• Kenya average years of schooling: 4.4, expected years of schooling: 8.8, literacy: 0.319, 82.2% (1994, 1995, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4, expected years of schooling: 5.5, literacy: 0.255, 59.1% (1994 and 1995; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 3.3, expected years of schooling: 5.5, literacy: 0.209, 56.1% (1994, 1995, and 1991; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Based on the middle to high literacy and low average years of schooling, educational vulnerability was medium.	• The National Environment Management Council Act was established in Tanzania in 1983 to advise on environmental policies (Pallangyo, 2007). • The National Environmental Management Policy was established in Uganda in 1994 (Akello, 2007). • Fisheries compliance in Tanzania was reported to be low in 1993 (Wilson, 1993 as cited in Eggert & Lokina, 2010). • All three countries had environmental regulations although the regulations were not solely related to environmental pollution. Given that laws existed but did not have consistent compliance, political vulnerability is considered high.
	2003 Establishment of the LVBC	High	High	Medium	Medium
		• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). These uses vary but can include untreated water for drinking. • In 1997 there was cholera outbreak which suggests that there was low coverage of water treatment and frequent consumption of raw lake water (Shapiro et al., 1999). • The basin's growth rate was approximately 3% in 2001 which was expected to put a greater strain on the lake (UNEP, 2006). • Kenya percent of people using at least basic/safe drinking water services: 49.5, percent of rural population: 39.4 (2003; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 31.6, percent of rural population: 20.4 (2003; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 30.3/5.2, percent of rural population: 22.5/1.6 (2003; The World Bank, 2020).	• Fishermen did not perceive agriculture as an opportunity generate a "cash" income (Geheb & Crean, 2003, p. 104). This pattern reaffirmed the patterns of subsistence in the basin. • Agricultural workers would turn to fishing for financial and food security; however, their access to the lake may have been limited unless fishermen perceived their livelihood change as justified (Geheb & Crean, 2003). • In 1996, the average annual income of agriculture was $90-$270 (The World Bank, 1996). • Kenya GNI per capita: $400, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.381 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $430, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.306 (2003, 2011, and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $250, gap at national poverty line: 8.7, rural gap at national poverty	• A low level of public awareness was reported in understanding how human activities cause degradation (Machiwa, 2003). • Kenya average years of schooling: 5.6, expected years of schooling: 8.9, literacy: 0.441, 82.2%, 82.2% (2003, 2005, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4.4, expected years of schooling: 7.1, literacy: 0.351, 67.8%, 69.4% (2003, 2005, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 4.3, expected years of schooling: 11.6, literacy: 0.273, 68.1%, 73.2% (2003, 2005, 2002, and 2010; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development threholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively).	• Harmonization of policies was identified as a "long-term" goal of the LVEMP (Kolding et al., 2014, p. 2). The lack of immediate action to harmonize policies was predicted to challenge management of the lake (Lubovich, 2009). • Additionally, existing regulations at various levels of scale were considered weak leading to the influx of domestic and industrial waste (Ntiba et al., 2001). • In 1997, the Kenyan government moved to decentralize management to communities (Ogendi & Ong'oa, 2009). • In 1999, the National Water Policy was established in Kenya to address water sanitation and water resources management; these rules were revised in 2002 (Ogendi & Ong'oa, 2009). The Environmental Management and Coordination Act was also established in 1999 to address environmental management and conservation (Okurut & Othero, 2012). • A National Environmental Policy was established in 1997 in Tanzania to promote

Stakeholder	Event	Regional Development	Economic	Education	Political
		• The rural access to basic drinking water services is low in all countries (<50%). Given the low rate of drinking water access, regional development vulnerability was high.	line: 9.7, adjusted income: 0.365 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$765; 2019). • On a per capita income basis, the three countries are in the lowest third of countries of the world (UNEP, 2006). • Given the primarily subsistence lifestyles, low GNI per capita, and lack of opportunity within the basin, economic vulnerability was high.	• Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	more sustainable management of resources (Pallangyo, 2007). • The Ugandan Water Policy, National Wetlands Management Policy, and Fisheries Policy were established between 1995 and 2000 (Akello, 2007). • The Uganda Water Act was established in 1997, and the National Environmental Act was established in 1995 (Uganda Legal Information Institute, n.d.; Akello, 2007). The act established the National Environment Management Authority to help to address pollution (Okurut & Othero, 2012). • Several factors limited implementation and enforcement of regulations. In Uganda, law enforcement professionals lacked sufficient legal resources, technical capacity, and political support (Akello, 2007). The other states also suffered from a lack of personnel and conservation initiatives (Lugo et al., 2014). Decentralization of fisheries management furthered patterns of insufficient staffing (Ntiba et al., 2001). • The lack of enforcement of water management and fishing regulations was credited for water quality degradation in the lake (Muli, 1996). • In 2003, the corruption perception index was 1.9/10 in Kenya, 2.5/10 in Tanzania, and 2.2/10 in Uganda (Transparency International, 2020). • Given that regulations were established in all countries that addressed pollution, but corruption was high (<33%) and enforcement was low, the political vulnerability is considered medium.
	2008 Tensions with Uganda	High	High	Medium	Medium
		• High population growth rates (3-4%) led to the expansion of unplanned rural settlements that do not have sufficient water services (UNEP, 2006; Lubovich, 2009). Poorer rural residents frequently resided in "remote and ecologically fragile" areas (UNEP, 2006, p. 7). • Lakeside communities also have poor access to healthcare (Muyodi et al., 2010). • Communities within the basin have high rates of diarrheal diseases compared to other parts of East Africa (UNEP, 2006). Along with other illnesses, this creates a health burden which can	• A trend towards monocultures and cash crops contributed to food insecurity in the basin and challenged the sustainable livelihood of farmers (UNEP, 2006). Although cash crops were used to generate income, the majority of agricultural livelihoods were subsistent (Ewald et al., 2004). • In 2004, the mean household poverty in the region was reported to be 46.4% (LBDA, 2004 as cited in UNEP, 2006; Lubovich, 2009). Additionally, 64.5% of Kenyans, 36% of Tanzanians, and 39% of Ugandans lived below the poverty lines (UNEP, 2006).	• A low understanding of sources of cyanobacteria was reported in 2008 (Bathwondi, 2008 as cited in Lugo et al., 2014). • In 2004, 18.3% of Kenyans, 23% of Tanzanians, and 33% of Ugandans did not have access to formal education (UNEP, 2006). • Kenya average years of schooling: 6, expected years of schooling: 10.2, literacy: 0.278, 72.2%, 82.2% (2008, 2007, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 5, expected years of schooling: 8.4, literacy:	• The LVBC was established with the goal to harmonize policies between the riparian countries; however, national coordination has been lacking (Song et al., 2018). • Additionally, although regulations existed in all three countries, enforcement was generally weak (UNEP, 2006). Therefore, the laws, implementation, enforcement, and penalties varied between the three countries (Njiru et al., 2008). • Local regulations exist but also differ, creating management challenges. The national authorities have not driven coordination of

Stakeholder	Event	Regional Development	Economic	Education	Political
		divert resources and further increase vulnerability. • Kenya percent of people using at least basic/safe drinking water services: 53.0, percent of rural population: 43.1 (2008; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 40.2, percent of rural population: 27.9 (2008; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 36.6/5.9, percent of rural population: 28.5/2.5 (2008; The World Bank, 2020). • Given the low coverage of drinking water access in rural areas (<50%) and incidence of gastrointestinal disease, regional development vulnerability was high.	• In 2006, approximately 70% of the basin population was reported to live in "abject poverty" (UNEP, 2006, p. 32). • Degradation of wetlands decreased alternate opportunities for livelihoods (UNEP, 2006). • Kenya GNI per capita: $820, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.391 (2008, 2005, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $600, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.317 (2008, 2011, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $440, gap at national poverty line: 6.8, rural gap at national poverty line: 7.6, adjusted income: 0.378 (2008, 2009, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$975; 2019). • Based on the primarily subsistence livelihood, the high levels of poverty in the basin, and low GNI per capita, the economic vulnerability was high.	0.286, 67.8%, 69.4% (2008, 2007, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 5.2, expected years of schooling: 10.9, literacy: 0.272, 68.1%, 71.3% (2008, 2007, 2010, and 2006; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	local municipalities (Wirkus & Böge, 2006). Additionally, a lack of coordination between districts and fisheries have caused conflict and complicated implementation (UNEP, 2006; EAC, 2005 as cited in Lubovich, 2009). • The Environmental Management Act was established in Tanzania in 2004 to provide a framework that addresses issues such as pollution prevention, establish a regulatory body, and decentralize enforcement to local authorities (Pallangyo, 2007). However, local authorities often do not have the resources to enforce regulations (Pallangyo, 2007). • A significant percent of fishermen reported that they do not consistently comply with regulations (Eggert & Lokina, 2010). • In 2008, the corruption perception index was 2.1/10 in Kenya, 3.0/10 in Tanzania, and 2.6/10 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high (<33%) and enforcement is low, the political vulnerability is considered medium.
	2020 Current Status	High	High	Medium	Medium
		• The basin has one of the highest rural population densities in the world (Lubovich, 2009). • Within small, riparian communities, dependence on lake water can be high. Within the small Kenyan town of Usoma, 38% of survey respondents use water from the lake for cooking, 86% use it for other domestic uses, and 42% use it for open defecation (Bisung et al., 2014). • Kenya percent of people using at least basic/safe drinking water services: 58.9, percent of rural population: 49.6 (2017; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 56.7, percent of rural population: 42.5 (2017; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 49.1/7.1,	• Within the basin, subsistence farming and fishing are still considered "the primary livelihoods of those most in need" (The World Bank, 2018b, p. 5). Additionally, in 2016, The World Bank reported a high dependence of local communities on the lake (The World Bank, 2016). • Approximately a third of the basin lives on less than $1.25/day (i.e., in extreme poverty; The World Bank, 2016). In 2018, approximately 43.4% of Kenyans, 46.6% of Tanzanians, and 34.6% of Ugandans in the basin lived in poverty with higher rates within the basin (The World Bank, 2018b). • Kenya GNI per capita: $1,620, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.420 (2018, 2005, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $1,020, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.362	• Low levels of public awareness in understanding sources of pollution were reported in 2012 (Wang, 2012). • Within the small community of Usoma, approximately 70% of survey respondents had a primary education, and 30% of respondents had education that exceeded primary education (Bisnug et al., 2014). • Kenya average years of schooling: 6.6, expected years of schooling: 11.1, literacy: 0.329, 78.7%, 81.5% (2018, 2015, 2014, and 2018; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 6, expected years of schooling: 8.0, literacy: 0.353, 77.9%, 69.4% (2018, 2015, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 6.1, expected years of schooling: 11.2, literacy: 0.291, 70.2%, 77.9% (2018, 2015, and 2012;	• The lack of coordination has been criticized for its impact that "hamper[s] development efforts" (Lubovich, 2009, p. 12). • The LVBC self-reported that it had weaknesses in financial sustainability, partnership framework, and inter-departmental coordination (2013). • Failure of regional bodies to implement projects has also impacted consistency within the region as part of LVEMP II (The World Bank, 2018a). This failure is largely affected by insufficient country funding of projects which includes monitoring of water quality and fisheries (The World Bank, 2018a). • It was reported that cities did not predict the growth of industries in the region; therefore, there are insufficient municipal regulations to manage discharges (Atieno, 2014). Additionally, existing regulations are not enforced and are regularly broken by industries (Atieno, 2014).

Stakeholder	Event	Regional Development	Economic	Education	Political
		percent of rural population: 41.3/4.5 (2017; The World Bank, 2020). • As a result of low rates of improved water access (<50%), regional development vulnerability is high.	(2018, 2011, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $620, gap at national poverty line: 5.2, rural gap at national poverty line: 5.9, adjusted income: 0.416 (2018, 2012, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is considered low income (<$996) and two are considered lower-middle income (<$3,895; 2019). • Given that poverty throughout the basin is considered medium (>20% and <50%) the GNI per capita is considered medium, but agriculture is still predominantly subsistence, the economic vulnerability is high.	UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is medium in two countries and high in one country (>50% and >80%, respectively). • Based on the low public awareness, medium to high literacy, and low average schooling, educational vulnerability is medium.	• In 2019, the corruption perception index was 28/100 in Kenya, 37/100 in Tanzania, 28/100 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high and medium (<33% and <66%, respectively) and enforcement is low, the political vulnerability is considered medium.
Mining industry	1947 Initiation of the LVFS	High	Medium	High	High
		• Development of rail transit to Kisumu and Kampala enabled greater migration to the lake basin in the early 1990s (Hecky et al., 2010). • Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas and higher rates in urban areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • It is assumed that mining communities are distributed throughout the basin in predominantly rural settings (Henckel et al., 2016). • Given the assumption of drinking water treatment was less than 50%, regional development vulnerability was high.	• The mining industry is highly dependent on water resources for extractive actions. Prior to 1941 there was a peak in gold mining in the region; however, in the 1940s, artisanal gold mines were beginning to close (Henckel et al., 2016). A variety of materials are extracted in the region including gold, quarrying, and sand, it is assumed that the extractive activity followed patterns of gold mining in the region (Kulindwa, 2006). Most extractive activities were located in Tanzania. • Kenya adjusted income: 0.304 (1950; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.235 (1950; Prados de la Escosura, 2019). • Uganda adjusted income: 0.313 (1950; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the strong extractive economy but low income parameter, economic vulnerability was medium.	• Kenya average years of schooling: 0.84, literacy: 0.055 (1945 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.35, literacy: 0.017 (1950; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 0.66, literacy: 0.068 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• Community governance of fisheries existed but was inconsistent in extent and enforcement throughout the lake (Jansen et al., 1999). • As a result of the absence of state environmental regulations and enforcement, the political vulnerability was high.
	1973 Establishment of the LVFC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas and higher rates in urban areas (The World Bank, 2020). However, it is likely that access to drinking	• Commercial gold mining stopped in Tanzania in 1972 because of a shift in policies (Henckel et al., 2016). “Unofficial” mines continued to operate and were financially successful (Henckel et al., 2016, p. 135).	• Kenya average years of schooling: 1.45, literacy: 0.113 (1970 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.79, literacy: 0.096 (1970; UNDP, 2020; Prados de la Escosura, 2019).	• In the 1970s there was limited government regulation of the lake’s fisheries, and any regulations were poorly enforced (Jansen et al., 1999). In some places, community governance had supplemented regulation and been institutionalized; however, this coverage was

Stakeholder	Event	Regional Development	Economic	Education	Political
		water treatment was less than 47.3% throughout the basin. • Given the assumption of drinking water treatment was less than 50%, regional development vulnerability is high.	• Kenya adjusted income: 0.360 (1970; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.282 (1970; Prados de la Escosura, 2019). • Uganda adjusted income: 0.351 (1970; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Given the changes in the legitimate extractive mining industry and the low income parameter, economic vulnerability was high.	• Uganda average years of schooling: 1.05, literacy: 0.098 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability is high.	not consistent throughout the lake (Jansen et al., 1999). • Given the absence of regulations and limited enforcement, political vulnerability is high.
	1977 Collapse of the LVFC and EAC	High	High	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially lower rates in rural areas and higher rates in urban areas (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Commercial mining was limited during the 1970s due to state control of the industry (Henckel et al., 2016). Although a state run corporation was leading continued mining operations, little profit was gained during this time period (Henckel et al., 2016). • Kenya adjusted income: 0.365 (1975; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.291 (1975; Prados de la Escosura, 2019). • Uganda adjusted income: 0.334 (1975; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Based on the low income from the extractive industry and low income parameter, economic vulnerability was high.	• Kenya average years of schooling: 1.86, literacy: 0.137 (1975 and 1950; UNDP, 2020; Prados de la Escosura, 2019).; • Tanzania average years of schooling: 2.18, literacy: 0.114 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.43, literacy: 0.111 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• The Water Act was established in Kenya in 1974 to centralize management of drinking water and improve access (Ogendi & Ong'oa, 2009). • The Water Utilisation and Control Act was established in Tanzania in 1974 as a resource-exploitation statue (Pallangyo, 2007). • Given that there were not regulations in all three countries, the existing regulations did not focus on pollution control, and there was limited enforcement, political vulnerability was high.
	1994 Establishment of the LVFO and initiation of the LVEMP	High	High	Medium	High
		• Kenya percent of people using at least basic drinking water services: 47.3, percent of rural population: 37.2 (2000; The World Bank, 2020). • It is assumed that Tanzania and Uganda have low access (<50%) to basic drinking water treatment based on the trends from 2003 (The World Bank, 2020). • The growth rate in the basin was estimated to be 3% in rural areas (Ntiba et al., 2001). Combined with the high population density of the region this implies a strain on water resources (Hecky et al., 2010).	• The commercial mining industry restarted in Tanzania in the 1980s; however, the industry was not extensive (Hecky et al., 2010). • Kenya GNI per capita: $260, adjusted income: 0.379 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $160, adjusted income: 0.266 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $180, adjusted income: 0.307 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019).	• Kenya average years of schooling: 4.4, expected years of schooling: 8.8, literacy: 0.319, 82.2% (1994, 1995, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4, expected years of schooling: 5.5, literacy: 0.255, 59.1% (1994 and 1995; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 3.3, expected years of schooling: 5.5, literacy: 0.209, 56.1% (1994, 1995, and 1991; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020).	• The National Environment Management Council Act was established in Tanzania in 1983 to advise on environmental policies (Pallangyo, 2007). • The National Environmental Management Policy was established in Uganda in 1994 (Akello, 2007). • Fisheries compliance in Tanzania was reported to be low in 1993 (Wilson, 1993 as cited in Eggert & Lokina, 2010). • All three countries had environmental regulations although the regulations were not solely related to environmental pollution. Given that laws existed but did not have

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Given the drinking water access and high growth rates that likely exceed existing infrastructure, the regional development vulnerability was high.	• Based on the World Bank income thresholds, all three countries are considered low income (<$725; 2019). • Given the low activity of legitimate extractive industry and the low income parameter, the economic vulnerability was high.	• Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Based on the middle to high literacy and low average years of schooling, educational vulnerability was medium.	consistent compliance, political vulnerability is considered high.
	2003 Establishment of the LVBC	High	Medium	Medium	Medium
		• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). These uses vary but can include untreated water for drinking. • In 1997 there was cholera outbreak which suggests that there was low coverage of water treatment and frequent consumption of raw lake water (Shapiro et al., 1999). • The basin's growth rate was approximately 3% in 2001 which was expected to put a greater strain on the lake (UNEP, 2006). • Kenya percent of people using at least basic/safe drinking water services: 49.5, percent of rural population: 39.4 (2003; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 31.6, percent of rural population: 20.4 (2003; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 30.3/5.2, percent of rural population: 22.5/1.6 (2003; The World Bank, 2020). • The rural access to basic drinking water services is low in all countries (<50%). Given the low rate of drinking water access, regional development vulnerability was high.	• Following a legislation change in 1998, international investment in mining grew, leading to an influx of financial resources in Tanzania (Henckel et al., 2016). • Kenya GNI per capita: $400, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.381 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $430, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.306 (2003, 2011, and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $250, gap at national poverty line: 8.7, rural gap at national poverty line: 9.7, adjusted income: 0.365 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$765; 2019). • On a per capita income basis, the three countries are in the lowest third of countries of the world (UNEP, 2006). • Given the growth in the mining sector and the low income parameter is low, economic vulnerability was medium.	• A low level of public awareness was reported in understanding how human activities cause degradation (Machiwa, 2003). • Kenya average years of schooling: 5.6, expected years of schooling: 8.9, literacy: 0.441, 82.2%, 82.2% (2003, 2005, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4.4, expected years of schooling: 7.1, literacy: 0.351, 67.8%, 69.4% (2003, 2005, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 4.3, expected years of schooling: 11.6, literacy: 0.273, 68.1%, 73.2% (2003, 2005, 2002, and 2010; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development threholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• Harmonization of policies was identified as a "long-term" goal of the LVEMP (Kolding et al., 2014, p. 2). The lack of immediate action to harmonize policies was predicted to challenge management of the lake (Lubovich, 2009). • Additionally, existing regulations at various levels of scale were considered weak leading to the influx of domestic and industrial waste (Ntiba et al., 2001). • In 1997, the Kenyan government moved to decentralize management to communities (Ogendi & Ong'oa, 2009). • In 1999, the National Water Policy was established in Kenya to address water sanitation and water resources management; these rules were revised in 2002 (Ogendi & Ong'oa, 2009). The Environmental Management and Coordination Act was also established in 1999 to address environmental management and conservation (Okurut & Othero, 2012). • A National Environmental Policy was established in 1997 in Tanzania to promote more sustainable management of resources (Pallangyo, 2007). • The Ugandan Water Policy, National Wetlands Management Policy, and Fisheries Policy were established between 1995 and 2000 (Akello, 2007). • The Uganda Water Act was established in 1997, and the National Environmental Act was established in 1995 (Uganda Legal Information Institute, n.d.; Akello, 2007). The act established the National Environment Management Authority to help to address pollution (Okurut & Othero, 2012). • Several factors limited implementation and enforcement of regulations. In Uganda, law

Stakeholder	Event	Regional Development	Economic	Education	Political
					enforcement professionals lacked sufficient legal resources, technical capacity, and political support (Akello, 2007). The other states also suffered from a lack of personnel and conservation initiatives (Lugo et al., 2014). Decentralization of fisheries management furthered patterns of insufficient staffing (Ntiba et al., 2001). • The lack of enforcement of water management and fishing regulations was credited for water quality degradation in the lake (Muli, 1996). • In 2003, the corruption perception index was 1.9/10 in Kenya, 2.5/10 in Tanzania, and 2.2/10 in Uganda (Transparency International, 2020). • Given that regulations were established in all countries that addressed pollution, but corruption was high (<33%) and enforcement was low, the political vulnerability is considered medium.
	2008 Tensions with Uganda	High	Medium	Medium	Medium
		• High population growth rates (3-4%) led to the expansion of unplanned rural settlements that do not have sufficient water services (UNEP, 2006; Lubovich, 2009). Poorer rural residents frequently resided in "remote and ecologically fragile" areas (UNEP, 2006, p. 7). • Lakeside communities also have poor access to healthcare (Muyodi et al., 2010). • Communities within the basin have high rates of diarrheal diseases compared to other parts of East Africa (UNEP, 2006). Along with other illnesses, this creates a health burden which can divert resources and further increase vulnerability. • Kenya percent of people using at least basic/safe drinking water services: 53.0, percent of rural population: 43.1 (2008; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 40.2, percent of rural population: 27.9 (2008; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 36.6/5.9, percent of rural population: 28.5/2.5 (2008; The World Bank, 2020). • Given the low coverage of drinking water access in rural areas (<50%) and incidence of	• Mines were successfully operating in Tanzania and Kenya during the early 2000s (Henckel et al., 2016). • High rates of poverty were observed in the basin. In 2004, the mean household poverty in the region was reported to be 46.4% (LBDA, 2004 as cited in UNEP, 2006; Lubovich, 2009). Additionally, 64.5% of Kenyans, 36% of Tanzanians, and 39% of Ugandans were below the poverty lines (UNEP, 2006). • In 2006, approximately 70% of the basin population was reported to live in "abject poverty" (UNEP, 2006, p. 32). • Degradation of wetlands has decreased alternate opportunities for livelihoods (UNEP, 2006). • Kenya GNI per capita: \$820, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.391 (2008, 2005, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: \$600, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.317 (2008, 2011, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: \$440, gap at national poverty line: 6.8, rural gap at national poverty	• A low understanding of sources of cyanobacteria was reported in 2008 (Bathwondi, 2008 as cited in Lugo et al., 2014). • In 2004, 18.3% of Kenyans, 23% of Tanzanians, and 33% of Ugandans did not have access to formal education (UNEP, 2006). • Kenya average years of schooling: 6, expected years of schooling: 10.2, literacy: 0.278, 72.2%, 82.2% (2008, 2007, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 5, expected years of schooling: 8.4, literacy: 0.286, 67.8%, 69.4% (2008, 2007, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 5.2, expected years of schooling: 10.9, literacy: 0.272, 68.1%, 71.3% (2008, 2007, 2010, and 2006; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively).	• The LVBC was established with the goal to harmonize policies between the riparian countries; however, national coordination has been lacking (Song et al., 2018). • Additionally, although regulations existed in all three countries, enforcement was generally weak (UNEP, 2006). Therefore, the laws, implementation, enforcement, and penalties varied between the three countries (Njiru et al., 2008). • Local regulations exist but also differ, creating management challenges. The national authorities have not driven coordination of local municipalities (Wirkus & Böge, 2006). Additionally, a lack of coordination between districts and fisheries have caused conflict and complicated implementation (UNEP, 2006; EAC, 2005 as cited in Lubovich, 2009). • The Environmental Management Act was established in Tanzania in 2004 to provide a framework that addresses issues such as pollution prevention, establish a regulatory body, and decentralize enforcement to local authorities (Pallangyo, 2007). However, local authorities often do not have the resources to enforce regulations (Pallangyo, 2007).

