

Swimming Against the Current: Valuation of White Sturgeon in Renewal of the Columbia River Treaty

By

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Abstract

The Columbia River Treaty (CRT) between Canada and the United States was implemented in 1964 to cooperatively manage water-related issues. Treaty terms were based on concerns of flood control and economic growth with no consideration for ecosystem health and the benefits therein. In turn, basin management has become fragmented and deleterious to the River's vast and complex watershed ecosystems. To ensure the Columbia River Basin (CRB) is able to absorb increasing demands while protecting environmental quality, provisions for the management of ecosystem services must be improved in the modernization of the Treaty. This study uses the white sturgeon as an example of how undervalued ecosystem goods and services can be integrated into the CRT. While the CRB once supported a productive population of white sturgeon, basin management has rendered them an endangered and threatened species. This study's analysis yields recommendations for a portfolio of policies to entities of the CRT.

Keywords: White sturgeon; ecosystem goods and services; Columbia River; Columbia River Treaty; integrated water resources management; adaptive governance; benefit transfer

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Table of Contents

| | |
|--|-----------|
| Approval..... | ii |
| Partial Copyright Licence | iii |
| Ethics Statement..... | iv |
| Abstract..... | v |
| Dedication | vi |
| Acknowledgements | vii |
| Table of Contents..... | viii |
| List of Tables..... | xi |
| List of Figures..... | xi |
| List of Acronyms..... | xii |
| Executive Summary | xiii |
| Quotation | xvi |
| | |
| Chapter 1. Introduction | 1 |
| | |
| Chapter 2. The Importance of Natural Capital..... | 4 |
| 2.1. Ecosystem Goods and Services | 4 |
| | |
| Chapter 3. The Columbia River | 7 |
| 3.1. The Columbia River Basin | 7 |
| 3.2. The Columbia River Treaty | 8 |
| 3.3. The Columbia River Treaty Post-2024..... | 9 |
| | |
| Chapter 4. The Great White Sturgeon..... | 11 |
| 4.1. Base Case: Current Conservation Measures..... | 13 |
| 4.2. Goods and Services Provided by White Sturgeon | 13 |
| 4.3. Drivers of loss: Pressures to White Sturgeon..... | 14 |
| | |
| Chapter 5. Governance..... | 16 |
| 5.1. United States Regional Goals..... | 17 |
| 5.2. British Columbia Treaty Review | 18 |
| 5.3. Flexibility within Current Governance Structure | 18 |
| | |
| Chapter 6. Methodology | 20 |
| 6.1. Measuring Ecosystem Goods & Services | 20 |
| 6.2. Benefit Transfer Methodology..... | 21 |
| 6.2.1. Challenges | 24 |
| 6.3. Semi-Structured Interviews..... | 26 |

| | |
|--|-----------|
| Chapter 7. Estimating White Sturgeon Ecosystem Goods & Services | 27 |
| 7.1. Recreation | 28 |
| 7.2. Food | 29 |
| 7.3. Existence | 30 |
| 7.4. Cultural | 31 |
| 7.5. Business as Usual | 32 |
| | |
| Chapter 8. Perspectives from the Basin..... | 34 |
| 8.1. White Sturgeon Ecosystem Goods and Services | 34 |
| 8.2. Treaty Framework Barriers | 35 |
| 8.3. Challenges to an Ecosystem Based Treaty | 35 |
| 8.4. Policy Considerations | 36 |
| | |
| Chapter 9. Criteria & Measures | 37 |
| 9.1. Criteria..... | 37 |
| | |
| Chapter 10. Rescaling Governance: Policy Options | 39 |
| 10.1. Option 1: Adaptive Governance | 39 |
| 10.2. Option 2: Treaty Modernization..... | 40 |
| 10.3. Option 3: Transboundary Watershed Group | 41 |
| 10.4. Option 4: Integrated Water Resources Management | 42 |
| | |
| Chapter 11. Analysis of Policy Options..... | 44 |
| 11.1. Option 1: Adaptive Governance | 44 |
| Flexibility | 44 |
| Ease of Implementation | 45 |
| Effectiveness | 46 |
| Equity | 47 |
| 11.2. Option 2: Treaty Modernization..... | 49 |
| Flexibility | 49 |
| Ease of Implementation | 50 |
| Effectiveness | 51 |
| Equity | 52 |
| 11.3. Option 3: Transboundary Watershed Group | 53 |
| Flexibility | 53 |
| Ease of Implementation | 54 |
| Effectiveness | 55 |
| Equity | 56 |
| 11.4. Option 4: Integrated Water Resources Management | 57 |
| Flexibility | 57 |
| Ease of Implementation | 58 |
| Effectiveness | 60 |
| Equity | 62 |
| 11.5. Evaluation Results | 63 |

| | |
|---|-----------|
| Chapter 12. Recommendations | 65 |
| 12.1. Short-Term Recommendations: In Preparation for 2024..... | 65 |
| 12.2. Long-Term Recommendations: 2024 Treaty Renegotiations | 66 |
| | |
| Chapter 13. Conclusion..... | 69 |
| | |
| References | 72 |
| | |
| Appendix A. Ecological State of the Columbia River | 84 |
| Appendix B. The Columbia River Treaty | 86 |
| Boundary Waters Treaty and International Joint Commission..... | 86 |
| Appendix C. White Sturgeon: A Brief Introduction | 87 |
| Current Conservation Measures | 88 |
| Appendix D. White Sturgeon Ecosystem Goods and Services | 92 |
| Provisioning Goods | 92 |
| Regulating Services..... | 92 |
| Supporting Services | 92 |
| Cultural Services | 92 |
| Appendix E. Drivers of Loss..... | 94 |
| Climate Change..... | 94 |
| Hydrosystem Operations | 95 |
| Water Quality..... | 96 |
| Fishery Effects..... | 97 |
| Competing Water Uses..... | 97 |
| Irrigation | 98 |
| Navigation | 99 |
| Hydropower | 99 |
| Recreation..... | 100 |
| Marine Mammal Predation..... | 100 |
| Appendix F. Fisheries Basin Management..... | 101 |
| Appendix G. Semi-Structured Interview Questions..... | 104 |
| Appendix H. Quantitative Findings | 106 |
| Annual Value of Recreational Angling in the U.S. Columbia River Basin | 106 |
| Annual Value of Food provided by White Sturgeon..... | 106 |
| Appendix I. Interview Summaries | 107 |
| Impacts to White Sturgeon | 107 |
| White Sturgeon Ecosystem Goods and Services..... | 108 |
| Treaty Framework Barriers | 110 |
| Bringing Ecosystems into the Framework..... | 111 |
| Challenges to an Ecosystem Based Treaty | 112 |
| Policy Considerations | 114 |
| Appendix J. Description of Criteria and Measures | 116 |
| Flexibility..... | 116 |
| Ease of Implementation..... | 116 |
| Equity 117 | |
| Effectiveness..... | 119 |

List of Tables

| | | |
|-------------|---|----|
| Table 2.1. | Examples of Ecosystem Goods and Services ^a | 5 |
| Table 6.1. | Non-Market Valuation Techniques | 21 |
| Table 6.2. | Total Economic Value of White Sturgeon EGS..... | 23 |
| Table 7.1. | Economic Value of White Sturgeon EGS | 28 |
| Table 9.1. | Criteria Matrix..... | 38 |
| Table 11.1. | Summary of Policy Evaluation and Calculations..... | 64 |

List of Figures

| | | |
|-------------|---|----|
| Figure 4.1. | Distribution of White Sturgeon in the U.S. Columbia River Basin | 12 |
|-------------|---|----|

List of Acronyms

| | |
|-------|---------------------------------------|
| AOP | Assured Operating Plan |
| BC | British Columbia |
| BPA | Bonneville Power Administration |
| BT | Benefit Transfer |
| CRB | Columbia River Basin |
| DOP | Detailed Operating Plan |
| EGS | Ecosystem Goods and Services |
| EON | Exchange of Notes |
| IJC | International Joint Commission |
| IWRM | Integrated Water Resources Management |
| LCA | Libby Coordination Agreement |
| MAF | Million Acre Feet |
| MW | Megawatt |
| NTSA | Non-Treaty Storage Agreement |
| NWPCC | Northwest Power Conservation Council |
| PES | Payment for Ecosystem Services |
| SOA | Supplemental Operating Agreements |
| TEV | Total Economic Value |
| US | United States |
| USACE | United States Army Corps of Engineers |
| WTP | Willingness to Pay |

Executive Summary

White sturgeon (*Acipenser transmontanus*) are one of the largest and longest-living species, often referred to as ‘dinosaurs of the deep.’ For centuries, the white sturgeon has been valued by humans as an iconic species, adding to cultural and social heritage as well as the economy. Historically, abundant populations of white sturgeon occupied the Pacific Northwest including the Columbia River Basin. Today, however, most stocks are imperiled. They are now classified as an endangered and threatened species in both the United States and Canada. Modelling predicts an 80 percent chance of extinction of the Columbia River population within the next two generations (Committee on the Status of Endangered Wildlife in Canada, 2014). As a keystone species, white sturgeon serve as a biological indicator of ecological health; their loss has resulted in decreased abundance of other aquatic species and altered nutrient recycling, resulting in detrimental effects to the functioning of the River system.

Distribution, abundance, and productivity of white sturgeon have been severely reduced by poor Basin management. In 1964, the Columbia River Treaty between Canada and the United States was implemented as a way to cooperatively manage water-related issues. Treaty terms were based primarily on flood control and hydropower generation with little consideration for ecosystem health and the benefits therein. The loss of habitat, fishery effects, competing water uses, climate change, and the alteration to water quantity and quality through dam impoundments have played a significant role in declining white sturgeon populations and the overall degradation of the Basin’s ecosystems. These changes call for caution in the structure and implementation of Basin management and indicate a need for a more holistic and integrated approach.

Measured in many different respects, the environmental goods and services of the Columbia River have tremendous value. Basin ecosystems are complex, integrated, and serve critical functions to maintaining the well-being of surrounding communities. Despite these significant benefits (i.e. clean water and air, food, recreation, cultural heritage, etc.) the topic is understudied in the Columbia River Basin and the magnitude of impacts is poorly understood. To help develop a better understanding and create

dialogue, this study uses the white sturgeon as an example of how undervalued ecosystem goods and services can be integrated into the management of the Columbia River Basin and Columbia River Treaty. The policy problem I investigate is that without consideration for white sturgeon and overall ecosystem health within the Columbia River Treaty, current Basin management continues to pose significant and unaccounted costs to ecosystems and society as a whole.

Notwithstanding methodological and data limitations (see Chapter 6), this study shows that restoring white sturgeon populations would generate substantial annual benefits to the U.S. portion of Columbia River Basin: \$178 million in food, \$1,200 million in its existence, \$0.053 million in recreational angling, and numerous intangible cultural benefits. By ignoring these values, costs are inflicted on Basin residents today and for generations to come. As one interviewee mentioned, “white sturgeon are unlike any other species, no other substitute exists for sturgeon in the Pacific Northwest.” Thus, without substitutes, the loss of sturgeon will create significant losses to economies in the region and overall well-being.

Both entities of the Treaty are preparing for renegotiations in 2024. As the highest governing structure for the Basin’s bilateral management, the Treaty and its renegotiation can help act as a vehicle of recognizing principles of sustainability and prudent environmental protection. Including ecosystem services into Basin management and Treaty renegotiations in 2024 could change the calculation of benefits, arrangements, and coordination between both countries; what was once deemed an acceptable trade-off could reveal net costs under the integrated approach proposed in this paper.

This study provides a portfolio of policy recommendations. In the near term, it is recommended that a transboundary watershed group be established. In order to improve coordination, fill critical research gaps, and develop a bilateral environmental strategy in the Basin, partnerships and data collection and analysis are a prerequisite. In the long term, it is essential that the Treaty include ecosystem function as an explicit objective alongside hydropower and flood control. The Treaty provides the backbone for coordinated management in the Basin; without a cohesive basin-wide strategy,

conservation efforts will continue to be fragmented, creating only marginal improvements. Modernization of the Treaty should be implemented in tandem with the implementation of an Integrated Water Resources Management Committee. The Committee would broaden the Treaty's scope and respond to impacts affecting sturgeon that the Treaty may be unable to address directly. Grounded in a strong legal framework and carried out by the design and use of an appropriate mix of instruments and tools, these recommendations will move towards integrated management and improved governance. This will extend the scope of the Treaty to allow for the full benefits of ecosystem preservation and restoration to be incorporated into the decision-making framework.

Lastly, under future scenarios of climate change and population growth, the trade-offs and impacts involved with Basin management will become increasingly uncertain and difficult to predict. As such, it is recommended that adaptive governance be integrated within all three of the above recommendations. Implementing these recommendations will not only better protect one of the biggest shared watersheds in North America but it will provide a framework for moving forward with balancing some of the key tradeoffs in natural resources management.

We cannot solve our problems with the same thinking we used when we created them

-Albert Einstein.

Chapter 1.

Introduction

White sturgeon (*Acipenser transmontanus*) are one of the largest and longest-living species, often referred to as ‘dinosaurs of the deep.’ For centuries, the white sturgeon has been valued by humans as an iconic species, adding to cultural and social heritage as well as the economy. Historically, abundant populations of white sturgeon occupied the Pacific Northwest including the Columbia River Basin. Today, however, most stocks are imperiled. The population of white sturgeon in the Columbia River – which runs a total of 2,000 kilometers from Northern British Columbia, through Washington and Oregon, and to the Pacific Ocean – has declined considerably over the last century. They are now classified as an endangered and threatened species in both the U.S. and Canada. Modelling predicts an 80 percent chance of extinction of the Columbia River population within the next two generations, with current estimated populations of 800–1,000 wild fish in the upper Columbia River and 1,500–2,000 fish in the mid-lower portion of the River (Committee on the Status of Endangered Wildlife in Canada, 2014).

As a keystone species, white sturgeon serve as a biological indicator of ecological health; their loss has resulted in decreased abundance of other aquatic species and altered nutrient recycling, resulting in detrimental effects to the functioning of the River system. White sturgeon play an integral role in the Columbia River aquatic ecosystems through natural predator-prey relationships. Actions focused on protecting white sturgeon are therefore likely to affect other components of the River system and benefit a range of resident and anadromous species sharing similar habitat requirements (Canada Department of Fisheries and Oceans, 2005). The complex interconnectedness of ecosystems demonstrates the importance of white sturgeon and their services. To residents and recreational anglers along the Columbia River, white sturgeon are highly valued, playing an important role in the cultural underpinnings of First Nations tribes in

the region. For its consumptive use, white sturgeon are widely marketed for caviar, meat, and medicinal purposes.

While the Columbia River once supported a large and productive population of white sturgeon, the distribution, abundance and productivity of white sturgeon have been severely reduced by poor Basin management. In 1964, the Columbia River Treaty between Canada and the United States was implemented as a way to cooperatively manage water-related issues. Treaty terms were based primarily on concerns of economic growth, focusing almost exclusively on flood control and hydropower generation with little consideration for ecosystem health and protection, and the benefits therein. The loss of habitat, competing water uses, climate change, and the alteration to water quantity and quality through dam impoundments have played a significant role in declining white sturgeon populations and the overall degradation of the Basin's ecosystems. A single population of white sturgeon is now separated into various sub-populations, creating functionally isolated groups. With the exception of the Kootenai white sturgeon population, efforts on either side of the border to protect and replenish this stock have been ineffectual. Cooperative fisheries management between Canada and the United States has been absent.

The year 2024 marks two important decisions for the Treaty. First, an option exists for either country to terminate or change provisions of the Treaty at the earliest date of September 16, 2014, giving the required 10 years notice. The second involves the expiration of the pre-paid assured flood control operation in Canada and the resulting shift to a "Called Upon" flood control operation (BC Ministry of Energy and Mines, June 25, 2013). If the Treaty is terminated, Canadian reservoirs will be managed for Canadian interests only, creating significant risk and uncertainty for United States fisheries and Basin management more broadly.

While both elements could significantly alter the coordination of benefits, the Treaty's renegotiation provides a unique opportunity to directly address ecosystem concerns. Despite being historically overlooked and undervalued, Basin ecosystems are complex, integrated, and serve critical functions to maintaining the well-being of surrounding communities. As the highest governing structure for the Basin's bilateral

management, the Treaty and its renegotiation can help act as a vehicle of recognizing principles of sustainability and prudent environmental protection.

This capstone uses the white sturgeon as an example of how undervalued natural resources can be recognized and integrated into the Columbia River Treaty. The policy problem I investigate is that without consideration for white sturgeon and overall ecosystem health within the Columbia River Treaty—the overarching framework for governing the shared resource—current Basin management continues to pose significant and unaccounted costs to ecosystems and society as a whole. While it is beyond the scope of this study to consider the Columbia River in its entirety, the midstream (see Figure 3.1) of the Basin (South of the 49th Parallel) is used to analyze the value of white sturgeon and the magnitude of impacts to its population.

This study begins with an introduction to the concepts of natural capital and ecosystem goods and services (EGS), followed by a description of the Columbia River and the bilateral Treaty between Canada and the United States. Sections on the importance of the white sturgeon and how management of the River has impacted the white sturgeon follow.

The primary analytical methodology of this study is benefit transfer. This method approximates the monetary value of white sturgeon in the mid and lower regions of the River to show their importance.¹ This study also uses semi-structured interviews with academics and key stakeholders to help ground the quantitative analysis. I then formulate options, based primarily on a comprehensive review of the academic literature, to address the policy problem. Evaluation of these options based on key criteria leads to a set of recommendations for both the United States and Canada to consider for Treaty renegotiations in 2024.

¹ Reported values are adjusted to a sustainable stock target (see Chapter 6).

Chapter 2.

The Importance of Natural Capital

Natural capital is the “planet’s stock of renewable and non-renewable natural resources (forests, minerals, oil, plant and animal species), environmental resources (atmosphere, water) and land” (Olewiler, 2007, p 125). From this stock of natural resources the ecological goods and services flow and benefit society in innumerable ways. The rapid increase in global living standards over the past two centuries is inextricably linked to our dependence on and continued exploitation of natural capital. The relationship between the flow of natural capital (i.e. the rate of extraction and consumption) and the subsequent degradation of the environment often invokes trade-offs of economic growth and environmental sustainability.

At a more regional level, the long-term sustainability of the Columbia River and its communities depend on ecosystem functions and provide a clear example of these trade-offs. The River has enhanced the economic livelihoods of local communities in the region, including income derived from the environmental assets that support commercial fishing, agriculture, recreational, and other sectors. However, the continuance of these activities is directly related to the extent and health of River ecosystems. If the River’s management incautiously continues for the production of economic output, eventually, the River will offer less for production and sustenance in the future. Put simply, the environmental goods and services offered by the Columbia River represent the ‘glue’ holding everything together.

2.1. Ecosystem Goods and Services

Ecosystem goods and services are defined as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill

human life” (Daily, 1997, p 3). The provision of ecological goods and services comes in the form of tangible and marketable items, such as fish, agriculture, and timber, and non-marketable goods and services. The latter are environmental goods and services that provide indirect benefits whose values are not readily recognized or captured within our current market system. Examples of these indirect services include carbon sequestration, the stabilization of hydrological flows and flood risk reduction, nutrient recycling, biodiversity maintenance, and regulation of climate. Without these benefits, human beings and society cannot thrive. Protection and enhancement of ecosystems improves water quality, decreases greenhouse gas emissions, increases recreational opportunities, sustains agricultural production, and leads to other direct and indirect benefits to society. Table 2.1 provides examples of EGS by ecosystem type.

Table 2.1. Examples of Ecosystem Goods and Services^a

| Ecosystem Type | Goods and Services Provided | Potential Benefits to Society |
|-----------------------|--|--|
| Forest | Carbon storage and sequestration, soil formation, waste treatment, biological control, cultural, air quality, storm water control, recreation, raw materials (timber), and water filtration. | Air quality, climate regulation, cultural/heritage conservation, tourism and recreation, and water supply. |
| Grasslands/Rangelands | Carbon storage and sequestration, erosion control, water regulation, soil formation, waste treatment, pollination, biological control, and food production. | Flood control, air quality, cultural/heritage conservation, tourism and recreation, and climate regulation |
| Wetlands | Regulation of water flow, water supply, waste treatment, cultural, habitat, storage of fresh water, and carbon storage. | Cultural/heritage conservation, tourism and recreation, food production, flood control, waste treatment, and water supply. |
| Lakes/Rivers | Water supply, waste treatment, food production, and maintenance of genetic diversity. | Food provision, cultural/heritage conservation, tourism and recreation, irrigation, and erosion prevention. |
| Cropland | Scenic, pollination, and soil fertility. | Provision of food and pollination of crops. |
| Undeveloped Land | Scenic | Cultural/heritage conservation |

^aAdapted from Sauer, A. (2002). The value of conservation easements discussion paper. World Resources Institute. West Hill Foundation for Nature, December 1, 2002; Olewiler, N. (2004). *The Value of Natural Capital in Settled Areas of Canada*. Published by Ducks Unlimited Canada and the Nature Conservancy of Canada. 36 pp

Most of the EGS in Table 2.1 provide innumerable benefits that are unrepresented in formal markets. Because the non-market values are difficult to estimate and measure, the goods and services provided by nature are often lost or compromised by decisions of government. Accordingly, the destruction and exploitation of natural areas entail costs to society. Communities can experience loss by having to find substitutes for EGS, or by having to make do without the ecosystem, causing losses to both financial and overall well-being (Olewiler, 2004). Loss can be experienced through the cost of flooding when, for example, riparian land is converted and can no longer provide its flood mitigation services. In some cases, finding substitutes through technology and science is not viable. Before finding substitutes for nature, decision-makers must ensure substitutes reproduce all the necessary functions of the ecosystem and that their costs do not exceed the original ecosystem (Olewiler, 2004). In this sense, developed substitutes must ensure that the needs of current and future generations are met.

In other instances, only specific ecosystems can provide services, allowing no room for substitutes. Thus, the more we know about the ecology and the value of an ecosystem, the better we can understand what is required to sustain it. While technological innovations might temporarily help sustain well-being, in the long-run no compensation can make up for the essential resources provided by nature. Some forms of ecosystems are vital to society—water and air are quintessential examples.

Thus, understanding natural capital is a prerequisite for making sensible conservation decisions (National Academy of Sciences, 2004). Choices between the conservation of some ecosystems and the continuation and expansion of human activities should be made with foresight to this potential conflict and recognition for the value of EGS (National Academy of Sciences, 2004). Public policies have an essential role in ensuring that these benefits are identified and taken into account in decisions.

Chapter 3.

The Columbia River

Governance of the Columbia River is complex and layered. While the management of the River has produced significant benefits to the economies of the region, the River's governance has also led to negative impacts on the flow of goods and services offered by environmental resources—the white sturgeon is but one example. To provide context to the policy problem, this chapter introduces the Columbia River, Columbia River Treaty, and significance of Columbia River Treaty renegotiations in 2024.

3.1. The Columbia River Basin

The Columbia River provides significant natural and managed water resources for the Pacific Northwest (Hamlet & Lettenmaier, 1999). It is the largest river in the region and fourth largest in North America (Osborn, 2012). The River is 2,000 kilometers in length with a drainage basin the size of France, covering a total of 670,800 square kilometers (Harrison, 2008a). In British Columbia, the River begins at Columbia Lake in the southern Rocky Mountain Trench of British Columbia. The River flows north for 518km before turning south for 700km and crossing the border into Washington State (Harrison, 2008a). South of the US-Canada border, the River continues to bend southwest, and forms the border between Oregon and Washington, as it runs towards the Pacific Ocean (Harrison, 2008a).²

² Despite only 15 percent of the Basin being comprised in Canada, 38 percent of the average annual flow and 50 percent of the peak flow originates in Canada (Cosens & Williams, 2012).

The Columbia River is one of the great rivers in terms of its diversity of ecosystems and runoff from its watershed. The health of its watershed affects the temperature, stream flow, aquatic species and other components of the River's biodiversity. Snowpack melt during the spring and early summer produce favourable conditions for freshwater species. The River's habitat is crucial for fish as they traverse through its flows to the ocean, and again later as they return to the River. The River's rich natural processes have provided environmental, economic, cultural and social benefits to the regions it passes through. Many industries vital to the Pacific Northwest depend on the River for sport and commercial fisheries, agriculture, transportation, recreation, and hydropower generation.

3.2. The Columbia River Treaty

Ratified in 1964, the Columbia River Treaty between Canada and the United States was implemented as a way to cooperatively manage water-related issues of the Columbia River system.³ Both signatories recognized that storing a higher volume of water to control the River's flooding would also become an efficient way to generate hydropower. Thus, the Treaty enabled three dams to be built in Canada (Mica, Duncan and Hugh Keenleyside) and one in the United States (Libby) (BC Ministry of Energy and Mines, June 25, 2013). The United States prepaid Canada \$64 million to rent 8.45 million acre feet of storage space in the new Canadian reservoirs for 60 years to support assured flood control (BC Ministry of Energy and Mines, June 25, 2013). In furtherance of the objectives for flood control and power generation, the Treaty established obligations and benefits for each country. In constructing the three storage dams in Canada, the Treaty required Canada to operate the dam reservoirs for optimum flood control and power in both countries.⁴ As payment for the U.S. benefits realized by Canadian storage operations, the U.S. annually returns 50 percent of the calculated

³ The U.S. entity consists of the Bonneville Power Administration administrator and the Northwestern Division engineer of the U.S. Army Corps of Engineers. The Canadian entity is the British Columbia Hydro and Power Authority (BC Hydro).

⁴ For further information on the Columbia River Treaty and its impacts to Canadians along the Columbia River refer to Appendix B.

downstream power benefits to Canada, known as the Canadian Entitlement, in the form of energy and capacity.⁵ Moreover, since the Treaty was signed, flood control measures have protected communities from major damage along the Columbia River, avoiding \$2 billion in potential damage in the year 2012 (BC Ministry of Energy and Mines, June 25, 2013). While flood control measures have priority over power generation, these two Treaty objectives are often complementary.

3.3. The Columbia River Treaty Post-2024

Water availability in the US depends on the integrity of the entire hydrological cycle and the water regime defined by the Treaty. Depending on the terms of Treaty renegotiation, the Basin could face significant changes. First, as water management in the Treaty relies heavily on predictable natural storage in the form of snow pack, climate change stands to alter the River's stationarity⁶ and the ability to predict changes to the hydrology of the river system. These changes are likely to have implications for water quantity, quality and timing of availability, posing risks to domestic water supply, irrigation, hydroelectricity generation, fish habitat and recreation in the Basin. High temperatures and prolonged low flow periods could pose risk to fish stocks and potentially lead to higher mortality rates (BC Ministry of Energy and Mines, June 25, 2013). Climate change projections increase the urgency to prepare for changes in the River. Reservoirs can assist in adapting to climate change by increasing storage during periods of increased water quantity and releasing stored water during periods of water scarcity. The coordination in the Treaty provides an important mechanism from which to address future challenges.

⁵ Downstream power benefits are “the difference in the hydroelectric power capable of being generated in the United States of America with and without the use of Canadian storage” (CRT Article VII). The Canadian Entitlement is estimated to range between \$100-350 million annually. The province of British Columbia owns the Canadian Entitlement. The entitlement is sold by Powerex to either BC Hydro or utilities in Alberta or the U.S. at market value. The money earned then goes into the general revenue account of the province.

⁶ Stationarity refers to seasonal weather and long-term climate conditions that fluctuate within a fixed envelop. A loss of stationarity means that the ability to project conditions based on experience is no longer reliable.

Second, in the year 2024, Canadian flood control commitments to the U.S. will be limited to a “Called Upon”⁷ approach. After this time, the U.S. will have to first make use of all related storage on its side before ‘calling upon’ Canada to provide flood control.⁸ This means that U.S. reservoirs will have to draft deeper more often. As a result, this will likely have impacts on U.S. fisheries, recreation, and irrigation. Regulation of the Columbia River by Canada is the means from which additional inflows and operations are coordinated throughout the lower portion of the River. Terminating the Treaty could therefore lead to significant uncertainty in the U.S. because operations in Canada would be uncoordinated. Since utilities have an obligation to meet electrical obligations, this coordination is extremely valuable to U.S. authorities.

Lastly, Treaty termination could have significant impacts on U.S. fisheries operations under low-flow conditions in the Basin (BC Ministry of Energy and Mines, June 25, 2013). If the Treaty is terminated, subsequent flows delivered by the Treaty that have stretched coordination beyond hydropower and flood control to include ecosystem objectives will be lost. Thus, the prospect of restoring ecosystem functions damaged and lost from dam construction in the River is at stake in negotiations on the renewal of the Treaty.

⁷ Assured Annual Flood Control expires automatically in 2024 and converts in 2024 to a Called Upon operation of Canadian storage space as needed by the United States for flood risk management. This also requires the U.S. to pay the Canadian operating costs and economic losses for each Called Upon request

⁸ This obligation exists whether the Treaty continues or is terminated.

Chapter 4.

The Great White Sturgeon

Historically, abundant populations of white sturgeon occupied the Basin. Today, the only population in the Columbia River that migrates to the ocean is downstream from one of the lowest hydropower systems, Bonneville Dam. Damming along the River has trapped and isolated white sturgeon into subpopulations upstream from Bonneville Dam into British Columbia.⁹ White sturgeon are now unable to migrate from areas of high densities or poor resources to seek out alternative spawning and rearing areas or access seasonal food resources (Jones et al., 2011). Natural recruitment has failed for most subpopulations, which now consist solely of aging cohorts of mature fish that are gradually declining as fish die and are not replaced (Northwest Power Conservation Council, 2013a). Instead of migrating to the ocean, these fish complete their life cycle in the main-stem Columbia River.

Of the twenty-seven species of sturgeon around the world, many are now listed as extinct, endangered, or threatened (Auer, 1996). Although the exact causes of decline are still uncertain, factors threatening this population in the mid to lower Columbia River include:

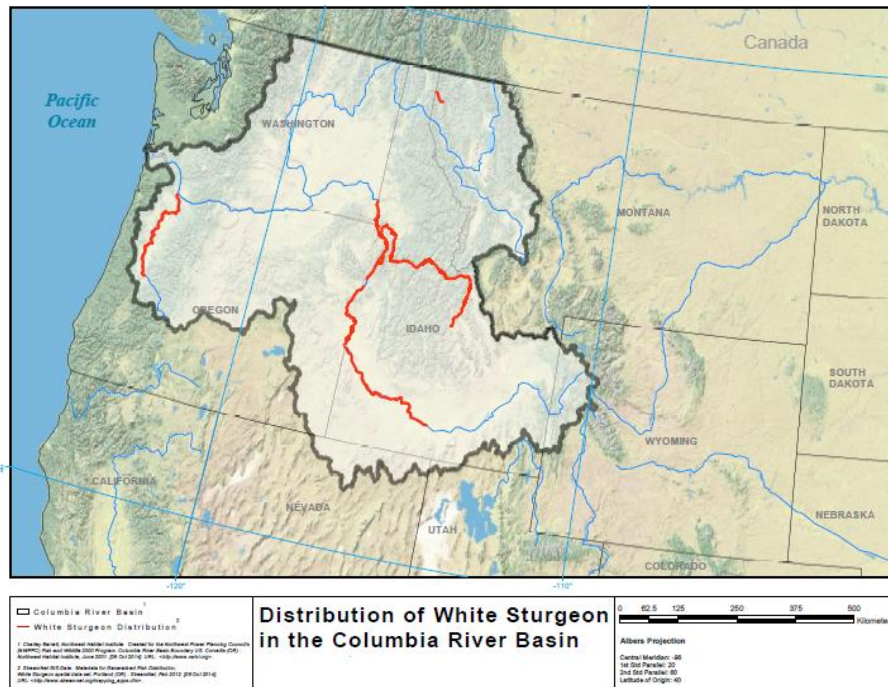
- Marine mammal predation;
- Habitat and population fragmentation;
- Altered seasonal river discharge and temperature;
- Over-fishing;

⁹ Dam construction has restricted sturgeon to river fragments that may no longer provide the full spectrum of habitats necessary to complete the life cycle. Status varies among impounded subpopulations of sturgeon from marginally productive to functionally extirpated (Northwest Power Conservation Council, 2013a).

- Hydro-electric dams and associated flow regulation;
- Water diversions and dyking for flood control and irrigation;
- Reduced water quality associated with land-use practices; and,
- Insufficient habitat to support all life stages.

Combining the above factors with a slow maturation rate (up to 25 years in some cases) and long lifespan places the White Sturgeon at greater risk if population size becomes too small (Jones et al., 2011).¹⁰ Figure 4.1 displays geographical data from 2012 representing the distribution of White Sturgeon in the lower and mid-Columbia River system.

Figure 4.1. Distribution of White Sturgeon in the U.S. Columbia River Basin¹¹



Source: StreamNet GIS Data (2012). Metadata for Generalized Fish Distribution, White Sturgeon spatial data set. Portland (OR): StreamNet, January 2012. [9 Oct 2014]. URL http://www.streamnet.org/gisdata/map_data_biological/FishDist_MSHv3_January2012/FishD_WhiteSturgeon_January2012.xml

¹⁰ For a comprehensive description of white sturgeon refer to Appendix C.

¹¹ Using 2012 GIS data, this figure identifies sturgeon presence in each reach of the United States Columbia River system.

4.1. Base Case: Current Conservation Measures

To date, the effort to improve conditions for threatened fish and wildlife species has dominated system planning and operations within the United States. Washington, Oregon, Idaho, Montana, and British Columbia all engage in extensive conservation efforts to protect and enhance white sturgeon populations in the Basin. While each of these projects receives favourable review, the Independent Scientific Review notes that an effective basin wide management plan for white sturgeon is lacking and is the most important need for planning future research and restoration (Northwest Power Conservation Council, 2013a). For a comprehensive description of current initiatives and the status of white sturgeon within each jurisdiction refer to Appendix C.

4.2. Goods and Services Provided by White Sturgeon

White sturgeon have a rich spiritual, aesthetic and economic history in the Pacific Northwest. The values attached to white sturgeon have changed from natural resource commodities to ones in which sturgeon are appreciated as a species and as a component of a healthy ecosystem. While no single classification system can capture the innumerable benefits provided by nature, EGS can be grouped into four broad categories: provisioning, regulating, cultural, and supporting services (Millennium Ecosystem Assessment, 2005). Table 4.2 outlines EGS provided by white sturgeon (see Appendix D for an in-depth explanation for each category).

Table 4.2. White Sturgeon Ecosystem Goods & Services

| Ecosystem Goods & Services Provided by White Sturgeon | |
|--|---|
| Provisioning Goods | Commercially harvested for caviar, meat, clothing, and medicinal purposes. |
| Regulating Services | Maintenance of healthy aquatic system and bioindicator of river health. |
| Supporting Services | Nutrient transfer through upstream migration of white sturgeon in nutrient poor regions, and potential control of pest organisms. |
| Cultural Services | Cultural heritage and identity, recreation, tourism, existence and intrinsic values, and sustenance values for tribal nations. |

These goods and services illustrate the benefits at stake to the River and economic, social and overall well-being for residents in the Pacific Northwest. By

measuring the value of EGS, policymakers can accurately assess the costs of losing or finding substitutes for sturgeon in the Columbia River.

4.3. Drivers of loss: Pressures to White Sturgeon

Drivers are the “natural or human-induced factors that directly or indirectly cause a change in ecosystems” (Rahl et al., 2007). Such losses reduce the fitness and adaptive potential of species and ecosystems, limiting the prospect for recovery after disturbance. The causes of white sturgeon population decline are complex and manifold. Table 4.3 lists the most pertinent threats to white sturgeon in the mid-lower Columbia River Basin. For a fulsome description of these drivers refer to Appendix E.

Table 4.3. Pressures Affecting White Sturgeon

| | |
|--------------------------------|---|
| Climate Change | <ul style="list-style-type: none"> • Earlier snowmelt flows and reduced summer flows will severely decrease white sturgeon spawning and repopulation. |
| Hydrosystem Operations | <ul style="list-style-type: none"> • Timing and magnitude of the spring freshet is altered. • Dams have closed off 55 % of the River’s drainage system and 31 % of the stream miles of original fish habitat in the River, creating major passage issues that interrupt all life stages of white sturgeon. • Other impacts include: changes in water quality/turbidity, habitat/population fragmentation, and nutrient losses. |
| Water Quality | <ul style="list-style-type: none"> • Point-source effluents, impoundments, water withdrawals, and nonpoint source pollution from irrigation. So far, 49 different contaminants have been detected. |
| Fishery Effects | <ul style="list-style-type: none"> • Illegal harvesting threatens white sturgeon populations. • Oregon State Police’s Fish and Wildlife Division reported 25 illegally harvested white sturgeon in 2008 and 48 in 2009. |
| Marine Mammal Predation | <ul style="list-style-type: none"> • Dams restrict white sturgeon from upstream movement and in doing so, increase their vulnerability to predation. • Observations near Bonneville Dam between January 2006 and May 2010 have recorded increases of white sturgeon predation from 442 cases in 2006 to 2,172 in 2010. |

In addition to these stressors, competing uses place even greater strain on the sturgeon and river ecosystems. The Columbia provides water to a multitude of different stakeholders, each with varying views on how the River and its reservoirs should be managed. Responding to the myriad of competing interests in the Basin has been difficult and will continue to be so in the future. Population in the interior Columbia Basin in the United States is roughly 5 million and projected to grow by 0.3 to 1.6 percent each year (National Academy of Sciences, 2004). Current estimates state that if population growth continues unabated, it will lead to a three to sevenfold increase in population in the Columbia Basin region (Independent Scientific Advisory Board, 2007). With this growth will come new demands for land, water, and hydroelectricity which, in turn, may pose greater pressure on the white sturgeon. For a comprehensive breakdown of competing needs in the Basin refer to Appendix E.

Chapter 5.

Governance

As it stands, the Treaty fails to facilitate and address the proper management of ecosystem health, needs, and challenges (Kruger, 2014)¹². The Columbia River Treaty addresses the use of storage facilities only for hydropower generation and flood control. To help fulfill these Treaty obligations, the U.S. and Canada created various bilateral committees: an Engineering Committee, Operating Committee, and a Hydro-meteorological Committee. While these committees provide ongoing weekly and sometimes daily co-operation and problem solving, committee work is ultimately bound by Treaty objectives (Bankes & Cosens, 2014). Moreover, to some extent, Treaty entities have used supplementary agreements in addressing ecosystem management. Treaty mechanisms could therefore be linked to the goal of ecosystem restoration and, more specifically, white sturgeon, protection, restoration, and enhancement. Formal Treaty reviews on both sides of the border have catalyzed broader conversations about governance and ecosystem issues in the Basin.

To understand the position of either party with regard to Treaty renegotiations and River governance, the following sections will first discuss current regional Treaty goals held by British Columbia and the United States.¹³ Both the U.S. and the British Columbia have published documents on their positions of the Treaty. While both entities wish to carry on with the Treaty, B.C. decided that Canada would continue the Treaty and "seek improvements within existing Treaty framework" (Government of British Columbia, 2012). Correspondingly, the U.S. supports the "modernization of the Treaty"

¹² For a full analysis, refer to Kruger (2014).

¹³ The U.S. entity delivered its recommendation in December 2013 and the province of British Columbia delivered its recommendation in March 2014. While both recommended continuing with the Treaty and modifying it, the two differed in terms of what issues should be considered in modifying the Treaty.

(U.S. Entities, 2013). Opposing statements reflect B.C.'s perception over the distribution of Treaty impacts and water resource pressures experienced by the U.S.¹⁴ In the view of the B.C. government, the U.S. receives significant benefits from the operation of flows in Canada. The province states that while the U.S. can flexibly manage Treaty flows for domestic requirements and water resource needs, B.C.'s ability to manage flows is limited and constrained by Treaty operations (BC Ministry of Energy and Mines, June 25, 2013). Section 5.3 later points toward administrative changes that have occurred within the existing governance structure to adjust flows for fisheries. This section illustrates how formal governance structures in the River have become somewhat more flexible in response to fishery and ecosystem concerns. Chapter 5 concludes by summarizing the policy problem and context from which my methodology and policy analysis address.

5.1. United States Regional Goals

In December 2013, the U.S. Entity's (Army Corps of Engineers and Bonneville Power Administration) Regional Recommendation was presented to the Federal Department of State. In this document, the United States articulated nine general principles to inform the modernization of the Treaty. Included in these principles is recognition for the implementation of ecosystem-based functions within the Treaty. Under this heading, the U.S. proposes specific recommendations related to ecosystem-based functions. For example, the U.S. recommends pursuing a joint program with Canada, with shared costs, to investigate and implement restored fish passage and reintroduction on the main-stem Columbia to Canadian spawning grounds (Pendergrass, 2014). Additionally, the U.S. recommends that the Treaty provide streamflow's that protect, enhance, and promote productive populations of resident and anadromous fish (Bankes & Cosens, 2014). The U.S. contends that this will require long-term assurance rather than current annual arrangements for flow augmentation. Other recommendations

¹⁴ The U.S. Endangered Species Act requires U.S. entities to allocate flows for endangered and threatened species. As a result, the U.S. must trade-off some of its potential downstream power benefits from the Treaty for fisheries restoration. Because B.C. does not face the same water resource pressures as the U.S., B.C. believes it should not bear the financial burden of the choices that the U.S. must make to regulate water for other purposes beyond identified Treaty priorities (BC Ministry of Energy and Mines, June 25, 2013).

emphasize that arrangements should be made adaptable to changing conditions (i.e. climate change). The section also addresses the operation of Libby dam and how its operations should continue based on variable flow operations “and with a view to achieving mutually desirable ecosystem benefits on both sides of the border” (Bankes & Cosens, 2014, p 9).