Stakeholder	Event	Regional Development	Economic	Education	Political
		gastrointestinal disease, regional development vulnerability was high.	line: 7.6, adjusted income: 0.378 (2008, 2009, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$975; 2019). • Although the GNI per capita is low and there is a high incidence of poverty in the region (>50%), the extractive industry is assumed to have greater financial resources then other members of the population. Based on the growth of the industry, the economic vulnerability was medium.	• Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• A significant percent of fishermen reported that they do not consistently comply with regulations (Eggert & Lokina, 2010). • In 2008, the corruption perception index was 2.1/10 in Kenya, 3.0/10 in Tanzania, and 2.6/10 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high (<33%) and enforcement is low, the political vulnerability is considered medium.
	2020 Current Status	High	Medium	Medium	Medium
		• The basin has one of the highest rural population densities in the world (Lubovich, 2009). • Within small, riparian communities, dependence on lake water can be high. Within the small Kenyan town of Usoma, 38% of survey respondents use water from the lake for cooking, 86% use it for other domestic uses, and 42% use it for open defecation (Bisung et al., 2014). • Kenya percent of people using at least basic/safe drinking water services: 58.9, percent of rural population: 49.6 (2017; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 56.7, percent of rural population: 42.5 (2017; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 49.1/7.1, percent of rural population: 41.3/4.5 (2017; The World Bank, 2020). • As a result of low rates of improved water access (<50%), regional development vulnerability is high.	• Limited growth was anticipated in the mining industry anticipated after 2009 (Henckel et al., 2016). • Approximately a third of the basin lives on less than $1.25/day (i.e., in extreme poverty; The World Bank, 2016). In 2018, approximately 43.4% of Kenyans, 46.6% of Tanzanians, and 34.6% of Ugandans in the basin lived in poverty with higher rates within the basin (The World Bank, 2018b). • Kenya GNI per capita: $1,620, gap at national poverty line: 16.3, rural gap at national poverty line: 17.5, adjusted income: 0.420 (2018, 2005, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $1,020, gap at national poverty line: 6.7, rural gap at national poverty line: 7.8, adjusted income: 0.362 (2018, 2011, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $620, gap at national poverty line: 5.2, rural gap at national poverty line: 5.9, adjusted income: 0.416 (2018, 2012, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is considered low income (<$996) and two are considered lower-middle income (<$3,895; 2019). • Given that poverty throughout the basin is considered medium (>20% and <50%) the GNI per capita is considered medium, and the mining industry was functioning and profitable, the economic vulnerability is medium.	• Low levels of public awareness in understanding sources of pollution were reported in 2012 (Wang, 2012). • Kenya average years of schooling: 6.6, expected years of schooling: 11.1, literacy: 0.329, 78.7%, 81.5% (2018, 2015, 2014, and 2018; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 6, expected years of schooling: 8.0, literacy: 0.353, 77.9%, 69.4% (2018, 2015, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 6.1, expected years of schooling: 11.2, literacy: 0.291, 70.2%, 77.9% (2018, 2015, and 2012; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is medium in two countries and high in one country (>50% and >80%, respectively). • Based on the low public awareness, medium to high literacy, and low average schooling, educational vulnerability is medium.	• The lack of coordination has been criticized for its impact that "hamper[s] development efforts" (Lubovich, 2009, p. 12). • The LVBC self-reported that it had weaknesses in financial sustainability, partnership framework, and inter-departmental coordination (2013). • Failure of regional bodies to implement projects has also impacted consistency within the region as part of LVEMP II (The World Bank, 2018a). This failure is largely affected by insufficient country funding of projects which includes monitoring of water quality and fisheries (The World Bank, 2018a). • It was reported that cities did not predict the growth of industries in the region; therefore, there are insufficient municipal regulations to manage discharges (Atieno, 2014). Additionally, existing regulations are not enforced and are regularly broken by industries (Atieno, 2014). • In 2019, the corruption perception index was 28/100 in Kenya, 37/100 in Tanzania, 28/100 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high and medium (<33% and <66%, respectively) and enforcement is low, the political vulnerability is considered medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
Hydropower industry	1947 Initiation of the LVFS	High	Low	High	High
		• Development of rail transit to Kisumu and Kampala enabled greater migration to the lake basin in the early 1990s (Hecky et al., 2010). • Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • It is assumed that hydropower industry is small and that participants are primarily located in urban areas. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Hydropower was not established in the basin until construction of the Owen Falls Dam in 1953 (Muyodi et al., 2010). • Kenya adjusted income: 0.304 (1950; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.235 (1950; Prados de la Escosura, 2019). • Uganda adjusted income: 0.313 (1950; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Given that the hydropower industry did not yet exist in the basin, economic vulnerability was low.	• Kenya average years of schooling: 0.84, literacy: 0.055 (1945 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.35, literacy: 0.017 (1950; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 0.66, literacy: 0.068 (1955; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• Community governance of fisheries existed but was inconsistent in extent and enforcement throughout the lake (Jansen et al., 1999). • As a result of the absence of state environmental regulations and enforcement, the political vulnerability was high.
	1973 Establishment of the LVFC	High	Medium	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• The establishment of the Owen Falls Dam likely created and provided employment opportunities following its construction and operation in 1959 (Scott et al., 2013; Kull, 2006). The industry has a high dependence on water resources for functioning and provides a source of financial income. • Kenya adjusted income: 0.360 (1970; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.282 (1970; Prados de la Escosura, 2019). • Uganda adjusted income: 0.351 (1970; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Given the financial opportunities through hydropower that are likely higher relative to the average basin population and the low income parameter, economic vulnerability was medium.	• Kenya average years of schooling: 1.45, literacy: 0.113 (1970 and 1950; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 1.79, literacy: 0.096 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Uganda average years of schooling: 1.05, literacy: 0.098 (1970; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• In the 1970s there was limited government regulation of the lake's fisheries, and any regulations were poorly enforced (Jansen et al., 1999). In some places, community governance had supplemented regulation and been institutionalized; however, this coverage was not consistent throughout the lake (Jansen et al., 1999). • Given the absence of regulations and limited enforcement, political vulnerability was high.
	1977 Collapse of the LVFC and EAC	High	Medium	High	High
		• Based on data from 2000, it is assumed that access to basic drinking water treatment in the basin was less than 47.3% with potentially higher rates in cities (The World Bank, 2020). However, it is likely that access to drinking	• The dam continued to function, providing continued economic opportunities for actors. • Kenya adjusted income: 0.365 (1975; Prados de la Escosura, 2019). • Tanzania adjusted income: 0.291 (1975; Prados de la Escosura, 2019).	• Kenya average years of schooling: 1.86, literacy: 0.137 (1975 and 1950; UNDP, 2020; Prados de la Escosura, 2019).; • Tanzania average years of schooling: 2.18, literacy: 0.114 (1975; UNDP, 2020; Prados de la Escosura, 2019).	• The Water Act was established in Kenya in 1974 to centralize management of drinking water and improve access (Ogendi & Ong'oa, 2009).

Stakeholder	Event	Regional Development	Economic	Education	Political
		water treatment was less than 47.3% throughout the basin. • Given the assumption of access to drinking water treatment, regional development vulnerability was high.	• Uganda adjusted income: 0.334 (1975; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Given the financial opportunities through hydropower that are likely higher relative to the average basin population and the low income parameter, economic vulnerability was medium.	• Uganda average years of schooling: 1.43, literacy: 0.111 (1975; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy is considered low (<0.5; UNDP, 2009). • Given the low literacy and average years of schooling, educational vulnerability was high.	• The Water Utilisation and Control Act was established in Tanzania in 1974 as a resource-exploitation statue (Pallangyo, 2007). • Given that there were not regulations in all three countries, the existing regulations did not focus on pollution control, and there was limited enforcement, political vulnerability was high.
	1994 Establishment of the LVFO and initiation of the LVEMP	Medium	Medium	Medium	High
		• Kenya percent of people using at least basic/safe drinking water services: 47.3, percent of urban population: 88.0/62.1 (2000; The World Bank, 2020). • It is assumed that Tanzania and Uganda have less access to basic drinking water services based on trends from 2003 (The World Bank, 2020). Based on the 2003 data, it is assumed that access to drinking water service in urban areas is medium in two countries and high in one (>50% and >80%, respectively). • The growth rate in the basin was estimated to be 6% in urban areas (Ntiba et al., 2001). Given the drinking water access and high growth rates that can exceed infrastructure, the regional development vulnerability is assumed to be medium.	• The dam continued to function providing continued economic opportunities for actors. • Kenya GNI per capita: $260, adjusted income: 0.379 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $160, adjusted income: 0.266 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $180, adjusted income: 0.307 (1994 and 1995; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered low development based on the income parameter (<0.5; UNDP, 2009). • Given the financial opportunities through hydropower that are likely higher relative to the average basin population and the low income parameter, economic vulnerability was medium.	• Kenya average years of schooling: 4.4, expected years of schooling: 8.8, literacy: 0.319, 82.2% (1994, 1995, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4, expected years of schooling: 5.5, literacy: 0.255, 59.1% (1994 and 1995; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 3.3, expected years of schooling: 5.5, literacy: 0.209, 56.1% (1994, 1995, and 1991; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Based on the middle to high literacy and low average years of schooling, educational vulnerability was medium.	• The National Environment Management Council Act was established in Tanzania in 1983 to advise on environmental policies (Pallangyo, 2007). • The National Environmental Management Policy was established in Uganda in 1994 (Akello, 2007). • Fisheries compliance in Tanzania was reported to be low in 1993 (Wilson, 1993 as cited in Eggert & Lokina, 2010). • All three countries had environmental regulations although the regulations were not solely related to environmental pollution. Given that laws existed but did not have consistent compliance, political vulnerability is considered high.
	2003 Establishment of the LVBC	Medium	Medium	Medium	Medium
		• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). These uses vary but can include untreated water for drinking. • In 1997 there was cholera outbreak which suggests that there was low coverage of water treatment and frequent consumption of raw lake water (Shapiro et al., 1999).	• The Kiira project that extends the Owen Falls dam was completed in 1999 (Kull, 2006). The project represents a high demand in the hydropower market and may have expanded employment opportunities. • Kenya GNI per capita: $400, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.381 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019).	• A low level of public awareness was reported in understanding how human activities cause degradation (Machiwa, 2003). • Kenya average years of schooling: 5.6, expected years of schooling: 8.9, literacy: 0.441, 82.2%, 82.2% (2003, 2005, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 4.4, expected years of schooling: 7.1, literacy: 0.351, 67.8%, 69.4% (2003, 2005, 2010, and	• Harmonization of policies was identified as a "long-term" goal of the LVEMP (Kolding et al., 2014, p. 2). The lack of immediate action to harmonize policies was predicted to challenge management of the lake (Lubovich, 2009). • Additionally, existing regulations at various levels of scale were considered weak leading to the influx of domestic and industrial waste (Ntiba et al., 2001).

Stakeholder	Event	Regional Development	Economic	Education	Political
		• The basin's growth rate was approximately 3% in 2001 and was expected to put a greater strain on the lake resources (UNEP, 2006). • Kenya percent of people using at least basic/safe drinking water services: 49.5, percent of urban population: 87.4/62.0 (2003; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 31.6, percent of urban population: 67.8/3.9 (2003; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 30.3/5.2, percent of urban population: 71.2/24.0 (2003; The World Bank, 2020). • The urban access to basic drinking water services is medium in two countries and high in one (>50% and >80%, respectively). • Given the medium to high rate of drinking water access and high growth rate, regional development vulnerability was medium.	• Tanzania GNI per capita: $430, gap at national poverty line: 6.7, urban gap at national poverty line: 3.9, adjusted income: 0.306 (2003, 2011, and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $250, gap at national poverty line: 8.7, urban gap at national poverty line: 3.5, adjusted income: 0.365 (2003 and 2005; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$765; 2019). • On a per capita income basis, the three countries are in the lowest third of countries of the world (UNEP, 2006). • Given the financial opportunities through hydropower that are likely higher relative to the average basin population and the low income parameter, economic vulnerability was medium.	2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 4.3, expected years of schooling: 11.6, literacy: 0.273, 68.1%, 73.2% (2003, 2005, 2002, and 2010; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development threholds, the average years of schooling is low based on the education parameter (<8.25 years), and the literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• In 1997, the Kenyan government moved to decentralize management to communities (Ogendi & Ong'oa, 2009). • In 1999, the National Water Policy was established in Kenya to address water sanitation and water resources management; these rules were revised in 2002 (Ogendi & Ong'oa, 2009). The Environmental Management and Coordination Act was also established in 1999 to address environmental management and conservation (Okurut & Othero, 2012). • A National Environmental Policy was established in 1997 in Tanzania to promote more sustainable management of resources (Pallangyo, 2007). • The Ugandan Water Policy, National Wetlands Management Policy, and Fisheries Policy were established between 1995 and 2000 (Akello, 2007). • The Uganda Water Act was established in 1997, and the National Environmental Act was established in 1995 (Uganda Legal Information Institute, n.d.; Akello, 2007). The act established the National Environment Management Authority to help to address pollution (Okurut & Othero, 2012). • Several factors limited implementation and enforcement of regulations. In Uganda, law enforcement professionals lacked sufficient legal resources, technical capacity, and political support (Akello, 2007). The other states also suffered from a lack of personnel and conservation initiatives (Lugo et al., 2014). Decentralization of fisheries management furthered patterns of insufficient staffing (Ntiba et al., 2001). • The lack of enforcement of water management and fishing regulations was credited for water quality degradation in the lake (Muli, 1996). • In 2003, the corruption perception index was 1.9/10 in Kenya, 2.5/10 in Tanzania, and 2.2/10 in Uganda (Transparency International, 2020). • Given that regulations were established in all countries that addressed pollution, but corruption was high (<33%) and enforcement was low, the political vulnerability is considered medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
	2008 Tensions with Uganda	High	High	Medium	Medium
		• High rates of rural to urban migration were occurring in 2006, and the three countries had higher than average population densities within the basin which strained available resources (Wirkus & Böge, 2006; The World Bank, 2008). The high population growth rates (3-4%) and urbanization in the basin led to the expansion of unplanned urban settlements that do not have sufficient water services (UNEP, 2006; Lubovich, 2009). • There are few hospitals in close proximity to communities within the basin (UNEP, 2006). • Communities within the basin have high rates of diarrheal diseases compared to other parts of East Africa (UNEP, 2006). Along with other illnesses, this creates a health burden which can divert resources and further increase vulnerability. • Water supply was not ubiquitous in cities.In Kisumu, 40% of coverage existed in planned parts of the cities and most community members accessed alternate water sources (Mireri et al., 2007). No coverage existed in the wide-spread informal settlements which are common to urban areas of Kenya (Mireri et al., 2007). Although alternate water sources were used, many of these sources (e.g., shallow wells) were at risk of contamination due to the low levels of sanitation coverage in the city (Mireri et al., 2007). Additionally, the Kisumu municipality was reported to regularly have water shortages (Mireri et al., 2007 • Kenya percent of people using at least basic/safe drinking water services: 53.0, percent of urban population: 86.4/57.7 (2008; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 40.2, percent of urban population: 75.2/24.3 (2008; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 36.6/5.9, percent of urban population: 72.6/21.1 (2008; The World Bank, 2020). • Given the low coverage of drinking water access in Kisumu and rates of growth in the basin, it is assumed that other cities lack water access for at least 50% of their populations.	• The dam continued to function providing continued economic opportunities for actors. However, the decrease in lake levels had a negative economic impact on hydropower in the lake (The World Bank, 2008). • In 2004, the mean household poverty in the region was reported to be 46.4% (LBDA, 2004 as cited in UNEP, 2006; Lubovich, 2009). Additionally, 64.5% of Kenyans, 36% of Tanzanians, and 39% of Ugandans were below the poverty lines (UNEP, 2006). • In 2006, approximately 70% of the basin population was reported to live in "abject poverty" (UNEP, 2006, p. 32). • Degradation of wetlands has decreased alternate opportunities for livelihoods (UNEP, 2006). • Kenya GNI per capita: $820, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.391 (2008, 2005, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $600, gap at national poverty line: 6.7, urban gap at national poverty line: 3.9, adjusted income: 0.317 (2008, 2011, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $440, gap at national poverty line: 6.8, urban gap at national poverty line: 1.8, adjusted income: 0.378 (2008, 2009, and 2007; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered low income (<$975; 2019). • Given the low GNI per capita, high incidence of poverty in the region (>50%), and the economic losses to the hydropower industry, economic vulnerability was high.	• A low understanding of sources of cyanobacteria was reported in 2008 (Bathwondi, 2008 as cited in Lugo et al., 2014). • In 2004, 18.3% of Kenyans, 23% of Tanzanians, and 33% of Ugandans did not have access to formal education (UNEP, 2006). • Kenya average years of schooling: 6, expected years of schooling: 10.2, literacy: 0.278, 72.2%, 82.2% (2008, 2007, and 2000; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 5, expected years of schooling: 8.4, literacy: 0.286, 67.8%, 69.4% (2008, 2007, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 5.2, expected years of schooling: 10.9, literacy: 0.272, 68.1%, 71.3% (2008, 2007, 2010, and 2006; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development classification, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is middle to high (>50% and >80%, respectively). • Given the low risk awareness, middle and high rates of literacy, and low average years of schooling, educational vulnerability was medium.	• The LVBC was established with the goal to harmonize policies between the riparian countries; however, national coordination has been lacking (Song et al., 2018). • Additionally, although regulations existed in all three countries, enforcement was generally weak (UNEP, 2006). Therefore, the laws, implementation, enforcement, and penalties varied between the three countries (Njiru et al., 2008). • Local regulations exist but also differ, creating management challenges. The national authorities have not driven coordination of local municipalities (Wirkus & Böge, 2006). Additionally, a lack of coordination between districts has caused conflict and complicated implementation (UNEP, 2006; EAC, 2005 as cited in Lubovich, 2009). • The Environmental Management Act was established in Tanzania in 2004 to provide a framework that addresses issues such as pollution prevention, establish a regulatory body, and decentralize enforcement to local authorities (Pallangyo, 2007). However, local authorities often do not have the resources to enforce regulations (Pallangyo, 2007). • A significant percent of fishermen reported that they do not consistently comply with regulations (Eggert & Lokina, 2010). • In 2008, the corruption perception index was 2.1/10 in Kenya, 3.0/10 in Tanzania, and 2.6/10 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high (<33%) and enforcement is low, the political vulnerability is considered medium.

Stakeholder	Event	Regional Development	Economic	Education	Political
		Therefore, access to drinking water is considered low. • As a result of low assumed rates of access to water treatment, regional development vulnerability was high.			
	2020 Current Status	Medium	Medium	Medium	Medium
		• Large rates of urbanization have occurred in cities along the lake including Mwanza, Kisumu, and Entebbe (The World Bank, 2018b). Industrial development has also rapidly increased within the region (The World Bank, 2018b). • Poor planning in municipalities has led to insufficient wastewater treatment (Atieno, 2014). • Within the city of Kisumu, approximately 65% of residents had an improved water source in 2010; alternate water sources include open wells, streams, ponds, and water purchased from vendors (Maoulidi, 2010). • It is assumed that water treatment trends in Kisumu are similar to other urban areas around the lake. Therefore, it is assumed that access to improved water sources in the lake is medium (>50% and <80%). • Kenya percent of people using at least basic/safe drinking water services: 58.9, percent of urban population: 84.6/50.0 (2017; The World Bank, 2020). • Tanzania percent of people using at least basic/safe drinking water services: 56.7, percent of urban population: 85.5/35.0 (2017; The World Bank, 2020). • Uganda percent of people using at least basic/safe drinking water services: 49.1/7.1, percent of urban population: 75.1/15.7 (2017; The World Bank, 2020). • As a result of medium assumed rates of improved water access, regional development vulnerability is medium.	• The dam continued to function providing continued economic opportunities for actors. • Approximately a third of the basin lives on less than $1.25/day (i.e., in extreme poverty; The World Bank, 2016). In 2018, approximately 43.4% of Kenyans, 46.6% of Tanzanians, and 34.6% of Ugandans in the basin lived in poverty with higher rates within the basin (The World Bank, 2018b). • Kenya GNI per capita: $1,620, gap at national poverty line: 16.3, urban gap at national poverty line: 11.4, adjusted income: 0.420 (2018, 2005, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania GNI per capita: $1,020, gap at national poverty line: 6.7, urban gap at national poverty line: 3.9, adjusted income: 0.362 (2018, 2011, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Uganda GNI per capita: $620, gap at national poverty line: 5.2, urban gap at national poverty line: 2.5, adjusted income: 0.416 (2018, 2012, and 2015; The World Bank, 2020; UNDP, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, one country is considered low income (<$996) and two are considered lower-middle income (<$3,895; 2019). • Given that poverty throughout the basin is considered medium (>20% and <50%) the GNI per capita is considered medium and the hydropower industry was functioning and generating income, economic vulnerability is medium.	• Low levels of public awareness in understanding sources of pollution were reported in 2012 (Wang, 2012). • Kenya average years of schooling • Kenya average years of schooling: 6.6, expected years of schooling: 11.1, literacy: 0.329, 78.7%, 81.5% (2018, 2015, 2014, and 2018; UNDP, 2020; Prados de la Escosura, 2019). • Tanzania average years of schooling: 6, expected years of schooling: 8.0, literacy: 0.353, 77.9%, 69.4% (2018, 2015, 2010, and 2002; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Uganda average years of schooling: 6.1, expected years of schooling: 11.2, literacy: 0.291, 70.2%, 77.9% (2018, 2015, and 2012; UNDP, 2020; Prados de la Escosura, 2019; The World Bank, 2020). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25 years), and literacy calculation is low (<0.5; UNDP, 2009). The literacy percentage is medium in two countries and high in one country (>50% and >80%, respectively). • Based on the low public awareness, medium to high literacy, and low average schooling, educational vulnerability is medium.	• The lack of coordination has been criticized for its impact that "hamper[s] development efforts" (Lubovich, 2009, p. 12). • The LVBC self-reported that it had weaknesses in financial sustainability, partnership framework, and inter-departmental coordination (2013). • Failure of regional bodies to implement projects has also impacted consistency within the region as part of LVEMP II (The World Bank, 2018a). This failure is largely affected by insufficient country funding of projects which includes monitoring of water quality and fisheries (The World Bank, 2018a). • It was reported that cities did not predict the growth of industries in the region; therefore, there are insufficient municipal regulations to manage discharges (Atieno, 2014). Additionally, existing regulations are not enforced and are regularly broken by industries (Atieno, 2014). • In 2019, the corruption perception index was 28/100 in Kenya, 37/100 in Tanzania, 28/100 in Uganda (Transparency International, 2020). • Given that regulations were established for all three countries and relate to pollution, but corruption is high and medium (<33% and <66%, respectively) and enforcement is low, the political vulnerability is considered medium.

Table 24. Comprehensive analysis of primary stakeholder risk in the Lake Victoria basin.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
Inhabitants of Urban Areas	1947 Initiation of the LVFS	No	High	No	High	No	High	No	Medium
		• Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006). However, as eutrophication was not observed, this is assumed to not have a major impact on drinking water exposure.	• In 2006, the lake supplied water to 5 million rural and urban residents including major cities (EAC Secretariat, 2006; The World Bank, 2018a). Additionally, in 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • It is assumed that these water use trends were consistent historically. • It is assumed that drinking water consumption is highest in riparian cities which make up a majority of the cities within the basin.	• Deep water oxygen concentrations were considered sufficient for biotic growth since 1820 (UNEP, 2006). • Although water quality impacts were occurring in the lake, given the lack of oxygen depletion and no observed impact on fisheries, water quality was assumed to not impact ingestion.	• Prior to 1980, most of the consumed animal protein in the basin came from the lake (Jansen et al., 1999). Fish were approximately 80% of the local diet (Muyodi et al., 2010). • It is assumed that agriculture was primarily rainfed in the basin with 60% of the population employed in rainfed agriculture (The World Bank, 2018b). This rainfed agriculture was an important source of food in the basin (UNEP, 2006). • Given the fraction of fish in the diet, ingestion exposure is considered high.	• Eutrophication was not observed as a result of increased nutrient loading. Therefore, it is assumed that there was not a dermal contact impact at this point.	• Dermal exposure is considered highest in riparian communities, which include most major cities along the lake (UNEP, 2006). Additionally, several jobs that are common within cities (e.g., car washing, sand scooping, and shipping) increase dermal contact with the lake (UNEP, 2006). Therefore, dermal contact exposure is high.	• Although water quality impacts were occurring, they are not assumed to have a substantial impact on industrial or commercial water use in cities.	• Employment in urban centers involved various sectors (e.g., transportation, building materials, power generation, commercial activities, trading, social services, fish processing, industry, academia, and disposal of waste; Wirkus & Böge, 2006; UNEP, 2006). • Not all sectors in cities had high water use. Given the diversity of employment, exposure is considered medium.
	1973 Establishment of the LVFC	Yes	High	Yes	Low	Yes	Medium	Yes	Low
		• Large quantities of sediment were deposited in the 1970s with anoxic conditions beginning to develop in the deep portions of the lake	• It is assumed that exposure is consistent with previous years.	• Signs of overfishing were observed in the lake in the 1970s (UNEP, 2006). It is possible that this decrease in fish stocks was related to	• Although fish were still the dominant fraction of local diets, because fisheries had not been strongly impacted by water	• Although algal blooms began to occur, it is assumed that a threshold was not surpassed for dermal exposure.	• It is assumed that dermal exposure was consistent with previous years. However, given that large impacts were not observed on the	• The increase in algal blooms may have caused some clogging of intake pipes for industrial and commercial uses of water. Therefore, there is	• The exposure to sector water use is considered consistent with previous years. However, since industrial impacts as