5.2. British Columbia Treaty Review

In Canada, the B.C. Ministry of Energy and Mines is the lead agency for Canada’s Treaty 2014 Review. The Ministry coordinates across provincial and federal agencies, and engages with the public to gather information and conduct studies in support of Treaty review. In March 2014, British Columbia released its decision on Treaty review. Within its decision, the province states that it wishes to continue with the Treaty and create improvements within its existing framework. In the 14 principles created to guide changes to the Treaty, the province references ecosystems in two ways. First, British Columbia states that it will explore ecosystem-based improvements recognizing that there are available mechanisms for doing so both inside and outside the Treaty. Second, the province makes reference to salmon migration by stating, “salmon migration into the Columbia River in Canada was eliminated by the Grand Coulee Dam (26 years prior to Treaty ratification), and as such is not a Treaty issue” (Bankes & Cosens, 2014, p 14). The province then continues to state that fish passage and habitat, if feasible, should instead be the responsibility of each party and its respective infrastructure (Bankes & Cosens, 2014). Thus, rather than compensating for losses, the province requires that the party responsible for disrupting fish passage also bear the costs of restoration.

5.3. Flexibility within Current Governance Structure

Over the last few decades, governance in the Columbia River has expanded to allow emphasis on maintaining flows for fish (see Table 13.1 in Appendix F).The Treaty

has also exhibited flexibility and allowed changes in coordinated operations to benefit fisheries.¹⁵ Yet, despite these efforts and developments, recruitment failures to white sturgeon persist. Scientific evidence suggests that because recovery programs attempt to work around the edges of hydropower operations, navigation, irrigation, flood control, timber harvest and other uses, these approaches cannot reverse declines in white sturgeon populations (Volkman, 1997). For the most part, decisions by Basin states occur without much spatial coordination. The lack of a basin-wide framework discourages efforts at conservation and improved management, since methods in one state will have limited effects if other states and entities do not enact similar measures. For flows to be altered to enhance migration of sturgeon, coordination across multiple hydroelectric projects and parties is required.

Despite advancements in fisheries' conservation and awareness, investment in the Columbia continues to lag behind other major water bodies (Lower Columbia River Estuary Partnership, 2010). The amount of restored habitat is less than half of the total area lost since the start of damming along the River. As more is learnt about the impacts of contaminants on fisheries, investment in water quality monitoring continues to decrease, reducing monitoring to one site along the lower portion of the River (Lower Columbia River Estuary Partnership, 2010). Because land-use change and impacts are not monitored at a basin-wide scale, as problems in one area are uncovered, new problems in other regions are created. Without a cohesive basin-wide strategy, conservation efforts create marginal improvements around the periphery of Treaty operations. Thus, as the Treaty provides the backbone for coordinated management of reservoirs for hydropower generation and flood control, coordinated management to address matters such as ecosystem services is lacking.

¹⁵ For a comprehensive description of these initiatives refer to Appendix F.

Chapter 6.

Methodology

To examine the value of white sturgeon within the Columbia River Basin, and to explore the options for policy reform in greater depth, this study uses benefit estimates and semi-structured interviews as methods of analysis. This chapter briefly reviews methods for estimating values of ecosystem goods and services that are not exchanged in markets and explains the approach taken.

6.1. Measuring Ecosystem Goods & Services

In economic analysis, EGS are represented through monetary valuation. In a policy context, the valuation of EGS contributes to policy formation and guides decision-making. By accounting for natural capital, economic and environmental objectives become aligned—providing future generations with at least the same benefits from natural resources that individuals currently enjoy. Table 6.1 outlines the principal techniques used for assigning economic values to non-market goods and services provided by nature.

Table 6.1. Non-Market Valuation Techniques

| Valuation Technique | Description | Example |
|----------------------------|--|--|
| Stated Preference Method | Survey used to elicit information about preferences for a good or service. Directly asks individuals (based on a hypothetical scenario) how much they would be willing to pay or accept as compensation for specific environmental services. | What individuals would pay for the substitute of a particular ecosystem good or services, such as water purification and treatment |
| Travel Cost Method | Value estimate based on ecosystems or sites used for recreation. | Actual expenditures made to get to nature sites (i.e. gas, time, park fee) used to infer the benefits of a recreational site |
| Damage Function | Values based on costs of avoided damages from lost ecosystem services | The value of improved water quality by measuring the costs of protecting against/ regulating effluent emissions |
| Substitution Method | Substitutability of related goods and services as an indicator of economic value for the ecosystem of study | What people would buy/use as a substitute if a specific ecosystem was not available |
| Hedonic Pricing | Marginal economic values for ecosystem services that directly affect market prices | Most often applied to property values impacted by the loss of ecosystem services |

While the techniques described in Table 6.1 have many limitations, failing to value nature implies assuming a zero value (Olewiler, 2004). Including these values of natural capital enables decision makers to compare alternatives efficiently and effectively while also allowing for sustainable policy.

Due to the lack of valuation studies for white sturgeon in the Columbia River Basin, the primary valuation method in my study is benefit transfer (BT). I apply the results from studies in other regions as a proxy for measuring EGS in the Columbia River.

6.2. Benefit Transfer Methodology

An economic value is a measurement of human well-being and helps identify the individual and societal trade-offs of scarce (and competing) resources (Boyle et al., 2003). These economic values can be separated into direct values (use-values) and indirect values (non-use values). Direct-use values apply to goods whose price is

determined by market processes. Examples include timber products derived from forest capital, harvested fish, and agricultural products; the market price paid by individuals reflects the value of a particular item. By comparison, indirect values come from the consumption or use of goods/services that do not have well-defined markets. For instance, the enjoyment we receive from walks in the forest or knowing that a species or ecosystem exists is not reflected in our formal market system. For the purposes of white sturgeon, this study employs the following direct and indirect values to estimate the benefits (see Figure 6.2)¹⁶ provided by white sturgeon populations in the U.S. portion of the River:

Direct-use Value (Consumptive): Harvesting white sturgeon for food, medicinal products, and fishing for consumption are examples of direct-use values. To derive this value, the ex-vessel price for meat and caviar offered by white sturgeon is used.¹⁷

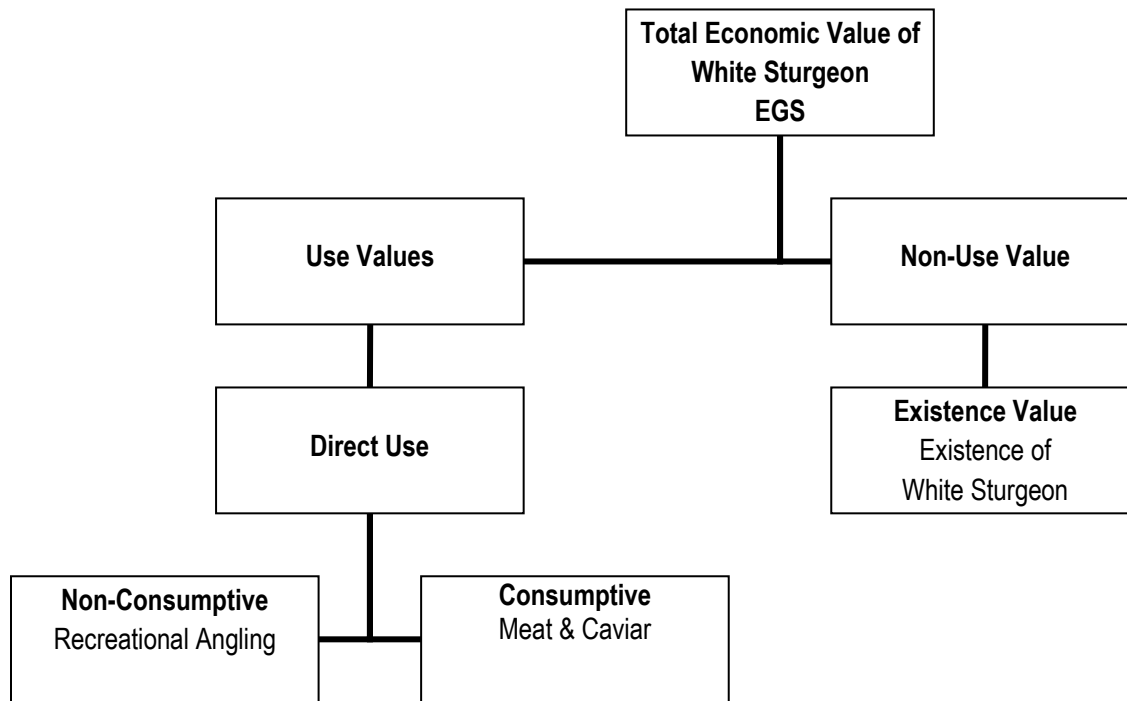
Direct-use Value (Non-Consumptive): Non-consumptive uses of white sturgeon include its recreational, social, and cultural values. These values are captured by the money spent on fishing equipment, the number of times individuals fish within a fishing season, and other expenses such as gas, time of travel, and parking fee. This method is performed for recreational angling participation by residents in the U.S. portion of the River.

Non-use Value (Existence): Individuals ascribe value to knowing that white sturgeon exist regardless of whether they use their services directly. This value is found from an outside study using a willingness-to-pay measure and is applied to Basin residents in the U.S. portion of the River.

¹⁶ By definition, the total economic value (TEV) (see Figure 6.1) relates the preferences of individual human beings. While, TEV cannot encompass measures of intrinsic value, WTP can sometimes help to include those intrinsic motives (Pearce, 2006).

¹⁷ Ex-vessel values represent the price fishers receive from selling their catch at the dock.

Table 6.2. Total Economic Value of White Sturgeon EGS



A benefit-transfer approach is used to obtain estimates of the various economic values of white sturgeon. Benefit transfer extrapolates estimates of economic benefits from a study that has already evaluated the subject (or one very similar) and transfers those values to the study of interest (Pearce, 1994). To undertake an accurate transfer of benefits from primary studies to white sturgeon in the U.S. Columbia River Basin context, the following best practices were followed to enable a consistent, rigorous, and adequate benefit estimation approach:

Currency Differences and Base Year: Currency estimates were adjusted for inflation in the primary study's domestic currency and converted to Canadian dollars using the exchange rate from the estimation year. All values are expressed in 2013 (CAD) dollars.¹⁸

¹⁸ Values are adjusted based on the Canadian Consumer Price Index retrieved from Statistics Canada (www.statscan.gc.ca).

Maintain Original Unit-Value Estimate: Because some estimates were made in different units of measure, each estimate is stated in common units.

Context of Value Estimate: Value estimates were completed in the specific context of the study. In this regard, estimates used in my analysis were applied only if they matched the U.S. Columbia River context and characteristics. The study selection criteria are described in Table 6.3.

Table 6.3. Benefit Estimation Study Selection Criteria

| Key Criteria | Characteristics | Desired Benchmarks |
|---------------------|--|---|
| Site differences | Physical characteristics | River watershed |
| | Geographic area | Pacific Northwest |
| Species differences | Population sample size | 10,000 |
| | Species type | Freshwater fish |
| Scale differences | Site size | Roughly 1,200 km |
| Framing differences | Types of threat/stressors | Hydroelectricity, fisheries, climate change, multiple water users, water quality, and water quality |
| Scope of study | Transferability over time (time scale) | Studies dated 1999 and onwards ¹⁹ |

6.2.1. Challenges

This study uses three types of values to estimate the benefits provided by white sturgeon to societal and individual well-being. However, one of the primary barriers to quantifying the benefits of white sturgeon is that the population has not been adequately tracked. As a result, it is still unknown just how many white sturgeon existed in the Pacific Northwest prior to damming along the River and how many exist today. A review of available scientific literature led to the determination of a population-specific sustainable rate of white sturgeon of 10,000 mature individuals in the lower portion of the

¹⁹ A time limit of 15 years is applied to the study selection process for two reasons. First, people's preferences may have changed over a fifteen-year period. Second, the accuracy of valuation studies has improved over the last few decades. Using later studies provides strength to the benefit estimations.

Basin (age 25 years or older). This number represents the population necessary for rebuilding over the next 20 years (Hatfield, 2005). Below this target considerable conservation concerns arise. The agreed upon target of 10,000 is therefore used as a reference point. The same target was used across all benefit estimations.²⁰

No fulsome economic valuation of the white sturgeon in the Columbia River system has been undertaken. The use of benefit transfer methodology represents an initial look at this iconic species, but it excludes benefits that I simply could not measure or estimate. First, these estimates do not include the connection between white sturgeon and tribal culture. The United States portion of the Basin is comprised of fifteen tribal nations who all share a dynamic relationship with white sturgeon. These values are extremely difficult to quantify and measure, and I am unable to undertake the sort of detailed study that a meaningful estimate requires.

Methodological limitations in the selected studies underestimate the value of white sturgeon as well. Because some of the studies used in my benefit transfers rely on contingent valuation surveys, any uncertainty of the original value is carried over to my analysis. Contingency valuations (see 'Stated Preference Method' in Table 6.1) most often rely upon willingness-to-pay (WTP) measures that identify the maximum amount an individual is willing to give up to procure a good or avoid an undesirable change. One disadvantage is that the WTP values are taken from one point in time, and thus do not reveal how residents' WTP shift with economic and social change. Moreover, WTP is based on varying and subjective circumstances. An individual's level of well-being can influence their WTP, and in turn this value could be an underestimate or overestimate. Differences in market conditions can also interfere with WTP measures. For example, the WTP to prevent a loss in water quality at a river where there are few substitutes would be greater than the WTP for avoiding the same loss at a river where substitutes exist (i.e. a clean aquifer). Thus, variation in the availability of substitutes can impact the magnitude of society's WTP to acquire a good or service. The way that a question is framed can also interfere with WTP measures.

²⁰ If better evidence is revealed in the future, estimation parameters could be changed easily to accommodate this information.

Finally, it should be stressed that economic valuation can ever only be one input into the decision process. With these methodological caveats in mind, contingency valuation and WTP are still useful estimators for the value that individuals and society place on specific goods and/or services. Even incomplete valuation not covering the full range of ecosystem services provides useful information for decision makers when compared with the benefits from conversion. The studies used in my analysis have been selected carefully, and any underlying methodological concerns are discussed in full.

6.3. Semi-Structured Interviews

Semi-structured interviews with academics and key stakeholders are used to gauge awareness of the value of white sturgeon and EGS. More generally, the interviews provide strength for policy options and insight on the trade-offs of potential policies.

Twelve telephone interviews were conducted in total.²¹ The same interview questions were used across all interviewees (see Appendix G). Participants were given the option to keep their identity, position, and organization confidential. Interview participants were selected based on their role and relationship to the Columbia River, Columbia River Treaty, and white sturgeon knowledge. A core group of participants were contacted after attendance at a recent conference²², whereas others were contacted using the snowball technique. Because of the small sample size, this sample is neither representative nor statistically significant. Despite this, interview results raise the urgency with which stakeholders on both sides of the border perceive the need to address environmental concerns and the loss of white sturgeon throughout the Basin.

²¹ Interviewees included government, NGO's, academics, fish and wildlife experts, and Basin residents on either side of the Columbia River.

²² The Columbia River Basin 2014 Conference in Spokane, Washington explored the future of the Columbia River by bringing together 320 participants from a wide representation of Basin perspectives and values.

Chapter 7.

Estimating White Sturgeon Ecosystem Goods & Services

If white sturgeon are effectively protected to reach the sustainable target (i.e. 10,000 fish) used in this study, the total valuation of goods and services provided by white sturgeon in the U.S. portion of the Columbia River Basin are outlined in Table 7.1. Quantitative results indicate the potential magnitude of benefits in restoring the white sturgeon fishery.²³ Each of these benefits contributes to the standard of living and experiences enjoyed by people living in the U.S. portion of the Columbia River Basin. Notwithstanding the methodological and data limitations discussed in Chapter 6, the benefit estimates for white sturgeon serve as a rough proxy for the potential value of other EGS located within the Columbia River Basin. While benefit estimates here provide an example of how to measure societal values of a particular species, a more thorough and first-hand valuation of EGS is necessary. As such, these estimates are a starting point for future work on the benefits provided by white sturgeon and natural capital in the Basin.

Benefit estimates in my study illustrate that white sturgeon in the U.S. Columbia River Basin generate substantial value if protected. Estimates imply that the value of the Columbia system in providing habitat to sturgeon is high and should receive greater consideration in public policy decisions concerning the River's resources. This chapter discusses white sturgeon benefit estimation results in greater detail.

²³ For reporting purposes, dollar figures are rounded to the nearest million or, for smaller figures, rounded to the nearest hundred thousandth or thousandth.

Table 7.1. Economic Value of White Sturgeon EGS ²⁴

| Benefit Values | \$/Year (CAD, 2013) |
|-----------------------|----------------------------|
| Meat | \$51 million |
| Caviar | \$127 million |
| Recreational Angling | \$0.053 million |
| Existence | \$1,200 million |

7.1. Recreation

The annual value of recreational angling in the United States portion of the Columbia River Basin was \$53,000 in 2011 (expressed in 2013 Canadian dollars).²⁵ This value is defined as the recreational users' minimum willingness to pay (WTP), in addition to travel expenses, to catch white sturgeon in the Columbia River Basin. In this case, recreational fishers have an individual WTP that is equal to or greater than what they actually spend. Given the level of enforcement on white sturgeon angling, the value derived is based on data for steelhead anglers in the Basin. Although white sturgeon are unique, steelhead display similar biological traits (e.g. they are both anadromous and bottom feeding species) and serve as a proxy for sturgeon for benefit transfer calculations. As a result, the estimated benefit may be an underestimate of the benefits of white sturgeon recreational angling. Because steelhead can be accessed more readily in the River, it would likely cost white sturgeon anglers more to locate sturgeon fisheries. Moreover, the value obtained for recreational angling is conservative as it does not account for capital costs on equipment used to fish.²⁶ Because of the size and strength of white sturgeon, sturgeon anglers require good quality, heavy-duty fishing gear. In this case, the cost of trip related expenditures may be greater than indicated for steelhead.

²⁴ Reported values reflect a target stock of 10,000 white sturgeon (see Chapter 6).

²⁵ The annual recreational value was obtained from the United States National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (2011).

²⁶ Expenditures on specific equipment (i.e. a fishing boat) were not included due to uncertainty on whether these costs represented a one time cost or a cost incurred for multiple trips.

Nevertheless, if population levels improve sufficiently for white sturgeon, this will lead to an expansion of recreational angling opportunities and economic impacts in the Columbia River region.²⁷ For more information refer to Appendix H.

7.2. Food

Two market values are computed for the provision of food provided by white sturgeon: meat and caviar. Benefit estimates of white sturgeon meat represent an annual value of \$51 million.²⁸ This value signifies the ex-vessel price of white sturgeon meat in 2013.²⁹ White sturgeon caviar amounts to an annual value of \$127 million in 2013.³⁰ Moreover, given the significant value attached to white sturgeon meat, the values found are underestimates if poaching is considered.³¹ In the 1990's, officials uncovered a poaching ring in Washington that had harvested roughly 2,000 Columbia River white sturgeon for caviar at an estimated market value of \$2 million (Cohen, 1997). More recently, five recreational anglers were fined a total of \$22,500 under the Fisheries Act in B.C. for poaching white sturgeon (Vancouver Sun, 2009). Earlier this year, in an effort to stop white sturgeon poaching, B.C.'s environment ministry closed night fishing on the Fraser River (CBC News, 2015). In accordance with the ministry of environment, a poacher can receive fines anywhere from \$1,000 to \$100,000 and/or one year in prison for offences related to the killing of white sturgeon. Notwithstanding these considerations, the values obtained for sturgeon meat and caviar serve as a rough proxy

²⁷ Recreational angling can elicit economic impacts through purchases that initiate cash flows having direct effects on businesses, income, tourism, and employment in economies of the region.

²⁸ This figure was converted from U.S. dollars per pound (2013) to Canadian dollars per kilogram using the exchange rate from January 7, 2015.

²⁹ Ex-vessel values represent the price fishers receive from selling their catch. The annual ex-vessel value of white sturgeon was obtained from the National Oceanic and Atmosphere Administration (2013).

³⁰ Due to limitations in the literature, this value was computed using market price per kilogram. Without incorporating processing and operating costs for caviar production, the value of caviar represents an overestimation of benefits.

³¹ Basic biological characteristics render white sturgeon especially vulnerable to illegal exploitation, especially because stocks have already been damaged by overfishing, dam construction, and pollution (Cohen, 1997). While only mature sturgeon can reproduce (each decade on average), those are the fish that are coveted among poachers (Sugiyama, 2009).

for benefits received by fishers, the commercial fishing industry, and consumers. For further information refer to Appendix H.