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		(Odada 2003; Verschuren et al., 2002; Mugidde, 1993). • Additionally, algal blooms began to increase after the 1960s (Odada 2003; Verschuren et al., 2002; Mugidde, 1993). • It is assumed that the algal blooms did not surpass a threshold in the lake for water consumption. However, the discharge of untreated wastewaters does increase pathogen loading and is considered a risk for communities that use water in close proximity to major city centers.		ambient water quality. • The water quality conditions also enabled the Nile perch to dominate fisheries (Hecky et al., 2010; UNEP, 2006). Nile perch were introduced to the lake in the 1950s (Hecky et al., 2010). • Substantial degradation of wetlands occurred between 1960 and 2006, thus decreasing wetland access and use (Kayombo & Jorgensen, 2005; Muyodi et al., 2010). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have an ingestion impact.	quality in the 1970s, and food from wetlands is assumed to be a minor fraction of urban diets, ingestion exposure is considered low.	• However, the presence of untreated wastewater posed a dermal exposure threat in waters near major urban centers.	lake, it is assumed that the pathogen concentrations were low. Therefore, exposure is considered medium.	considered to be an impact on livelihood use.	a result of water quality were not reported in the 1970s, the exposure is considered low.
	1977 Collapse of the LVFC and EAC	Yes	High	Yes	Low	Yes	Medium	Yes	Low
		• Stable anoxic conditions were reached throughout the deep waters of the lake by the late 1970s (Verschuren, et al., 2002; Kayombo & Jorgensen, 2005; Muyodi et al., 2010). • Although the spread of anoxia shows a progression	• It is assumed that water ingestion exposure is consistent with previous years.	• The signs of overfishing and degradations of wetlands occurred over this time period (UNEP, 2006; Mwakubo & Obare, 2009). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is	• The exposure and relative impact on food sources is considered consistent with previous years.	• The presence of pathogens as a result of wastewater discharges causes an impact to dermal exposure in proximity of urban centers.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The increase in algal blooms may have caused some clogging of intake pipes for industrial and commercial uses of water. Therefore, there is considered to be an impact on livelihood use.	• The exposure and relative impact on livelihood use in urban centers is considered consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		of water quality impacts, it is assumed that anoxia did not surpass a threshold for water consumption exposure. However, given the presence of pathogens from untreated wastewater, water in proximity to major city centers is considered a risk for water ingestion.		assumed to have impact on ingestion.					
	1994 Establishment of the LVFO and initiation of the LVEMP	Yes	High	Yes	High	Yes	High	Yes	Medium
		• In the 1980s, large algal blooms occurred that were dominated by cyanobacteria; the presence of the algal blooms was also concurrent with microbial contamination (Muyodi et al., 2010; Hecky et al., 2010). The presence of cyanobacteria introduced toxins that are harmful when ingested. • In 1988, water hyacinth was introduced into the lake and rapidly proliferated given the high lake nutrient concentrations and the large inflow of the weed (UNEP, 2006).	• It is assumed that exposure is consistent with previous years.	• The deep water anoxic conditions, algal blooms, wetland degradation, and Nile perch dramatically altered the fish community leading to the collapse of endemic fish species and domination of the Nile perch (Muli, 1996; Zilov, 2013; Lubovich, 2009; UNEP, 2006). There was a loss of 200 cichlid species and decline in tilapia stock (Zilov, 2013; Lubovich, 2009). • The water hyacinth further shifted fish habitats and decreased biodiversity and fish density in its proximity (Zilov, 2013; UNEP, 2006).	• Tilapia was regularly consumed by local communities (Zilov, 2013; Lubovich, 2009). However, market pressure began to decrease local access to fish (Jansen et al., 1999). Therefore, the decrease in fish stock and market created barriers were felt by the local population. • Wetlands can be a food source for communities; therefore, the degradation of wetlands can directly impact nearby communities (Nakijoba, 1996 as cited in UNEP, 2006). • These trends impacted food	• The presence of cyanobacteria produces toxins that are a risk to dermal contact. In addition to the release of pathogens into the system, there is an impact to dermal exposure.	• Dermal exposure is considered highest in riparian communities, which include most major cities along the lake. Additionally, several jobs that are common within cities (e.g., car washing, sand scooping, and shipping) increased dermal contact with the lake (UNEP, 2006). Therefore, dermal exposure is considered high.	• The eutrophication and water hyacinth may have impacted water intakes for commercial and industrial activities. • The boom in Nile perch may also have impacted fish processing facilities in urban areas; however, this impact likely expanded processing capacity and livelihood opportunities (Kulindwa, 2006).	• Not all sectors in cities (e.g., industrial, commercial, service, academic, governmental) had high water use. Given the diversity of employment, exposure is considered medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• The water hyacinth provided a habitat for vectors of disease and altered the lake's water chemistry (Zilov, 2013; UNEP, 2006). By the mid-1990s, the water hyacinth covered 75% of Uganda's shoreline (UNEP, 2006). Additionally, an increase in water treatment costs was observed in relation to the presence of the water hyacinth (UNEP, 2006). • Given the presence of cyanobacteria, pathogens, and altered water chemistry from the water hyacinth, there was an impact on drinking water ingestion.		Together, these impacts complicated fishing patterns. • Additionally, wetlands continued to degrade over this time period (Mwakubo & Obare, 2009). • As a result of the impact to fisheries and wetlands, there was a risk to ingestion.	security in the region, and therefore ingestion exposure was considered high.				
	2003 Establishment of the LVBC	Yes	High	Yes	High	Yes	High	Yes	High
		• Illegal fishing practices (i.e., poisoning) caused several fatalities in the lake (Muyodi et al., 2010). • A major water hyacinth outbreak occurred in 1997 (Lubovich, 2009). • The water hyacinth was 80% contained by 2000; however, resurgences of the weed occurred in	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This water use is assumed to include for drinking water and/or domestic use. • It is assumed that water ingestion	• In 2000, bioaccumulation of mercury was observed in Nile perch (Campbell, 2000 as cited in UNEP, 2006). • Pesticides were also measured in the waterbody which have potential to bioaccumulate and magnify concentrations in aquatic species	• Food insecurity was high in the basin as related, in part, to changes in the lake protein (Abila, 2000; Odongkara, Abila, & Onyango, 2005; Geheb et al., 2007).	• The cyanobacteria, pathogens, and disease vectors continued to impact dermal exposure. • Cyanobacteria in the lake led to complaints of itchiness and "malaria-like" symptoms (Bathwondi, 2008 as cited in Lugo et al., 2014, p. 230). Thus there was a	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include water for domestic use. • The cholera outbreak of 1997 may also be related	• The water hyacinth impacted water transport by preventing access to boats and affected industries by the clogging of water intakes (UNEP, 2006). • The decrease of water levels in the lake further challenged transport, as existing infrastructure could	• The eutrophic waters and hyacinth had a high impact on economic activities in urban areas. • The water hyacinth caused a 70% decrease in activity in the port of Kisumu (Mailu, 2001). • The 1997 water hyacinth outbreak cost the three

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		the following years to a lesser extent than the 1997 outbreak (The World Bank, 2008). • Although the water hyacinth was contained, high nutrient loads and untreated wastewaters were discharged into the lake, serving as a source for eutrophication and pathogens. These nutrient loads enabled the propagation of the hyacinth while also constituting a drinking water risk. • This drinking ingestion risk was demonstrated by a cholera outbreak in 1997 that was linked to ingestion of lake water (Shapiro et al., 1999). Additionally, water quality impacts affected drinking water systems with eutrophication causing an increase of $1.7 million USD in drinking water treatment costs for increased chemical use (Muyodi et al., 2010). • Additionally, incidences of pathogenic risk increased in times of	exposure is consistent with previous years.	(Madadi, 2004). These chemicals compounded challenges in decreased fish stocks and the decreased availability of fish protein to local communities. • The decrease in water levels enabled a greater spread of water hyacinth on beaches which could have increased impacts to fish and wildlife habitats that were occurring from changing water levels (Lubovich, 2009). • As a result of bioaccumulation and changing fish stocks, there was a continued ingestion impact.		continued dermal exposure impact.	to dermal contact with water (Shapiro et al., 1999). • The riparian and employment nature of large urban centers implies that exposure was high.	no longer be accessed by water and the same cargo loads could no longer be transported (The World Bank, 2018a).	countries approximately $6-$10 million USD. (The World Bank, 2000). • The decrease in water level caused "huge financial losses" to shipping companies (The World Bank, 2008, p. 3).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		flooding, as related to El Niño, such as in 1997 (UNEP, 2006). • Additional impacts were related to the decrease in lake levels over this time period. Decrease in water levels impacted water access in Tanzania, causing three intake pumps to be closed down (Lubovich, 2009). The decrease in water levels also concentrated pollutants (Lubovich, 2009). • As a result of the water quality pollutants and changing water levels, there was a continued water ingestion risk.							
	2008 Tensions with Uganda	Yes	High	Yes	High	Yes	High	Yes	Medium
		• Although the hyacinth became more controlled, large portions of the lake continued to be eutrophic (The World Bank, 2018a). • Additionally, regular outflow of wastewater discharges (millions of liters daily) made fecal coliforms one of the most common water contamination issues in the region	• In 2006, 5 million people in cities and rural communities used water from the lake for drinking water and industrial use (EAC Secretariat, 2006). Some of the major cities that used the lake as a drinking water source include Kampala, Entebbe, Jinja, Kisumu, Homa Bay, Migori, Mwanza, Musoma, Bukoba, Shinyanga,	• A 2007 study indicated that there was bioaccumulation of contaminants in urban farms as a result of contaminated wells and surface water runoff (Mireri et al., 2007). • The lake's water quality, combined with fishing patterns, severely threatened the quantity of fish in	• By 2010, increased prices and declining catches altered local diets. Fish became approximately 20% of the local diet (as opposed to 80% in the 1980s; Muyodi et al., 2010). Additionally, rainfed agriculture was a major food source in the basin (UNEP, 2006). • In cities, urban agriculture also became a common	• Given the continued eutrophic conditions and wastewater discharges, it is assumed that cyanobacteria and pathogens continued to impact dermal exposure within the lake.	• Various common employment opportunities in riparian cities led to high dermal contact exposure (UNEP, 2006).	• Although the water hyacinth was primarily managed by 2008, there were still outbreaks that could affect water intakes for industrial and commercial uses. Therefore, there still was a livelihood use impact.	• Given the diversity of industry within cities and the decreased severity of the water hyacinth, livelihood use exposure was considered medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		which likely affected alternate water sources in flooding events (UNEP, 2006). As follows, a higher incidence of disease occurred in the wet season (Muyodi et al., 2010). • The basin had a high rate of diarrheal disease, commonly related to contaminated drinking water or lack of water access (UNEP, 2006). These diseases include cholera, typhoid, dysentery, and parasites (UNEP, 2006). • Agricultural, industrial, and household waste were also regularly disposed of in the lake increasing the contaminant loading and potential toxicity of water sources (Wirkus & Böge, 2006; The World Bank, 2018a). • As a result of the various sources of pollution, there was a continued impact on drinking water ingestion.	and Kahama (The World Bank, 2008). • As a result of the broad use of the lake for drinking water, ingestion exposure is high.	the lake (Kolding & van Zwieten, 2006). • Additionally, by 2006, approximately 75% of the wetlands had been significantly affected by degradation (Kayombo & Jorgensen, 2005). • As a result of impacts to various food sources, there is an ingestion impact.	alternate food source for urban residents. • Although the basin diet was primarily agricultural based, the risk of contaminated agriculture in urban farms and bioaccumulation of existing fish species causes a high risk and ingestion exposure.				
	2020 Current Status	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• Although some water quality	• Consistent with previous years, it is	• It is predicted that the tilapia and Nile	• Although approximately 75%	• High concentrations of pathogens were	• It is assumed that dermal exposure is	• With the general control of the water	• Livelihood impacts in cities have

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		interventions have occurred, water quality continues to impact the water ingestion pathway as a result of high nutrient and pathogen loading. • It is anticipated that climate change will exacerbate eutrophic conditions and the spread of disease (The World Bank, 2018b). Additionally, it is anticipated that the lake will take a long time to recover as it has a 23 year residence time and 123 year flushing time (UNEP, 2006; Okurut & Othero, 2012). • The lake is considered to currently be in a "stable state" with its higher nutrient input (Hecky et al., 2010, p. 38).	assumed that large, riparian urban areas use water from the lake for drinking water. Therefore, water ingestion exposure is high.	perch fisheries may decrease as a result of growing anoxic conditions (Hecky et al., 2010). Decreases occurred between 2015 and 2016 with a 33% drop in fish stocks (World Bank, 2018a). • The loading of other pollutants into the waterbody (e.g., mining wastes and pesticides) may threaten irrigated agriculture. • Continued urban agriculture is considered to be at risk of bioaccumulation due to poorly managed water sources. • As a result, there is a continued impact to ingestion.	of basin farms are rainfed, there is a risk of consumption related to irrigated crops (Mwiturbani, 2010; The World Bank, 2018b). Additionally, there is a risk to bioaccumulation in urban agricultural crops. • Given that a majority of the basin no longer consumes fish and rainfed agriculture is still prevalent, it is assumed that ingestion risk is medium.	found at beaches along the lake in Uganda (Muyodi et al., 2010). It is assumed that this contamination is consistent along beaches in all riparian countries. • The continued eutrophication and pathogen loading constitute a risk of dermal exposure throughout the lake.	consistent with previous years.	hyacinth, only algal blooms may cause clogging of intake pipes for industrial and commercial uses of water. Given the continuation of eutrophication, there is considered to be an impact on livelihood use.	decreased with the management of the water hyacinth. Therefore, exposure to livelihood use is considered low.
Rural traditional fishermen	1947 Initiation of the LVFS	No	High	No	High	No	High	No	High
		• Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006). However, as eutrophication was not observed, this is assumed to not have a major	• It is assumed that fishing communities are riparian and thus are more likely to use the lake for a drinking water and domestic source (Jansen et al., 1999). • This likelihood is compounded by the fact that in 2002,	• Deep water oxygen concentrations were considered sufficient for biotic growth since 1820 (UNEP, 2006). • Although water quality impacts were occurring in the lake, given the lack of oxygen depletion	• Prior to 1980, most of the consumed animal protein was from the lake (Jansen et al., 1999). Fish were approximately 80% of the local diet (Muyodi et al., 2010).	• Eutrophication was not observed as a result of increased nutrient loading therefore it is assumed that there was not a dermal contact impact at this point.	• It is assumed that fishing communities are riparian (Jansen et al., 1999). The close proximity and action of fishing suggest that fishermen will have a high exposure to dermal contact (UNEP, 2006).	• Given the sufficient oxygen conditions (UNEP, 2006), the fisheries were not anticipated to be impacted at this point.	• Fishing communities have a high reliance on water quality within the lake; therefore any impact will have a high exposure on the livelihood of fishermen.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		impact on drinking water exposure.	approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This water use is assumed to include for drinking water and/or domestic use and trends are assumed to be consistent through history.	and no observed impact on fisheries, water quality was assumed to not impact ingestion.	• It is assumed that agriculture was primarily rainfed in the basin with 60% of the population employed in rainfed agriculture (The World Bank, 2018b). This rainfed agriculture is an important source of food in the basin (UNEP, 2006). • Given the fraction of fish in the diet, exposure is considered high.				
	1973 Establishment of the LVFC	Yes	High	Yes	Low	Yes	Medium	Yes	Medium
		• Increase in algal blooms are not assumed to surpass a threshold in the lake for water consumption. However, the discharge of untreated wastewaters does increase pathogen load and is considered a risk for communities that use water in close proximity to riparian communities.	• The exposure to drinking water ingestion is assumed to be consistent with previous years.	• Signs of overfishing were observed in the lake in the 1970s (UNEP, 2006). It is possible that this decrease in fish stocks was related to ambient water quality. • The water quality conditions also enabled the fisheries dominance of Nile perch which had been introduced to the lake in the 1950s (Hecky et al., 2010; UNEP, 2006). • Substantial degradation of wetlands occurred between 1960 and 2006, thus decreasing wetland access and use (Mwakubo & Obare, 2009;	• Although fish was still the dominant fraction of local diets, because fisheries had not been strongly impacted by water quality in the 1970s, and food from wetlands is assumed to be a fraction of rural diets, exposure is considered low.	• Although algal blooms began to occur, it is assumed that a threshold was not surpassed for dermal exposure. • However, the presence of untreated wastewater does pose a threat of exposure to pathogens in waters near rural communities.	• It is assumed that dermal exposure is consistent with previous years. However, given that large impacts were not observed on the lake, it is assumed that the pathogen concentrations were low. Therefore, exposure is considered medium.	• Nile perch were introduced to the lake in the 1950s, and anoxic conditions were beginning to develop within the 1970s (Odada 2003; Verschuren et al., 2002; Mugidde, 1993). These actions begin to put a strain on local fisheries. • Signs of overfishing were observed in the lake in the 1970s which were likely also linked to water quality and the Nile perch presence (UNEP, 2006). This alteration in fish stocks is an impact on fisheries.	• Although fishermen are directly dependent on fish stocks, because signs of overfishing were observed but not rampant, the livelihood use exposure is considered to be medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				Kayombo & Jorgensen, 2005). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.					
	1977 Collapse of the LVFC and EAC	Yes	High	Yes	Low	Yes	Medium	Yes	Medium
		• Although the spread of anoxia shows a progression of water quality impacts, it is assumed to not surpass a threshold for water consumption exposure. However, given the presence of pathogens from untreated wastewater, water in proximity to major city centers is considered a risk for water ingestion.	• It is assumed that exposure is consistent with previous years.	• The signs of overfishing and degradations of wetlands occurred over this time period (UNEP, 2006; Mwakubo & Obare, 2009). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The presence of pathogens as a result of wastewater discharges causes an impact to dermal exposure in proximity of rural communities.	• The dermal exposure is considered consistent with previous years.	• The continued impact on fish stocks demonstrates an impact on livelihood use.	• The exposure and relative impact on livelihood use in urban centers is considered consistent with previous years.
	1994 Establishment of the LVFO and initiation of the LVEMP	Yes	High	Yes	High	Yes	High	Yes	Low
		• The large algal blooms, cyanobacteria, and microbial contamination provide a risk through drinking water ingestion. • The water hyacinth introduction also altered water quality in its proximity, adding to the impact of water quality ingestion. .	• It is assumed that exposure is consistent with previous years.	• The deep water anoxic conditions, algal blooms, wetland degradation, and water hyacinth propagation altered the fish community leading to endemic species collapse and (Muli, 1996; Zilov, 2013; Lubovich, 2009; UNEP, 2006). • Additionally, wetlands continued to degrade over this time period	• Tilapia was regularly consumed by local communities and this food source was impacted by the decrease in fisheries (Zilov, 2013; Lubovich, 2009). Although market pressure decreased local access to fish stocks (Jansen et al., 1999), this was not assumed to impact the fishing community.	• The presence of cyanobacteria produces toxins that are a risk to dermal contact. In addition to the release of pathogens into the system, there is an impact to dermal exposure.	• Dermal exposure is considered highest in riparian communities and with fishermen who regularly interact with the water resources. Therefore, exposure is considered high.	• The boom in Nile fish perch provided opportunities to local fishermen even though local fisheries collapsed (Jansen et al., 1999). • However, the alteration of fishing patterns was considered to impact livelihood use.	• Because many fishermen profited in the 1990s from increased catches of Nile perch, the livelihood exposure is considered low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				(Mwakubo & Obare, 2009).	• Wetlands can be a food source for communities; therefore, the degradation of wetlands can directly impact nearby communities (Nakijoba, 1996 as cited in UNEP, 2006). • These trends impacted food security in the region and therefore exposure was considered high.				
	2003 Establishment of the LVBC	Yes	High	Yes	High	Yes	High	Yes	High
		• Fishing practices, hyacinth outbreak, eutrophication, and pathogen loading all increased impact to the lake and riparian water sources. • The decrease in water levels also concentrated pollutants increasing the impact within the lake (Lubovich, 2009).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • It is assumed that exposure is consistent with previous years.	• In 2000, bioaccumulation of mercury was observed in Nile perch (Campbell, 2000 as cited in UNEP, 2006). • Pesticides were also measured in the waterbody which have potential to bioaccumulate and magnify concentrations in aquatic species (Madadi, 2004). These chemicals compounded challenges in decreased fish stocks and the decreased availability of fish protein to local communities. • The decrease in water levels enabled	• Given that fishermen likely had access to fish in spite of market pressures, the exposure is considered high to the bioaccumulation of chemicals within fish. • Additionally, rural communities are assumed to me more dependent on wetlands for alternate food sources, and therefore likely experience the impact of degradation with a higher frequency.	• The cyanobacteria, pathogens, and disease vectors continued to impact dermal exposure. • Cyanobacteria in the lake led to complaints of itchiness and “malaria-like” symptoms (Bathwondi, 2008 as cited in Lugo et al., 2014, p. 230).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • The cholera outbreak of 1997 may also be related to dermal contact with water (Shapiro et al., 1999). • The riparian and employment nature of fishing communities implies that exposure was high.	• The water hyacinth decreased the presence of fish near shore, and access to boats/ability to launch boats in order to go fishing (UNEP, 2006). The water hyacinth further destroyed fishing nets (UNEP, 2006). • The fisheries also experienced a decrease in fish stocks with a decrease in volume of catch per fishermen since the 1990s (Muyodi et al., 2010).	• The decrease in fish catch directly affects the livelihood use of fishing communities; therefore, exposure is considered high.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				a greater spread of water hyacinth on beaches which could have increased impacts to fish and wildlife habitats that were occurring from changing water levels (Lubovich, 2009).					
	2008 Tensions with Uganda	Yes	High	Yes	Medium	Yes	High	Yes	High
		• Although the hyacinth became more controlled, large portions of the lake continued to be eutrophic and experience a high loading of pathogens (The World Bank, 2018a; UNEP, 2006). • Flooding events also increased the impacts on alternate water sources (Muyodi et al., 2010). • Continued discharge of agricultural, industrial, and household waste also increased the contaminant loading and potential toxicity of water sources (Wirkus & Böge, 2006; The World Bank, 2018a).	• It is assumed that drinking water exposure was consistent with previous years.	• The water quality combined with fishing patterns severely threatened the quantity of fish in the lake (Kolding & van Zwieten, 2006). • Additionally, by 2006, approximately 75% of the wetlands had been significantly affected by degradation (Kayombo & Jorgensen, 2005).	• Although patterns of fish consumption had changed in the basin, these patterns were assumed to not impact fishermen (who had direct access to catch). • Additionally, fishing communities were assumed to be moderately reliant on wetlands. • Based on the access to fish proteins and rainfed agriculture, the exposure was considered to be medium.	• Given the continued eutrophic conditions and wastewater discharges it is assumed that cyanobacteria and pathogens continue to impact dermal exposure within the lake.	• The dermal exposure is assumed to be consistent with previous years.	• The decrease in fish catches continued throughout the 2000s (Muyodi et al., 2010). Therefore, water quality in the lake was considered to have an impact on fisheries.	• The decrease in fish catch directly affects the livelihood use of fishing communities; therefore, exposure is considered high.
	2020 Current Status	Yes	High	Yes	Medium	Yes	High	Yes	High
		• Although some water quality interventions have occurred, water	• It is assumed that riparian communities comprise of the	• It is predicted that the tilapia and Nile perch fisheries may decrease as a result	• It is assumed that ingestion exposure is consistent with previous years.	• High concentrations of pathogens were found at beaches along the lake in	• It is assumed that dermal exposure is highest in riparian communities. For	• In addition to overfishing, water quality in the lake has continued to	• Livelihood use exposure is considered

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		quality continues to impact the drinking pathway in the lake as a result of high nutrients and pathogen loading.	approximately 5 million people who use water from the lake for drinking water (EAC Secretariat, 2006). • This pattern can be observed in some riparian communities. For instance, in the community of Usoma, 38% of respondents use the lake for cooking (Bisung et al., 2014). • Therefore, it is assumed that exposure to drinking water ingestion is high.	of growing anoxic conditions (Hecky et al., 2010). • The loading of other pollutants into the waterbody (e.g., mining wastes and pesticides) may threaten irrigated agriculture. • Continued urban agriculture is considered to be at risk of bioaccumulation due to poorly managed water sources.		Uganda (Muyodi et al., 2010). It is assumed that this contamination is consistent along beaches in all riparian countries. • The continued eutrophication and pathogen loading constitute a risk of dermal exposure throughout the lake.	instance, in the small riparian community of Usoma, 86% of respondents use the lake for other domestic uses (Bisung et al., 2014).	decrease available fish stock (e.g., a 33% decrease occurred between 2015 and 2016; The World Bank, 2018b). • As a result, there is an impact on livelihood use.	consistent with previous years.
Rural agriculture communities	1947 Initiation of the LVFS	No	Medium	No	High	No	Medium	No	Low
		• Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006). However, as eutrophication was not observed, this is assumed to not have a major impact on drinking water exposure.	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). However, drinking water use was assumed to be highest in riparian communities. Rural agriculture communities span throughout the basin, and are not solely riparian. • As a result of the wide use of water in the basin and span of rural agriculture,	• Deep water oxygen concentrations were considered sufficient for biotic growth since 1820 (UNEP, 2006). • Although water quality impacts were occurring in the lake, given the lack of oxygen depletion and no observed impact on fisheries, water quality was assumed to not impact ingestion.	• Prior to 1980, most of the consumed animal protein was from the lake (Jansen et al., 1999). Fish were approximately 80% of the local diet (Muyodi et al., 2010). • It is assumed that agriculture was primarily rainfed in the basin with 60% of the population employed in rainfed agriculture (The World Bank, 2018b). This rainfed agriculture is an important source of	• Eutrophication was not observed as a result of increased nutrient loading therefore it is assumed that there was not a dermal contact impact at this point.	• It is assumed that riparian communities will have the highest rates of dermal exposure due to ease of access and interaction with the waterbody (UNEP, 2006). • Because agriculture communities are distributed throughout the basin (including some riparian communities), dermal contact exposure is considered medium.	• Although water quality impacts were occurring, they are not assumed to have a substantial impact on irrigated agriculture given the low rates of organic contaminants in the waterbody.	• Given the low rates of irrigated agriculture, livelihood use exposure to water quality impacts is considered low (The World Bank, 2018b).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			the ingestion exposure is considered medium.		food in the basin (UNEP, 2006). • Given the fraction of fish in the diet, exposure is considered high.				
	1973 Establishment of the LVFC	Yes	Medium	Yes	Low	Yes	Low	No	Low
		• Increase in algal blooms are not assumed to surpass a threshold in the lake for water consumption. However, the discharge of untreated wastewaters does increase pathogen load and is considered a risk for communities that use water in close proximity to riparian communities.	• The exposure to drinking water ingestion is assumed to be consistent with previous years.	• Signs of overfishing were observed in the lake in the 1970s (UNEP, 2006). It is possible that this decrease in fish stocks was related to ambient water quality. • The water quality conditions also enabled the fisheries dominance of Nile perch which had been introduced to the lake in the 1950s (Hecky et al., 2010; UNEP, 2006). • Substantial degradation of wetlands occurred between 1960 and 2006, thus decreasing wetland access and use (Mwakubo & Obare, 2009; Kayombo & Jorgensen, 2005). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.	• Although fish was still the dominant fraction of local diets, because fisheries had not been strongly impacted by water quality in the 1970s, and food from wetlands is assumed to be a fraction of rural diets, exposure is considered low.	• Although algal blooms began to occur, it is assumed that a threshold was not surpassed for dermal exposure. • However, the presence of untreated wastewater does pose a threat of exposure to pathogens in waters near rural communities.	• It is assumed that dermal exposure is consistent with previous years. However, given that large impacts were not observed on the lake, it is assumed that the pathogen concentrations were low. Therefore, exposure is considered low.	• The impact is assumed to be consistent with previous years.	• Given the low rates of irrigated agriculture, livelihood use exposure to water quality impacts is considered low (The World Bank, 2018b).
		Yes	Medium	Yes	Low	Yes	Low	No	Low

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
	1977 Collapse of the LVFC and EAC	• Although the spread of anoxia shows a progression of water quality impacts, it is assumed to not surpass a threshold for water consumption exposure. However, given the presence of pathogens from untreated wastewater, water in proximity to rural communities is considered a risk for water ingestion.	• It is assumed that ingestion exposure is consistent with previous years.	• The signs of overfishing and degradations of wetlands occurred over this time period (UNEP, 2006; Mwakubo & Obare, 2009). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The presence of pathogens as a result of wastewater discharges causes an impact to dermal exposure in proximity of rural communities.	• The exposure and relative water concentrations are considered consistent with previous years.	• The impact is assumed to be consistent with previous years.	• Given the low rates of irrigated agriculture, livelihood use exposure to water quality impacts is considered low (The World Bank, 2018b).
	1994 Establishment of the LVFO and initiation of the LVEMP	Yes	Medium	Yes	High	Yes	Low	Yes	Low
		• The large algal blooms, cyanobacteria, and microbial contamination provide a risk through drinking water ingestion. • The water hyacinth introduction also altered water quality in its proximity, adding to the impact of water quality ingestion. • This broad distribution of impact provides a risk to any stakeholders who consume water from the lake. .	• It is assumed that ingestion exposure is consistent with previous years.	• The deep water anoxic conditions, algal blooms, wetland degradation, and water hyacinth propagation altered the fish community leading to endemic species collapse and (Muli, 1996; Zilov, 2013; Lubovich, 2009; UNEP, 2006). • Additionally, wetlands continued to degrade over this time period (Mwakubo & Obare, 2009).	• Tilapia was regularly consumed by local communities and this food source was impacted by the decrease in fisheries (Zilov, 2013; Lubovich, 2009). Access was further decreased by an export oriented market pressure (Jansen et al., 1999), this was not assumed to impact the fishing community. • Wetlands can be a food source for communities; therefore, the degradation of wetlands can directly impact nearby communities (Nakijoba, 1996 as	• The presence of cyanobacteria produces toxins that are a risk to dermal contact. In addition to the release of pathogens into the system, there is an impact to dermal exposure.	• The exposure and relative water concentrations are considered consistent with previous years.	• The increased pathogen loading is assumed to reach a threshold where it can impact irrigated agriculture.	• Given the low rates of irrigated agriculture, livelihood use exposure to water quality impacts is considered low (The World Bank, 2018b).