7.3. Existence

Society's choices for acquiring market and non-market goods or services are expressed through individuals' willingness to pay (WTP). An increase in an individual's well-being, utility, and welfare can be measured by the maximum amount of dollars that he or she would be willing to forego to obtain a change in environment (Pearce et al., 2006). Moreover, the magnitude of WTP and existence value depends upon the individual's socioeconomic characteristics, the amount of the valued good available, and the availability of close substitutes for the good. The existence value expressed in this study represents the amount individuals are willing to sacrifice to protect and maintain the existence of white sturgeon even if they do not intend to directly benefit from it.³²

The WTP to preserve its existence and increase white sturgeon populations in the Columbia River Basin is an estimated \$1.2 billion. To preserve the existence and increase the number of Columbia River freshwater fish, Layton, Brown and Plummer (2001) found WTP per household to be \$180 per year.³³ This value was converted into an annual figure and multiplied by the estimated number of households in the Columbia River Basin.³⁴ Due to the limitations discussed in Chapter 6 and the broad nature of the question posed to participants, the WTP may be overestimated.³⁵ However, while this annual payment is considerable, it shows consistency with other existence and

³² Motivations could vary to include either having a feeling of concern for threatened/ endangered sturgeon or a stewardship motive whereby the valuer feels responsibility for sturgeon.

³³ Individuals' WTP was represented across 1,917 Washington state households. Randomly selected respondents based their WTP on knowing that Columbia River freshwater fish would continue to decline over the next 20 years at the same rate they declined over the previous 20 years.

³⁴ An estimated number of households living along the United States portion of the Columbia River Basin is derived from United States Census (2010).

³⁵ Respondents based their WTP on all freshwater fish as opposed to sturgeon alone. Freshwater fish are those that spend some or all of their lives in fresh water, such as rivers and lakes. White sturgeon are represented within this group, being the largest freshwater species in North America.

preservation studies. For example, in focusing on the Monongahela River, Desvousges et al. (1983) found \$196 annual WTP. Correspondingly, Hanemann et al. (1991) study of WTP to increase salmon in the San Joaquin River elicited \$415 annually. Aside from the methodological and data limitations mentioned in Chapter 6, WTP from Layton et al. (2001) serves as a proxy to preserve the existence of Columbia River white sturgeon. Because no fulsome economic valuation of the white sturgeon in the Columbia River system has been undertaken, this value should be taken with caution and interpreted as an estimate of the potential benefits provided by the existence of white sturgeon. The increase in white sturgeon populations could enhance existence values to residents along the River from knowing the resource is available regardless of whether one intends to directly benefit from it.

7.4. Cultural

White sturgeon contribute to communities along the Columbia River through cultural services, delivering spiritual and aesthetic benefits. Quantifying these benefits is extremely difficult; however, they can be approximated by measuring the expenditures on education, scientific research, and conservation efforts. Cultural services provide humans with meaningful interaction with nature such as learning about white sturgeon through science and education. While the annual benefits attached to white sturgeon education programs is not represented in the total economic value quantified in this study, their cultural significance is discussed to highlight what these benefits could be. The value of funds allocated by agencies in the United States portion of the Basin to white sturgeon conservation and public education and information programs is used to illustrate the cultural benefits provided by white sturgeon if they could be quantified.

Approximately 4 percent (\$9.5 million) of annual Fish and Wildlife program expenditures of \$246 million in 2012 were directed towards white sturgeon conservation in the Columbia River (Northwest Power Conservation Council, 2013a). Importantly, these costs do not include other sturgeon-related work funded privately including the Public Utility Districts and Idaho Power Company. For instance, in 2013, the United

States Army Corps of Engineers dedicated \$98 million to Columbia River fish mitigation in Washington, Oregon, and Idaho.³⁶ Similarly, in 2012, Bonneville Power Administration (BPA) invested \$450 million across the U.S. portion of the Columbia River to mitigate and address the impacts of federal dams and provide fisheries education through public information programs (Bonneville Power Administration, 2013). For the 2013 fiscal year, Bonneville's fish and wildlife costs totaled approximately \$682 million (Northwest Power Conservation Council, 2015). While these numbers do not directly correspond to white sturgeon populations, they reveal authorities minimum willingness to pay to protect and preserve resident species in the River. Expenditures made by BPA have been interpreted as actions illustrative of society's value to these services (National Academy of Sciences, 2004). Resident species in the River are linked closely to the social and cultural heritage amongst residents in the Pacific Northwest. Yet, while expenditures for fisheries education and conservation in the River could underestimate the value held by society for fish in the River, they could also be overestimates because through their expenditures, authorities inform individuals (who may not have known otherwise) how important fisheries are.

7.5. Business as Usual

Without intervention, the benefits provided by white sturgeon will be substantially reduced. At roughly 1,500 to 2,000 white sturgeon currently in the mid-lower portion of the River, the benefits provided by white sturgeon are far below the potential benefits of having a sustainable benchmark population of 10,000. Under current stock levels, benefit estimates of white sturgeon meat fall from an annual value of \$51 million to \$20-25 million, while benefit estimates of white sturgeon caviar fall from \$127 million to \$10 million. Without addressing white sturgeon stressors and biological needs, population levels throughout the River will continue to diminish eventually reducing benefits to zero. Decision-makers with access to information on goods and services provided by sturgeon

³⁶ Money spent is used to fund projects that restore the Columbia River velocities and depths to levels similar to those prior to river alterations and provide the access to historic spawning reaches. The United States Army Corps of Engineers have identified the eight hydroelectric projects on the Columbia as major contributors to the mortality of downstream migrating fish (United States Army Corps of Engineers, 2013).

are better placed to make efficient, cost-effective and equitable choices, ensuring benefits last long into the future.

Chapter 8.

Perspectives from the Basin

The semi-structured interviews complement the quantitative results. Semi-structured interviews uncover multiple themes to be considered in this study. First, the interviews reinforce the significance of goods and services provided by white sturgeon to the River and its communities and strengthen background research on stressors affecting white sturgeon in the Basin. Second, interviewees highlight potential actions to protect white sturgeon and ecosystems within the Columbia River. Third, several barriers inherent with the Columbia River Treaty were identified and key considerations for policymaking were revealed. The following is a brief summary of the themes, perspectives, and opinions represented across interviews. A full summary of the interviews is included in Appendix I.

8.1. White Sturgeon Ecosystem Goods and Services

- The concept of natural capital is recognized by various stakeholders in the Basin; economic valuation is regarded as necessary for ecosystem function to be integrated into Basin management.
- White sturgeon occupy strong cultural values especially among Tribal First Nations in the Basin. White sturgeon are historic, iconic, and spiritual species that are fundamental to residents' well-being.
- White sturgeon have a unique value among anglers. No other substitute for white sturgeon exists in the Pacific Northwest.
- Policymakers lack knowledge regarding services provided by fish and wildlife and their value to humans. With a heightened level of awareness of ecosystem services and its relation to the River, substantive policy changes could occur.
- Participants felt that if a dollar value wasn't assigned to sturgeon, the default would be zero, which could impair any potential changes to the Treaty.

- Research and data gaps impede policy development for white sturgeon protection and population remediation.
- The best approach in the interim is to exercise precaution in order to conserve the species and their role within the broader river ecosystem, while mitigating negative effects of hydropower operations on sturgeon and their habitats.

8.2. Treaty Framework Barriers

- The Columbia River Treaty was created in sole focus of flood control and hydropower generation with larger ecological issues not addressed, and changed the River's hydrograph.
- Treaty prioritization of hydropower and flood control undermine the ability of entities of the Treaty to rely on Canadian storage to meet domestic obligations related to fisheries conservation.
- While non-Treaty dams have affected the migration of various fish, the operation of these dams affects fish runs in both countries and thus, should be addressed consistently and collaboratively.

8.3. Challenges to an Ecosystem Based Treaty

- All participants indicated institutional, political, and stakeholder inclusion as the main bottlenecks to incorporating ecosystem health and white sturgeon needs into the Treaty.
- Building structures outside of the Treaty to address ecosystem needs in the Basin is difficult and requires continued and effective leadership. Because regional strategies lack durability, the Treaty shows more promise.
- Several participants express the need to broaden representation of interests in Treaty decision-making.
- Ecological literacy among Basin residents is a barrier to incorporating ecosystem health into the Treaty.

8.4. Policy Considerations³⁷

- The majority of participants asserted that policymakers should both modernize the Treaty to include ecological considerations and implement adaptive governance within its framework.
- Many felt that individuals on both sides of the border now place greater value on natural resources and that the Treaty should be modernized to reflect this change.
- While flood control is coordinated in the Basin, drought responses are not. The Treaty should incorporate climate change adaptation to address drought and the impacts of low summer flow to water users and aquatic ecosystems.
- An IWRM committee will facilitate information sharing, increase research efforts, and fill gaps in understanding on ecosystems and white sturgeon populations.
- Adaptive governance could serve to bridge identified differences between Canada and the United States on the treatment of ecosystem values.

³⁷ The main policies presented to interviewees for consideration included: treaty modernization, transboundary watershed group, integrated water resources management committee, and adaptive governance.

Chapter 9.

Criteria & Measures

The overall goal for any policy chosen to mitigate the decline in white sturgeon populations is the preservation of natural capital in the Columbia River Basin. With this goal in mind, the criteria and measures were developed *a priori* to evaluate policies for the white sturgeon, and also lend themselves to a more fulsome analysis of ecosystem goods and services in the Columbia River Basin.

This section introduces the policy objectives to consider when analyzing and developing the policy alternatives in Chapter 10. It outlines the criteria and measures that provide the analytical foundation from which to evaluate the tradeoffs of the policy alternatives for government (described in Chapter 10).

9.1. Criteria

The criteria used to evaluate policy options are: flexibility, ease of implementation, equity, and effectiveness. Each criterion scores high (3), medium (2) or low (1) based on the given measures (see Table 9.1). For a comprehensive description of each criterion refer to Appendix J.

Table 9.1. Criteria Matrix

| Policy Objective | Criteria | Measure |
|--------------------------------------|--|--|
| <i>Flexibility</i> | Could the policy adapt to scientific developments and changes in the future? | Degree to which decision-makers can alter their approach in the future as scientific knowledge improves |
| <i>Ease of Implementation</i> | Level of institutional inertia faced by policy | The expressed (official) positions from Canadian and U.S. governments and the extent to which the policy will be politically feasible/supported by Canada and the United States |
| | Will the policy be well-received by stakeholders/accepted by the public? | Amount of Industry, First Nations, and community acceptability of the policy Anticipated public feedback on the policy proposal; experience with similar policies in the past or in other jurisdictions |
| | Administrative complexity | The degree of administrative complexity required to implement the policy |
| <i>Equity</i> | Intergenerational equity | The degree to which future costs and benefits are distributed |
| | Transboundary equity | The distribution of economic and social impacts to the U.S., Canada, and communities along the River |
| <i>Effectiveness</i> | Short- and long-term sustainability of white sturgeon population | Probability of sustained protection in the long-term versus temporary security |
| | Effectiveness of responding to white sturgeon stressors | The impacts on the vulnerability of white sturgeon and resiliency |
| | Benefits of protecting white sturgeon | Economic benefits of white sturgeon conservation Impact on white sturgeon EGS |

Chapter 10.

Rescaling Governance: Policy Options

This chapter discusses the policy options identified in my research. Viable policy options must account for the barriers and impacts to white sturgeon highlighted in the literature, while also ensuring the benefits flowing from the goods and services provided by white sturgeon are not lost. The options described below are nonexclusive, and aim to improve the governing structure of the Columbia River Basin to better protect and preserve natural ecosystems (represented here by impacts to white sturgeon).

10.1. Option 1: Adaptive Governance

Adaptive governance involves testing and evaluating projects wherever possible to allow adjustments in the face of changing conditions and uncertainty. Adaptive governance not only includes monitoring how ecological or physical systems respond to operations, but also identifies what options are available, what outcomes are desired, the level of risk, and how to choose among alternative actions. This approach has been applied by the International Joint Commission (2014) to harmful algal blooms and hypoxia impacting ecosystems in Lake Erie. Through the use of transitional targets, the Lake Erie adaptive management focuses on the uncertainty surrounding recommended measures for reducing nutrient loads to the lake and its tributaries.

For the purposes of this study, adaptive governance is defined as operating within the Columbia River Treaty and requires amendment to its structure and operations to expand its scope to incorporating new knowledge, uncertainties, and values. Thus, this policy option involves changing the existing framework to incorporate

adaptive governance and gives Treaty entities the necessary precaution and flexibility to respond to uncertainty in the Basin and operational impacts to ecosystem health.³⁸

10.2. Option 2: Treaty Modernization

This alternative speaks to objectives of the current Treaty and suggests including ecosystem function as a distinct goal that is given equal standing alongside hydropower and flood control. Adding ecosystem function to the Columbia River Treaty has materialized in the literature over recent years and was also discussed throughout conversations with interviewees (Bankes & Cosens, 2012). Generally, the motive for implementing ecosystem function is to protect, enhance, and conserve white sturgeon, lower negative environmental impacts for the sturgeon, and/or ensure intergenerational interests are met so that the ability of future generations to receive both non-market and market benefits from the white sturgeon are ensured.

This option builds on the status quo by adding a new section to the Treaty explaining ecosystem function as a third purpose alongside hydropower and flood control. Although including ecosystem function in the Treaty could lead to basin-wide ecosystem remediation, the scope, management, and definition of ecosystem function will be defined by Treaty entities. While both entities of the Treaty include environmental goals within their respective governmental mandates,³⁹ the Treaty implemented by the entities is silent on environmental objectives. Including ecosystem function as a third purpose into the Treaty will ensure that Treaty entities are held legally accountable in meeting their mandate. In doing so, entities would establish broad principles and formulate clear objectives and thresholds for the management of ecosystems, hydropower, and flood control in the River. Because current sturgeon recovery efforts

³⁸ While the Columbia River Treaty provides a framework for addressing high flow, it does not address low flow under a climate change scenario. A future water supply that is outside the historic water supply regime could have impacts to ecosystems. Adaptive governance would provide Treaty entities with the necessary precaution and flexibility to respond to uncertainty under future climate change scenarios in the Basin.

³⁹ BC Hydro, U.S. Army Corps of Engineers, and Bonneville Power Administration all include environmental principles within their governmental mandate. While each of these bodies must meet their mandates, failing to meet set government objectives renders the entities deficient.

have been undermined by fragmented jurisdictions and laws, creating an ecosystem purpose into the Treaty could lead to a clearly defined collaborative strategy among both countries. Thus, this option involves modernizing the Treaty.

10.3. Option 3: Transboundary Watershed Group

This option pertains to the creation of a transboundary watershed group to facilitate dialogue, information and data sharing, transboundary research, priority and objective setting, action plans, advisory, and monitoring across the Columbia River Basin. This option assumes that the group would create an information network for sharing data and setting standards, and would operate outside of the formal Treaty framework. This would support the sharing of knowledge and best practices across borders and jurisdictions and help smaller communities make cost-effective and informed choices related to the River.

This new organization would function from the bottom-up and operate outside the Treaty to advise Treaty entities and provide oversight to the entire Basin through bilateral collaboration. The new committee would be comprised of First Nations tribes, academics, NGO's, residents, private sector companies, and a multidisciplinary team of experts specializing in various areas related to governance of the River. For example, experts could include biodiversity and ecosystem specialists, climate scientists, and/or fisheries biologists. To establish its formal mandate, the group could begin with a consultative phase to identify pressures on the Basin's ecosystems and scenarios for ecosystem enhancement. A priority of this phase could involve arriving at a shared overarching vision on how both Canada and the United states can better manage the River to support ecosystem function. A shared vision would identify ecosystem objectives and measures of success for Treaty authorities to consider. This group would then meet each month to review plans and objectives and share feedback, academic reports, needs, and concerns that arise over the state of the Basin. Thus, this would create collaboration among users of the River to create a unified vision for ecosystem function and basin-wide framework for addressing watershed management that Treaty authorities could use. The group would review science-based reports together with other

relevant information (e.g. risk and uncertainty assessment), and make recommendations to the Treaty.⁴⁰

10.4. Option 4: Integrated Water Resources Management

Integrated Water Resources Management (IWRM) reflects the “coordinated development and management of water, land, and related resources to maximize the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Roy et al., 2011, p 8). Further, IWRM goes beyond managing water resources within political boundaries and instead operates at a watershed level, often requiring both regional and local stakeholder cooperation to do this. Recognizing the economic benefits of managing water and related natural resources, IWRM understands the value in ecosystem services and how EGS valuation is a practical way to achieve both IWRM goals and additional benefits (Roy et al., 2011). As population on both sides of the River continues to expand in the context of a changing climate, pressures on water resources will grow, requiring the need for an integrated approach to managing these resources is now increasingly being recognized within and across federal, provincial, and state jurisdictions. Ultimately, the move is towards improved governance, integrated management, better data and information, greater transparency and accountability, stakeholder involvement, and clear goals and results. An IWRM framework has been applied to cases such as the Danube River Basin, the St. Lawrence, and the Yakima Basin where transboundary conflict over navigational rights, water supply, agriculture, hydropower, and water quality figured heavily in cooperatively managing the natural resources.

⁴⁰ This approach has been applied by River’s Without Borders (RWB), a distinct transboundary watershed group operating strategically across the Alaska–British Columbia border (RWB, 2015). Holding a shared vision between both sides of the border, RWB’s is guided by a bilateral team from Alaska, British Columbia, and northwest Washington. The group works to protect and promote declining salmon populations, ecology, wildlife and marine habitat, and cultural values of the transboundary watersheds.

This option would establish a separate and distinct IWRM committee stemming from the Treaty. As mentioned, institutional barriers currently prevent management from treating the Basin as a whole. Over time, the Basin has been managed by multi-layered political structures on both sides of the border to deal with water resources and sturgeon health. Intergovernmental relations have provided an opportunity for collaboration between levels of government and between nations; however, it has also led to constitutional ambiguity, overlapping jurisdictions, and incremental benefits in protecting sturgeon. Moreover, due to the number of organizations involved in dealing with the Treaty and the Columbia River, inertia limits the ability for sturgeon and, more broadly, ecosystem conservation. Parties of the Treaty could agree to the adoption of an addendum to include IWRM across the Basin through efforts of a designated IWRM committee. The goal of the committee would be to align government management and create engagement and participation between nations, levels of government, and First Nations that hold a stake and jurisdictional mandate to address sturgeon and environmental health in the Basin.

Chapter 11.

Analysis of Policy Options

While each policy option has its strengths and weaknesses for addressing the remediation of white sturgeon populations, the most desirable policy option is the one with the best performance on the criteria and measures from Chapter 9. Each option is ranked based on a scale of high, medium, and low. In each case, a ranking of 'high' reflects the policy's desirability relative to the other options, indicating it scores highly against the established criteria.

11.1. Option 1: Adaptive Governance

| Flexibility | Ease Of Implementation | Effectiveness | Equity |
|-------------|---------------------------|---------------|--------|
| High | Medium | Medium | Medium |

Flexibility

Flexibility promotes the underpinnings of adaptive management and thus scores highly with Option 1. Incorporating adaptive governance directly into the Treaty provides authorities with sufficient flexibility to adapt operations to support white sturgeon conservation as knowledge, data, and science develops and increases. For instance, a stock assessment of white sturgeon was started in 2013 to estimate the number of white sturgeon in the River between Hugh L. Keenleyside and Grand Coulee Dams (Nelitz et al., 2007). This study represents the first basin-wide estimate for this population and will be used as a baseline for recovery planning. Because the stock assessment will be complete in 2017, Treaty authorities could incorporate this new information into Treaty operations and planning through integrating adaptive governance into its overarching framework. Moreover, as stocks of sturgeon trapped behind dams depend on a different

set of habitat conditions, managers can look at differences in reproduction, growth, and survival and in turn regulate population size and species productivity.

While the structured objectives of the Treaty will remain in place, adaptive governance would enable entities in British Columbia and the United States to maneuver around these goals to revisit and reassess operations in relation to ecosystem needs as new information and changes occur in the Basin. For example, to improve conditions for white sturgeon during low-flow periods, experimental plans involving turbidity augmentation through the use of bentonite or other turbidity agents to the River have been proposed (BC Hydro, n.d.).⁴¹ Including adaptive governance within the Treaty would allow experimental work plans and feasibility studies to be conducted specifically as new information, regulatory concerns, turbidity agents, and associated fisheries and ecosystem effects arise. Because the present understanding of white sturgeon, their relationship to the ecosystem, and the EGS they provide is still limited, implementing rigid policies could be ineffective. Thus, the cyclical process of this policy results in knowledge accumulation, orientation towards risk, and reduced uncertainty.