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
					cited in UNEP, 2006). • These trends impacted food security in the region and therefore exposure was considered high.				
	2003 Establishment of the LVBC	Yes	Medium	Yes	High	Yes	Medium	Yes	Low
		• Fishing practices, hyacinth outbreak, eutrophication, and pathogen loading all increased impact to the lake and riparian water sources. • The decrease in water levels also concentrated pollutants increasing the impact within the lake (Lubovich, 2009).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. The primary consumers of lake water are assumed to be riparian communities. • Ingestion exposure is assumed to be consistent with previous years.	• In 2000, bioaccumulation of mercury was observed in Nile perch (Campbell, 2000 as cited in UNEP, 2006). • Pesticides were also measured in the waterbody which have potential to bioaccumulate and magnify concentrations in aquatic species (Madadi, 2004). These chemicals compounded challenges in decreased fish stocks and the decreased availability of fish protein to local communities. • The decrease in water levels enabled a greater spread of water hyacinth on beaches which could have increased impacts to fish and wildlife habitats that were occurring from changing water	• Food insecurity is high within the lake basin as linked to partially linked to changes in lake protein (Abila, 2000; Odongkara et al., 2005; Geheb et al., 2007). • Additionally, rural communities are assumed to me more dependent on wetlands for alternate food sources, and therefore likely experience the impact of degradation with a higher frequency. • Given the changing consumption patterns, ingestion exposure is considered high.	• The cyanobacteria, pathogens, and disease vectors continued to impact dermal exposure. • Cyanobacteria in the lake led to complaints of itchiness and “malaria-like” symptoms (Bathwondi, 2008 as cited in Lugo et al., 2014, p. 230).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • The cholera outbreak of 1997 may also be related to dermal contact with water (Shapiro et al., 1999). • Given the distribution of rural communities throughout the basin, the exposure is considered medium.	• The livelihood use impact is assumed to be consistent with previous years	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				levels (Lubovich, 2009).					
	2008 Tensions with Uganda	Yes	Medium	Yes	High	Yes	Medium	Yes	Low
		• Although the hyacinth became more controlled, large portions of the lake continued to be eutrophic and experience a high loading of pathogens (The World Bank, 2018a; UNEP, 2006). • Flooding events also increased the impacts on alternate water sources (Muyodi et al., 2010). • Continued discharge of agricultural, industrial, and household waste also increased the contaminant loading and potential toxicity of water sources (Wirkus & Böge, 2006; The World Bank, 2018a).	• It is assumed that drinking water exposure was consistent with previous years.	• The water quality combined with fishing patterns severely threatened the quantity of fish in the lake (Kolding & van Zwieten, 2006). • Additionally, by 2006, approximately 75% of the wetlands had been significantly affected by degradation (Kayombo & Jorgensen, 2005).	• By 2010, increased prices and declining catches have altered local diets. Fish became approximately 20% of the local diet (as opposed to 80% in the 1980s; Muyodi et al., 2010). Rainfed agriculture was a major food source in the basin (UNEP, 2006). • Additionally, rural communities were assumed to be moderately reliant on wetlands. • Based on the lack of access to fish proteins and wetlands, the exposure was considered to be high.	• Given the continued eutrophic conditions and wastewater discharges it is assumed that cyanobacteria and pathogens continue to impact dermal exposure within the lake.	• The dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years	• The livelihood use exposure is assumed to be consistent with previous years.
	2020 Current Status	Yes	Medium	Yes	High	Yes	Medium	Yes	Low
		• Although some water quality interventions have occurred, water quality continues to impact the drinking pathway in the lake as a result of high nutrients and pathogen loading.	• It is assumed that riparian communities comprise of the approximately 5 million people who use water from the lake for drinking water which was approximately 14% of the basin (EAC	• It is predicted that the tilapia and Nile perch fisheries may decrease as a result of growing anoxic conditions (Hecky et al., 2010). • The loading of other pollutants into the waterbody (e.g., mining wastes and	• It is assumed that ingestion exposure is consistent with previous years.	• High concentrations of pathogens were found at beaches along the lake in Uganda (Muyodi et al., 2010). It is assumed that this contamination is consistent along beaches in all riparian countries.	• It is assumed that dermal exposure is highest in riparian communities. For instance, in the small riparian community of Usoma, 86% of respondents use the lake for other domestic uses	• The livelihood use impact is assumed to be consistent with previous years	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			Secretariat, 2006; The World Bank, 2018a). • This pattern can be observed in some riparian communities. For instance, in the community of Usoma, 38% of respondents use the lake for cooking (Bisung et al., 2014). • Given the distribution of rural communities, the exposure is considered medium.	pesticides) may threaten irrigated agriculture. • Continued urban agriculture is considered to be at risk of bioaccumulation due to poorly managed water sources.		• The continued eutrophication and pathogen loading constitute a risk of dermal exposure throughout the lake.	(Bisung et al., 2014). • Given the distribution of rural communities, the exposure is considered medium.		
Mining industry	1947 Initiation of the LVFS	No	Medium	No	High	Yes	Medium	No	High
		• Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006). However, as eutrophication was not observed, this is assumed to not have a major impact on drinking water exposure.	• Mines are assumed to be distributed throughout the basin ranging from artisanal to large mines (Mato & Kassenga, 2018; Kulindwa, 2006; Henckel et al., 2016). • Based on the distribution of gold in the basin, the mines are assumed to be both riparian and at a distance from the alke (Henckel et al., 2016). Notably, gold is not the only mineral in the basins' extractive activity. • In 2002, approximately 70%	• Deep water oxygen concentrations were considered sufficient for biotic growth since 1820 (UNEP, 2006). • Although water quality impacts were occurring in the lake, given the lack of oxygen depletion and no observed impact on fisheries, water quality was assumed to not impact ingestion.	• Prior to 1980, most of the consumed animal protein was from the lake (Jansen et al., 1999). Fish were approximately 80% of the local diet (Muyodi et al., 2010). • It is assumed that agriculture was primarily rainfed in the basin with 60% of the population employed in rainfed agriculture (The World Bank, 2018b). This rainfed agriculture is an important source of food in the basin (UNEP, 2006). • Given the fraction of fish in the diet,	• Eutrophication was not observed as a result of increased nutrient loading therefore it is assumed that there was not a dermal contact impact in the lake at this point. • However, the mining industry can incur heavy metal pollution in nearby waterbodies. Therefore, it is assumed that there was a dermal contact impact in nearby surface water.	• It is assumed that riparian communities will have the highest rates of dermal exposure due to ease of access and interaction with the waterbody (UNEP, 2006). • Because mining communities are distributed throughout the basin (including some riparian communities), dermal contact exposure to the lake is considered medium. • Many mining operations often occur near surface waterbodies. Given	• Although water quality impacts were occurring, they are not assumed to have a substantial impact mining processes.	• Mining is a water intensive industry. Therefore, livelihood use exposure to water quality is considered to be high.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). However, drinking water use was assumed to be highest in riparian communities. • Given the wide use of lake water and distance to the mines, ingestion exposure is considered medium.		exposure is considered high.		the possibility of exposure through surface waters that drain to the lake, the dermal contact exposure is considered medium.		
	1973 Establishment of the LVFC	Yes	Medium	Yes	Low	Yes	Medium	No	Low
		• Increase in algal blooms are not assumed to surpass a threshold in the lake for water consumption. However, the discharge of untreated wastewaters does increase pathogen load and is considered a risk for communities that use water in close proximity to riparian communities.	• The exposure to drinking water ingestion is assumed to be consistent with previous years.	• Signs of overfishing were observed in the lake in the 1970s (UNEP, 2006). It is possible that this decrease in fish stocks was related to ambient water quality. • The water quality conditions also enabled the fisheries dominance of Nile perch which had been introduced to the lake in the 1950s (Hecky et al., 2010; UNEP, 2006). • Substantial degradation of wetlands occurred between 1960 and 2006, thus decreasing wetland access and use (Mwakubo & Obare, 2009;	• Although fish was still the dominant fraction of local diets, because fisheries had not been strongly impacted by water quality in the 1970s, and food from wetlands is assumed to be a fraction of rural diets, exposure is considered low.	• Although algal blooms began to occur, it is assumed that a threshold was not surpassed for dermal exposure. • However, the presence of untreated wastewater does pose a threat of exposure to pathogens in waters near rural communities. • Additionally, mining effluent poses a dermal contact risk in nearby surface waters.	• It is assumed that dermal exposure is consistent with previous years for both the exposure to the lake and to surface water bodies.	• The impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				Kayombo & Jorgensen, 2005). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.					
	1977 Collapse of the LVFC and EAC	Yes	Medium	Yes	Low	Yes	Medium	No	Low
		• Although the spread of anoxia shows a progression of water quality impacts, it is assumed to not surpass a threshold for water consumption exposure. However, given the presence of pathogens from untreated wastewater, water in proximity to rural communities is considered a risk for water ingestion.	• It is assumed that ingestion exposure is consistent with previous years.	• The signs of overfishing and degradations of wetlands occurred over this time period (UNEP, 2006; Mwakubo & Obare, 2009). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The presence of pathogens as a result of wastewater discharges causes an impact to dermal exposure in proximity of rural communities. • Additionally, mining effluent poses a dermal contact risk in nearby surface waters.	• The exposure and relative water concentrations are considered consistent with previous years.	• The impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.
	1994 Establishment of the LVFO and initiation of the LVEMP	Yes	Medium	Yes	High	Yes	Medium	Yes	Low
		• The large algal blooms, cyanobacteria, and microbial contamination provide a risk through drinking water ingestion. • The water hyacinth introduction also altered water quality in its proximity, adding to the impact of water quality ingestion.	• It is assumed that ingestion exposure is consistent with previous years.	• The deep water anoxic conditions, algal blooms, wetland degradation, and water hyacinth propagation altered the fish community leading to endemic species collapse and (Muli, 1996; Zilov, 2013; Lubovich, 2009; UNEP, 2006). • Additionally, wetlands continued to degrade over this time period	• Tilapia was regularly consumed by local communities and this food source was impacted by the decrease in fisheries (Zilov, 2013; Lubovich, 2009). Access was further decreased by an export oriented market pressure (Jansen et al., 1999), this was not assumed to impact	• The presence of cyanobacteria produces toxins that are a risk to dermal contact. In addition to the release of pathogens into the system, there is an impact to dermal exposure. • Additionally, mining effluent poses a dermal contact risk in nearby surface waters.	• The exposure and relative water concentrations are considered consistent with previous years.	• The initial presence of water hyacinth has a potential to clog water intakes from the lake. As it is likely that some lake water is used in the industry, this is considered to have an impact.	• The livelihood use exposure is assumed to be consistent with previous years and water use from the lake is assumed to be low given pumping fees.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• This broad distribution of impact provides a risk to any stakeholders who consume water from the lake.		(Mwakubo & Obare, 2009).	the fishing community. • Wetlands can be a food source for communities; therefore, the degradation of wetlands can directly impact nearby communities (Nakijoba, 1996 as cited in UNEP, 2006). • These trends impacted food security in the region and therefore exposure was considered high.				
	2003 Establishment of the LVBC	Yes	Medium	Yes	High	Yes	Medium	Yes	Low
		• Fishing practices, hyacinth outbreak, eutrophication, and pathogen loading all increased impact to the lake and riparian water sources. • The decrease in water levels also concentrated pollutants increasing the impact within the lake (Lubovich, 2009).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. The primary consumers of lake water are assumed to be riparian communities. • Ingestion exposure is assumed to be consistent with previous years.	• In 2000, bioaccumulation of mercury was observed in Nile perch (Campbell, 2000 as cited in UNEP, 2006). • Pesticides were also measured in the waterbody which have potential to bioaccumulate and magnify concentrations in aquatic species (Madadi, 2004). These chemicals compounded challenges in decreased fish stocks and the decreased availability of fish protein to local communities.	• Food insecurity is high within the lake basin as linked to partially linked to changes in lake protein (Abila, 2000; Odongkara et al., 2005; Geheb et al., 2007). • Additionally, rural communities are assumed to me more dependent on wetlands for alternate food sources, and therefore likely experience the impact of degradation with a higher frequency. • Given the changing consumption patterns, ingestion	• The cyanobacteria, pathogens, and disease vectors continued to impact dermal exposure. • Cyanobacteria in the lake led to complaints of itchiness and “malaria-like” symptoms (Bathwondi, 2008 as cited in Lugo et al., 2014, p. 230). • Additionally, mining effluent poses a dermal contact risk in nearby surface waters and is occurring at sufficient concentrations to be observed in lake fish (Campbell, 2000 as	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • The cholera outbreak of 1997 may also be related to dermal contact with water (Shapiro et al., 1999). • Given the distribution of mining communities throughout the basin and the potential exposure to alternate surface water	• The presence of water hyacinth likely clogged any water intakes from the lake (UNEP, 2006).	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				• The decrease in water levels enabled a greater spread of water hyacinth on beaches which could have increased impacts to fish and wildlife habitats that were occurring from changing water levels (Lubovich, 2009).	exposure is considered high.	cited in UNEP, 2006).	sources, the exposure is considered medium.		
	2008 Tensions with Uganda	Yes	Medium	Yes	High	Yes	Medium	No	Low
		• Although the hyacinth became more controlled, large portions of the lake continued to be eutrophic and experience a high loading of pathogens (The World Bank, 2018a; UNEP, 2006). • Flooding events also increased the impacts on alternate water sources (Muyodi et al., 2010). • Continued discharge of agricultural, industrial, and household waste also increased the contaminant loading and potential toxicity of water sources (Wirkus & Böge, 2006; The World Bank, 2018a).	• It is assumed that drinking water exposure was consistent with previous years.	• The water quality combined with fishing patterns severely threatened the quantity of fish in the lake (Kolding & van Zwieten, 2006). • Additionally, by 2006, approximately 75% of the wetlands had been significantly affected by degradation (Kayombo & Jorgensen, 2005).	• By 2010, increased prices and declining catches have altered local diets. Fish became approximately 20% of the local diet (as opposed to 80% in the 1980s; Muyodi et al., 2010). Rainfed agriculture was a major food source in the basin (UNEP, 2006). • Additionally, rural communities were assumed to be moderately reliant on wetlands. • Based on the lack of access to fish proteins and wetlands, the exposure was considered to be high.	• Given the continued eutrophic conditions and wastewater discharges it is assumed that cyanobacteria and pathogens continue to impact dermal exposure within the lake. • Additionally, mining effluent poses a dermal contact risk in nearby surface waters.	• The dermal exposure is assumed to be consistent with previous years.	• The general control of the water hyacinth decreases potential impacts to the mining industry. Therefore, there is not assumed to be an impact.	• The livelihood use exposure is assumed to be consistent with previous years.
	2020 Current Status	Yes	Medium	Yes	High	Yes	Medium	No	Low

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• Although some water quality interventions have occurred, water quality continues to impact the drinking pathway in the lake as a result of high nutrients and pathogen loading.	• It is assumed that riparian communities comprise of the approximately 5 million people who use water from the lake for drinking water which was approximately 14% of the basin (EAC Secretariat, 2006; The World Bank, 2018a). • This pattern can be observed in some riparian communities. For instance, in the community of Usoma, 38% of respondents use the lake for cooking (Bisung et al., 2014). • Given the distribution of rural communities, the exposure is considered medium.	• It is predicted that the tilapia and Nile perch fisheries may decrease as a result of growing anoxic conditions (Hecky et al., 2010). • The loading of other pollutants into the waterbody (e.g., mining wastes and pesticides) may threaten irrigated agriculture. • Continued urban agriculture is considered to be at risk of bioaccumulation due to poorly managed water sources.	• It is assumed that ingestion exposure is consistent with previous years.	• High concentrations of pathogens were found at beaches along the lake in Uganda (Muyodi et al., 2010). It is assumed that this contamination is consistent along beaches in all riparian countries. • The continued eutrophication and pathogen loading constitute a risk of dermal exposure throughout the lake. • Additionally, mining effluent poses a dermal contact risk in nearby surface waters.	• It is assumed that dermal exposure is highest in riparian communities. For instance, in the small riparian community of Usoma, 86% of respondents use the lake for other domestic uses (Bisung et al., 2014). • Given the distribution of mining communities and potential risk from adjacent surface waters, the exposure is considered medium.	• The livelihood use impact is assumed to be consistent with previous years	• The livelihood use exposure is assumed to be consistent with previous years.
Hydropower industry	1947 Initiation of the LVFS	No	High	No	High	No	High	No	Low
		• Increased nutrient loading began to impact the lake as early as 1930 (UNEP, 2006). However, as eutrophication was not observed, this is assumed to not have a major impact on drinking water exposure.	• In 2006, the lake supplied water to 5 million rural and urban residents including major cities (EAC Secretariat, 2006; The World Bank, 2018a). Additionally, in 2002, approximately 70% of the basin population used untreated water	• Deep water oxygen concentrations were considered sufficient for biotic growth since 1820 (UNEP, 2006). • Although water quality impacts were occurring in the lake, given the lack of oxygen depletion and no observed impact on fisheries, water quality was	• Prior to 1980, most of the consumed animal protein was from the lake (Jansen et al., 1999). Fish were approximately 80% of the local diet (Muyodi et al., 2010). • It is assumed that agriculture was primarily rainfed in the basin with 60%	• Eutrophication was not observed as a result of increased nutrient loading therefore it is assumed that there was not a dermal contact impact at this point.	• Dermal exposure is considered highest in riparian communities, which include most major cities along the lake (UNEP, 2006). There is also potential (though limited) exposure to water sources through the hydropower industry.	• The hydropower industry was not operational until the 1950s, therefore there was no livelihood use impact.	• The hydropower industry was not operational until the 1950s, therefore there was no/low exposure.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • It is assumed that these trends was consistent through time. It is also assumed that members of the hydropower industry are concentrated in urban areas. • It is assumed that drinking water consumption is highest in riparian cities which make up a majority of the cities within the basin.	assumed to not impact ingestion.	of the population employed in rainfed agriculture (The World Bank, 2018b). This rainfed agriculture is an important source of food in the basin (UNEP, 2006). • Given the fraction of fish in the diet, exposure is considered high.				
	1973 Establishment of the LVFC	Yes	High	Yes	Low	Yes	Medium	Yes	Low
		• Increase in algal blooms are not assumed to surpass a threshold in the lake for water consumption. However, the discharge of untreated wastewaters does increase pathogen load and is considered a risk for communities that use water in close proximity to urban communities.	• It is assumed that exposure is consistent with previous years.	• Signs of overfishing were observed in the lake in the 1970s (UNEP, 2006). It is possible that this decrease in fish stocks was related to ambient water quality. • The water quality conditions also enabled the fisheries dominance of Nile perch which had been introduced to the lake in the 1950s (Hecky et al., 2010; UNEP, 2006).	• Although fish was still the dominant fraction of local diets, because fisheries had not been strongly impacted by water quality in the 1970s, and food from wetlands is assumed to be a minor fraction of urban diets, exposure is considered low.	• Although algal blooms began to occur, it is assumed that a threshold was not surpassed for dermal exposure. • However, the presence of untreated wastewater does pose a threat of exposure to pathogens in waters near major urban centers.	• It is assumed that dermal exposure is consistent with previous years. However, given that large impacts were not observed on the lake, it is assumed that the pathogen concentrations were low. Therefore, exposure is considered medium.	• The increase in algal blooms may have caused some clogging of hydropower intake pipes.	• The hydropower industry is highly reliant on water resources for livelihood. However, since industrial impacts as a result of water quality were not reported in the 1970s, the exposure is considered low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				• Substantial degradation of wetlands occurred between 1960 and 2006, thus decreasing wetland access and use (Mwakubo & Obare, 2009; Kayombo & Jorgensen, 2005). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.					
	1977 Collapse of the LVFC and EAC	Yes	High	Yes	Low	Yes	Medium	Yes	Low
		• Although the spread of anoxia shows a progression of water quality impacts, it is assumed to not surpass a threshold for water consumption exposure. However, given the presence of pathogens from untreated wastewater, water in proximity to urban communities is considered a risk for water ingestion.	• It is assumed that exposure is consistent with previous years.	• The signs of overfishing and degradations of wetlands occurred over this time period (UNEP, 2006; Mwakubo & Obare, 2009). • Given the slight impact to fisheries and the direct impact to wetlands, the water quality is assumed to have impact.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The presence of pathogens as a result of wastewater discharges causes an impact to dermal exposure in proximity of urban centers.	• The exposure and relative impact on food sources is considered consistent with previous years.	• The increase in algal blooms may have caused some clogging of intake pipes. Therefore, there is considered to be an impact on livelihood use.	• The exposure and relative impact on livelihood use is considered consistent with previous years.
	1994 Establishment of the LVFO and initiation of the LVEMP	Yes	High	Yes	High	Yes	High	Yes	Medium
		• The large algal blooms, cyanobacteria, and microbial contamination provide a risk through drinking water ingestion.	• It is assumed that exposure is consistent with previous years.	• The deep water anoxic conditions, algal blooms, wetland degradation, and Nile perch dramatically altered the fish community	• Tilapia was regularly consumed by local communities (Zilov, 2013; Lubovich, 2009). Additional market pressure started to decrease	• The presence of cyanobacteria produces toxins that are a risk to dermal contact. In addition to the release of pathogens into the system, there is an	• Dermal exposure is considered highest in riparian communities, which include most major cities along the lake. Therefore, exposure is considered high.	• The eutrophication and water hyacinth may have impacted hydropower water intakes.	• Based on the increased water quality impacts, the livelihood use exposure is considered medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• The water hyacinth introduction also altered water quality in its proximity, adding to the impact of water quality ingestion. • This broad distribution of impact provides a risk to any stakeholders who consume water from the lake. .		leading to the collapse of endemic fish species and domination of the perch (Muli, 1996; Zilov, 2013; Lubovich, 2009; UNEP, 2006). There was a loss of 200 cichlid species and decline in tilapia (Zilov, 2013; Lubovich, 2009). • The water hyacinth further shifted fish habitats and decreased biodiversity and fish density in its proximity thus complicating potential fishing patterns (Zilov, 2013; UNEP, 2006). • Additionally, wetlands continued to degrade over this time period (Mwakubo & Obare, 2009).	local access to fish (Jansen et al., 1999). Therefore, the decrease in fish stock was felt by the local population. • Wetlands can be a food source for communities; therefore, the degradation of wetlands can directly impact nearby communities (Nakijoba, 1996 as cited in UNEP, 2006). • These trends impacted food security in the region and therefore exposure was considered high.	impact to dermal exposure.			
	2003 Establishment of the LVBC	Yes	High	Yes	High	Yes	High	Yes	High
		• Fishing practices, hyacinth outbreak, eutrophication, and pathogen loading all increased impact to the lake and riparian water sources. • The decrease in water levels also concentrated pollutants increasing the impact within the lake (Lubovich, 2009).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • It is assumed that exposure is	• In 2000, bioaccumulation of mercury was observed in Nile perch (Campbell, 2000 as cited in UNEP, 2006). • Pesticides were also measured in the waterbody which have potential to bioaccumulate and magnify concentrations in	• Food insecurity is high within the lake basin as linked to partially linked to changes in lake protein (Abila, 2000; Odongkara et al., 2005; Geheb et al., 2007).	• The cyanobacteria, pathogens, and disease vectors continued to impact dermal exposure. • Cyanobacteria in the lake led to complaints of itchiness and “malaria-like” symptoms (Bathwondi, 2008 as cited in Lugo et al., 2014, p. 230).	• In 2002, approximately 70% of the basin population used untreated water from the lake (Machiwa, 2002 as cited in Lubovich, 2009). This is assumed to include for drinking water and/or domestic use. • The cholera outbreak of 1997	• The water hyacinth clogged the intakes of hydropower infrastructure (UNEP, 2006). water transport by preventing access to boats and affected industry as water intakes clogged (UNEP, 2006).	• The 1997 water hyacinth outbreak cost the three countries approximately $6-$10 million USD. (The World Bank, 2000). • Given that the clogging of intake pipes directly relates to the functioning of the hydropower plants, the

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			consistent with previous years.	aquatic species (Madadi, 2004). These chemicals compounded challenges in decreased fish stocks and the decreased availability of fish protein to local communities. • The decrease in water levels enabled a greater spread of water hyacinth on beaches which could have increased impacts to fish and wildlife habitats that were occurring from changing water levels (Lubovich, 2009).			may also be related to dermal contact with water (Shapiro et al., 1999). • Based on the generally riparian nature of urban areas, the dermal exposure is considered high.		livelihood use exposure is considered high.
	2008 Tensions with Uganda	Yes	High	Yes	High	Yes	High	Yes	Medium
		• Although the hyacinth became more controlled, large portions of the lake continued to be eutrophic and experience a high loading of pathogens (The World Bank, 2018a; UNEP, 2006). • Flooding events also increased the impacts on alternate water sources (Muyodi et al., 2010). • Continued discharge of agricultural, industrial, and household waste	• In 2006, 5 million people in cities and rural communities used water from the lake for drinking water and industrial use (EAC Secretariat, 2006). Some of the major cities that use the lake as a drinking water source include Kampala, Entebbe, Jinja, Kisumu, Homa Bay, Migori, Mwanza, Musoma, Bukoba, Shinyanga, and Kahama (The World Bank, 2008).	• A 2007 study indicated bioaccumulation of contaminants in urban farms as a result of contaminated wells and surface water runoff (Mireri et al., 2007). • The water quality combined with fishing patterns severely threatened the quantity of fish in the lake (Kolding & van Zwieten, 2006). • Additionally, by 2006, approximately 75% of the wetlands	• By 2010, increased prices and declining catches have altered local diets. Fish became approximately 20% of the local diet (as opposed to 80% in the 1980s; Muyodi et al., 2010). Rainfed agriculture was a major food source in the basin (UNEP, 2006). • In cities, urban agriculture also became a common alternate food source for urban residents.	• Given the continued eutrophic conditions and wastewater discharges it is assumed that cyanobacteria and pathogens continue to impact dermal exposure within the lake.	• The dermal contact exposure is assumed to be consistent with previous years.	• Although the water hyacinth was primarily managed by 2008, there were still outbreaks that could affect hydropower water intakes.	• Given the decreased severity of the water hyacinth, exposure was considered to be medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		also increased the contaminant loading and potential toxicity of water sources (Wirkus & Böge, 2006; The World Bank, 2018a).		had been significantly affected by degradation (Kayombo & Jorgensen, 2005).	• Although the primary diet is agricultural based, the risk of contaminated agriculture in urban farms and bioaccumulation in existing fish species makes the risk of exposure to contaminants high.				
	2020 Current Status	Yes	High	Yes	Medium	Yes	High	Yes	Low
		• Although some water quality interventions have occurred, water quality continues to impact the drinking pathway in the lake as a result of high nutrients and pathogen loading.	• Consistent with previous years, it is assumed that large, riparian urban areas use water from the lake for drinking water.	• It is predicted that the tilapia and Nile perch fisheries may decrease as a result of growing anoxic conditions (Hecky et al., 2010). • The loading of other pollutants into the waterbody (e.g., mining wastes and pesticides) may threaten irrigated agriculture. • Continued urban agriculture is considered to be at risk of bioaccumulation due to poorly managed water sources.	• Although approximately 75% of farms were rainfed, there is a risk of consumption related to irrigated crops (Mwiturbani, 2010; The World Bank, 2018b). Additionally, there is a risk to bioaccumulation in urban agricultural crops. • Given that a majority of the basin no longer consumes fish and rainfed agriculture is still prevalent, it is assumed that ingestion risk is medium.	• High concentrations of pathogens were found at beaches along the lake in Uganda (Muyodi et al., 2010). It is assumed that this contamination is consistent along beaches in all riparian countries. • The continued eutrophication and pathogen loading constitute a risk of dermal exposure throughout the lake.	• It is assumed that dermal exposure is consistent with previous years.	• With the general control of the water hyacinth, only algal blooms may cause clogging of intake pipes for industrial and commercial uses of water. Given the continuation of eutrophication, there is considered to be an impact on livelihood use.	• The clogging of the intake pipes have increased with the management of the water hyacinth. Therefore, exposure to livelihood impacts is considered low.

APPENDIX C: Lake Constance

Table 25. Comprehensive analysis of primary stakeholder power in the Lake Constance basin.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
Inhabitants of large cities/ municipalities	1893 Establishment of the IBKF	Low	Low	Low	Low
		• Given that transboundary management was not occurring prior to 1893, municipalities were not engaged in transboundary formal authority. As a result, formal authority is considered low.	• Given the lack of a clear representative organization and that municipalities were only beginning to treat water starting in the 1890s, it is assumed that resources power was low.	• Limited expression of voice was located during this time period. Therefore, discursive legitimacy is assumed to be low.	• Given the absence of transboundary action related to municipalities prior to 1893, state interest is assumed to be low.
	1959 Formation of the IGKB	Low	Medium	Medium	High
		• The International Conference for Fishing at Lake Constance (IBKF) uses limited public participation and information with the exception of information produced by the Lake Constance Conference of Government Leaders (IBK; Schröder, 2004). • It does not appear that stakeholders other than fishermen were represented within the IBKF. • Given the lack of institutionalized participation and decision making, formal authority is low.	• Given the technical nature of water treatment, it is assumed that municipalities could independently generate data. However, a representative organization was not located. Given the capacity to generate information, resources power is assumed to be medium.	• Municipalities provided drinking water to a majority of people within the basin. Based on this, it is assumed that there was some public support for municipalities and discursive legitimacy is considered to be medium.	• Drinking water is perceived to be the primary driver of international cooperation (Hammerl & Gattenloehner, 2005). This desire to protect drinking water supply led to the establishment of the International Commission for the Protection of Lake Constance (IGKB; Bloesch & Schröder, 2008).
	1967 Establishment of Environmental Regulations	Medium	Medium	Medium	High
		• Stakeholders participated in the IGKB based on "national legal possibilities" (Hammerl & Gattenloehner, 2005, p. 154). In general, the IGKB was reported to not engage in public participation or information sharing until 1994 (Schröder, 2004). As a result, the IGKB was considered somewhat "un-public" (Schröder, 2004, p. 12). • Given that there is some institutionalized participation of stakeholders, but this participation is limited, formal authority is medium.	• Resources power is assumed to be consistent with previous years.	• Discursive legitimacy is assumed to be consistent with previous years.	• The formation of the IGKB designates an important investment in water quality and commitment to conservation on the lake. • Additionally, dependence on drinking water in the lake was considered highest in Germany (Scherer & Zumbush, 2011). • Within the region, water was also seen as a uniting symbol for the region and represented the building of cooperation in the region, thus furthering state interest in water conservation (Blatter, 2009). • Given the commitment to drinking water, and thus municipalities, state interest is high.
	1991 Establishment of Emissions Regulations	High	High	High	High
		• The Syndicate of the Waterworks in the Region of Lake Constance-Rhine (AWBR) is represented within the IGKB (Schröder, 2004). • The International Shipping Association of Lake Constance (ISKB; established in 1973) operated with only "low" use of stakeholder information (Schröder, 2004, p. 12). • Stakeholders were also able to engage with the IBK that was established in 1972 (Schröder, 2004). The local population is represented by the "Parlamentarier-Komission" (Hammerl &	• The AWBR was formed by 66 waterworks in all three countries in 1968 (Blatter, 2001). These waterworks cumulatively supplied water for more than 10 million people within the basin (Scherer & Zumbusch, 2011). • The AWBR has a budget for research and monitoring (Blatter, 2001). • In 1982, the AWBR publicized a report on the effect of shipping in the lake which gathered public attention and emphasized the water pollution impacts from boating (Blatter, 2001).	• The AWBR was perceived to maintain "political neutrality" when addressing the public which increased its credibility (Blatter, 2001, p. 110). • The AWBR was also considered to be one of the "most important international actors in IGKB cooperation" (Bloesch & Schröder, 2008, p. 132). • The AWBR was perceived as influential in pushing for stricter emission regulations and was capable of widely distributing a study on the impacts of boating which was considered in	• The establishment of environmental regulations demonstrates a clear commitment by the riparian states to decrease contamination in the lake. Given that the narrative was that pollution threated water supplies, this further demonstrates an interest in municipalities. • In 1976, portions of the basin were designated as a Convention on Wetlands of International Importance especially as Waterfowl Habitat (RAMSAR) site, showing an international commitment to conservation (Global Nature Fund, n.d.a.; Hammerl & Gattenloehner, 2005).

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		Gattenloehner, 2005). The IBK does not have legally binding power (Blatter, 2001). • Given the formalized participation and capacity to influence decision making of the AWBR in the IGKB, formal authority is high.	• The AWBR formed a coalition with environmentalists and the IBKF for stricter boat emission regulations in the 1960s (Blatter, 2001). • The AWBR was also perceived to form a coalition with the IGKB by working within the IGKB structure (Scherer & Zumbusch, 2011). • The AWBR regularly implemented research and monitoring programs (Schröder, 2005). • Given the large, transboundary, representative organization with participation in all countries and the capacity to generate information, resources power is high.	the state discussion of emissions regulation (Blatter, 2001). • Given the existence of the organization in public spaces, the reaction of the state, and perception of credibility, discursive legitimacy is high.	• Given the expressed and demonstrated interested in water quality protection as related to drinking water, state interest is assumed to be high.
	2020 Current Status	High	High	High	High
		• Formal authority is assumed to be consistent with previous years.	• Resources power is assumed to be consistent with previous years.	• Given that the AWBR still exists, it is assumed that it maintains the same credibility. • In 2019, the freedom of the press index in Austria, Germany, and Switzerland were 15.33, 14.60, and 10.52, respectively (RSF, 2020). These rankings are classified by RSF as "fairly good" in Austria and "good" in the other two countries (RSF, 2020). • Given the assumed credibility and public voice of the organization, discursive legitimacy is high.	• Nature preserves are being established in Germany and Austria as part of the NATURA 2000 network (Hammerl & Gattenloehner, 2005). This action shows a commitment to environmental protection which can benefit drinking water within the region. • State interest is assumed to be consistent with previous years.
Fishermen	1893 Establishment of the IBKF	Low	Low	Low	High
		• Fishermen were not involved in institutionalized transboundary management of fisheries because this form of governance did not exist prior to 1893 (Schröder, 2005). • Given the lack of involvement in governance, formal authority was low.	• No recorded cross-border organizations or fishermen-initiated projects were located. • "Impoverishment" of fishermen occurred in the 1800s (Schröder, 2005, p. 29). • In the early 1900s and likely in the 1890s, approximately 400 fishermen were employed in the basin (Eckmann & Rösch, 1998). • Given that a joint organization as not located and fishermen did not constitute a dominant fraction in the basin, resources power is assumed to be low.	• Limited expression of voice was located during this time period. Therefore, discursive legitimacy is assumed to be low.	• There was interest in transboundary regulation of fishing as early as 1869 (Schröder, 2005). • The interest and efforts to establish the IBKF demonstrated a state interest in fisheries and thus, fishermen. • Given the demonstrated interest in fisheries, state interest was high.
	1959 Formation of the IGKB	High	High	Medium	High
		• The International Fishermen's Association (IBF) has been represented within the IBKF since 1912 (Schröder, 2005). However, the IBF has not always been in agreement with the IBKF (Schröder, 2005). Additionally, fishermen have been present and vocal within meetings since 1895 (Strubelt, 1993 as cited in Schröder, 2004).	• The IBF was formed in 1909 to represent the international interests of fishermen (Schröder, 2005). • The IBF was an international organization with participation in all three countries. Given this status and distribution, resources authority was medium.	• A regional environmental consciousness was dominant in the basin from 1955 to 1975 (Scherer & Zumbusch, 2011). This increase in environmental consciousness may have benefited fishermen who often represent a connection to the environment. As a result of this assumed connection, it is anticipated that there was some public support for fishermen.	• The continued efforts of the IBKF demonstrated a national commitment to fisheries. Therefore, state interest is assumed to be consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		• The IBKF is considered to use limited public participation and information, with the exception of information produced by the IBK (Schröder, 2004). • The IBF formed a commission on wastewater which later became central to the IGKB (Schröder, 2005). • The IBKF considered water quality within its actions (Schröder, 2005). • Given the institutionalized participation of fishermen in a transboundary organization, and the capacity for fishermen to produce information that influences decision making, formal authority was high.		Therefore, discursive legitimacy is assumed to be medium.	
	1967 Establishment of Environmental Regulations	High	High	Medium	High
		• The IBKF switched its focus from water quality to overfishing in the 1960s, which may have decreased some of the IBF's influence over water quality within the lake (Blatter, 2001). • Stakeholders participated in the IGKB based on "national legal possibilities" (Hammerl & Gattenloehner, 2005, p. 154). In general, the IGKB was reported to not engage in public participation or information sharing until 1994 (Schröder, 2004). As a result, the IGKB was considered somewhat "un-public" (Schröder, 2004, p. 12). • Given the institutionalized participation and influence in decision making of fishermen in the IBKF, formal authority was high.	• The IBKF (and thus, potentially the IBF and fishermen on the lake) formed a coalition with the environmentalists and municipalities for stricter boat emission regulations in the 1960s (Blatter, 2001). This coalition was strong and provided fishermen access to actors with resources and decision making abilities. • Based on the continued coordination between fishermen in the IBF and the strong coalition, resources power was high.	• Discursive legitimacy is assumed to be consistent with previous years.	• The initial efforts of the IGKB focused primarily on fisheries (Schröder, 2004). Additionally, the IBKF continued to function. Therefore, state interest in fisheries was high and demonstrated in several institutions.
	1991 Establishment of Emissions Regulations	High	High	Medium	High
		• Stakeholders were able to engage with the IBK that was established in 1972 (Schröder, 2004). The local population is represented by the "Parlamentarier-Komission" (Hammerl & Gattenloehner, 2005). The IBK does not have legally binding power (Blatter, 2001). • Although participation was limited in the IGKB and IBK, because the IBF had institutionalized participation in the IBKF, formal authority was high.	• In 1995, approximately 150 fishermen were employed in fishing (IBKF, 1996 as cited in Eckmann & Rösch, 1998). • Based on the continued coordination between transboundary fishermen in the IBF, resources power was high.	• Discursive legitimacy is assumed to be consistent with previous years.	• In 1976, the lake was designated as a RAMSAR site demonstrating an international commitment to conservation (Global Nature Fund, n.d.a). • In 1987, the IGKB expanded its mandate to consider ecosystem approach (Scherer & Zumbush, 2011). • In 1979, the IBKF began to focus on protection of threatened fish species (Schröder, 2004). • Given the active efforts to address fisheries on a transboundary level, state interest was high.
	2020 Current Status	High	High	Medium	Low
		• The IGKB and other institutions on the lake began to disperse greater public information in 1994 as a result of pressure from an environmental NGO; however, it is not clear	• By 2000, there were approximately 179 fishermen that were operating in the lake (Hammerl & Gattenloehner, 2005).	• The volume of lake fishermen has dropped as a result of decreasing fish density in the lake. Fishermen perceive that their issues are not	• Few projects have been implemented to address the declining volume of fish in the lake; therefore, state interest is perceived to be low.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
		that public participation was increased (Scrhoder, 2004). • Given that the IBF has continued institutionalized participation in the IBKF, formal authority is high.	• By 2012, there were 7 fishermen operating full time on the German side of the lake (DPA, 2013). • Although fishermen had substantially decreased in numbers, due to the ongoing functioning of the IBK, resources power is considered high.	being prioritized (Scheven, 2014; Baer, Eckmann, Rösch, & Arlinghaus, 2017). • In 2019, the freedom of the press index in Austria, Germany, and Switzerland were 15.33, 14.60, and 10.52, respectively (RSF, 2020). These rankings are classified by RSF as "fairly good" in Austria and "good" in the other two countries (RSF, 2020). • Fishermen have exerted their voices in public spaces via the media. • Because fishermen have had public expressions of voice that have not yielded a state response, discursive legitimacy is medium.	
Environmentalists	1893 Establishment of the IBKF	Low	Low	Low	Low
		• Given that transboundary management was not occurring prior to 1893, environmentalists were not engaged in transboundary formal authority. As a result, formal authority is considered to be low.	• No environmentalist organizations could be located. It is also assumed that environmentalists were not the majority fraction of the basin. Given the lack of an organized group and lack of dominance in the basin, resources power is assumed to be low.	• Limited expression of voice was located during this time period. Therefore, discursive legitimacy is assumed to be low.	• Given the absence of transboundary action related to environmentalists prior to 1893, state interest is assumed to be low.
	1959 Formation of the IGKB	Low	High	High	Medium
		• The IBKF was considered to use limited public participation and information with the exception of information produced by the IBK (Schröder, 2004). • It does not appear that stakeholders other than fishermen were represented in the IBKF. As a result, formal authority was low.	• The Lake Constance Ornithological Working Group was established in 1958 (Hammerl & Gattenloehner, 2005). • Environmentalists had previously worked together to protect the Rhine indicating the existence of a coalition that has access to resources (Blatter, 2001). • Given the existence of a broad and active representative organization, resources power was high.	• A regional environmental consciousness was dominant in the basin from 1955-1975 (Scherer & Zumbusch, 2011). • Environmentalists were able to highlight damage to the lake related to shipping (Blatter, 2001). • Boating emissions regulations became a topic of international discussion, in part, because of pressure from environmentalists. Given the access to expression of voice and subsequent state response, discursive legitimacy was high.	• Drinking water was perceived to be the primary driver of international cooperation (Hammerl & Gattenloehner, 2005). This desire to protect drinking water supply led to the establishment of the IGKB (Bloesch & Schröder, 2008). Environmental conservation is closely tied to drinking water protection. Therefore, although the narrative was not framed as environmental protection, it can be considered that there is some state interest in conservation. • Based on the extension of some regional that is not specific to environmental protection, state interest is assumed to be medium.
	1967 Establishment of Environmental Regulations	Medium	High	High	Medium
		• Stakeholders participated in the IGKB based on "national legal possibilities" (Hammerl & Gattenloehner, 2005, p. 154). In general, the IGKB was reported to not engage in public participation or information sharing until 1994 (Schröder, 2004). Asa result, the IGKB was considered somewhat "un-public" (Schröder, 2004, p. 12). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• Given the continuation of existing organizations, it is assumed that resources power is consistent with previous years.	• Regional environmental consciousness continued to be dominant in the basin from 1955-1975 (Scherer & Zumbusch, 2011). • Given the broad support for environmental actions, discursive legitimacy is assumed to be high.	• Although drinking water and fisheries continued to be the focus of international efforts on the lake, because these efforts also addressed the general region and concerns of environmentalists, state interest is assumed to be medium.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	1991 Establishment of Emissions Regulations	Medium	High	High	High
		• The ISKB (established in 1973) operated with only "low" use of stakeholder information (Schröder, 2004, p. 12). • Stakeholders were also able to engage with the IBK that was established in 1972 (Schröder, 2004). The local population is represented by the "Parlamentarier-Komission" (Hammerl & Gattenloehner, 2005). The IBK does not have legally binding power (Blatter, 2001). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• The Study Group for Environmental Protection of Lake Constance (ANU) was formed around 1970 between civil society and private nature protection groups and represents 18,000 citizens in the region and 33 groups (Jacobi & Umwelthilfe, 1994 as cited in Blatter, 2001). • The Working Committee Natural Protection of Lake Constance (ANB) was established in 1971 (Scherer & Zumbush, 2011). • The Lake Constance Foundation was formed in 1994 by 6 private environmental organizations to promote conservation (Schröder, 2005). • The Environmental Council of Lake Constance was formed in 1994 by private environmental organizations to promote sustainable tourism, agriculture, and the economy (Schröder, 2005). • Given the transboundary nature of the organizations with access to resources, resources power was high.	• The Council of Europe declared 1970 was the "European Year of Nature Protection" by the Council of Europe (Blatter, 2001). Additionally, the first environmental movement affected Europe in the 1970s, building a broader public support for environmental conservation (Mol, 2000). • Recreational boat damage continued to be an international focus, including as a topic of discussion by the International Lake Constance Conference and the German-Swiss Spatial Planning Conference at the end of the 1970s (Blatter, 2001). • Given the state response to the voice of environmentalists and continued support for the environmental movement, discursive legitimacy is assumed to be high.	• The lake became a RAMSAR site in 1976 demonstrating an international commitment to conservation (Global Nature Fund, n.d.a). • In 1987, the IGKB expanded its mandate to consider ecosystem protection, further demonstrating a commitment to conservation (Scherer & Zumbusch, 2011). • In 1979, the IBKF began to focus on protection of threatened fish species (Schröder, 2004). • These actions show a state commitment to environmental conservation. As a result, state interest was high.
	2020 Current Status	Medium	High	High	High
		• Formal authority is assumed to be consistent with previous years.	• Given the continuation of existing organizations, it is assumed that resources power is consistent with previous years.	• Environmentalist priorities were perceived to be prioritized in the management of the lake (DPA, 2013). • Additionally, the water quality in the lake is promoted by various sectors, such as tourism, to attract interest in the region (Gerner et al., 2009). Given the general support for high water quality, it is assumed that this generates some public support for environmental actors. • In 2019, the freedom of the press index in Austria, Germany, and Switzerland were 15.33, 14.60, and 10.52, respectively (RSF, 2020). These rankings are classified by RSF as "fairly good" in Austria and "good" in the other two countries (RSF, 2020). • Given the perception of prioritization, discursive legitimacy is assumed to be high.	• Nature preserves are being established in Germany and Austria as part of the NATURA 2000 network (Hammerl & Gattenloehner, 2005). This action shows a continued commitment to environmental protection. As a result, state interest is considered high.
Recreational boaters	1893 Establishment of the IBKF	Low	Low	Low	Low
		• Given that transboundary management was not occurring prior to 1893, recreational boaters were not engaged in transboundary formal authority. As a result, formal authority was low.	• Recreation on the lake was primarily limited to the financial elite (Blatter, 2001). • No organization could be located. Given that the stakeholders were not a majority fraction in the basin and lacked organization, the resource power is assumed to be low.	• Limited expression of voice was located during this time period. Therefore, discursive legitimacy is assumed to be low.	• Given the absence of transboundary action related to recreational boaters prior to 1893, state interest is assumed to be low.
		Low	Medium	Medium	Medium