Ease of Implementation

Adaptive governance may be deemed unacceptable by Treaty entities, leading decision-makers to encounter institutional barriers in its adoption to the Treaty. The stated position of both governmental entities on Treaty revisions (see Chapter 5) exposes the difficulty in incorporating adaptive governance to Basin management. Both British Columbia and the United States' positions on the Treaty make no explicit reference to adaptive governance; however, statements from the U.S. appear more open to the idea of incorporating ecosystem issues within its purview (Bankes & Cosens, 2014). The United States expresses the need for flexibility in responding to ecosystem function, a change in management priorities, or any future arrangements whereas British Columbia states that it seeks to “continue the Columbia River Treaty and seek improvements within the existing Treaty framework” (Bankes & Cosens, 2014, p 13).

⁴¹ Agents such as these can help during low flow periods when sturgeon eggs are hatching and larvae are undergoing their downstream drift phase, becoming vulnerable to predation.

Adaptive governance requires that the number of parties involved in governing the River be expanded to include experts and scientists from outside the Treaty. Expanding the number of parties involved in the Treaty could be burdensome, costly, and complex to manage. For example, monitoring and evaluating expenditures from adaptive management comprised roughly 30 percent of the Northwest Power Conservation Council's Fish and Wildlife Program budget (\$644 million) in the U.S. portion of the Basin (Northwest Power Conservation Council, 2014). If implemented basin-wide, these costs would undoubtedly increase. One benefit of this approach is that it offers more of a "bottom-up" solution than "top-down" government-driven approach; however it could be difficult to make progress in a system that includes more interests and players. Yet, if each party can see at least some benefit from a proposed adjustment to governance, change could occur. These changes could be perceived as complex and undesirable to authorities in the United States, and Canada in particular, which raises the question of whether there is sufficient political/institutional willingness to engage in amendments and continually adapt the Treaty to new science and information.

Interview feedback, conference dialogue, and academic literature all reaffirm the merits of adaptive governance.⁴² First Nation tribes, fish and wildlife experts, recreational anglers, and community residents along the River have all voiced acceptance for adaptive governance in the River (Spirit of the Salmon, 2014). Interviewees discussed the importance of continually having new dialogue and science to respond to and monitor white sturgeon health. Another interviewee expressed how mechanisms for public participation in adaptive governance enable those with a vested interest and cultural attachment to white sturgeon in the River to communicate this importance to decision-makers. Without the acceptance from the institutional entities to make the necessary changes to the Treaty, adaptive governance is unlikely to be implemented across the Columbia River, and thus increases the overall implementation complexity.

Effectiveness

The Northwest Power Conservation Council's (2015b) Fish and Wildlife program undertakes an adaptive approach and uses research and monitoring data to better

⁴² For domestic models of adaptive water governance, see Bankes & Cosens (2014).

understand how projects related to sturgeon are performing. While the effectiveness of this program remains to be evaluated, information will be evaluated to determine if projects and measures are having intended measurable benefits for sturgeon and their habitat. Similarly, implementing adaptive governance within the Treaty has potential to reduce the ecological risks for white sturgeon populations in the Columbia River. The ability of adaptive governance to continually monitor and assess the health of white sturgeon and respond to their needs as new information develops enables sustained protection across time. This principle would be of even greater value if implemented to monitor River ecosystems more broadly.

Despite the potential of adaptive governance to ensure the prudent management of natural capital, the framework in which adaptive governance is implemented by Treaty authorities could ineffectively place greater focus on the maintenance of economic interests. For instance, BC Hydro (n.d.) states that the financial costs involved with specific flow augmentation strategies for sturgeon impedes operational changes from occurring in the Basin. Thus, the Treaty's precaution over economic operations (i.e. hydropower) may take precedence over adaptive responses for resource sustainability, limiting the ability of adaptive governance to provide long-term security to white sturgeon (Nelson et al., 2008). To support the effective application of adaptive governance, clear objectives and values around ecosystem health should be built into the Treaty. A lack of uniformity demonstrated in case studies⁴³ points towards the importance of increased specificity in mandating, exercising, and assessing and adaptive exercises of power.

Equity

Responding to the needs of white sturgeon populations through adaptive governance could create impacts and trade-offs among water users in both countries. For instance, while flow augmentation is used as a strategy to optimize river discharge and velocity for sturgeon spawning, the social and economic costs associated with modifications in the hydropower system preclude changes in water allocation for sturgeon (Beamesderfer & Farr, 1997). Providing these flows means that power

⁴³ Case studies reveal variation in the definition, interpretation, and application of the principles of adaptive governance. Refer to Benidickson et al. (2005).

generation could be reduced during the winter as water is stored in reservoirs to ensure that sufficient water is available in the spring. Storing water at this time renders it unable to meet power needs, especially when needs are greatest. Thus, depending on the time of release, the cost associated with revenue losses from reduced power production, and costs of replacement power could be significant.⁴⁴ However, the extent of revenue loss and the distribution of impacts will be dependent upon Treaty objectives, goals, and focus on sturgeon. As identified in Chapter 5, B.C. foresees any changes to governance remaining within the current scope of the Treaty. Without this changing, adaptive governance would likely be implemented within the current scope of the Treaty, limiting any additional financial impacts to hydropower or other water users in the Basin.

If Treaty entities decided to expand their scope to include ecosystem health across the Basin, adaptive governance would enable authorities to analyze the differences in timing and volume of flow and to develop recommendations for using available water to optimize spawning conditions and redistribute and lessen impacts to water users within the Basin. The ability of adaptive governance to keep up with new science and information, while also conducting scenario modelling to locate optimal strategies, will help treaty entities find the best way to reduce impacts to affected Basin stakeholders. The continual refinement of operations will also enable impacts to be monitored and ameliorated. Understanding the economic benefits provided by white sturgeon and ecosystems in the Basin will also help decision-makers determine impacts and weigh responses appropriately. Finding solutions with equal impacts to both parties will be challenging, and thus, the Treaty's compensatory mechanism (known as entitlement benefits) will be vital for adaptive governance to meet equity requirements.

As white sturgeon and river ecosystems become continually monitored and assessed based on the best available science and data, adaptive governance would ensure that the sustenance of its population and EGS carry on into the future. In this way, individuals from future generations inherit the benefits provided by white sturgeon. Yet, it remains to be seen whether and to what scope adaptive governance would

⁴⁴ Costs estimate at approximately \$430 million annually in the United States (Vail & Skaggs, 2002).

provide a focus on sturgeon and broader ecosystem concerns, Option 1 scores moderately on equity.

11.2. Option 2: Treaty Modernization

| Flexibility | Ease Of Implementation | Effectiveness | Equity |
|-------------|---------------------------|---------------|--------|
| Medium | Medium | Medium | Medium |

Flexibility

Incorporating ecosystem function as a distinct goal into the Treaty is ranked as being ‘medium’ on flexibility. While Chapter 5 demonstrates the avenues to incorporate flexibility within the Treaty, it remains to be seen whether the inclusion of environmental protection will lead to greater flexibility in the Treaty’s operational plans for fish throughout the Basin or ecosystems more broadly. Even with the inclusion of ecosystem function in the Treaty, how entities define ecosystem function will determine the level of flexibility used to address sturgeon recruitment and biological needs. If ecosystem function is not explicitly defined, entities of the Treaty could assume different meanings, leading to miscommunication on operations and mandate.

The significance placed on hydropower and flood control by Treaty entities makes it unlikely that the Treaty could exercise a high level of flexibility. Given the constraints and need for flood control, the Treaty may not be able to tolerate a sufficient level of flexibility required for ecosystems to be enhanced in the Basin. Yet, in some instances this could be done. For instance, the Libby Coordination Agreement (see Section 5.3) allows the U.S. to operate Libby dam for sturgeon benefits such that there are power generation losses on the lower Kootenay River. To compensate for this, British Columbia will run other facilities, and is permitted to draw-down the Arrow Lakes Reservoir and exchange power with Bonneville Power Administration (Columbia Basin Trust, n.d.). Thus, in some cases, a balance between all three Treaty objectives could be struck.

Ease of Implementation

The implementation of ecosystem function into the Treaty as a distinct objective would likely lead to disagreement between the entities. In its recommendations for Treaty revisions, the United States proposes major revisions of the Treaty to explicitly incorporate ecosystem-based function as a third primary purpose of the Treaty (Bankes & Cosens, 2014).⁴⁵ By contrast, the view of the B.C. government is that ecosystem considerations can be accommodated in the current Treaty (Bankes & Cosens, 2014). While British Columbia is less likely to agree to the inclusion of ecosystem function in the Treaty, residents and communities along the River predominantly side in favour of balancing ecosystem needs with flood control and hydropower generation (CRTR, 2014). Although some Basin residents identify the trade-offs between the Canadian Entitlement and ecosystem gains,⁴⁶ overall, interviewees and stakeholders suggest an interest in consideration of ecosystem function as a third purpose of the Treaty (McKinney et al., 2010).⁴⁷

Incorporating ecosystem function into the Treaty will also require operational changes, additional experts and staff, new goals, objectives, changes to operating plans. While the complexity involved with these changes depends on the amount of weight

⁴⁵ Legal changes (i.e. Endangered Species Act, Northwest Power Planning and Conservation Act, and established Native American fishing rights) in the U.S. support fisheries conservation and provide incentive to the U.S. to modernize the Treaty. For example, in 1951, 1975, and 1991 the Colville and Spokane Tribes took legal actions against the U.S. government for the loss of traditional fishing. In 1994, partial agreement was reached with Colville Tribes receiving a lump sum of \$53million and \$15 million annually thereafter (Ortolano & Cushing, 1999). For information on legal constraints refer to Appendix F.

⁴⁶ These residents feel that if water flows at the border were altered to benefit ecosystems, less power would be generated both in Canada and in the U.S. and, ultimately, reduce the Canadian Entitlement. These Basin residents questioned whether the Province could afford the loss of Canadian Entitlement power or approximately \$100-300 million value it generates if the Treaty is changed.

⁴⁷ In 2013, a coalition of twelve environmental organizations formed the Columbia River Treaty Conservation Caucus. In alliance with fifteen U.S. Columbia River Tribes, the Caucus advocated for an updated Treaty that created ecosystem as a co-equal Treaty goal alongside power production and flood control (CELP, 2015c). Additionally, in May 2014, a declaration was signed calling for the inclusion of tribes and First Nations in the implementation of the treaty; balancing flows for healthy fish populations along with power and flood control; and managing flows to help people and ecosystems withstand a warming climate (Osborn, 2014). Taken together, stakeholders demonstrate strong support for modernization of the Treaty.

given to ecosystem function, modernizing the Treaty will entail added costs and operational changes. For example, the costs of altering operations at Mica dam, B.C., to provide environmental benefits for fish range between \$16-25 million per year depending upon the operational scenario (CRTR, 2012); the River's U.S. counterparts cite \$152 million in forgone hydropower revenue resulting from dam operations to benefit fish (Northwest Power Conservation Council, 2014). In some of these cases, the costs acquired were judged too high to undertake ecosystem remediation. Yet, given the level of management complexity, disagreement between entities, and the reasons above, Option 2 scores low on the ease of implementation.

Effectiveness

Option 2 scores moderately on effectiveness. Similar to its implementation scoring, the effectiveness of Option 2 is highly reliant on how ecosystem function or health is weighted and defined within the Treaty. For instance, the US Regional Recommendation uses the term, ecosystem-based function but does not define it. In response, public comments on the Working Draft of the U.S. Regional Recommendation express difficulty in supporting the topic without a clear definition. It is therefore uncertain in this case which ecosystems would be given recognition and the level of flexibility exercised.

If defined clearly and prioritized with the other two objectives of the Treaty, this option could be effective at providing top-down and explicit acknowledgement for ecosystems and sturgeon in the Basin. Because current sturgeon recovery efforts have been undermined by fragmented jurisdictions and laws, creating an ecosystem purpose into the Treaty could lead to a clearly defined collaborative strategy among both countries. Including ecosystems into the Treaty framework would create legal and political commitments and binding objectives, allowing decision-makers to be held accountable by law for environmental issues and impacts. While both entities of the Treaty include environmental goals within their respective governmental mandates,⁴⁸ the

⁴⁸ BC Hydro, U.S. Army Corps of Engineers, and Bonneville Power Administration all include environmental principles within their governmental mandate. While each of these bodies must meet their mandates, failing to meet set government objectives renders the entities deficient.

existing Treaty is silent on environmental objectives. Furthermore, including ecosystem function as a third purpose into the Treaty will ensure that Treaty entities are held accountable in meeting their mandate. Making decision-makers accountable for ecosystem health then may translate into routine stock assessments and sustained environmental protection. Yet, given British Columbia's opinion on ecosystem function and the weight placed on hydropower and flood control by authorities of the River, it is unlikely that a broad scope will be applied holistically toward ecosystem function. Hence a limited scope will prevent authorities from identifying and responding to the variety of impacts affecting ecosystems, accessing new science and information, and ultimately, limiting their ability to provide long-term security to white sturgeon in the Basin.

Equity

The addition of ecosystem function in the Treaty does not mandate cooperation between the two parties or flexibility on how ecosystem impacts will be received and distributed on either side of the border. For instance, British Columbia suggests that the party responsible for disrupting the passage of migrating fish should bear the costs of restoration measures within its jurisdiction rather than such costs being shared (Bankes & Cosens, 2014). Thus, while ecosystem function would become a designated priority of the Treaty and work towards environmentally favourable impacts in both jurisdictions, Option 2 provides little flexibility or adaptability in managing impacts to strategize win-win or less costly scenarios to meet equity concerns, leading to considerable costs, disagreement, and a potential stalemate between the parties. Moreover, while the Treaty's established compensatory mechanism (entitlement benefits) will help meet equity requirements, its use is compromised by the lack of flexibility and disagreement between parties on costs and compensation. For example, the B.C. government states that the level of benefits to the province, in the form of the Canadian Entitlement, does not account for the full range of benefits in the U.S. or impacts in its own region (BC Ministry of Energy and Mines, June 25, 2013). If ecosystem function is incorporated into the Treaty, entities of the Treaty would need to clarify the compensation model to reflect

the magnitude of benefits and costs associated with operational changes, environmental flows,⁴⁹ and EGS.⁵⁰

Intergenerational equity concerns could be effectively addressed by Option 2. The specific designation of ecosystem function within the treaty will impose a commitment on both parties to address impacts to the environment and ecosystem needs. This could translate into sustained conservation efforts long into the future, making it less likely that generations in the future will be negatively impacted. However, similar to effectiveness and implementation criteria, much hinges on the structural details and adds significant uncertainty. If either party cannot work cooperatively to address environmental concerns, this will severely impact future generations along the River. Due to this assessment, Option 2 is ranked ‘medium’ on equity.

11.3. Option 3: Transboundary Watershed Group

| Flexibility | Ease Of Implementation | Effectiveness | Equity |
|-------------|------------------------|---------------|--------|
| High | High | Medium | High |

Flexibility

Option 3 operates outside of the Treaty, allowing it to be removed from the rigidity of the Treaty and increasing its level of flexibility. By creating a broader setting for learning, collaboration, and discussion, this committee would serve as a means to help provide better cohesive management and reduce uncertainties to the River. As new information, concerns, and science are brought forward and shared by members of the group, the committee can adjust objectives and operation plans for Treaty authorities to

⁴⁹Environmental flows indicate the quantity, quality, and timing of water flows required to sustain freshwater ecosystems and the benefits therein.

⁵⁰The potential for high legal costs related to environmental legislation and Native American fishing rights could incentivize the U.S. to negotiate an alternative payment scheme for ecosystem services. This could include direct payments (such as payment for ecosystem services) from the U.S. to Canada for environmental services in the form of natural flows for fisheries conservation. For information on payment for ecosystem services refer to Roy et al. (2011).

review and consider. Regular meetings enable the committee to discuss the status of the Basin, while also allowing the cumulative impacts and uncertainties of management decisions to be considered, understood, and exchanged between nations and stakeholders. For these reasons, a transboundary watershed management committee scores high on flexibility.

Ease of Implementation

Creating a committee to consolidate information, provide oversight, and advice to Treaty entities would be less complex to implement than options requiring amendments to the Treaty. Despite the unlikelihood of Treaty authorities directly implementing plans offered by the group, the group would continue to operate, enhance collaboration, raise awareness, and strategize remedial efforts to areas of need across the Basin. While the formation of the committee would involve assembling and organizing stakeholders across the Basin, the creation of unified goals and objectives, and the establishment of funding for the committee, the willingness of parties makes this option viable.⁵¹

Dialogue at a recent conference transpired about the possibility of a committee to address transboundary challenges, with the Columbia Basin Trust and Northwest Power Conservation Council (NPCC) being nominated to take the lead on creating and funding the committee.⁵² Both organizations responded favourably to this request and have organized a bilateral forum this year to discuss the opportunity further (Lake Roosevelt Forum, 2015). Collective action could also help to reduce cost and individual spending on fish and wildlife protection in the Basin. If the efforts and funding by various parties

⁵¹ The Columbia River Basin 2014 Conference in Spokane, Washington explored the future of the Columbia River by bringing together 320 participants from a wide representation of Basin perspectives and values. Consensus among participants stated that a transboundary watershed group should be established. Both the Northwest Power Conservation Council and the Columbia Basin trust worked extensively to conduct and co-chair this conference. For information refer to <http://columbiabasin-2014conference.org>

⁵² Discussion on this option was held at the Columbia River Basin 2014 Conference in Spokane, Washington. The Columbia Basin Trust was created by the Columbia Basin Trust Act in 1995 to provide benefits to the Canadian region most adversely affected by the Columbia River Treaty. Total provincial funding has been \$353 million (Davidson & Paisley, 2009). The Northwest Power Conservation Council is charged with balancing environmental protection and the energy needs of the U.S. region. The Fish and Wildlife Program developed by the Council is funded by ratepayers (Davidson & Paisley, 2009).

were combined into collaborative action, over time, enhanced protection could reduce spending on ecosystem remediation through economies of scale.

Public feedback on the possibility of a transboundary group is mostly positive. In 2012, public consultation in British Columbia found that many residents expressed a desire for greater transboundary collaboration to enhance ecosystem function at the basin level (CRTR, 2012). Various interviewees and recent conference attendees also stated that the prospect of a transboundary group would be extremely beneficial but reliant on strong leadership and stable funding. Others stated that a transboundary committee was important toward building a common knowledge base, connecting fish and wildlife recovery efforts and, ultimately, facilitating a unified transboundary population of white sturgeon. The interest in discussing governance of ecosystems, fish, and wildlife across the Basin is strong. The level of implementation ease involved with this option leads to a 'high' ranking.

Effectiveness

A transboundary committee scores moderately on effectiveness. This option would explicitly widen the scope of ecosystem function in the basin towards a transboundary ecosystem perspective. The impacts to white sturgeon can be identified and addressed cooperatively through shared goals, objectives, new knowledge and science, and the continual monitoring and refinement of operations and stock assessments. Cohesive management and the integration of a multidisciplinary team of experts, academics, and stakeholders working across the Basin could help to fill research gaps regarding ecosystem loss and lead to long-term protection of sturgeon populations, a reduction in vulnerabilities, and the preservation of benefits provided by white sturgeon populations.

Option 3 also enables communication to ensure that countries understand and learn from impacts to sturgeon and ecosystem changes in both regions of the River. For instance, in 2013, the U.S. entity representatives stated that they were unaware of ecosystem issues in Canada and therefore these issues had not been considered in their recommendations regarding ecosystems (CRTR, 2013). Because sturgeon have become spatially segregated groups of fish, the identification of genetic differences

across the Basin through Option 3 offers the opportunity to bilaterally examine the presence of differences between groups, as well as a means to collaboratively develop hypotheses regarding the contribution of environmental and genetic factors that affect sturgeon growth patterns (Poorten & McAdam, 2010). The group could also conduct environmental impact assessments, scientific, academic, and economic analyses to inform authorities for decision-making purposes. To ensure awareness across the Basin, the group could also establish a natural capital database⁵³ created in partnership between nations and continually assessed by the group in terms of ecosystem health, function, and quantity. A transboundary group could effectively ensure that the current patchwork of Basin governance is smoothed out and consistent across the River to reconnect white sturgeon populations into one group. Moreover, sharing knowledge and information between nations will help to keep each country informed.

Despite its ability to be highly effective, Option 3 is compromised by the possibility of Treaty entities being less willing to adopt the committee's proposed plans. Because the committee would have no legal standing within the Treaty, the Treaty would have no obligation to implement its recommendations.

Equity

Option 3 scores 'high' for its equity impacts. Overall, a transboundary group would foster a cooperative environment, enable interested parties to participate in dialogue, and ensure ecosystem protection and remediation is done through a collaborative effort on both sides. From a basin-wide perspective, a transboundary committee could assess and monitor projects, stressors, and ecosystem health to restore the natural resilience in the Columbia system. The committee can respond to white sturgeon needs and ecosystem health of the River so that sturgeon can also be supported by the ecology of the River. Doing this will allow future generations to experience the benefits provided by the River.