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	1959 Formation of the IGKB	• The IBKF was considered to use limited public participation and information with the exception of information produced by the IBK (Schröder, 2004). • It does not appear that stakeholders other than fishermen were represented in the IBKF. As a result, formal authority was low.	• Recreational water use became widely popular following the end of the world wars (Blatter, 2001). This led to a rapid increase of recreational goats on the lake until the 1970s (Blatter, 2001). • Although the number of boaters was increasing, no organization was identified, and boaters did not constitute a majority fraction of the basin. Therefore, resources power was medium.	• Lake Constance Week promoted tourism and watersports (Blatter, 2001). Given this promotion, it is assumed that there was some public support for recreational boating and tourist activities. As a result, discursive legitimacy was medium.	• In 1908, a Lake Constance Week was held to promote tourism and watersports (Blatter, 2001). This action designates a commitment and interest in tourism related to recreational boaters. However, the action was not clearly implemented by the national governments, therefore, state interest is assumed to be medium.
	1967 Establishment of Environmental Regulations	Medium	High	Medium	Medium
		• Stakeholders participated in the IGKB based on "national legal possibilities" (Hammerl & Gattenloehner, 2005, p. 154). In general, the IGKB was reported to not engage in public participation or information sharing until 1994 (Schröder, 2004). Asa result, the IGKB was considered somewhat "un-public" (Schröder, 2004, p. 12). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• The International Lake Constance Motorboat Union was formed in the 1960s in response to calls for greater regulations (Blatter, 2001). • Additionally, there was a continued rapid growth of recreational boats until the 1970s (Blatter, 2001). • Given the existence of a transboundary organization with participation from all countries, resources power was high.	• Discursive legitimacy is assumed to be consistent with previous years.	• State interest is assumed to be consistent with previous years.
	1991 Establishment of Emissions Regulations	Medium	High	Medium	High
		• The ISKB (established in 1973) operated with only "low" use of stakeholder information (Schröder, 2004, p. 12). • Stakeholders were also able to engage with the IBK that was established in 1972 (Schröder, 2004). The local population is represented by the "Parlamentarier-Komission" (Hammerl & Gattenloehner, 2005). The IBK does not have legally binding power (Blatter, 2001). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• The International Lake Constance Motorboat Union formed a coalition with the International Navigation Commission for Lake Constance (ISKB; Blatter, 2001). The ISKB has direct access to decision making. • Additionally, the Internationaler Bodensee-Motorboot-Verband (IMBV) and Internationale Wassersport-gem Bodensee (IWGB) were formed in 1970 and 1982, respectively to advocate for recreational boaters (Blatter, 2001) The IMBV had 32 national organizations as members (Blatter, 2001). • The registration of recreational boats stabilized on the lake around the 1990s to approximately 55,000 boats (Blatter, 2001). • Given the existence of transboundary organization and strong coalition with an actor engaged in decision making, resources power was high.	• Discursive legitimacy is assumed to be consistent with previous years.	• The ISKB was established in 1973 and perceived to be "sympathetic" to recreational boaters (Schröder, 2005; Blatter, 2001, p. 114). • The regulations set by the ISKB in 1973 were not very restrictive on boats (Blatter, 2001). • In 1995, travel and tourism contributed to 15.4%, 10.7%, and 9.1% of the GDP in Austria, Germany, and Switzerland, respectively (World Travel and Tourism Council, 2019). It is assumed that this contribution to the GPD was consistent with 1991. It is also assumed that recreational boaters contributed to this income as sporting activities were a common driver of tourism within the region (Ostendorp et al., 2004). • Additionally, motorboat producer interests were considered strongest in Switzerland during the negotiations over boating regulations (Scherer & Zumbusch, 2011). The Swiss connection between recreational boats and tourism was a major point of discussion in negotiations. • Given the perceived interest in recreational boats by the Swiss government and ISKB, state interest was high.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	2020 Current Status	Medium	High	Medium	Medium
		• Formal authority is assumed to be consistent with previous years.	• In 1992, the Study Group on Tourism and Nature (ARGUE FUN) was formed by recreational water users including organizations related to boating, fishing, and automobiles (Blatter, 2001). • ARGUE FUN is capable of funding scientific studies that deny the water quality impacts of boats on the lake (Blatter, 2001). • Given the existence of a transboundary representative group that has implementation and research capacity, resources power is high.	• In 2019, the freedom of the press index in Austria, Germany, and Switzerland were 15.33, 14.60, and 10.52, respectively (RSF, 2020). These rankings are classified by RSF as "fairly good" in Austria and "good" in the other two countries (RSF, 2020). • Given the access to press and likely continued public support, it is assumed that discursive legitimacy is consistent with previous years.	• It is assumed that recreational boating is closely tied to tourism. In 2005, tourism was considered one of the "most significant economic values in the German portion" of the lake (Hammerl & Gattenloehner, 2005, p. 146). • In 2018, travel and tourism contributed to 15.4%, 8.6%, and 8.5% of the GDP in Austria, Germany, and Switzerland, respectively (World Travel and Tourism Council, 2019). It is assumed that recreational boaters contributed to the GDP. • Although tourism provides a high contribution to the economy of the region and is perceived as high importance, given that recreational boating is only a portion of this income and no specific state action was taken in regards to recreational boats, state interest is assumed to be medium.
Tourism industry	1893 Establishment of the IBKF	Low	Low	Low	Low
		• Given that transboundary management was not occurring prior to 1893, the tourism industry was not engaged in transboundary formal authority. As a result, formal authority was low.	• Although tourism was occurring in the region in 1893, no transboundary organizations were located. Therefore, resources power is assumed to be low.	• Limited expression of voice was located during this time period. Therefore, discursive legitimacy is assumed to be low.	• Given the absence of transboundary action related to tourism prior to 1893, state interest is assumed to be low.
	1959 Formation of the IGKB	Low	High	Medium	Medium
		• The IBKF was considered to use limited public participation and information with the exception of information produced by the IBK (Schröder, 2004). • It does not appear that stakeholders other than fishermen were represented in the IBKF. As a result, formal authority was low.	• The Lake Constance Association (IBV) was formed in 1908 by local tourism offices, national tourism associations, and private travel agencies to promote tourism in the region (Blatter, 2001). • Given the existence of a transboundary organization that had access to resources, resources power is assumed to be high.	• Given the promotion of tourism along the lake, it is assumed that there is some public support for tourist activities. As a result, discursive legitimacy is assumed to be medium.	• In 1908, a Lake Constance Week was held to promote tourism and watersports (Blatter, 2001). This action demonstrates a commitment to and interest in tourism. However, the action was not clearly implemented by the national governments, therefore, state interest is assumed to be medium.
	1967 Establishment of Environmental Regulations	Medium	High	Medium	Medium
		• Stakeholders participated in the IGKB based on "national legal possibilities" (Hammerl & Gattenloehner, 2005, p. 154). In general, the IGKB was reported to not engage in public participation or information sharing until 1994 (Schröder, 2004). Asa result, the IGKB was considered somewhat "un-public" (Schröder, 2004, p. 12). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• Given that the IBV continued to exist, resources power is assumed to be high.	• Discursive legitimacy is assumed to be consistent with previous years.	• State interest is assumed to be consistent with previous years.

Stakeholder	Event	Formal Authority	Resources	Discursive Legitimacy	State Interest
	1991 Establishment of Emissions Regulations	Medium	High	Medium	High
		• The ISKB (established in 1973) operated with only "low" use of stakeholder information (Schröder, 2004, p. 12). • Stakeholders were also able to engage with the IBK that was established in 1972 (Schröder, 2004). The local population is represented by the "Parlamentarier-Komission" (Hammerl & Gattenloehner, 2005). The IBK does not have legally binding power (Blatter, 2001). • Given that there was some institutionalized participation of stakeholders, but this participation was limited, formal authority was medium.	• Given that the IBV continued to exist, resources power is assumed to be high.	• Discursive legitimacy is assumed to be consistent with previous years.	• In 1995, travel and tourism contributed to 15.4%, 10.7%, and 9.1% of the GDP in Austria, Germany, and Switzerland, respectively (World Travel and Tourism Council, 2019). It is assumed that this contribution to the GPD was consistent with 1991. • The importance of tourism was specified during the negotiation phase of the boating regulations (Scherer & Zumbusch, 2011). • Given the high contribution to the national economies and perceived national importance, state interest was high.
	2020 Current Status	Medium	High	Medium	High
		• Formal authority is assumed to be consistent with previous years.	• In 1992, the Study Group on Tourism and Nature (ARGUE FUN) was formed by recreational water users (Blatter, 2001). • ARGUE FUN is capable of funding scientific studies that deny the water quality impacts of boats on the lake (Blatter, 2001). • The Environmental Council of Lake Constance was formed in 1994 by private environmental organizations to promote sustainable tourism, agriculture and the economy (Schröder, 2005). • In 2005, there were approximately 15,000 people employed full time in the tourism industry (Hammerl & Gattenloehner, 2005). • Given the existence of multiple transboundary institutions that promote tourism and have access to resources, resources power is high.	• In 2019, the freedom of the press index in Austria, Germany, and Switzerland were 15.33, 14.60, and 10.52, respectively (RSF, 2020). These rankings are classified by RSF as "fairly good" in Austria and "good" in the other two countries (RSF, 2020). • Given the access to press and likely continued public support, it is assumed that discursive legitimacy is consistent with previous years.	• Ecological interventions were focused in areas that were near the shoreline to benefit tourism (Bloesch & Schröder, 2008). • In 2005, tourism was considered one of the "most significant economic values in the German portion" of the lake (Hammerl & Gattenloehner, 2005, p. 146). Tourism was concentrated in Germany due to the prices in Switzerland and small the Austrian shoreline (Thimm & Seepold, 2016). However, tourism was considered important in all areas of the lake, and by 2011, 10 million overnight tourists per year with 27 million day tourists were visiting the basin (Scherer & Zumbusch, 2011; Hammerl & Gattenloehner, 2005). • In 2018, travel and tourism contributed to 15.4%, 8.6%, and 8.5% of the GDP in Austria, Germany, and Switzerland, respectively (World Travel and Tourism Council, 2019). • Given the high contribution to the economy of the region and perceived importance to the states, state interest is high.

Table 26. Comprehensive analysis of primary stakeholder vulnerability in the Lake Constance basin.

Stakeholder	Event	Regional Development	Economic	Education	Political
Inhabitants of large cities/ municipalities	1893 Establishment of the IBKF	Medium	Medium	High	High
		• There is evidence that drinking water treatment was spreading in Switzerland in the late 1800s (Floris & Staub, 2019). • For riparian communities, the lake provided high quality drinking water due to its oligotrophic nature. • Based on limited data but high ambient surface water quality, it is conservatively assumed that regional development vulnerability was medium.	• Economic activities in large cities and municipalities are diverse, including the service, academia, industrial, and commercial sector (Global Nature Fund, n.d.a). It is assumed that there was less economic diversity in the 1980s; however, there was still a diversity of production. Not every sector has a high reliance on water resources. • Austria adjusted income: 0.527 (1890; Prados de la Escosura, 2019). • Germany adjusted income: 0.536 (1890; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.526 (1890; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the diversity of production, variable dependence on water resources, and medium income parameter, economic vulnerability was medium.	• Austria average years of schooling: 2.64, literacy: 0.452 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 2.84, literacy: 0.673 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 4.62, literacy: 0.761 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25), and the literacy calculation is considered low in one country and medium in two countries (<0.5 and <0.8, respectively; UNDP, 2009). • Based on the medium and low literacy and the low average years of schooling, educational vulnerability was high.	• Water quality protections were not located, and therefore, political vulnerability is considered high.
	1959 Formation of the IGKB	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The establishment of an aviation company, Zeppelin, in the region led to a surge in industrial growth in the basin from the 1900s to the 1920s (Gerner et al., 2009). It was also reported that it was "relatively easy" to find employment in various industries around the lake (Baer et al., 2017, p. 38). • The employment opportunities in urban areas within the basin were assumed to be diverse with an intermediate dependence on water resources. The services industry was also assumed to be a major facet of urban employment. • Austria GNI per capita: $1060, adjusted income: 0.679 (1962 and 1960; The World Bank, 2020; Prados de la Escosura, 2019). • Germany adjusted income: 0.688 (1960; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.784 (1960; Prados de la Escosura, 2019).	• Austria average years of schooling: 5.94, literacy: 1.0 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.53, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 8.91, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009. • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Austria began to regulate effluents in 1959 with the Federal Water Act (Frischenschlager & Lenz, 2018). • However, regulations were not consistent or implemented in all countries; therefore, political vulnerability was high.

Stakeholder	Event	Regional Development	Economic	Education	Political
			• Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the diversity of production, variable dependence on water resources, and medium income parameter, the economic vulnerability was medium.		
	1967 Establishment of Environmental Regulations	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The University of Konstanz was founded in the region in 1966 (Universität Konstanz, 2000). • The employment opportunities in urban areas within the basin were assumed to be diverse with an inclusion of academic and manufacturing sectors that had an intermediate dependence on water resources. The services industry was also assumed to be a major facet of urban employment. • Austria GNI per capita: $1560, adjusted income: 0.707 (1967 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $3600, adjusted income: 0.719 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $5370, adjusted income: 0.809 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, two of the countries are considered medium and one country is high development based on the income parameter (>0.5 and >0.8, respectively; UNDP, 2009). • Given the diversity of production, variable dependence on water resources, and medium income parameter, the economic vulnerability is considered medium.	• Austria average years of schooling: 6.93, literacy: 1.0 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.68, literacy: 0.912 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.29, literacy: 0.979 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Water was regulated by states in Germany; however, at the end of the 1960s and the beginning of the 1970s, it was observed that water protection measures were insufficient (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The establishment of pollution prevention guidelines initiates environmental protections in all three countries once adopted; however, prior to 1967, regulations did not exist or were insufficient in some of the riparian countries. • Given that not all countries had water regulations related to pollution controls, political vulnerability was high.
	1991 Establishment of Emissions Regulations	Low	Low	Low	Low
		• Austria percent of people using at least basic/safe drinking water services: 100/97.7, percent of urban population: 100 (2000; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of urban population: 100 (2000; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/92.8,	• The employment opportunities in urban areas of the basin were assumed to be diverse with an intermediate dependence on water resources. The services industry was also assumed to be a major facet of urban employment. • Austria GNI per capita: $21,810, adjusted income: 0.834 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019).	• Austria average years of schooling: 8.7, expected years of schooling: 14.1, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 8.9, expected years of schooling: 14.7, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.7, expected years of schooling: 13.6, literacy: 1.0	• In 1971, Switzerland began to require wastewater treatment (Ammann, 2017). • In 1976 the Effluent Charges Act was initiated in Germany (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The lake basin pollution prevention guidelines were updated in 1972 and 1987 (Schröder, 2005).

Stakeholder	Event	Regional Development	Economic	Education	Political
		percent of urban population: 100 (2000; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability was low.	• Germany GNI per capita: $22,890, adjusted income: 0.824 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $37,550, adjusted income: 0.873 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$7,910; 2019). • Given the diversity of production, variable dependence on water resources, and high GNI per capita, economic vulnerability was low.	(1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 and <10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and medium years of schooling, educational vulnerability was low.	• The phosphorus regulations in 1967 represented harmonized legislation. • Standardized regulations were implemented and updated in all three countries; therefore, political vulnerability was low.
	2020 Current Status	Low	Low	Low	Low
		• Population growth in riparian communities was predicted to be between 4 and 12% by the year 2005 (Hammerl and Gattenloehner, 2005). • Austria percent of people using at least basic/safe drinking water services: 100/98.9, percent of urban population: 100 (2017; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of urban population: 100 (2017; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/95.5, percent of urban population: 100 (2017; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability is low.	• Zeepelin University was founded in the region in 2003 (Bodensee AIRea, 2020). • The employment opportunities in urban areas of the basin were assumed to be diverse with an intermediate dependence on water resources. By 2014, an academic and high tech industrial sector was established in the basin (e.g., solar energy, sport boats, aviation; Gerner et al., 2009). The services industry was also assumed to be a major facet of urban employment. • Austria GNI per capita: $49,310, adjusted income: 0.890 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $47,090, adjusted income: 0.880 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $84,410, adjusted income: 0.907 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$12,055; 2019). • Given the diversity of production, variable dependence on water resources, and high GNI per capita, economic vulnerability is low.	• The IGKB has been publishing brochures to distribute to the public since 1994 (Schröder, 2005). Technical reports can also be found on the IGKB website (Schröder, 2005). • Austria average years of schooling: 12.6, expected years of schooling: 16.3, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 14.1, expected years of schooling: 17.1, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 13.4, expected years of schooling: 16.2, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is high based on the education parameter (>10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the high risk awareness and high literacy, educational vulnerability is low.	• The Wastewater Ordinance was established in Germany in 1996 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The European Water Framework Directive was established in 2000 (European Commission, 2019). • In 2019, the corruption perception index was 77/100 in Austria, 80/100 in Germnay, and 85/100 in Switzerland (Transparency International, 2020). • The harmonized, binding regulations throughout the lake, commitment to supranational regulations, and low levels of corruption (>66%) implies that the political vulnerability is low.
Fishermen	1893 Establishment of the IBKF	Medium	Medium	High	High
		• There is evidence that drinking water treatment was spreading in Switzerland in the late 1800s (Floris & Staub, 2019). • For riparian communities, the lake provided high quality drinking water due to its oligotrophic nature. • Based on limited data but high ambient surface water quality, it is conservatively assumed that	• Fisheries historically existed within the basin and had a high dependence on water resources (Eckmann & Rösch, 1998). Given the low volume of fish in the lake, fishing was not a major source of income (Scheven, 2014.). • Additionally, in the 1800s there was a "rapid impoverishment of numerous fishermen in the region" (Schröder, 2005, p. 29).	• Austria average years of schooling: 2.64, literacy: 0.452 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 2.84, literacy: 0.673 (1890; UNDP, 2020; Prados de la Escosura, 2019).	• Water quality protections were not located, and therefore, political vulnerability is considered high.

Stakeholder	Event	Regional Development	Economic	Education	Political
		regional development vulnerability was medium. • Fishermen are assumed to live in both urban and rural areas adjacent to the lake. Therefore, rates of urban and rural drinking water access will be considered for fishermen.	• Austria adjusted income: 0.527 (1890; Prados de la Escosura, 2019). • Germany adjusted income: 0.536 (1890; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.526 (1890; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Although there was a high dependence on water resources, given the potential cash income from fishing and the medium income parameter, economic vulnerability was considered medium.	• Switzerland average years of schooling: 4.62, literacy: 0.761 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25), and the literacy calculation is considered low in one country and medium in two countries (<0.5 and <0.8, respectively; UNDP, 2009). • Based on the medium and low literacy and the low average years of schooling, educational vulnerability was high	
	1959 Formation of the IGKB	Low	Low	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• Fish stocks began to increase in the late 1950s as a result of eutrophication (Baer et al., 2017). This increase generated financial gains in fisheries. During this time period, the fish catch exceeded the local demand and was sold externally (Baer et al., 2017). It was also reported that it was "relatively easy" for fishermen to find employment in various industries around the lake (Baer et al., 2017, p. 38). • Austria GNI per capita: $1060, adjusted income: 0.679 (1962 and 1960; The World Bank, 2020; Prados de la Escosura, 2019). • Germany adjusted income: 0.688 (1960; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.784 (1960; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the increase in the fishing industry and livelihood flexibility for fishermen, economic vulnerability was low.	• Austria average years of schooling: 5.94, literacy: 1.0 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.53, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 8.91, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively) and the literacy calculation is considered very high (>0.9; UNDP, 2009. • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Austria began to regulate effluents in 1959 with the Federal Water Act (Frischenschlager & Lenz, 2018). • However, regulations were not consistent or implemented in all countries; therefore, political vulnerability was high.
	1967 Establishment of Environmental Regulations	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The volume of fish catch increased since the 1950s due to the greater productivity in the lake (Eckmann & Rösch, 1998). Although volumes of fish were increasing there was	• Austria average years of schooling: 6.93, literacy: 1.0 (1965; UNDP, 2020; Prados de la Escosura, 2019).	• Water was regulated by states in Germany; however, at the end of the 1960s and the beginning of the 1970s, it was observed that water protection measures were insufficient (Federal Ministry for the Environment, Nature

Stakeholder	Event	Regional Development	Economic	Education	Political
			decreasing diversity in the lake and varying consistency of fisheries (Baer et al., 2017). • Austria GNI per capita: $1560, adjusted income: 0.707 (1967 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $3600, adjusted income: 0.719 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $5370, adjusted income: 0.809 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, two of the countries are considered medium and one country is high development based on the income parameter (>0.5 and >0.8, respectively; UNDP, 2009). • Given the high dependence on water resources, medium income parameter, and temporal instability in the fishing industry, economic vulnerability was medium.	• Germany average years of schooling: 7.68, literacy: 0.912 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.29, literacy: 0.979 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium	Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The establishment of pollution prevention guidelines initiates environmental protections in all three countries once adopted; however, prior to 1967, regulations did not exist or were insufficient in some of the riparian countries. • Given that not all countries had water regulations related to pollution controls, political vulnerability was high.
	1991 Establishment of Emissions Regulations	Low	Low	Low	Low
		• Austria percent of people using at least basic/safe drinking water services: 100/97.7, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/92.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability was low.	• Although the total density of fish began to decrease, there had not been a significant drop of fish catch by 1991, and diversity in the lake increased (Baer et al., 2017). This time period was considered a “golden age” for fisheries enabling profits for fishermen (Baer et al., 2017, p. 39). • Austria GNI per capita: $21,810, adjusted income: 0.834 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $22,890, adjusted income: 0.824 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $37,550, adjusted income: 0.873 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$7,910; 2019). • Given the stability of the fishing industry, high income parameter, and in spite of the high dependence on water resources, the economic vulnerability was low.	• Austria average years of schooling: 8.7, expected years of schooling: 14.1, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 8.9, expected years of schooling: 14.7, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.7, expected years of schooling: 13.6, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 and <10.5 years) and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and medium years of schooling, educational vulnerability was low.	• In 1971, Switzerland began to require wastewater treatment (Ammann, 2017). • In 1976 the Effluent Charges Act was initiated in Germany (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The lake basin pollution prevention guidelines were updated in 1972 and 1987 (Schröder, 2005). • The phosphorus regulations in 1967 represented harmonized legislation. • Standardized regulations were implemented and updated in all three countries; therefore, political vulnerability was low.
	2020 Current Status	Low	Medium	Low	Low
		• Population growth in riparian communities was predicted to be between 4 and 12% by the year 2005 (Hammerl and Gattenloehner, 2005).	• The volume of fishermen has decreased because of the decrease in fish stock and related income (Hammerl & Gattenloehner,	• The IGKB has been publishing brochures to distribute to the public since 1994 (Schröder,	• The Wastewater Ordinance was established in Germany in 1996 (Federal Ministry for the Environment, Nature Conservation and

Stakeholder	Event	Regional Development	Economic	Education	Political
		• Austria percent of people using at least basic/safe drinking water services: 100/98.9, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/95.5, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability is low.	2005). Many fishermen have had to diversify employment to sustain their livelihoods (Hammerl & Gattenloehner, 2005). By 2012, only seven fishermen on the coast of Germany were able to sustain their livelihoods (DPA, 2013). • Austria GNI per capita: $49,310, adjusted income: 0.890 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $47,090, adjusted income: 0.880 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $84,410, adjusted income: 0.907 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$12,055; 2019). • Given the substantial impact to the fishing industry, decrease in participants, and opportunities for employment outside of the fishing industry, economic vulnerability is medium.	2005). Technical reports can also be found on the IGKB website (Schröder, 2005). • Austria average years of schooling: 12.6, expected years of schooling: 16.3, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 14.1, expected years of schooling: 17.1, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 13.4, expected years of schooling: 16.2, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is high based on the education parameter (>10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the high risk awareness and high literacy, educational vulnerability is low.	Nuclear Safety & Federal Environmental Agency, 2001). • The European Water Framework Directive was established in 2000 (European Commission, 2019). • In 2019, the corruption perception index was 77/100 in Austria, 80/100 in Germnay, and 85/100 in Switzerland (Transparency International, 2020). • The harmonized, binding regulations throughout the lake, commitment to supranational regulations, and low levels of corruption (>66%) implies that the political vulnerability is low.
Environmentalists	1893 Establishment of the IBKF	Medium	Medium	High	High
		• There is evidence that drinking water treatment was spreading in Switzerland in the late 1800s (Floris & Staub, 2019). • For riparian communities, the lake provided high quality drinking water due to its oligotrophic nature. • Based on limited data but high ambient surface water quality, it is conservatively assumed that regional development vulnerability was medium.	• Environmental organizations are assumed to be based in cities and reflect similar economic activity and vulnerability as urban areas because environmentalists may participate in civil society externally of their occupation. Economic activities in urban areas are considered diverse with varying reliance on water resources. Environmental interest groups address water resources and may attract greater economic resources given an increase in degradation. Therefore, they are considered independent of water resources. • Austria adjusted income: 0.527 (1890; Prados de la Escosura, 2019). • Germany adjusted income: 0.536 (1890; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.526 (1890; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009).	• Austria average years of schooling: 2.64, literacy: 0.452 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 2.84, literacy: 0.673 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 4.62, literacy: 0.761 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25), and the literacy calculation is considered low in one country and medium in two countries (<0.5 and <0.8, respectively; UNDP, 2009). • Based on the medium and low literacy and the low average years of schooling, educational vulnerability was high.	• Water quality protections were not located, and therefore, political vulnerability is considered high.

Stakeholder	Event	Regional Development	Economic	Education	Political
			• Given the diversity of production and medium income parameter, economic vulnerability was medium.		
	1959 Formation of the IGKB	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The economic vulnerability of environmentalists is assumed to parallel urban areas with a diversity of production. • Austria GNI per capita: $1060, adjusted income: 0.679 (1962 and 1960; The World Bank, 2020; Prados de la Escosura, 2019). • Germany adjusted income: 0.688 (1960; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.784 (1960; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the diversity of production and medium income parameter, the economic vulnerability was medium.	• Austria average years of schooling: 5.94, literacy: 1.0 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.53, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 8.91, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009. • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Austria began to regulate effluents in 1959 with the Federal Water Act (Frischenschlager & Lenz, 2018). • However, regulations were not consistent or implemented in all countries; therefore, political vulnerability was high.
	1967 Establishment of Environmental Regulations	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The economic vulnerability of environmentalists is assumed to parallel urban areas with a diversity of production. • Austria GNI per capita: $1560, adjusted income: 0.707 (1967 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $3600, adjusted income: 0.719 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $5370, adjusted income: 0.809 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, two of the countries are considered medium and one country is high development based on the income parameter (>0.5 and >0.8, respectively; UNDP, 2009). • Given the diversity of production and medium income parameter, economic vulnerability was medium.	• Austria average years of schooling: 6.93, literacy: 1.0 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.68, literacy: 0.912 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.29, literacy: 0.979 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Water was regulated by states in Germany; however, at the end of the 1960s and the beginning of the 1970s, it was observed that water protection measures were insufficient (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The establishment of pollution prevention guidelines initiates environmental protections in all three countries once adopted; however, prior to 1967, regulations did not exist or were insufficient in some of the riparian countries. • Given that not all countries had water regulations related to pollution controls, political vulnerability was high.
		Low	Low	Low	Low

Stakeholder	Event	Regional Development	Economic	Education	Political
	1991 Establishment of Emissions Regulations	• Austria percent of people using at least basic/safe drinking water services: 100/97.7, percent of urban population: 100 (2000; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of urban population: 100 (2000; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/92.8, percent of urban population: 100 (2000; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability was low.	• The economic vulnerability of environmentalists is assumed to parallel urban areas with a diversity of production. • Austria GNI per capita: $21,810, adjusted income: 0.834 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $22,890, adjusted income: 0.824 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $37,550, adjusted income: 0.873 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$7,910; 2019). • Given the diversity of production and high income parameter, economic vulnerability was low.	• Austria average years of schooling: 8.7, expected years of schooling: 14.1, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 8.9, expected years of schooling: 14.7, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.7, expected years of schooling: 13.6, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 and <10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and medium years of schooling, educational vulnerability was low.	• In 1971, Switzerland began to require wastewater treatment (Ammann, 2017). • In 1976 the Effluent Charges Act was initiated in Germany (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The lake basin pollution prevention guidelines were updated in 1972 and 1987 (Schröder, 2005). • The phosphorus regulations in 1967 represented harmonized legislation. • Standardized regulations were implemented and updated in all three countries; therefore, political vulnerability was low.
	2020 Current Status	Low	Low	Low	Low
		• Population growth in riparian communities was predicted to be between 4 and 12% by the year 2005 (Hammerl and Gattenloehner, 2005). • Austria percent of people using at least basic/safe drinking water services: 100/98.9, percent of urban population: 100 (2017; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of urban population: 100 (2017; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/95.5, percent of urban population: 100 (2017; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability is low.	• The economic vulnerability of environmentalists is assumed to parallel urban areas with a diversity of production. • Austria GNI per capita: $49,310, adjusted income: 0.890 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $47,090, adjusted income: 0.880 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $84,410, adjusted income: 0.907 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$12,055; 2019). • Given the diversity of production and high income parameter, economic vulnerability was low.	• The IGKB has been publishing brochures to distribute to the public since 1994 (Schröder, 2005). Technical reports can also be found on the IGKB website (Schröder, 2005). • Austria average years of schooling: 12.6, expected years of schooling: 16.3, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 14.1, expected years of schooling: 17.1, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 13.4, expected years of schooling: 16.2, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is high based on the education parameter (>10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the high risk awareness and high literacy, educational vulnerability is low.	• The Wastewater Ordinance was established in Germany in 1996 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The European Water Framework Directive was established in 2000 (European Commission, 2019). • In 2019, the corruption perception index was 77/100 in Austria, 80/100 in Germnay, and 85/100 in Switzerland (Transparency International, 2020). • The harmonized, binding regulations throughout the lake, commitment to supranational regulations, and low levels of corruption (>66%) implies that the political vulnerability is low.
		Medium	Low	High	High

Stakeholder	Event	Regional Development	Economic	Education	Political
Recreational boaters	1893 Establishment of the IBKF	• There is evidence that drinking water treatment was spreading in Switzerland in the late 1800s (Floris & Staub, 2019). • For riparian communities, the lake provided high quality drinking water due to its oligotrophic nature. • Based on limited data but high ambient surface water quality, it is conservatively assumed that regional development vulnerability was medium.	• It is assumed that access to water sports was consistent with the early 1990s when only wealthy citizens were participating in water sports (Blatter, 2001). This trend implies that recreational boaters had greater financial resources (Blatter, 2001). • Austria adjusted income: 0.527 (1890; Prados de la Escosura, 2019). • Germany adjusted income: 0.536 (1890; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.526 (1890; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the likely high income of recreational boaters and medium income parameter, economic vulnerability was low.	• Austria average years of schooling: 2.64, literacy: 0.452 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 2.84, literacy: 0.673 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 4.62, literacy: 0.761 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25), and the literacy calculation is considered low in one country and medium in two countries (<0.5 and <0.8, respectively; UNDP, 2009). • Based on the medium and low literacy and the low average years of schooling, educational vulnerability was high.	• Water quality protections were not located, and therefore, political vulnerability is considered high.
	1959 Formation of the IGKB	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• Following the end of the world wars, a greater range of the population began to participate in water sports and recreational boating (Blatter, 2001). Given that financial resources are required to participate in recreational activities, it is assumed that recreational boaters had a financial income and likely paralleled the general economic trends within the countries. • Austria adjusted income: 0.679 (1960; Prados de la Escosura, 2019). • Germany adjusted income: 0.688 (1960; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.784 (1960; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the medium income parameter and implication of sufficient financial resources, the economic vulnerability was medium.	• Austria average years of schooling: 5.94, literacy: 1.0 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.53, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 8.91, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009. • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Austria began to regulate effluents in 1959 with the Federal Water Act (Frischenschlager & Lenz, 2018). • However, regulations were not consistent or implemented in all countries; therefore, political vulnerability was high.
	1967 Establishment of Environmental Regulations	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring	• Given that financial resources are required to participate in recreational activities, it is assumed that recreational boaters had a	• Austria average years of schooling: 6.93, literacy: 1.0 (1965; UNDP, 2020; Prados de la Escosura, 2019).	• Water was regulated by states in Germany; however, at the end of the 1960s and the beginning of the 1970s, it was observed that water protection measures were insufficient

Stakeholder	Event	Regional Development	Economic	Education	Political
		within the basin. Therefore, it is likely that regional development vulnerability was low.	financial income and likely paralleled the general economic trends within the countries. • Austria GNI per capita: $1560, adjusted income: 0.707 (1967 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $3600, adjusted income: 0.719 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $5370, adjusted income: 0.809 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, two of the countries are considered medium and one country is high development based on the income parameter (>0.5 and >0.8, respectively; UNDP, 2009). • Given the medium income parameter and implication of sufficient financial resources, economic vulnerability was medium.	• Germany average years of schooling: 7.68, literacy: 0.912 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.29, literacy: 0.979 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	(Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The establishment of pollution prevention guidelines initiates environmental protections in all three countries once adopted; however, prior to 1967, regulations did not exist or were insufficient in some of the riparian countries. • Given that not all countries had water regulations related to pollution controls, political vulnerability was high.
	1991 Establishment of Emissions Regulations	Low	Low	Low	Low
		• Austria percent of people using at least basic/safe drinking water services: 100/97.7, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/92.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability was low.	• Given that financial resources are required to participate in recreational activities, it is assumed that recreational boaters had a financial income and likely paralleled the general economic trends within the respective countries. • Austria GNI per capita: $21,810, adjusted income: 0.834 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $22,890, adjusted income: 0.824 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $37,550, adjusted income: 0.873 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$7,910; 2019). • Given the high income parameter and implication of sufficient financial resources, economic vulnerability was low.	• Austria average years of schooling: 8.7, expected years of schooling: 14.1, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 8.9, expected years of schooling: 14.7, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.7, expected years of schooling: 13.6, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 and <10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and medium years of schooling, educational vulnerability was low.	• In 1971, Switzerland began to require wastewater treatment (Ammann, 2017). • In 1976 the Effluent Charges Act was initiated in Germany (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The lake basin pollution prevention guidelines were updated in 1972 and 1987 (Schröder, 2005). • The phosphorus regulations in 1967 represented harmonized legislation. • Standardized regulations were implemented and updated in all three countries; therefore, political vulnerability was low.
	2020 Current Status	Low	Low	Low	Low
		• Population growth in riparian communities was predicted to be between 4 and 12% by the year 2005 (Hammerl and Gattenloehner, 2005). • Austria percent of people using at least basic/safe drinking water services: 100/98.9, percent of rural population: 100, percent of	• The recreational boating community is still strong within the lake although the quantity of recreational fishermen stabilized in the 1990s (Blatter, 2001). • Given that financial resources are required to participate in recreational activities, it is	• The IGKB has been publishing brochures to distribute to the public since 1994 (Schröder, 2005). Technical reports can also be found on the IGKB website (Schröder, 2005). • Austria average years of schooling: 12.6, expected years of schooling: 16.3, literacy: 1.0	• The Wastewater Ordinance was established in Germany in 1996 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001).

Stakeholder	Event	Regional Development	Economic	Education	Political
		urban population: 100 (2017; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/95.5, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability is low.	assumed that recreational boaters had a financial income and likely paralleled the general economic trends within the countries. • Austria GNI per capita: $49,310, adjusted income: 0.890 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $47,090, adjusted income: 0.880 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $84,410, adjusted income: 0.907 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$12,055; 2019). • Given the high income parameter and implication of sufficient financial resources, the economic vulnerability is low.	(2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 14.1, expected years of schooling: 17.1, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 13.4, expected years of schooling: 16.2, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is high based on the education parameter (>10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the high risk awareness and high literacy, educational vulnerability is low.	• The European Water Framework Directive was established in 2000 (European Commission, 2019). • In 2019, the corruption perception index was 77/100 in Austria, 80/100 in Germnay, and 85/100 in Switzerland (Transparency International, 2020). • The harmonized, binding regulations throughout the lake, commitment to supranational regulations, and low levels of corruption (>66%) implies that the political vulnerability is low.
Tourism industry	1893 Establishment of the IBKF	Medium	Medium	High	High
		• There is evidence that drinking water treatment was spreading in Switzerland in the late 1800s (Floris & Staub, 2019). • For riparian communities, the lake provided high quality drinking water due to its oligotrophic nature. • Based on limited data but high ambient surface water quality, it is conservatively assumed that regional development vulnerability was medium.	• Tourism around the lake began as early as the 1800s (Gerner et al., 2009). Tourism was also increased in 1847 with greater rail access to the region (Gerner et al., 2009). The tourist industry is assumed to have generated an income, provided some economic diversity, and have some dependence on water resources given that most tourist activity is centered on water resources (Ostendorp et al., 2004). • Although the financial elite were accessing the lake for tourism in the early 1800s, given that most tourism was national, it is assumed that the tourism industry was similar to the general economy of the region (Hammerl & Gattenloehner, 2005). • Austria adjusted income: 0.527 (1890; Prados de la Escosura, 2019). • Germany adjusted income: 0.536 (1890; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.526 (1890; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the connection between the regional economy and tourism and the medium income parameter, the economic vulnerability was medium.	• Austria average years of schooling: 2.64, literacy: 0.452 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 2.84, literacy: 0.673 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 4.62, literacy: 0.761 (1890; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low based on the education parameter (<8.25), and the literacy calculation is considered low in one country and medium in two countries (<0.5 and <0.8, respectively; UNDP, 2009). • Based on the medium and low literacy and the low average years of schooling, educational vulnerability was high.	• Water quality protections were not located, and therefore, political vulnerability was considered high.

Stakeholder	Event	Regional Development	Economic	Education	Political
	1959 Formation of the IGKB	Low	Medium	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• The region continued to invest in infrastructure to support tourism (Gerner et al., 2009). • It is assumed that most tourism was national, as was common prior to the 1970s, and that the tourism industry was similar to the local economy (Gerner et al., 2009). • Austria GNI per capita: $1060, adjusted income: 0.679 (1962 and 1960; The World Bank, 2020; Prados de la Escosura, 2019). • Germany adjusted income: 0.688 (1960; Prados de la Escosura, 2019). • Switzerland adjusted income: 0.784 (1960; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the countries are considered medium development based on the income parameter (>0.5 and <0.8; UNDP, 2009). • Given the connection between the regional economy and tourism and the medium income parameter, economic vulnerability was medium.	• Austria average years of schooling: 5.94, literacy: 1.0 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.53, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 8.91, literacy: 0.960 (1960; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009. • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Austria began to regulate effluents in 1959 with the Federal Water Act (Frischenschlager & Lenz, 2018). • However, regulations were not consistent or implemented in all countries; therefore, political vulnerability was high.
	1967 Establishment of Environmental Regulations	Low	Low	Medium	High
		• The existence of extensive municipalities capable of forming the AWBR by 1968 implies that broad water treatment was occurring within the basin. Therefore, it is likely that regional development vulnerability was low.	• It is assumed that most tourism was national, as was common prior to the 1970s, and that the tourism industry was similar to the local economy (Gerner et al., 2009). • Austria GNI per capita: $1560, adjusted income: 0.707 (1967 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $3600, adjusted income: 0.719 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $5370, adjusted income: 0.809 (1972 and 1965; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, two of the countries are considered medium and one country is high development based on the income parameter (>0.5 and >0.8, respectively; UNDP, 2009). • Given the connection between the regional economy and tourism and the high income parameter, economic vulnerability was low.	• Austria average years of schooling: 6.93, literacy: 1.0 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 7.68, literacy: 0.912 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.29, literacy: 0.979 (1965; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is low in two countries and medium in one based on the education parameter (<8.25 and <10.5 years, respectively), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and low to medium average years of schooling, educational vulnerability was medium.	• Water was regulated by states in Germany; however, at the end of the 1960s and the beginning of the 1970s, it was observed that water protection measures were insufficient (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The establishment of pollution prevention guidelines initiates environmental protections in all three countries once adopted; however, prior to 1967, regulations did not exist or were insufficient in some of the riparian countries. • Given that not all countries had water regulations related to pollution controls, political vulnerability was high.
		Low	Low	Low	Low

Stakeholder	Event	Regional Development	Economic	Education	Political
	1991 Establishment of Emissions Regulations	• Austria percent of people using at least basic/safe drinking water services: 100/97.7, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/92.8, percent of rural population: 100, percent of urban population: 100 (2000; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability was low.	• Although interest in international tourism detracted some of interest in the lake region during the 1970s, the region continued to invest in infrastructure to attract tourists (Gerner et al., 2009). It is assumed that tourism was closely tied to the local economy based on the trends of distance traveled in 2005 (Hammerl & Gattenloehner, 2005). • Austria GNI per capita: $21,810, adjusted income: 0.834 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $22,890, adjusted income: 0.824 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $37,550, adjusted income: 0.873 (1991 and 1990; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$7,910; 2019). • Given the connection between the regional economy and tourism and the high income parameter, economic vulnerability was low.	• Austria average years of schooling: 8.7, expected years of schooling: 14.1, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 8.9, expected years of schooling: 14.7, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 9.7, expected years of schooling: 13.6, literacy: 1.0 (1991 and 1990; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is medium based on the education parameter (>8.25 and <10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the very high literacy and medium years of schooling, educational vulnerability was low.	• In 1971, Switzerland began to require wastewater treatment (Ammann, 2017). • In 1976 the Effluent Charges Act was initiated in Germany (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The lake basin pollution prevention guidelines were updated in 1972 and 1987 (Schröder, 2005). • The phosphorus regulations in 1967 represented harmonized legislation. • Standardized regulations were implemented and updated in all three countries; therefore, political vulnerability was low.
	2020 Current Status	Low	Low	Low	Low
		• Population growth in riparian communities was predicted to be between 4 and 12% by the year 2005 (Hammerl and Gattenloehner, 2005). • Austria percent of people using at least basic/safe drinking water services: 100/98.9, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Germany percent of people using at least basic/safe drinking water services: 100/99.8, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Switzerland percent of people using at least basic/safe drinking water services: 100/95.5, percent of rural population: 100, percent of urban population: 100 (2017; The World Bank, 2020). • Based on the high rates of basic drinking water services, the regional development vulnerability is low.	• There were increasing rates of tourism in 2005, and the lake area was reported to have "the best economic region outside the urban centers" (Hammerl & Gattenloehner, 2005; Gerner et al., 2009, p. 197). • The average distance traveled to the lake by tourists is 91 km, implying that many tourists are from the riparian countries (Hammerl & Gattenloehner, 2005). • Austria GNI per capita: $49,310, adjusted income: 0.890 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Germany GNI per capita: $47,090, adjusted income: 0.880 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Switzerland GNI per capita: $84,410, adjusted income: 0.907 (2018 and 2015; The World Bank, 2020; Prados de la Escosura, 2019). • Based on the World Bank income thresholds, all three countries are considered high income (>$12,055; 2019). • Given the tie between the economy of the region and tourism and the high income parameter, the economic vulnerability is low.	• The IGKB has been publishing brochures to distribute to the public since 1994 (Schröder, 2005). Technical reports can also be found on the IGKB website (Schröder, 2005). • Austria average years of schooling: 12.6, expected years of schooling: 16.3, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Germany average years of schooling: 14.1, expected years of schooling: 17.1, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Switzerland average years of schooling: 13.4, expected years of schooling: 16.2, literacy: 1.0 (2018 and 2015; UNDP, 2020; Prados de la Escosura, 2019). • Based on the former UNDP human development thresholds, the average years of schooling is high based on the education parameter (>10.5 years), and the literacy calculation is considered very high (>0.9; UNDP, 2009). • Based on the high risk awareness and high literacy, educational vulnerability is low.	• The Wastewater Ordinance was established in Germany in 1996 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety & Federal Environmental Agency, 2001). • The European Water Framework Directive was established in 2000 (European Commission, 2019). • In 2019, the corruption perception index was 77/100 in Austria, 80/100 in Germnay, and 85/100 in Switzerland (Transparency International, 2020). • The harmonized, binding regulations throughout the lake, commitment to supranational regulations, and low levels of corruption (>66%) implies that the political vulnerability is low.

Table 27. Comprehensive analysis of primary stakeholder risk in the Lake Constance basin.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
Inhabitants of large cities/ municipalities	1893 Establishment of the IBKF	No	Medium	No	High	No	Medium	No	Medium
		• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005). • Prior to 1960, the lake was oligotrophic suggesting high quality water and limited to no water quality and water ingestion impact (Petri, 2006).	• Drinking water was used from the lake as early as 1885 (Petri, 2006). Distribution of lake water did not occur until 1895 (Blatter, 2001). • Given the historically high quality water, it is assumed that riparian communities used the lake as a drinking water source. • Given that several of the large cities within the basin are not adjacent to the lake, it is assumed that large distribution systems did not exist in the 1890s, and therefore, exposure is considered medium.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The lake water is often used for irrigation (Ostendorp et al., 2004). • Fish from the lake also provides a potential local food source. • It is assumed that a substantial fraction of diets came from food sources within the basin in the 1800s. Therefore, ingestion exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• It is assumed that dermal exposure is highest in riparian communities due to ease of access. • Given that the large cities are distributed throughout the basin (riparian and at a distance from the lake), the dermal exposure is considered medium.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• There was assumed to be diverse sectors in urban areas in the 1890s. These sectors likely had varied water use, and therefore exposure is medium.
	1959 Formation of the IGKB	Yes	High	No	Medium	Yes	Low	Yes	Low
		• The lake was considered close to “collapse” in the 1950s due to high nutrient loads (Scherer & Zumbusch, 2011, p. 109). Phosphorous was the limiting nutrient with algal growth and was already showing	• In 1958, there was a pipeline extension to Ludwigsberg (Zweckverband Bodensee-Wasserversorgung, n.d.) • Given the broad distribution of water users in 2005 and the high volume of	• As a result of increased nutrient inputs and alterations to fisheries, fish yield began to increase towards the end of the 1950s (Baer et al., 2017). • It is assumed that increased nutrient inputs did not	• It is assumed that a portion of the food supply came from sources within the basin, and that additional food came from other regions or was imported. As a result, it is assumed that ingestion	• The algal growth in the lake was reported to hamper recreational activities including swimming and boating (Ostendorp et al., 2004). • As a result of impaired mobility, it is assumed that	• The dermal exposure is assumed to be consistent with previous years. • However, given algal growth may have limited some activity but not necessarily harmed that activity,	• The increase in nutrient loading may have had some impact on industrial and commercial water uses and required treatment prior to use in production. Therefore, there was an impact to livelihood use.	• The increase in manufacturing in the Lake Constance region is assumed to increase sectoral water use in urban areas (Gerner et al., 2009). • Given that not all sectors used water, and industry was not reported to be