⁵³ Established international collaboration between Environment Canada, the U.S. Environmental Protection Agency, and the U.K. Ministry with environmental responsibilities has resulted in the development the EVRI system. As a searchable database, EVRI provides economic values of environmental benefits for researchers to access. While EVRI contains 1,600 study entries, further research still remains. Refer to www.evri.ca.

Through cooperation, a transboundary group would respond to stresses by understanding each country's interests and assist with the mutual utilization of the River. Under this mutually beneficial framework, the effects of any proposed decision by the group will be evaluated based on its impacts and repercussions to stakeholders so that equity is found whether it be through impacts or reimbursement. Projects aimed at facilitating white sturgeon function in the River would be evaluated in terms of impacts across the Basin and ability to provide the necessary resources for implementation. Regions that are unable to meet project goals could be aided in their efforts. While no formal mechanism for compensation exists within Option 3, its ability to exercise flexibility and engage in collaboration and cooperation between parties of the committee could lead to agreed forms of compensation. Given that Option 3 operates outside of the Treaty, this relieves decisions from directly conflicting with Treaty objectives and allows ensuing impacts and the distribution of impacts to be significantly reduced. Decision-makers concerned with equity issues can make a strong contribution to increasing social benefits derived from sturgeon and natural capital in the Basin.

11.4. Option 4: Integrated Water Resources Management

| Flexibility | Ease Of Implementation | Effectiveness | Equity |
|-------------|---------------------------|---------------|--------|
| Medium | Medium | High | High |

Flexibility

An IWRM framework provides an opportunity to collaboratively and bilaterally assess the River through all its thematic dimensions. The committee could coordinate development and management of the River across jurisdictions, levels of government, and First Nations. The committee's ability to create collaboration and partnerships between government and authorities will lead to well-defined priorities and facilitate greater opportunities for operational flexibility around shared goals to manage sturgeon and ecological objectives.

The IWRM committee would also have the necessary flexibility to collaborate with stakeholders outside of the Treaty. To accurately assess white sturgeon health and

related ecosystem problems in the Basin, the committee would continually collect and share information to evaluate measures taken and monitor programs aimed at preserving ecosystem services in the River. In doing so, an IWRM committee could continually readjust to accommodate changes in the Basin. The operational regime of the IWRM committee is meant to be flexible and adaptive; flows may change depending on storage available and water supply forecasts and needs. An IWRM committee would also address potential future changes in water needs or hydrology, including potential climate change effects.

In many cases, flexibility could also be challenging. Flexibility will be heavily dependent on the dynamics and composition of the committee. Crafting appropriate responses to Basin management means aligning and integrating administratively disconnected organizations to form alliances across all levels of government and First Nations governments (Morin & Cantin, 2009). Collaboration and adaptability among government and jurisdictions could be difficult to achieve and limit the level of flexibility exercised within the committee. While in theory IWRM has the potential to be a flexible process that can adapt to changing conditions and unique characteristics of watersheds, the uncertainty in its implementation leads it to score moderately on this criterion.

Ease of Implementation

Implementing this option is likely to be burdensome. Creating a committee under the Treaty would depend on the willingness of Treaty entities to set new goals and objectives, and would likely increase operational costs.⁵⁴ Because the committee would involve varying levels of government and a number of stakeholders from outside the committee, this could increase the complexity in finding shared goals and common objectives.

⁵⁴ As an example, the Yakima Basin's IWRM capital costs are estimated to be approximately \$4.2 billion in 2012 dollars. These costs include permitting, design, environmental analyses, construction of infrastructure projects, implementation of programmatic activities, and environmental. For a summary of capital costs, refer to Table 2 from U.S. Bureau of Reclamation, 2012.

While the varying rules and approaches used across jurisdictions and government to address environmental concerns in the Basin involve a complex and costly regulatory system, an IWRM committee could reduce the administrative complexity involved in Basin governance through collaboration and streamlined efforts. Improved coordination among levels of government and the development of a strategic approach would maximize the effectiveness of government efforts by ensuring involvement in the Basin is targeting areas of specific need. For example, having a method for identifying instream flow needs to which all governments could subscribe would ease the decision-making process (Morin & Cantin, 2009). Moreover, similar to the Yakima Basin's IWRM method for funding, costs for IWRM projects could be shared among a range of partners. This means that various state, provincial, federal, and related parties would partner in funding implementation of many elements of the IWRM plan. Moreover, because the IWRM committee would work with stakeholders outside of the Treaty, this would relieve the committee of a portion of the burden; the committee would help facilitate engagement with stakeholders outside of the Treaty around set objectives. Because various challenges could limit the ability of stakeholders to meet water management objectives, the committee can play a role through coordinating data, science, innovation, and financing schemes (such as payment for ecosystem services).⁵⁵

The implementation of an IWRM committee depends on the willingness of government, First Nations, and ultimately authorities of the Treaty. Research indicates that the political will to adhere to IWRM rests partially on the benefits nations receive from the integrated management of rivers (Roy et al., 2011). Benefits can be altered to generate political will through ecosystem services valuation, and by creating payment schemes to manage natural capital. Thus, by displaying the ecosystem benefits generated through integrated resource management, Treaty parties could see what is at

⁵⁵ Payment for ecosystem services (PES) is a market-based mechanism used to encourage conservation of natural resources and is a tool that could be used to enhance white sturgeon populations and ecosystem health in the Basin. PES addresses environmental degradation by paying landowners for the ecosystem services that their land provides. In the case of white sturgeon in the Columbia River, agricultural practices have negatively impacted water quality and degraded riparian habitat used by sturgeon for spawning. In responding to these impacts, a PES scheme could be used to incentivize farmers' conservation efforts while promoting sturgeon health and remediating lost riparian land and the EGS it provides.

stake and how the implementation of an IWRM committee can act to protect the Basin's natural assets. Neither Treaty party, nor the varying levels of government involved in the Basin, have explicitly commented or voiced opinion on this option; however the U.S. Army Corps of Engineers has voiced willingness by pointing to IWRM in managing and coordinating system planning and operation in the U.S. portion of the River (U.S. Army Corps of Engineers, 2010). Additionally, Canadian jurisdictions (such as Saskatchewan and Ontario) are moving to adopt an IWRM strategy (Morin & Cantin, 2009).

Although the public response to this option is unclear, other neighbouring rivers using an IWRM approach have been well received. For example, the Yakima Basin Integrated Water Resource Management Plan has facilitated relationships among decision-makers, state departments, community members, and agricultural producers (Flatt, 2012). Moreover, given that IWRM relies on partnerships and collaborative responses, it is likely to garner public support from residents, industry, and stakeholders in the Basin. Based on the above, IWRM is ranked 'medium' on implementation ease.

Effectiveness

With a focus on ecosystem services, this option will ensure the sustainability of white sturgeon populations in the Basin and respond with a precautionary approach to uncertainties and stressors affecting populations in the River. Because the IWRM committee's mandate and operational plans are informed by stakeholders and harmonized knowledge across the Basin, the committee would be well situated to respond appropriately to ecosystem and sturgeon needs. Established objectives and coordinated governance would help judge whether stock assessments reach set targets and if not, the committee's multidisciplinary team of experts would reassess sturgeon vulnerabilities. Moreover, because information is held in many different databases by various levels of government located across countries and between nations, an IWRM committee would help to improve the access of this information by building a comprehensive information system that interconnects databases to provide one-window access to the committee (Morin & Cantin, 2009). For example, Statistics Canada's national environmental reports summarize trends in water quantity, water quality, water

use, and human impacts on waterways (Morin & Cantin, 2009).⁵⁶ Incorporating this type of information into a database would be useful for the IWRM committee to use in monitoring effects to sturgeon and other ecosystems. In doing so, the benefits provided by sturgeon would receive proper oversight and long-term security.

The committee can also play an active role in strengthening partnerships by bringing together stakeholders that are typically difficult to engage with and developing local-level leadership. Through a collaborative process, the committee could help to enforce compliance among stakeholders, the province, and states around set objectives. Research indicates that the economic value of a river basin can increase as institutional mechanisms evolve to synchronize inter-linkages of different land and water users (Gottfried 1992).

Expanding the Treaty to incorporate Option 4 would provide a unique opportunity to restore the Columbia River. Operating at the watershed scale,⁵⁷ a broadened scope will enable the various impacts affecting white sturgeon to be researched, responded to, and continually monitored through the committee's multidisciplinary background and mandate, providing sustained health to sturgeon populations and the ecosystems they inhabit. Because different ecological and social processes are governed at different spatial and temporal scales in the River, addressing issues through the cross-scale cooperation of an IWRM committee could be more successful at assessing problems through a holistic lens, while also determining ecologically and politically sustainable solutions (Cervoni et al., 2013). In addition, restoration of sturgeon stocks will also help resolve problems associated with flooding and Treaty flood control operations (Osborn, 2012). Remediating floodplains, wetlands, and riparian areas offer ecological benefits for

⁵⁶ Similarly, in 2013, Statistics Canada released a report documenting information on the quantity, quality and value of Canada's ecosystems and EGS. The report presents preliminary results achieved through a two-year interdepartmental project to develop experimental ecosystem accounts. For information refer to Statistics Canada (2013).

⁵⁷ The use of watershed management units is important when implementing IWRM initiatives. Using the watershed or river basin as an appropriate management unit is an important spatial consideration for IWRM. A watershed is defined as the "entire catchment area, both land and water, drained by a watercourse and its tributaries" (Cervoni et al., 2013).

sturgeon spawning and habitat needs and storage potential to reduce flooding.⁵⁸ Floodplain restoration can increase groundwater upwelling into rivers and improve cool water habitat for white sturgeon and other aquatic species. Innovative instruments at the watershed level (e.g. PES) that collaborate with the River's water users (municipalities, agricultural producers, etc.) will facilitate partnerships, incentives, and enhance the effectiveness of responses and programs aimed at addressing white sturgeon health.

Equity

An IWRM committee would affect the services provided by white sturgeon and therefore the magnitude and distribution of costs and benefits. An IWRM approach ranks highly with equity in process and impacts. Operating from a holistic approach, an IWRM committee would tackle management of the River with foresight about its impacts on other areas, resource users, and jurisdictions. Before setting its objectives and creating a plan, the IWRM committee would bring together stakeholders across various sectors that impact water resources to set agreed upon objectives and make balanced decision in response to specific challenges. While it will be demanding to find solutions with equitable impacts, projects that anticipate placing costs on either country will be met with a form of compensation or financing scheme (i.e. PES, WTP conservation fund, etc.). Compensation will be used to reimburse stakeholders for opportunity costs and to incentivize stakeholder participation.

The IWRM committee could also integrate innovative strategies to reduce impacts to affected parties and create positive impacts to the Columbia system as a whole. For instance, in a scenario of water scarcity during summer months, agencies in the United States could move toward wastewater treatment for irrigational needs and in doing so, leave open opportunities for other water uses such as flows for sturgeon. In

⁵⁸ If implemented, a PES tool for IWRM could effectively address sturgeon needs while also providing important buffers for natural flood control protection and alleviate short-term difficulties such as temporary droughts. Conservation of riparian area could also translate into cost savings of roughly \$4,000 per acre for short term flood protection (Heimlich et al., 1998). The Columbia River Irrigators Association has been advancing irrigated agriculture through the implementation of irrigation Best Management Practices (BMPs). BMP's emphasize the adoption of high efficiency water use practices that meet the production and cost-effectiveness needs of commercial agriculture.

other cases, funds already being spent on fish and wildlife conservation in the Basin (see Section 7.1.4) could be redistributed to align with IWRM objectives and plans (i.e. improving passage for sturgeon at dams). Costs and impacts to specific stakeholders would be reduced. Integrated strategies such as these could reduce potential economic and social costs to parties on either side of the River. To offset these costs and ensure transboundary equity, an IWRM committee would work towards integrated win-win solutions.

The integrated framework and strategies used by an IWRM committee, by its very mandate, would ensure intergenerational equity concerns are met. Proactive measures aimed at the Columbia system as a whole will help to protect, enhance, and conserve not only sturgeon populations, but ecosystem health as whole for future generations to benefit. This will significantly ensure that the full range of benefits outlined in Chapter 7 are realized and left intact.

11.5. Evaluation Results

To consolidate the criteria assessments and facilitate comparisons of trade-offs between policies, Table 11.1 converts the qualitative descriptions into numerical rankings. Each criterion received a ranking of high (3), medium (2) or low (1). The sum of each option's criteria was calculated to determine which approach should be recommended. While the total values of rankings are merely illustrative, calculations helped to identify a recommended approach.

Table 11.1. Summary of Policy Evaluation and Calculations

| Criteria | Adaptive Governance | Treaty Modernization | Transboundary Watershed Group | Integrated Water Resources Management Committee |
|-------------------------------|----------------------------|-----------------------------|--------------------------------------|--|
| Flexibility | 3 | 2 | 3 | 2 |
| Ease of Implementation | 2 | 2 | 3 | 2 |
| Effectiveness | 2 | 2 | 2 | 3 |
| Equity | 2 | 2 | 3 | 3 |
| TOTAL⁵⁹ | 9/4 = 2.25 | 8/4 = 2 | 11/4 = 2.75 | 10/4 = 2.5 |

⁵⁹ Absolute values of these rankings are illustrative and represent equal weighting of criteria. Decision-makers could likely have a different weighting scheme. Total ranking equals the ratio of the total score to the number of measures.

Chapter 12.

Recommendations

Based on the evaluation and ranking from the analysis in Chapter 11, establishing a transboundary watershed group and integrated water resources management committee receive the highest scores of the assessed approaches; however none of the options clearly dominates. None of the policy options on its own can effectively address the policy problem; each option builds upon the other. Thus, given that each option has the potential to address white sturgeon and ecosystem health within the Columbia River, and that the options are not mutually exclusive, the recommendations focus on a short- and long-term time-line of implementation. Recommendations are designed to address the policy problem and its challenges outlined throughout this study. While the valuation of white sturgeon serves as a proxy for valuing other components of the Basin ecosystems, recommendations also aim to address these wider concerns. If implemented, my recommendations serve as an effective framework from which entities of the Columbia River Treaty and Basin management can move forward.

12.1. Short-Term Recommendations: In Preparation for 2024

In the near term, as a transition measure in preparation for Treaty renegotiations in 2024, I recommend a transboundary watershed group (Option 3) be established. In order to improve coordination, fill critical research gaps, and develop a bilateral environmental strategy in the Basin, partnerships and data collection and analysis is a prerequisite. The quality and depth of the benefit estimates in this study are limited. To gain a better understanding of the benefits and costs of sturgeon, and ecosystems more broadly, data is a fundamental first step. This includes, for example, better data on

sturgeon-related recreation and tourism, a longitudinal survey on willingness to pay by Basin residents for the preservation and existence of sturgeon, expressed cultural values related to sturgeon, and better data on impacts and stressors affecting sturgeon and their role within the River ecosystem. Using this information, the group could develop a natural capital target model to build objectives and goals.

Without a better understanding of white sturgeon and the benefits therein, finding effective solutions to respond to their loss will be increasingly difficult. To improve data collection, both the Northwest Power Conservation Council and the Columbia Basin Trust should commission a bilateral group to analyze the pressures, impacts, and responses of sturgeon to various conservation and mitigation options throughout the Basin. A bilateral strategy will also help align various groups, organizations, and academics studying white sturgeon in the River and work toward the preparation of research, data, and information necessary to include ecosystem function into Treaty renegotiations in 2024. Overall, the more we know about the ecology and value of sturgeon, the better we can understand what is at stake and what is required to increase and sustain populations. Because this study uses the white sturgeon as an example of how undervalued natural resources can be recognized and integrated into bilateral Basin management, ultimately, better data and analysis would be necessary for all ecosystems across the Columbia River Basin.

12.2. Long-Term Recommendations: 2024 Treaty Renegotiations

For the Basin's ecological footprint to be addressed, it is essential that the Treaty include ecosystem function (Option 2) as an explicit objective alongside hydropower and flood control. The Treaty provides the backbone for coordinated management in the Basin; without a cohesive basin-wide strategy, conservation efforts will continue to be fragmented, creating only marginal improvements. Moreover, while both entities include environmental objectives within their separate mandates, the Treaty remains silent on the issue, creating deficiencies in meeting government and societal objectives. Incorporating ecosystem function as a distinct purpose within the Treaty ensures that entities are held accountable. Implementing ecosystem function as a co-purpose to flood

control and hydropower will give weight to sturgeon and other ecosystem-related objectives.

For example, while white sturgeon are identified as a species of priority in the Canadian portion of the River, the significant value attached to power generation by the Treaty has led some flow alterations on the system for sturgeon to be deemed unfeasible (BC Hydro, 2011). Providing equal standing to ecosystem function and incorporating the benefits therein will mean that the fundamental trade-offs required to remediate sturgeon will be undertaken. While endangered listings in both countries has legally required Treaty entities to make changes to their operations, these efforts still fail to make considerable progress. Including ecosystem function in the Treaty will enable entities to collaboratively and cohesively exercise as much precaution in order to conserve as best as possible the species and their role within the broader river ecosystem. Yet, while this option creates a clear mandate to address environmental issues in the Treaty, on its own, this option cannot meet the criteria outlined in this study.

Introducing Option 2 in tandem with the implementation of an Integrated Water Resources Management Committee (IWRM) (Option 4) will help resolve the limitations that arise from implementing Option 2 on its own. This scenario would broaden the Treaty's scope and respond to impacts affecting sturgeon that the Treaty may be unable to address. Grounded in a strong legal framework and carried out by the design and use of an appropriate mix of instruments and tools, both Option 2 and 4 would move towards improved governance, integrated management, full stakeholder involvement, and clearly set goals (Morin & Cantin, 2009). An IWRM committee extends the scope of the Treaty to allow for the full benefits of ecosystem preservation and restoration to be incorporated into the decision-making framework.

Under future scenarios of climate change and population growth, the trade-offs and impacts involved with Basin management will become increasingly uncertain and difficult to predict. Because sturgeon are still relatively understudied and require further analysis, new science and data will be necessary to assess and monitor various impacts and strategies. As such, the IWRM committee should incorporate adaptive governance (Option 1) into its framework as well. Including adaptive governance will allow the IWRM

committee to evolve over time to respond to new available information and future impacts to sturgeon and ecosystems in the Basin, including the periodic assessments of proposed actions taken.

Chapter 13.

Conclusion

Ecosystem goods and services (EGS) are essential to sustaining societal well-being and provide innumerable benefits. Yet, despite these significant benefits (i.e. clean water and air, food, recreation, culture, etc.) the topic is understudied in the Columbia River Basin and the magnitude of impacts is poorly understood. To help develop a better understanding and create dialogue, this study uses the white sturgeon as an example of how undervalued EGS can be integrated into the management of the Columbia River Basin and Columbia River Treaty. The policy problem investigated is that without consideration for white sturgeon and overall ecosystem health within the Columbia River Treaty, current Basin management continues to pose significant and unaccounted costs to ecosystems and society as a whole.

Notwithstanding the methodological and data limitations, this study shows that restoring white sturgeon populations would generate substantial benefits to the U.S. portion of Columbia River Basin: \$178 million in food, \$1,200 million in its existence, \$0.053 million in recreational angling, and numerous intangible cultural benefits. By ignoring these values in policy decision-making, costs will continue to be incurred by Basin residents today and for generations to come. As one interviewee points out, “white sturgeon are unlike any other species, no other substitute exists for sturgeon in the Pacific Northwest.” Thus, without substitutes, the decline of sturgeon creates significant losses to economies in the region and overall well-being. More importantly, sturgeon act as a powerful biological indicator of the broader ecological health of the Basin, providing an example of the interconnectedness and complexity of natural systems; the decline of sturgeon acts as a wake-up call to how governments manage highly valued public resources.

Impacts to white sturgeon overlap and connect with stressors faced by ecosystems throughout the Basin. Effectively, this means that because white sturgeon are interconnected with ecosystems in the River, each targeted policy used to improve the River's environment could lead to a cascade of effects to sturgeon and related species and habitat. The policy approaches recommended in Chapter 10 are therefore targeted approaches to white sturgeon remediation but also serve toward addressing Basin ecosystems. Finding solutions to address the policy problem in this study requires a renewed method. Overall, to be effective, identified recommendations extend beyond present day Basin management to a holistic approach that includes adaptive mechanisms, bilateral management, and harmonized information sharing. Because Endangered Species Act (ESA) biological opinion requirements are presently incorporated into the Columbia River Treaty operations, a "new" ecosystem function must be included to expand the Treaty's scope in exercising a precautionary rather than reactive approach to sturgeon and ecosystem health within the Basin.