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		impacts in the lake (Bloesch & Schröder, 2008). • The high concentration of nutrients was seen to have "endangered" drinking water (Ostendorp et al., 2004, p. 383). Therefore, there was a drinking water ingestion impact.	municipalities that used lake water in 1968 (at least 72), it is assumed that drinking water exposure was high (Shroder, 2005).	provide a risk to irrigated agriculture. • This nutrient increase was not assumed to have a negative impact on ingestion exposure.	exposure is medium.	there was a dermal contact impact.	exposure is considered low.		affected by water quality in the 1950s, exposure is considered low.
	1967 Establishment of Environmental Regulations	Yes	High	No	Medium	Yes	Medium	Yes	Medium
		• Phosphorus concentrations continued to increase in the lake (Bloesch & Schröder, 2008). • Harmful algal blooms which generated cyanobacteria were reported during the 1960s and 1970s (EAWAG, 2009). • Given the rising presence of nutrients and potential toxins released from cyanobacteria, there was a water quality ingestion impact.	• Drinking water exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • The density of fish in the lake increased by up to six orders of magnitude in the 1960s (IGKB, 2004 as cited in Baer et al., 2017). • Fish grew larger in shorter time periods during the periods of severe eutrophication in the 1960s (Thomas & Eckmann, 2007). • The nutrient loading decreased the diversity of fish in the lake during this time period (Eckmann & Rösch, 1998). Additionally, specific species of	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria releases toxins that can be harmful through dermal exposure. • In addition to the impaired recreational activity related to algal growth, there was likely a dermal contact impact.	• Given the increased risk from cyanobacteria and assumed varied exposure in residents of cities, dermal exposure is assumed to be medium.	• The continued increase in nutrient loading and eutrophic conditions may have continued to have an impact on industrial water uses, thus requiring treatment prior to use in production.	• Given the existing manufacturing industry at the lake and the increased amount of eutrophication, it is likely that there was a high exposure to production sectors. • However, because there was a diversity of livelihoods within urban areas, exposure is considered medium.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				fish were reported to have high parasite loads (IBKF, 1966 as cited in Baer et al., 2017). • Although biota was impacted by the presence of nutrients, the net impact was not assumed to be negative.					
	1991 Establishment of Emissions Regulations	Yes	High	No	Medium	Yes	Medium	Yes	Medium
		• The phosphorous concentration in the lake increased twelvefold from 1951 to 1979 (Bloesch & Schröder, 2008). However, in 1979, phosphorous concentrations began to decrease enabling the lake to reverse eutrophic trends (Bloesch & Schröder, 2008). • The lake response to pollutant loadings represents a 7 year lag with nutrients sequestered in sediments for 20-30 years (Wehrli & Wüest, 1996 as cited in Bloesch & Schröder, 2008). • Concerns arose that sport boats were increasing hydrocarbon and phosphate loading	• In 1971, the distribution of lake water was expanded with the construction of a pipeline to Stuttgart (Zweckverband Bodensee-Wasserversorgung, n.d.). • Given the large volume of water consumers in 2005, it is assumed that water ingestion exposure was consistent in previous years. Therefore, water ingestion exposure is considered high.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • Several fish species returned to the lake with the decline in eutrophic conditions (Ostendorp et al., 2004). • The fish yield was relatively consistent in the early 1990s with previous years. Therefore, there was not assumed to be an impact to the ingestion exposure route.	• It is assumed that ingestion exposure is consistent with previous years.	• Although nutrient inputs were declining in the lake, the lake still had elevated concentrations and algal growth. • Therefore, exposure is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• The impact is assumed to be consistent with previous years.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		in the lake which was highlighted in 1982 (Blatter, 2001). However, the recreational boat impact on water quality was contested (Blatter, 2001). • Given the elevated nutrient concentrations in the lake, there was an impact to drinking water ingestion.							
	2020 Current Status	No	High	Yes	Low	No	Medium	No	Medium
		• The lake returned to oligotrophic conditions at the end of the 1990s, although concentrations in 2005 were considered "still too high" (Bresciani et al., 2011; Hammerl & Gattenloehner, 2005, p. 151). • Continued water quality concerns include trace heavy metals, endocrine disruptors, and pesticides (Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006). • The surrounding countries boast that the lake has high water quality (Gerner et al., 2009). Therefore, there is not assumed	• By 2005, at least 10 million people were supplied with drinking water from the lake (Shroder, 2005). This distribution includes 320 municipalities (Ostendorp et al., 2004). • Given the widespread water use, including in urban areas, water ingestion exposure is high.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). • A decrease in fish stock accompanied the return to oligotrophic conditions which may have impacted the volume of fish available for consumption (Baer et al., 2017). • Given the decrease in fish stocks, it is assumed that there is an ingestion impact.	• Demand for regional organic food was low in 2005 (Hammerl & Gattenloehner, 2005). • However, it is assumed that there is still a market for local crops in the region that are not organic. • There is also evidence that the decrease in fish stocks has altered local food supply leading to an increase of imports in the region (Baer et al., 2017). • Given the decrease in fish stocks and the likely increase in imports, the ingestion exposure is low.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). As a result, there was not a dermal exposure impact.	• Dermal exposure is assumed to be consistent with previous years.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). Therefore, it is assumed that water quality did not negatively impact urban water uses. • It is also suggested that improved water quality bolsters economic growth in the region by attracting employees and companies (Gerner et al., 2009).	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		to be an impact to ingestion exposure.							
Fishermen	1893 Establishment of the IBKF	No	High	No	High	No	High	No	High
		• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005). • Prior to 1960, the lake was oligotrophic suggesting high quality water and limited to no water quality impact (Petri, 2006).	• Drinking water was used from the lake as early as 1885 (Petri, 2006). Distribution of lake water did not occur until 1895 (Blatter, 2001). • It is assumed that fishermen reside in riparian communities. • Given the historically high quality water, it is assumed that riparian communities used the lake as a drinking water source, and therefore, exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The lake water is often used for irrigation (Ostendorp et al., 2004). • Fish from the lake also provides a potential local food source. • It is assumed that a substantial fraction of diets came from food sources within the basin in the 1800s, especially for fishermen who were directly catching fish. Therefore, ingestion exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• It is assumed that dermal exposure is highest in riparian communities. • It is assumed that fishermen reside in riparian communities and have high exposure to water resources due to their occupation. • Therefore, dermal exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• Fishermen are highly dependent on water resources for their livelihood and are directly impacted by changes in the lake. Therefore, the exposure is considered high.
	1959 Formation of the IGKB	Yes	High	No	High	Yes	Medium	No	High
		• The lake was considered close to “collapse” in the 1950s due to high nutrient loads (Scherer & Zumbusch, 2011, p. 109). Phosphorous was the limiting nutrient with algal growth and was already showing impact in the lake (Bloesch & Schröder, 2008).	• Given the broad distribution of water users in 2005, and assumed riparian location of fishermen residences, the drinking water ingestion exposure is assumed to be high.	• As a result of increased nutrient inputs and alterations to fisheries, fish yield began to increase towards the end of the 1950s (Baer et al., 2017). • It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture.	• It is assumed that a portion of the food supply came from sources within the basin, but that additional food sources came from other regions or were imported. • It is also assumed that fishermen regularly consumed fish from the lake as they were directly catching this food source.	• The algal growth in the lake was reported to hamper recreational activities including swimming and boating (Ostendorp et al., 2004). • As a result of impaired mobility, it is assumed that there was a dermal contact exposure impact.	• The dermal exposure is assumed to be consistent with previous years. • However, given algal growth may have limited some activity but not necessarily harmed that activity, exposure is considered medium.	• Starting in 1956, there was beneficial fishing conditions that enabled increased yields and income for fishermen (Baer et al., 2017). Therefore, there was not an adverse impact on livelihoods.	• Livelihood use is considered consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• The high concentration of nutrients was seen to have “endangered” drinking water (Ostendorp et al., 2004, p. 383). Therefore, there was a drinking water ingestion impact.		• This increase was not assumed to be a negative impact on ingestion exposure.	Therefore, exposure is assumed to be high.				
	1967 Establishment of Environmental Regulations	Yes	High	No	High	Yes	High	Yes	Low
		• Phosphorus concentrations continued to increase in the lake (Bloesch & Schröder, 2008). • Harmful algal blooms which generated cyanobacteria were reported during the 1960s and 1970s (EAWAG, 2009). • Given the rising presence of nutrients and potential toxins released from cyanobacteria, there was a water quality ingestion impact.	• Drinking water exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • The density of fish in the lake increased by up to six orders of magnitude in the 1960s (IGKB, 2004 as cited in Baer et al., 2017). • Fish grew larger in shorter time periods during the periods of severe eutrophication in the 1960s (Thomas & Eckmann, 2007). • The nutrient loading decreased the diversity of fish in the lake during this time period (Eckmann et al. 2005). • Although biota was impacted by the presence of nutrients, the	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria releases toxins that can be harmful through dermal exposure. • In addition to the impaired recreational activity related to algal growth, there was likely a dermal contact impact.	• Given the increased risk from cyanobacteria and assumed high exposure of fishermen, dermal exposure is assumed to be high.	• Algal blooms decreased efficiency of fishing techniques and decreased consistency of fish yields (Thomas, 2009). • However, in the late 1960s, fish yields were still high (Baer et al., 2017). • Given that there was an impact on the quality and consistency of fish, there is considered to be an livelihood use impact on fisheries.	• Although livelihood use is high and directly tied to water, because there were still gains in the fishing industry due to high yields, exposure is considered low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				increase in fish supply was considered to not have a negative impact on ingestion.					
	1991 Establishment of Emissions Regulations	Yes	High	No	High	Yes	High	No	High
		• The high nutrient conditions continued in the lake and were accompanied by concerns of hydrocarbon pollution due to sport boats (Bloesch & Schröder, • 2008; Blatter, 2001). Given the elevated nutrient concentrations in the lake, there was an impact to drinking water ingestion.	• The ingestion exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture • Several fish species returned to the lake with the decline in eutrophic conditions (Ostendorp et al., 2004). • The fish yield was relatively consistent in the early 1990s with previous years. Therefore, there was not assumed to be an impact on the ingestion exposure route.	• It is assumed that ingestion exposure is consistent with previous years.	• Although nutrient inputs were declining in the lake, the lake still had elevated concentrations and algal growth. • Therefore, exposure is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• Although there had been some instability in the fisheries prior to 1991, yields were considered stable by 1991 (Baer et al., 2017). • Given the stability and continued high fish yields, there is not a livelihood use exposure.	• Fishermen are highly dependent on water resources for their livelihood and are directly impacted by changes in the lake. Therefore, the exposure is considered high.
	2020 Current Status	No	High	Yes	Medium	No	High	Yes	High
		• The lake returned to oligotrophic conditions at the end of the 1990s, although concentrations in 2005 were considered "still too high" (Bresciani et al., 2011; Hammerl & Gattenloehner, 2005, p. 151). • Continued water quality concerns include trace heavy metals, endocrine	• The ingestion exposure is assumed to be consistent with previous years.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). • A decrease in fish stock accompanied the return to oligotrophic conditions which may have impacted the volume available for consumption (Baer et al., 2017).	• There is also evidence that the decrease in fish stocks has altered local food supply leading to an increase of imports in the region (Baer et al., 2017). • It is assumed that fishermen still consume available fish stock, but that these patterns have decreased with decrease in stock.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011).	• Dermal exposure is assumed to be consistent with previous years.	• Decreased fish yields related to the return to oligotroph conditions have directly impacted fisheries. Therefore there is considered to be a livelihood use impact.	• The livelihood use exposure is considered consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		disruptors, and pesticides (Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006). • However, the surrounding countries boast high quality water in the lake (Gerner et al., 2009). Therefore, there is not assumed to be an impact.		• Given the decrease in fish stocks, it is assumed that there is an ingestion impact.	• Given the decrease in fish stocks and the likely increase in imports, the exposure is considered medium.				
Environmentalists	1893 Establishment of the IBKF	No	Medium	No	High	No	Medium	No	Low
		• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005). • Prior to 1960, the lake was oligotrophic suggesting high quality water and limited to no water quality impact (Petri, 2006).	• Drinking water was used from the lake as early as 1885 (Petri, 2006). Distribution of lake water did not occur until 1895 (Blatter, 2001). • Given the historically high quality water, it is assumed that riparian communities used the lake as a drinking water source. • It is assumed that environmentalists are dispersed throughout the basin and largely follow patterns of cities in the region. • Given that several of the large cities within the basin are not adjacent to the lake, it is assumed that large distribution systems	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The lake water is often used for irrigation (Ostendorp et al., 2004). • Fish from the lake also provides a potential local food source. • It is assumed that a substantial fraction of diets came from food sources within the basin in the 1800s. Therefore, ingestion exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• It is assumed that dermal exposure is highest in riparian communities due to ease of access. • It is assumed that environmentalists follow distribution patterns of cities. • Given that the large cities are distributed throughout the basin (riparian and at a distance from the lake) and environmentalists are assumed to be affiliated with these urban areas, the dermal exposure is considered medium.	• Because some environmentalists focus on water resources, it is assumed that they are impacted by degradation as this may funnel more funding towards their advocacy. • Given that water quality issues were not observed in Lake Constance, there was likely no livelihood use impact.	• It is assumed that environmentalists are either full time professionals or interested parties who participate in civil society outside of their occupation. • Given that not all environmentalists rely on environmental advocacy for their livelihood, livelihood use exposure is considered to be low.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
			did not exist in the 1890s, and therefore, exposure is considered medium.						
	1959 Formation of the IGKB	Yes	High	No	Medium	Yes	Low	No	Low
		• The lake was considered close to "collapse" in the 1950s due to high nutrient loads (Scherer & Zumbusch, 2011, p. 109). Phosphorous was the limiting nutrient with algal growth and was already showing impact in the lake (Bloesch & Schröder, 2008). • The high concentration of nutrients was seen to have "endangered" drinking water (Ostendorp et al., 2004, p. 383). Therefore, there was a drinking water ingestion impact.	• In, there was 1958 pipeline extension to Ludwigsberg (Zweckverband Bodensee-Wasserversorgung, n.d.) • Given the broad distribution of water users in 2005, high volume of municipalities that used lake water in 1968 (at least 72), and assumption that environmentalists follow city distribution patterns, it is assumed that drinking water exposure was high (Shroder, 2005).	• As a result of increased nutrient inputs and alterations to fisheries, fish yield began to increase towards the end of the 1950s (Baer et al., 2017). • It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • This increase was not assumed to be a negative impact on ingestion exposure.	• It is assumed that a portion of the food supply came from sources within the basin, but that additional food sources came from other regions or were imported. As a result, it is assumed that ingestion exposure is medium.	• The algal growth in the lake was reported to hamper recreational activities including swimming and boating (Ostendorp et al., 2004). • As a result of impaired mobility, it is assumed that there was a dermal contact exposure impact.	• The dermal exposure is assumed to be consistent with previous years. • However, given algal growth may have limited some activity but not necessarily harmed that activity, exposure is considered low.	• It is assumed that water quality degradation increased funding and attention for actors who are employed in the environmental advocacy sector. Therefore, there is not anticipated to be a negative livelihood use impact.	• The livelihood exposure is assumed to be consistent with previous years.
	1967 Establishment of Environmental Regulations	Yes	High	No	Medium	Yes	Medium	No	Low
		• Phosphorus concentrations continued to increase in the lake (Bloesch & Schröder, 2008). • Harmful algal blooms which generated cyanobacteria were reported during the	• Drinking water exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • The density of fish in the lake increased by up to six orders of magnitude in the	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria releases toxins that can be harmful through dermal exposure. • In addition to the impaired recreational activity related to algal growth, there was	• Given the increased risk from cyanobacteria and assumed varied exposure of environmentalists, dermal exposure is assumed to be medium.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		1960s and 1970s (EAWAG, 2009). • Given the rising presence of nutrients and potential toxins released from cyanobacteria, there was a water quality ingestion impact.		1960s (IGKB, 2004 as cited in Baer et al., 2017). • Fish grew larger in shorter time periods during the periods of severe eutrophication in the 1960s (Thomas & Eckmann, 2007). • The nutrient loading decreased the diversity of fish in the lake during this time period (Eckmann et al. 2005). • Although biota was impacted by the presence of nutrients, the increase in fish supply was considered to not have a negative impact on ingestion.		likely a dermal contact impact.			
	1991 Establishment of Emissions Regulations	Yes	High	No	Medium	Yes	Medium	No	Low
		• The high nutrient conditions continued in the lake and were accompanied by concerns of hydrocarbon pollution due to sport boats (Bloesch & Schröder, 2008; Blatter, 2001). • Given the elevated nutrient concentrations in the lake, there was an impact to	• In 1971, the distribution of lake water was expanded with construction of a pipeline to Stuttgart (Zweckverband Bodensee-Wasserversorgung, n.d.). • Given the large volume of water consumers in 2005 and assumption that environmentalists follow city distribution patterns, it is	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture • Several fish species returned to the lake with the decline in eutrophic conditions (Ostendorp et al., 2004). • The fish yield was relatively consistent in the early 1990s with previous years. Therefore, there was not assumed to	• It is assumed that ingestion exposure is consistent with previous years.	• Although nutrient inputs were declining in the lake, the lake still had elevated concentrations and algal growth. • Therefore, exposure is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• The livelihood use impact is assumed to be consistent with previous years.	• The livelihood exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		drinking water ingestion.	assumed that water ingestion exposure was consistent in previous years. Therefore, water ingestion exposure is considered to be high.	be an impact on the ingestion exposure route.					
	2020 Current Status	No	High	Yes	Low	No	Medium	No	Low
		• The lake returned to oligotrophic conditions at the end of the 1990s, although concentrations in 2005 were considered "still too high" (Bresciani et al., 2011; Hammerl & Gattenloehner, 2005, p. 151). • Continued water quality concerns include trace heavy metals, endocrine disruptors, and pesticides (Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006). • However, the surrounding countries boast high quality water in the lake (Gerner et al., 2009).	• By 2005, at least 10 million people were supplied with drinking water from the lake (Shroder, 2005). This distribution includes 320 municipalities (Ostendorp et al., 2004). • Given the widespread water use, including in urban areas, and assumption that environmentalists follow city distribution patterns, exposure is considered high.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). • A decrease in fish stock accompanied the return to oligotrophic conditions which may have impacted the volume available for consumption (Baer et al., 2017). • Given the decrease in fish stocks, it is assumed that there is an ingestion impact.	• Demand for regional organic food was low in 2005 (Hammerl & Gattenloehner, 2005). • However, it is assumed that there is still a market for local crops in the region that are not organic. • There is also evidence that the decrease in fish stocks has altered local food supply leading to an increase of imports in the region (Baer et al., 2017). • Given the decrease in fish stocks and the likely increase in imports, the exposure is considered low.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011).	• Dermal exposure is assumed to be consistent with previous years.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011).	• The livelihood exposure is assumed to be consistent with previous years.
Recreational boaters	1893 Establishment of the IBKF	No	Medium	No	High	No	High	No	Low
		• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• Drinking water was used from the lake as early as 1885 (Petri, 2006). Distribution of lake water did not occur	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The lake water is often used for irrigation (Ostendorp et al., 2004). • Fish from the lake also provides a	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The recreational boating activity yields a high interaction with water resources and thus high dermal	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• Recreational boaters often participate in boating as a recreational activity and not as a form of employment.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• Prior to 1960, the lake was oligotrophic suggesting high quality water and limited to no water quality impact (Petri, 2006).	until 1895 (Blatter, 2001). • Given the historically high quality water, it is assumed that riparian communities used the lake as a drinking water source. • It is assumed that recreational boaters followed similar distribution patterns to urban areas within the basin. • Given that several of the large cities within the basin are not adjacent to the lake, it is assumed that large distribution systems did not exist in the 1890s, and therefore, exposure is considered medium.		potential local food source. • It is assumed that a substantial fraction of diets came from food sources within the basin in the 1800s. Therefore, ingestion exposure is assumed to be high.		exposure during boating. • Therefore, it is assumed that dermal exposure is high.		• However, some recreational boaters are employed as part of the tourism industry and there is a recreational boating industry in manufacturing of boats. • The recreational boating industry that produce recreational boats are dependent on a market which is tied to the status of surface water bodies. • However, because markets are not solely local and not all recreational boaters are dependent on boating for their livelihoods, livelihood use exposure is considered to be low.
	1959 Formation of the IGKB	Yes	High	No	Medium	Yes	Medium	No	Low
		• The lake was considered close to "collapse" in the 1950s due to high nutrient loads (Scherer & Zumbusch, 2011, p. 109). Phosphorous was the limiting nutrient with algal growth and was already showing impact in the lake	• In, there was 1958 pipeline extension to Ludwigsberg (Zweckverband Bodensee-Wasserversorgung, n.d.) • Given the broad distribution of water users in 2005, the high volume of municipalities that used lake water in 1968 (at least 72),	• As a result of increased nutrient inputs and alterations to fisheries, fish yield began to increase towards the end of the 1950s (Baer et al., 2017). • It is assumed that increased nutrient inputs did not provide a risk to	• It is assumed that recreational boating distributions align with urban areas. Furthermore, it is assumed that a portion of the food supply came from sources within the basin, but that additional food sources came from other regions or were imported. As a	• The algal growth in the lake was reported to hamper recreational activities including swimming and boating (Ostendorp et al., 2004). • As a result of impaired mobility, it is assumed that there was a dermal contact exposure impact.	• The dermal exposure is assumed to be consistent with previous years. • However, given that algal growth may have limited some recreational boating but did not necessarily harm actors within that activity, exposure is considered medium.	• Although water quality impacts were occurring, the volume of recreational boaters continue to grow on the lake (Blatter, 2001). • Given that participants and the industry was growing, there was not considered to be a livelihood impact.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		(Bloesch & Schröder, 2008). • The high concentration of nutrients was seen to have "endangered" drinking water (Ostendorp et al., 2004, p. 383). Therefore, there was a drinking water ingestion impact.	and the assumption that recreational boater distributions align with urban areas, it is assumed that drinking water exposure was high (Shroder, 2005).	irrigated agriculture. • This increase was not assumed to be a negative impact on ingestion exposure.	result, it is assumed that ingestion exposure is medium.				
	1967 Establishment of Environmental Regulations	Yes	High	No	Medium	Yes	High	No	Low
		• Phosphorus concentrations continued to increase in the lake (Bloesch & Schröder, 2008). • Harmful algal blooms which generated cyanobacteria were reported during the 1960s and 1970s (EAWAG, 2009). • Given the rising presence of nutrients and potential toxins released from cyanobacteria, there was a water quality ingestion impact.	• Drinking water exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • The density of fish in the lake increased by up to six orders of magnitude in the 1960s (IGKB, 2004 as cited in Baer et al., 2017). • Fish grew larger in shorter time periods during the periods of severe eutrophication in the 1960s (Thomas & Eckmann, 2007). • The nutrient loading decreased the diversity of fish in the lake during this time period (Eckmann et al. 2005). • Although biota was impacted by the	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria releases toxins that can be harmful through dermal exposure. • In addition to the impaired recreational activity related to algal growth, there was likely a dermal contact impact.	• Given the increased risk from cyanobacteria and assumed high exposure of recreational boaters, dermal exposure is assumed to be high.	• Although water quality impacts were increasing, the volume of recreational boaters continue to grow on the lake through the 1960s (Blatter, 2001). • Given that participants and the industry was growing, there was not considered to be a livelihood impact	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
				presence of nutrients, the increase in fish supply was considered to not have a negative impact on ingestion.					
	1991 Establishment of Emissions Regulations	Yes	High	No	Medium	Yes	High	No	Low
		• The high nutrient conditions continued in the lake and were accompanied by concerns of hydrocarbon pollution due to sport boats (Bloesch & Schröder, 2008; Blatter, 2001). • Given the elevated nutrient concentrations in the lake, there was an impact to drinking water ingestion.	• In 1971, the distribution of lake water was expanded with construction of a pipeline to Stuttgart (Zweckverband Bodensee-Wasserversorgung, n.d.). • Given the large volume of water consumers in 2005 and assumption of urban distribution, it is assumed that water ingestion exposure was consistent in previous years. Therefore, water ingestion exposure is considered to be high.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture • Several fish species returned to the lake with the decline in eutrophic conditions (Ostendorp et al., 2004). • The fish yield was relatively consistent in the early 1990s with previous years. Therefore, there was not assumed to be an impact on the ingestion exposure route.	• It is assumed that ingestion exposure is consistent with previous years.	• Although nutrient inputs were declining in the lake, the lake still had elevated concentrations and algal growth. • Therefore, exposure is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• The volume of boats on the lake continued to increase until the 1990s (Blatter, 2001). • Given the continued trend in growth, the water quality was assumed to not impact the livelihood use of recreational boaters.	• The livelihood use exposure is assumed to be consistent with previous years.
	2020 Current Status	No	High	Yes	Low	No	High	Yes	Low
		• The lake returned to oligotrophic conditions at the end of the 1990s, although concentrations in 2005 were considered "still too high" (Bresciani et al., 2011; Hammerl & Gattenloehner, 2005, p. 151).	• By 2005, at least 10 million people were supplied with drinking water from the lake (Shroder, 2005). This distribution includes 320 municipalities (Ostendorp et al., 2004).	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). • A decrease in fish stock accompanied the return to oligotrophic conditions which may have impacted	• Demand for regional organic food was low in 2005 (Hammerl & Gattenloehner, 2005). • However, it is assumed that there is still a market for local crops in the region that are not organic.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011).	• Dermal exposure is assumed to be consistent with previous years.	• The volume of recreational boats has stabilized on the lake since the 1990s (Blatter, 2001). • The recreational boating community is very active and is an important aspect of tourism on the lake (Hammerl &	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		• Continued water quality concerns include trace heavy metals, endocrine disruptors, and pesticides (Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006). • However, the surrounding countries boast high quality water in the lake (Gerner et al., 2009).	• Given the widespread water use, including in urban areas, and assumption of recreational boater distribution patterns, exposure is considered high.	the volume available for consumption (Baer et al., 2017). • Given the decrease in fish stocks, it is assumed that there is an ingestion impact.	• There is also evidence that the decrease in fish stocks has altered local food supply leading to an increase of imports in the region (Baer et al., 2017). • Given the decrease in fish stocks and the likely increase in imports, the exposure is considered low.			Gattenloehner, 2005). • However, the strict boating may have impacted recreational boating industries in proximity to the lake. Therefore, it is assumed that there is a livelihood use impact on recreational boating.	
Tourism industry	1893 Establishment of the IBKF	No	High	No	High	No	High	No	High
		• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005). • Prior to 1960, the lake was oligotrophic suggesting high quality water and limited to no water quality impact (Petri, 2006).	• Drinking water was used from the lake as early as 1885 (Petri, 2006). Distribution of lake water did not occur until 1895 (Blatter, 2001). • Given the historically high quality water, it is assumed that riparian communities used the lake as a drinking water source. • Based on current patterns of tourism, it is assumed that tourism is concentrated in riparian areas; therefore, exposure is considered high (Ostendorp et al., 2004; Gerner et al., 2009).	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• The lake water is often used for irrigation (Ostendorp et al., 2004). • Fish from the lake also provides a potential local food source. • It is assumed that a substantial fraction of diets came from food sources within the basin in the 1800s. Therefore, ingestion exposure is assumed to be high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005).	• Tourism activities are assumed to occur primarily near the lake, given the promotion of recreational boating and the appeal of the natural environment (Blatter, 2001; Ostendorp et al, 2004). • Given the nature of recreational activities and close proximity, it is assumed that dermal exposure is high.	• Substantive water quality issues were not observed in Lake Constance until the 1950s (Schröder, 2005). • Given the absence of impact, there likely not an impact on the livelihood use of the tourism industry.	• Because much of the tourism in the region is focused along the waterbody, the livelihood use is considered high.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
	1959 Formation of the IGKB	Yes	High	No	Medium	Yes	Medium	No	High
		• The lake was considered close to "collapse" in the 1950s due to high nutrient loads (Scherer & Zumbusch, 2011, p. 109). Phosphorous was the limiting nutrient with algal growth and was already showing impact in the lake (Bloesch & Schröder, 2008). • The high concentration of nutrients was seen to have "endangered" drinking water (Ostendorp et al., 2004, p. 383). Therefore, there was a drinking water ingestion impact.	• It is assumed that exposure is consistent with previous years.	• As a result of increased nutrient inputs and alterations to fisheries, fish yield began to increase towards the end of the 1950s (Baer et al., 2017). • It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • This increase was not assumed to be a negative impact on ingestion exposure.	• It is assumed that food in tourist areas came from local sources as well as imports from other regions. Given the variations of food patterns, it is assumed that ingestion exposure is medium.	• The algal growth in the lake was reported to hamper recreational activities including swimming and boating (Ostendorp et al., 2004). • As a result of impaired mobility, it is assumed that there was a dermal contact exposure impact.	• The dermal exposure is assumed to be consistent with previous years. • However, given that algal growth may have limited some recreational activity but did not necessarily harm actors within that activity, exposure is considered medium.	• Although water quality impacts were occurring, given the increasing presence of recreational boats it is assumed that tourism continued to grow throughout this time period. Therefore, it is assumed that there was not a livelihood use impact.	• The livelihood use exposure is assumed to be consistent with previous years.
	1967 Establishment of Environmental Regulations	Yes	High	No	Medium	Yes	High	No	High
		• Phosphorus concentrations continued to increase in the lake (Bloesch & Schröder, 2008). • Harmful algal blooms which generated cyanobacteria were reported during the 1960s and 1970s (EAWAG, 2009). • Given the rising presence of	• Drinking water exposure is assumed to be consistent with previous years.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture. • The density of fish in the lake increased by up to six orders of magnitude in the 1960s (IGKB, 2004 as cited in Baer et al., 2017).	• It is assumed that ingestion exposure is consistent with previous years.	• The presence of cyanobacteria releases toxins that can be harmful through dermal exposure. • In addition to the impaired recreational activity related to algal growth, there was likely a dermal contact impact.	• Given the increased risk from cyanobacteria and assumed high exposure of recreational lake activities, dermal exposure is assumed to be high.	• Although water quality impacts were occurring, given the increasing presence of recreational boats it is assumed that tourism continued to grow throughout this time period. Therefore, it is assumed that there was not a livelihood use impact.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
		nutrients and potential toxins released from cyanobacteria, there was a water quality ingestion impact.		• Fish grew larger in shorter time periods during the periods of severe eutrophication in the 1960s (Thomas & Eckmann, 2007). • The nutrient loading decreased the diversity of fish in the lake during this time period (Eckmann et al. 2005). • Although biota was impacted by the presence of nutrients, the increase in fish supply was considered to not have a negative impact on ingestion.					
	1991 Establishment of Emissions Regulations	Yes	High	No	Medium	Yes	High	No	High
		• The high nutrient conditions continued in the lake and were accompanied by concerns of hydrocarbon pollution due to sport boats (Bloesch & Schröder, 2008; Blatter, 2001). • Given the elevated nutrient concentrations in the lake, there was an impact to drinking water ingestion.	• Given the large volume of water consumers in 2005 and likely riparian distribution, it is assumed that water ingestion exposure was consistent in previous years. Therefore, water ingestion exposure is considered to be high.	• It is assumed that increased nutrient inputs did not provide a risk to irrigated agriculture • Several fish species returned to the lake with the decline in eutrophic conditions (Ostendorp et al., 2004). • The fish yield was relatively consistent in the early 1990s with previous years. Therefore, there was not assumed to be an impact on the ingestion exposure route.	• It is assumed that ingestion exposure is consistent with previous years.	• Although nutrient inputs were declining in the lake, the lake still had elevated concentrations and algal growth. • Therefore, exposure is assumed to be consistent with previous years.	• Dermal exposure is assumed to be consistent with previous years.	• Giving the increase of recreational boats until the 1990s, it is assumed that tourism continued to grow throughout the this this time period. Therefore, it is assumed that there was not a livelihood use impact.	• The livelihood use exposure is assumed to be consistent with previous years.

Stakeholder	Event	Ingestion (water)		Ingestion (aquatic biota, irrigated crops, and/or livestock)		Dermal Contact (domestic and/or recreational)		Livelihood Use (aquatic biota, irrigation, livestock, and/or industrial use)	
		Impact	Exposure	Impact	Exposure	Impact	Exposure	Impact	Exposure
	2020 Current Status	No	High	Yes	Medium	No	High	No	High
		• The lake returned to oligotrophic conditions at the end of the 1990s, although concentrations in 2005 were considered “still too high” (Bresciani et al., 2011; Hammerl & Gattenloehner, 2005, p. 151). • Continued water quality concerns include trace heavy metals, endocrine disruptors, and pesticides (Bloesch & Schröder, 2008; Zilov, 2013; Petri, 2006). • However, the surrounding countries boast high quality water in the lake (Gerner et al., 2009).	• By 2005, at least 10 million people were supplied with drinking water from the lake (Shroder, 2005). This distribution includes 320 municipalities (Ostendorp et al., 2004). • Given the widespread water use and assumed high water use in riparian communities, exposure is considered high. ä	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011). • A decrease in fish stock accompanied the return to oligotrophic conditions which may have impacted the volume available for consumption (Baer et al., 2017). • Given the decrease in fish stocks, it is assumed that there is an ingestion impact.	• Demand for regional organic food was low in 2005 (Hammerl & Gattenloehner, 2005). • However, it is assumed that there is still a market for local crops in the region that are not organic. • Additionally, it is assumed that demand for local food is higher in the tourism industry than in the ambient community (Hammerl & Gattenloehner, 2005). • There is also evidence that the decrease in fish stocks has altered local food supply leading to an increase of imports in the region (Baer et al., 2017). • Given the decrease in fish stocks and tourism interest in local foods, exposure is considered medium.	• The lake returned to oligotrophic conditions at the end of the 1990s (Bresciani et al., 2011).	• As of 2004, most tourist activities were still riparian (Ostendorp et al., 2004). Therefore, dermal exposure is considered high.	• The international recognition of good water quality has become an important facet of tourism in the lake (Gerner et al., 2009; DPA, 2013). • Given the positive impact of the oligotrophic conditions on the lake, there is not considered to be a livelihood use impact.	• The livelihood use exposure is assumed to be consistent with previous years.