The layered and complex nature of governing the Columbia River Basin necessitates nuanced and comprehensive policy solutions. As such, a suite of policy recommendations is offered, each addressing a component of the policy problem. Moving forward, government, academics, NGO's, First Nations, and other stakeholders planning to meet later this year at the Lake Roosevelt Forum should continue to discuss the logistics and formal formation of a transboundary watershed group. If this remains the process of choice, the group should begin to formulate objectives and goals to work collaboratively towards a more flexible and integrated approach where information is more easily exchanged and used for policy-making. In preparation for 2024, this group should also begin to assemble research, data, and information for entities of the Treaty to draw upon in negotiations. Between now and 2024, entities of the Treaty should convene with levels of government and First Nations governments to begin discussing the possibility of an integrated water resources management committee. Public and stakeholder consultations around this approach will enhance the process.

While this study uses the white sturgeon as an example of an ecosystem under threat, policy makers should obtain estimates of the sum of all use and non-use values to determine the total economic value of water allocations in the Columbia River.

Incorporating these values into the decision-making process can help delineate the costs and benefits of proposed management strategies and provide insight to implementation. Including ecosystem services into Basin management and Treaty renegotiations in 2024 could change the calculation of benefits, arrangements, and coordination between both countries; what was once deemed an acceptable trade-off could reveal net costs. Implementing these recommendations will not only better protect one of the biggest shared watersheds in North America but it will provide a framework for moving forward with balancing some of the key tradeoffs in natural resources management.

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Appendix A.

Ecological State of the Columbia River

Officials in the United States have focused much of their efforts on forested ecosystems, rangelands, and special status species with a focus on aquatic/riparian species habitat management (Gravenmier et al., 2014). Old forests represent an important source of habitat for wildlife. Federal lands across the Interior of the Columbia River Basin contain vast amounts of late-successional and old growth forests, which have experienced strong and widespread decline (Wisdom et al., 2000). Flooding of riparian areas due to dam construction along the major tributaries in the Columbia River Basin has led to the decline of many species of trees. The loss of forest ecosystem services and functions (i.e. carbon sequestration and storage, air quality, etc.) in this region has been met with an associated decline in a range of species dependent upon the region's features as a source of habitat (Wisdom et al., 2000).

Rangelands in the Basin such as grasslands, savannas, shrublands, tundra, and wetlands have experienced extensive alteration over time. Wetlands represent one of the most important components to the maintenance of ecosystem health for wildlife, fish, and humans. From their ability to provide critical ecological functions, most wildlife along the Basin is wetland dependent to varying degrees. While the Columbia River system has received extensive conservation efforts, a significant proportion of low elevation wetlands downstream have been lost due to dam impoundment, drainage or filling for the purposes of agriculture, settlement, urban development, and industry (Biodiversity Atlas, 2014). Agricultural land conversion and livestock grazing have also contributed to the decline of other ecosystem habitats, such as shrubland and woodland (Gravenmier et al., 2014).

Riparian ecosystems are distributed along the Columbia River. Riparian areas represent the interface between water and land allowing components of both ecosystems, allowing aquatic and terrestrial organisms to thrive. Some ecosystem goods and services provided by riparian areas include: carbon storage, shade and stabilization of stream water temperature, soil conservation, sediment filtering of run off, water storage, flood mitigation, aquifer recharge, and landscape aesthetics. The loss and degradation of riparian habitat has been caused by factors such as dams, livestock grazing, urban development, agriculture, timber harvesting, transportation infrastructure, and changes to the natural hydrological regime of the River (Thomas & Dombeck, 1996). The loss of riparian areas has also adversely affected many species of birds, amphibians, reptiles, aquatic organisms and fish, and large mammals.

The lower bounds of the Columbia River in the United States have experienced extensive modification by human activity. The construction of an estimated 400 dams has acted as a barrier to the movement of fish (McKinney et al., 2010). In December 2012, the United States Army Corps of Engineers (USACE) cited thirteen species of anadromous fish in the Columbia River Basin as either threatened or endangered (United States Army Corps Engineers, 2012). The USACE (2012) highlight historic losses of 52,000 acres of wetland/marsh habitats, 13,800 acres of riparian forest habitat, and 27,000 acres of forested wetland habitat downstream of Portland, Oregon, to

illustrate the impacts on ecosystems and their ability to sustain fish resources. Much of this loss can be attributed to the 84,000 acres encompassed by diking districts and the 20,000 acres increase in urban development along the lower Columbia River.

In 2013, land cover data from 2010 was compared to GIS interpretations of the late-1800s pre development maps. This comparison showed a 70 percent loss of vegetated tidal wetlands and 55 percent of forest uplands (Spirit of the Salmon, 2014). Moreover, between 2005 and 2010, the USACE dredged over 130 miles of riverbed to create a 43-foot-deep shipping channel from the mouth of the River to ports in Portland, Oregon, and Vancouver, Washington (Spirit of the Salmon, 2014). This has resulted in sandy islands supporting predatory birds, placing fish at threat.

After years of human development and land use impacts, watershed restoration in the Basin is still a work-in-progress. Substantial funds from Bonneville Power Administration, the Pacific Coast Salmon Recovery Fund, and various other federal, state, tribal, public utility districts, and private sources are being spent on watershed restoration every year. Despite these efforts, estimates suggest that hundreds of millions more dollars are needed annually for watershed restoration, land protections, eliminations of passage barriers, instream flows, water quality, program operations, monitoring, outreach and education, and regulatory actions (Washington State, 2011).

Appendix B.

The Columbia River Treaty

Since the Treaty was signed, flood control measures have protected communities from major damage along the Columbia River, avoiding \$2 billion in potential damage in the year 2012 (BC Ministry of Energy and Mines, June 25, 2013). On average, the United States Army Corps of Engineers estimate annual flood damages avoided by the United States along the Columbia River to be \$100-200 million. Treaty coordination has also enabled the hydro system to respond to seasonal challenges when inflows are reduced or during hot summers when irrigation, fisheries, and recreation compete for the same low flows.

Two types of hydroelectric operating plans exist: assured operating plans and detailed operation plans. Prepared five years in advance, the assured operating plans are designed to achieve a joint optimum power operation in Canada and the United States by regulating the River's flows. These plans are used to determine the downstream benefits. Before the beginning of each operating year (July – August), both entities prepare the detailed operations plan. These plans allow changes to be made to operations where Canada and the United States agree there are mutual benefits. Each year, Treaty Storage Regulation studies and weekly coordination phone calls provide the United States with certainty of flows.

Boundary Waters Treaty and International Joint Commission

In 1909, the Boundary Waters Treaty (BWT) was signed between the United Kingdom (on behalf of Canada) and the United States. The BWT established a number of legal rules to govern how Canada and the United States manage boundary and transboundary waters. The Treaty also established the International joint Commission (IJC). The IJC, as an independent body, regulates, reviews, and resolves issues relating to boundary and transboundary waters of Canada and the United States (Norman, 2014). While there are a number of flexibilities built within the BWT and practice of the IJC, the existence and use of the IJC's advisory jurisdiction is an important instrument. Within the Columbia River, the IJC was able to use this mechanism to establish the technical foundation from which to consider dams and storage options (Bankes & Cosens, 2014)⁶⁰. Because the advisory jurisdiction of the IJC represents an evolving instrument of use, new references can continually be made to the IJC. Thus, while this represents one way from which new concerns of the River may be taken into account, the IJC can only become involved in an issue at the request of both countries (Norman, 2014).

⁶⁰ Where the IJC approves a project, it will issue an order of approval containing terms and conditions that include regular reporting to maintain oversight over the project.

Appendix C.

White Sturgeon: A Brief Introduction

The Columbia River Basin is a biologically diverse and dynamic ecosystem. The Basin is home to over 700 species of amphibians, birds, mammals, flora, fish, and reptiles. The land mass is characterized by: mountainous, forested ecoregions; widespread plateaus, plains and basins; rich vegetation; and areas of grasslands, wetlands, scrub and tundra (Biodiversity Atlas, 2014). Yet, despite the abundance in nature, the health and population of species within the Basin is deteriorating. In the United States, the federal Columbia River Power System is comprised of 31 interconnected dams (BC Ministry of Energy and Mines, June 25, 2013).⁶¹ Fluctuating reservoir levels and daily hydroelectric flow cycles have impacted biodiversity in the Basin. Shoreline and riparian zones have been subject to a recurring 'watered-dewatered loop' as reservoirs are drawn down for peak flow and later refilled, affecting the habitat of white sturgeon (Jones et al., 2011). Approximately 268 species, sub-species, and fish stocks in the Basin have United States Federal listings for endangerment: 241 candidates, 11 threatened, and 16 endangered (Thomas & Dombeck, 1996).⁶² The white sturgeon is one of these.

Historically, white sturgeon inhabited the Columbia River from the lower river to British Columbia, the Snake River to Shoshone Falls, and the Kootenai River from Kootenay Lake, British Columbia, to Kootenai Falls, Montana (Harrison, 2008b). White sturgeon "are a rare species with prehistoric lineage only found on North America's Pacific Coast" (Canada Department of Fisheries and Oceans, 2005, p 19). The white sturgeon represents the biggest freshwater species in North America. These fish have been found to weigh over 600 kg, grow up to 6 metres long, and live over 100 years (Ministry of Environment, 2013). While diet varies with fish size and prey availability, the massive size of this species has been dependent on its feeding of salmon, steelhead, pacific lamprey, and freshwater mussels. From the early 1900s to 1970s, the construction of dams along the Columbia River and its major tributaries isolated white sturgeon and significantly reduced the amount of food sources (Idaho Department of Fish and game, 2014).

White sturgeon rely on various conditions related to spring spawning to survive. Environmental necessities during this season include: water temperature, day length, strength of water current and riverbed material (Ministry of Environment, 2014). Lower white sturgeon populations undertake upstream spawning migrations starting in fall or winter. While the extent of sturgeon spawning migrations prior to hydropower development is uncertain, it is likely that fish using marine waters, the estuary, and Lower River migrated further upstream to search for a proper spawning habitat (Northwest Power Conservation Council, 2013a). In the upper basin, white sturgeon spawn later in the year and over shorter time periods. High water velocity is an important

⁶¹ The creation of U.S. dams, starting in the later 1930s, has nearly eliminated salmon and white sturgeon from the upper Canadian portion of the Basin.

⁶² Appendix A provides a comprehensive description of the ecological state of the Basin.

attribute of spawning (Northwest Power Conservation Council, 2013a, p 33). Because of the unique features of their large river habitats and their role within it, sturgeon require a broader definition of habitat than usually applied considered fish habitat improvements. Sturgeon habitat is defined in terms of system-wide conditions including large areas of diverse habitat; natural variation in flow, velocity, temperature, and turbidity; high water quality; a broad prey base; and free-flowing sections, providing suitable spawning sites (Beamesderfer & Farr, 1997). Disturbance to habitat needs has largely resulted from the construction and operation of hydropower dams. Upstream from Bonneville Dam, a series of main-stem dams have trapped stocks of white sturgeon in a series of reservoirs, rarely allowing sturgeon to pass upstream or downstream dams. As a result, sturgeon swim trapped in reservoirs that lack optimal conditions for different intervals of their life cycle (Beamesderfer & Farr, 1997). Dams have blocked migration into the upper Columbia River and eliminated salmon, an important pre-development food source to white sturgeon. Food sources for the white sturgeon in the Columbia River are now considerably less diverse.

The length of time needed to reach sexual maturity places the recovery of white sturgeon at even greater risk. As males sexually mature between the ages of 12-25, females typically mature between ages 15-30. The time before sexual maturation can be extremely vulnerable. If white sturgeon face significant challenges to their biological needs, this could lead to insufficient numbers of juveniles and potentially result in detrimental effects to their repopulation. For example, in some areas where repopulation has failed, populations consisting of large and older fish are all that remain, gradually declining as fish die and cannot be replaced. The population of white sturgeon now consists of known or suspected subpopulations that are isolated from each other. While the distribution, abundance, and diversity of white sturgeon have drastically declined throughout the Columbia River Basin, naturally self-sustaining subpopulations continue to be found in segments of their historical range (Northwest Power Conservation Council, 2013a). Overall, population size and distribution continue to decline in many areas of the River, demonstrating how natural production has become inadequate at replacing remnant populations (Northwest Power Conservation Council, 2013a, p 50). Scientists now believe that the production of sturgeon will ultimately be limited by the diminished capacity of the rearing habitat in the Columbia River.

Current Conservation Measures

Washington, Oregon, Idaho, & Montana

The Washington Department of Fish and Wildlife (WDFW) work with white sturgeon as a species on its Priority Habitats and Species List (Northwest Power Conservation Council, 2013a).⁶³ WDFW shares management of white sturgeon with Oregon to

⁶³ The WDFW placed sturgeon on this list based on the following criteria: a vulnerable aggregation susceptible to significant population declines within a specific area; WDFW contains populations of recreational or commercial importance, “whose ecological characteristics enable them to become vulnerable to decline in Washington or that are dependent on habitats that are vulnerable or in limited availability” (Northwest Power Conservation Council, 2013a, p 16).

maintain consistent management and provide a healthy population. It does this in the first three impoundments upstream of Bonneville Dam with the Columbia River Treaty Tribes as well. The Columbia River Treaty Tribes manage sturgeon populations in this area to provide long-term sustainable harvest opportunities for First Nations and non-treaty fisheries (Northwest Power Conservation Council, 2013a).

Oregon is a part of a state conservation planning effort for impounded white sturgeon from Bonneville Dam to the Washington border in the McNary Reservoir (Northwest Power Conservation Council, 2013a). Based on the white sturgeon's ecological, economical, and social importance, Oregon has identified this population as a conservation priority. In 2009, the Oregon Native Fish Conservation Policy called upon conservation plans for species with "high public interest or economic or other impact on the local community" (Northwest Power Conservation Council, 2013a, p 17). In August 2011, Oregon adopted the Lower Columbia River and Oregon Coast White Sturgeon Conservation Plan. This conservation plan provides a framework from which to manage, protect, and enhance white sturgeon while also allowing for sustainable harvest opportunities (Northwest Power Conservation Council, 2013a).

The purpose of Idaho's Department of Fish and Game (IDFG) for the Snake River (a major tributary of the Columbia River) white sturgeon population is to "preserve, restore, and enhance populations capable of providing sport fishing opportunities" (Northwest Power Conservation Council, 2013a, p 18). IDFG has developed a Management Plan for the Conservation of Snake River white sturgeon in order to provide direction towards staff and the long-term preservation of white sturgeon similar to its historical population size. IDFG also works in collaboration with conservation and recovery efforts for the federally-listed Kootenai River population. The Kootenai River white sturgeon population is located in waters shared between Canada and Montana and is managed by the U.S. Fish and Wildlife Service, the Kootenai Tribe of Idaho, the province of British Columbia, the U.S. Army Corps of Engineers, and the Bonneville Power Administration (Northwest Power Conservation Council, 2013a).

Montana Fish, Wildlife and Parks (MFWP) has designated Kootenai River white sturgeon as a Tier I species, requiring the greatest need for conservation. The goal is to protect and restore white sturgeon to a sustainable population that is capable of providing recreational angling opportunities within the state of Montana (Northwest Conservation Council, 2013a). While MFWP has authority over the management of white sturgeon in the Montana portion of the Kootenai River, it recognizes the importance of collaborating with Idaho, Kootenai Tribe of Idaho, and British Columbia, in order to recover endangered white sturgeon.

In 1986 a joint Sturgeon Management Task Force (SMTF) between Oregon, Washington, and the Columbia River Treaty Tribes was established. The SMTF meets regularly to review management issues and set harvest guidelines for the next year (Northwest Conservation Council, 2013a). Management issues reviewed include: recreational, commercial and subsistence landings for each reservoir between Bonneville and McNary Dam (Northwest Power Conservation Council, 2013a).

British Columbia

Since the 1990s, the province of British Columbia has undertaken a series of conservation measures to address the decline of white sturgeon. In 2000, the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) was created under the agreement of Fisheries and Oceans Canada, BC Environment, BC Fisheries and BC Hydro (Northwest Power Conservation Council, 2013a). The UCWSRI has grown into a transboundary collaboration of over 25 partners from government, First Nations and American tribes, industry, environmental groups, and others concerned in the future of white sturgeon in the upper Columbia River in British Columbia and Washington (Northwest Power Conservation Council, 2013a).

Listing Status

In 1994, in response to sharp population declines, the Kootenai River population of white sturgeon were listed as endangered under the United States Endangered Species Act (Northwest Conservation Council, 2013a). Lower and mid-Columbia River white sturgeon are not currently listed under the Endangered Species Act or subject to plans for listing. Neither of these populations receives biological opinions, recovery plans, or habitat conservation plans (Northwest Conservation Council, 2013a). While lower and mid-Columbia River sturgeon do not receive federal endangered listings, the states of Washington, Idaho, and Oregon monitor white sturgeon. The state of Washington cites white sturgeon on its Priority Habitats and Species List, “meeting criteria as a species comprised of aggregations vulnerable to significant declines” (Northwest Power Conservation Council, 2013a, p 23). Likewise, both Oregon and Idaho have identified white sturgeon as a conservation priority.

In 2006, the Government of Canada added white sturgeon populations from the Kootenay, Nechako, Upper Columbia, and Upper Fraser rivers to the *Species at Risk Act*. This designation provides protection to white sturgeon and their critical habitat through a series of objectives and strategies used to create specific recovery measures, research, and ongoing monitoring.

Hatcheries

The first attempts to address the declines in sturgeon came in the form of fish hatcheries. Recovery efforts on both ends of the border have included the release of hatchery sturgeon in the transboundary reach. There are 208 hatchery programs in the Columbia River Basin; of those, 90 hatcheries rear and release Endangered Species listed fish (Columbia River Federal Caucus, 2015). For example, in 2014, the Kootenai Tribe of Idaho completed a 35,000 square foot, \$15 million hatchery to restore white sturgeon to the Kootenai River. Since the 1980’s, the tribe has been working to preserve the genetic stock of the endangered white sturgeon with aquaculture as well as habitat restoration and flow regimes. This new hatchery attempts to expand sturgeon production capability.

Despite these efforts, sturgeon still experience limited recruitment. For example, in Lake Roosevelt, fisheries agencies in both the U.S. and British Columbia have begun collecting eggs and sperm from adult fish and rearing them in hatchery before stocking

them back into the reservoir. In measuring the success of this hatchery program, conducted studies find that nearly all (about 98 %) of the fish that have been recovered are of hatchery origin, indicating that no naturally reproduced juveniles are recruiting to the population anymore (CELP, 2015a).

Analyzing over 50 estimates of reproductive success from various case studies, researchers found reduced fitness due to hatchery rearing evident across all study species, locations, hatchery practices, and geographic locations (Ford et al., 2014). While uncertainty remains as to what exactly causes reduced fitness in hatchery fish, there is clear evidence for genetic and environmental factors. As such, hatcheries have often been regarded as a short term strategy that must include the ecosystem at a watershed level to be successful in the long term. Because system-wide habitat protection and enhancement measures face various barriers and obstacles in implementation, managers have had to rely on aquaculture. As a result, efforts failing to address habitat degradation have generally failed to restore sturgeon populations to historic levels of productivity. In 1996, the Northwest Power Conservation Council's Independent Scientific Advisory Board suggested that "the industrial river cannot work for [fish] over the long-run, even with the technological and other fixes we have devised over the last twenty years... [the choice] is between a more complex working river with healthy [fish] populations and a simpler river without them" (Volkman, 1997, p 142). These concerns now dominate the discussion on water management in the River.

Appendix D.

White Sturgeon Ecosystem Goods and Services

Provisioning Goods

Provisioning services include the tangible goods and services provided by ecosystems, such as food, fiber, timber and fuel. For example, fish for harvest provide food that is represented in the marketplace by a clear indication of its monetary value. The Columbia River is the site of intense fishing, with major commercial landings coming from white sturgeon. White sturgeon are widely marketed for its caviar, meat, and medicinal purposes. While in 2009, sturgeon prices were between \$1.50 and \$2.00 per pound, by 2011-2012, the price increased to \$2.50 and \$3.00 per pound (Spirit of the Salmon, 2014). Other provisioning goods provided by white sturgeon include: smoked sturgeon, fresh, frozen or dried sturgeon, and sturgeon soup. In some cases, sturgeon skin is used as leather for handbags and clothing (Coppens International, 2007).

Regulating Services

Regulating services represent the indirect benefits that people obtain from ecosystem processes. For example, vegetation can absorb and neutralize atmospheric pollutants and contribute towards better air quality. Fish provide services by providing regulation of food web dynamics (Holmlund et al., 1999). White sturgeon can function as biological indicators used to monitor the health of the River and indicate when a problem arises. Their decline in population size allows researchers to assess related changes in the River. Moreover, the overall erosion of aquatic diversity will have detrimental effects to the functioning of a river system by altering nutrient recycling.

Supporting Services

These services are necessary for the support of all other ecosystem services. Examples of supporting services include nutrient cycling, soil formation, and primary production. The white sturgeon is an ecological cornerstone (Jones et al., 2011). The white sturgeon plays an integral part in the Columbia River aquatic ecosystems through natural predator-prey relationships. Actions taken to protect the white sturgeon could also benefit a range of resident and anadromous species that share similar habitat and water quality requirements (Canada Department of Fisheries and Oceans, 2005). Similarly, white sturgeon can pose as potential pest control organisms. In other ways, the overall health of the River is supported through the migration of white sturgeon and their ability to transfer nutrients into nutrient-poor regions.

Cultural Services

Cultural services have nonmaterial and intangible dimensions that benefit individuals through spiritual, aesthetic, existence, tourism and recreational activities. In some ways, these benefits can matter more to individuals than material benefits. For example, while

the white sturgeon provides food it also represents a valued way of life through fishing. Fishing can contribute to communities by shaping who they are and what they value. White sturgeon is important to First Nations people along the Columbia River. In the past, the white sturgeon was an integral part of their diet. Sturgeon were a “focal point of several stories passed from one generation to the next and as such, comprise an important component of First Nations culture in the region” (Canada Department of Fisheries and Oceans, 2005, p 20). In Washington State, a recent stakeholder survey found that recreation, tourism, and cultural values represented among the top five values reported as most important (Iceland et al., 2008). On both sides of the border, white sturgeon are highly valued for recreational and commercial fisheries purposes, with the fish becoming extremely popular among anglers. Moreover, white sturgeon have also acquired a highly intrinsic value to the public. A number of outreach programs have been created to work towards sturgeon conservation. Omitting these cultural benefits in decision-making could lead to the compromise of community and biodiversity objectives.

Appendix E.

Drivers of Loss

Climate Change

Water resources and the ecosystem goods and services depended upon by individuals along the Columbia River could all be affected by anthropogenic climate change. While the exact nature of future hydrologic changes in the Basin is unknown, the potential impacts and pressures these changes could have on white sturgeon are important.

Historically, flood flows on the lower river were strongly affected by snowmelt runoff from Canada (Cohen et al., 2000). Despite only 15 percent of the basin being comprised in Canada, 38 percent of the average annual flow and 50 percent of the peak flow originates from Canada (Cosens & Williams, 2012). Because runoff from snowpack occurs later in the higher latitudes of Canada, 50 percent of the critical late summer flow originates from the headwaters of the River, making Canadian dams vital to water needs in the United States during dry months (Cosens & Williams, 2012).

Over the next several decades, average temperature is projected to increase. Climate change is predicted to impact the seasonal distribution of runoff by producing warmer temperatures that will cause earlier snowmelt and change winter precipitation from snow to rain over parts of the River (Cohen et al., 2000). Annual precipitation has increased by 26% in the Basin, composed of an increase of 32% in rainfall and a 6% decrease in snowfall (PCIC, 2006). This will lead to an earlier peak in flows and as a result, a possible reduction in summer flows in parts of the Columbia River. Decreased snowpack and a loss of stationarity on the United States portion of the Basin could threaten its ability to meet water resource needs.⁶⁴ Between 1985 and 2000, the average loss for all glaciers in the CRB was 16%, with some losing as much as 60% (PCIC, 2006). Climate projections predict a rise in mean temperature within the Basin by 1.1 to 1.3 °C by the 2020s, 2.4 to 3.0 °C by the 2050s, and 3.3 to 5.0 °C by the 2080s (PCIC, 2006). In a worst-case scenario, by the year 2050, stream flow is projected to drop by 50 percent in the lower portion of the Basin (Hamlet and Lettenmaier, 1999).

Climate change is likely to have a variety of effects on Columbia River white sturgeon populations. While some warmer freshwater fish species could benefit from warmer climate and water temperature, researchers worry about the potential for exotic species to displace white sturgeon and Columbia salmon that require cold water temperatures to survive (Cohen et al., 2000).⁶⁵ Under future scenarios of warming water temperatures and reduced summer flows, white sturgeon may also be stimulated to spawn earlier. If

⁶⁴ Stationarity refers to seasonal weather and long-term climate conditions that fluctuate within a fixed envelope. A loss of stationarity means that our ability to project conditions based on experience are no longer reliable.

⁶⁵ Each of the 43 sub-basins of the Columbia River system has its own sub-basin management plan for fish and wildlife; none of these plans comprehensively address reduced summertime flows under climate change.

white sturgeon are unable to spawn earlier, predicted lower summer flows could severely decrease white sturgeon repopulation in the Columbia River (Northwest Power Conservation Council, 2013a). Additionally, warmer water could shorten the duration of white sturgeon spawning window. While the projected impacts of climate change to white sturgeon are not fully understood, the changes that could occur may amplify specific stressors to its population.

Hydrosystem Operations

In the United States, the federal Columbia River Power System is comprised of 31 interconnected dams on the Columbia, Snake, and Willamette Rivers (BC Ministry of Energy and Mines, June 25, 2013). Of the 31 dams, there are 11 hydroelectric facilities on the United States Columbia River main stem with a combined generation capacity of 20,347 MW (BC Ministry of Energy and Mines, June 25, 2013). What was once a free-flowing river has now become a chain of reservoirs linked by rivers, impacting the downstream migration of juvenile fish and the upstream migration of adults (National Academy of Sciences, 2004). The River's current operational regime has resulted in a pronounced shift in the hydrograph as well as in dramatic daily fluctuations in river levels to meet electrical demand. Prior to this development, the hydrograph was variable. Spring freshets historically carried heavy sediment loads, helping to provide critical habitat features for sturgeon. Today, sediment remains trapped behind dams, eliminating a vital function of a natural river. The timing and magnitude of the spring freshet has been significantly altered as a result of power and flood control operations. Dams have closed off 55 percent of the River's drainage system and 31 percent of the stream miles of original fish habitat in the River (National Academy of Sciences, 2004). Because white sturgeon seldom use fish ladders, this creates major passage issues that interrupt all life stages of white sturgeon (Jones et al., 2011). River fragmentation has reduced the quality of habitat, altered migration patterns, and limited upstream movement (Jones et al., 2011). White sturgeon are now unable to migrate from areas of high densities or poor resources to seek out alternative spawning and rearing areas or access seasonal food resources (Jones et al., 2011).

In 1978, academics began to study the effects of dam impoundments on white sturgeon populations. Researchers found that within a decade of the completion of the Libby Dam, the white sturgeon population became recruitment limited⁶⁶ (Paragamian, 2012). More recently, in a footprint impact assessment of hydropower dams on the Columbia, a wide range of impacts were cited in relation to sturgeon. The major impacts reported included changes in flow regimes, changes in water quality/turbidity, habitat/population fragmentation, and nutrient losses (Utzig & Schmidt, 2011). Damming along the River has "flattened" the River's annual discharge patterns decreasing high seasonal summer flows and increasing low seasonal winter flows (National Academy of Sciences, 2004). Over time, the summer-winter division of flows has shifted to a 50:50 balance in response to dam construction and hydroelectric power operations. In addition, the operation and construction of dams and reservoirs has decreased water velocity. A

⁶⁶ This means that white sturgeons are failing to replace themselves due to either unsuccessful spawning or insufficient survival of the young (Ministry of Environment, 2014).

decrease in water velocity has significantly increased the amount of time needed for juvenile fish to travel downstream and into the sea. This alteration has affected white sturgeon spawning occurring in high velocity habitats. Reduced flow during white sturgeon spawning has been associated with reduced recruitment of white sturgeon in the lower portion of the Basin (Jones et al., 2011). Moreover, in riparian habitat, researchers have recorded deposited white sturgeon eggs that, because of fluctuating water flows and elevation, have resulted in dewatered zones, leading to unsuccessful sturgeon reproduction. In a recent U.S. Geological Survey, researchers found that the eggs of endangered Kootenai River white sturgeon were less likely to hatch in the river because of flow changes caused by Libby Dam (Parsley & Kofoot, 2013). The alteration and loss of complex spawning and rearing habits through hydroelectricity management has impacted the abundance of white sturgeon in the River.

Water Quality

Water quality problems have been persistent across the Columbia. These include point-source effluents, impoundments, water withdrawals, and nonpoint source pollution from irrigation (Davidson & Paisley, 2009). The River receives pollution from sewage treatment plants, pulp mills, aluminum smelters, mining operations, and agriculture and urban runoff (Feist et al., 2005). So far, 49 different contaminants have been detected in the River stemming from municipal waste and human activities. The U.S. Environmental Protection Agency (2013) lists a number of potentially harmful levels of compounds being discharged into the U.S. portion of the River. These substances include: manganese, methanol, formaldehyde, nitrate, hydrogen sulfide, ammonia, lead, dioxin, and acetaldehyde.⁶⁷ Information on pollutant releases in the Canadian portion of the River reveals similar findings (Environment Canada, 2013).⁶⁸ These toxic contaminants are present in water and soils throughout the Basin, threatening the health of fish and wildlife. For example, a smelter run by Teck Cominco in British Columbia was charged with depositing waste into the Columbia River in early 1990, which later accumulated downstream in a portion of the River posing danger to nearby communities, fish, and wildlife (Davidson & Paisley, 2009).

White sturgeon can absorb a variety of pollutants and contaminants through direct contact or bioaccumulation through the food chain (Northwest Power Conservation Council, 2013a). Longevity, late maturation, and benthic habitats make white sturgeon susceptible to exposure of contaminants. As bottom feeders, sturgeon frequently come into contact with sediments that could contain sediment-absorbed hydrophobic pollutants (Webb 2002). Toxic contamination is a significant concern in the Columbia River. Endocrine disrupters and carcinogens such as chlorinated pesticides (e.g., DDT) and PCBs have been detected in white sturgeon sampled throughout the Columbia River Basin (Kruse, 2000; Foster et al., 2001; Environmental Protection Agency, 2002).

⁶⁷ Information on pollutant releases in the U.S. portion of Columbia River was retrieved from the U.S. Environmental Protection Agency polluter inventory spreadsheet (http://oaspub.epa.gov/enviro/ez_build_sql_v2.get_table).

⁶⁸ Information on pollutant releases in the Canadian portion of the Columbia River was retrieved from Environment Canada's national pollutant release inventory datasets (<http://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=0EC58C98-#Facility>)

Moreover, studies between 1994 and 2010 suggest that increased agricultural land use and mixtures of pesticides have impacted the Basin's aquatic ecosystems (U.S. Environmental Protection Agency, 2014). Tissue samples from sturgeon suggest a relationship between abnormalities (i.e. depressed sex steroid hormones, unsuccessful reproduction, and gonadal lesions) and concentrations of pesticides and polychlorinated biphenyls (PCBs) found in the River (U.S. Environmental Protection Agency, 2014; Feist, et al., 2005). In Studies conducted on Kootenai River white sturgeon, Kruse (2000) found a significant positive correlative between PCB concentrations in embryos and mortality. Dam impoundments exacerbate this problem by blocking sturgeon and exposing them to contaminants stuck behind the dams (Jones et al., 2011).⁶⁹ A substantial amount of money is spent to restore critical habitat for endangered fish and wildlife that depend on the River. In spite of these toxic-reduction efforts, the health of people, aquatic life, and ecosystems continue to be threatened. To successfully reduce toxics and restore critical habitat, a greater understanding of the contaminants and its sources is necessary.

Fishery Effects

White sturgeon in the lower Columbia River are subject to pressure from fisheries. Prior to the damming of the Columbia River, the white sturgeon experienced extensive harvesting efforts. While no record exists for the number of white sturgeon prior to hydroelectricity production on the River, earlier harvest (coupled with current river management) has been used as an example of why white sturgeon have not fully recovered to a sustainable stock level. Today, over-fishing of white sturgeon is still a threat. If recreational and commercial fisheries' harvest exceeds the sustainable level of harvest, legally allowable fishing quotas could significantly decrease the size of white sturgeon populations. While past exploitation rates have been excessive and caused decline in white sturgeon populations, fishery managers have decided to set harvest levels based on population responses to management in recent years.

Because of the monetary value of white sturgeon, especially with respect to caviar, illegal harvesting has become a threat to white sturgeon populations (Jones et al., 2011). In 2003, a poaching ring was discovered connected specifically to the Columbia and Sacramento rivers (Bailey, 2003). Researchers project that if 2,000 adult white sturgeon are illegally removed each year, this would represent 10-15 percent of current adult populations (Jones et al., 2011). Although the extent of illegal harvesting is difficult to capture, Oregon State Police's Fish and Wildlife Division reported 25 illegally harvested white sturgeon in 2008 and 48 in 2009 (Jones et al., 2011). While these are identified illegal harvest, the true number is likely much higher.

Competing Water Uses

In Idaho, Washington, and Oregon, freshwater withdrawals for domestic and public use are projected to increase by 71-85% by 2050 (Independent Scientific Advisory Board,

⁶⁹ Tissue samples from white sturgeon in Bonneville, the Dalles, and John Day reservoirs showed considerable traces of contaminants (Feist, et al., 2005).

2007). Continued population growth will increase residential, irrigation, recreational, commercial, and industrial water uses and heighten competition for limited water supplies. This situation will be exacerbated by the effects of climate change on the quantity and temperature of flows in the Basin. Many rivers within the Columbia River system have already been fully appropriated and aquifers heavily pumped. Despite this, demands continue to increase, threatening both present and future uses. Collectively, this creates a scenario of competition among the various users of the River, pitting the needs of the regions against the needs of ecosystems. Even without looking to the future, the worry now lies in how the River can meet all its needs while also allowing for fish to safely roam and spawn. Renegotiation of the Columbia River Treaty may exacerbate these conflicts, or help resolve them.

Irrigation

Irrigation is a major use of water in the Basin.⁷⁰ Roughly 6 million acres are irrigated in the mid-lower portions of the River (Cohen et al., 2000). Irrigation from surface and ground water is the dominant off-stream use of water in the Basin. Idaho has the largest irrigated area with 3.3 million acres (45% of the total Basin), Washington with 1.8 million acres (25%), Oregon with 1.3 million acres (18%) and Montana with 433 thousand acres (6%) (U.S. Department of Energy, 1995; Davidson & Paisley, 2009). Washington's \$49 billion agriculture industry represents 13 percent of the state's economy (Washington State Department of Agriculture, 2014). Moreover, in 2009, agriculture amounted to more than 15 percent of all economic activity in Oregon (Sorte et al., 2011). In 2009, agriculture production added \$22 billion dollars to Oregon's Gross Domestic Product (Sorte et al., 2011). Irrigated crops include potatoes, sugar beets, hops, mint, and fruit, as well as other vegetables and hay (Volkman, 1997). Irrigated crop values range from \$150 per acre for hay to \$6000 per acre for apple orchards and vineyards (Volkman, 1997). The production of viable agricultural land in the Basin adds to the sustenance of livelihoods in the region.

Throughout much of the Basin, agriculture expansion has led to the greatest change in land patterns. Large areas of the Basin have been converted to irrigated farming, amounting to 7,324,000 irrigated acres, including Canada (Volkman, 1997). While irrigation supports a lucrative agricultural industry, it reduces instream flows, fills streams with silt, and alters the timing of flow release for fish that have conflicting needs. Through the diversion of water and a failure to use screens in the process, juvenile fish are increasingly placed at risk and most often lost (National Academy of Sciences, 2004). Irrigation requirements have also created water quality problems (Cohen et al., 2000). Together, these pressures alter the hydrological conditions for the River's fish. As the climate changes and populations increase, water-related conflicts will become worse as demands for the River's resources also increase. This was dramatically illustrated in the low snowpack year of 2001 in the Klamath Basin where to maintain water levels for endangered species, authorities shut off irrigation channels, affecting 12,000 farms (34 percent of irrigated land in the basin) (Erickson & Gowdy, 2007). Gross farm incomes fell

⁷⁰ For example, the massive Columbia Basin Irrigation Project (CBIP) located at the Grand Coulee dam diverts 3 million acre-feet of water per year from the Columbia River to 671, 000 acres of farmland (Osborn, 2012).

between \$48 and \$64 million, in a region that generated average revenues of \$97 million the previous three years (Erickson & Gowdy, 2007).

Empirical evidence suggests that when water becomes tightly restricted within the Columbia River Basin, marginal value of crops are inferred to be \$46 per acre-foot, whereas when water is readily available, it values at only a few dollars per acre-foot (National Research Council, 2004). Assuming an equivalent land base for irrigated agriculture in the future, a 2030 forecast found a 2.5 percent rise in demand for irrigation water across the entire Columbia River Basin (Washington State Department of Ecology, 2011). Thus, as agricultural farmers increasingly draw down upon the River, fish could be left to fend for themselves.

Navigation

Commercial navigation on the Columbia River is a key contributor to economic sustainability in the U.S. Pacific Northwest (BC Ministry of Energy and Mines, June 25, 2013). The Columbia River is an important commercial waterway for transportation of goods to domestic and international markets. The River has over 790 kilometers of navigable river and serves 36 ports and carries approximately 40 percent of all United States wheat (BC Ministry of Energy and Mines, June 25, 2013). Over 35 million tons of goods each year worth roughly \$12 billion annually are exported and imported along the River. While suppliers rely on dependable shipping conditions, seasonal anticipated adjustments and competition between water users could both impact the safety and cost of navigation and port operations (i.e. halting traffic or having to use alternate modes of transportation). Reservoirs must be maintained to a 14-foot depth to allow safe passage of the barges and other traffic on the River. Between \$50 million and \$200 million is spent annually to maintain sufficient navigation channel depth and support economic development (BC Ministry of Energy and Mines, June 25, 2013).

Commercial navigation can directly impact white sturgeon through the habitat displacement, dredging for channels, as well as sound and pressure disturbances from propeller cavitation, and engine noise (Jones et al., 2011). Since white sturgeon use habitats where dredging occurs, evidence suggests that dredging operations can alter or destroy juvenile and adult habitat while also, attracting white sturgeon. Dredging spoils can be “pumped into upland holding ponds, dumped into the water column for dispersal or disposed of in shallows and on islands, and may result in direct mortalities of white sturgeon entrained in the dredging device” (Northwest Power Conservation Council, 2013a, p 100).

Hydropower

Adding to this equation are hydropower needs. The Columbia River and its tributaries power one of the world’s largest hydroelectric systems. For example, in 1998, the system produced an average of 12,000 megawatts of electricity (this is enough to supply a city ten times the size of Seattle) (National Research Council, 2004). If stream flow were reduced, this would have serious implications for the value of water in hydropower production. Moreover, storing water in the summer to be released in the winter for hydropower generation could strain the River’s capacity to meet competing demands,

leading to a potentially “irreconcilable competition for water” (Hamlet and Lettenamaier, 2000, p 1620).

Recreation

Recreational use of the River and its reservoirs varies across fishing, swimming, water skiing, windsurfing, picnicking, camping, rafting, boating, sightseeing, hunting and bird watching. While many recreational activities require stable specific water levels, flood risk management and power demands mandate the fluctuation of reservoir water levels.

Marine Mammal Predation

Dams restrict white sturgeon from upstream movement and in doing so, increases their vulnerability to predation. Observations near Bonneville Dam between January 2006 and May 2010 have recorded increases of white sturgeon predation from 442 cases in 2006 to 2,172 in 2010 (Jones et al., 2011). Marine mammal predation in the lower Columbia River affects rearing and life stages of white sturgeon (Jones et al., 2011).

Appendix F.

Fisheries Basin Management

Figure F.1. Timeline of Fisheries Basin Management

| Year | Event |
|------|--|
| 1973 | United States Endangered Species Act. This enforced operational changes at various dams in the Columbia River for recovery of ESA-listed species. These activities were also incorporated into the Treaty via annual Detailed Operating Plans and Supplemental Operating Agreements. |
| 1980 | Northwest Power Act. This provided increasing control over hydropower management to states in the United States along the Columbia Basin, while also recognizing the need for flows to protect fish and wildlife in the River. |
| 1984 | Non-Treaty Storage Agreement. This provided flows from non-treaty dams, allowing support for fish flow requirements in the United States under the Endangered Species Act. |
| 1991 | Columbia River's anadromous fish populations listed under Endangered Species Act (eight salmon and four steelhead species). |
| 1995 | Columbia Basin Trust established in British Columbia to mitigate environmental impacts of Columbia projects in Canada. |
| 1998 | B.C. issued Water Use Plan Guidelines to find ways to balance competing uses of water, such as domestic water supply, fish and wildlife, recreation, heritage, flood control and electrical power needs. ⁷¹ |
| 2000 | Libby Coordination Agreement. This allowed a portion of non-treaty flows to be given to fish and wildlife management in the United States. |
| 2005 | Northwest Power and Conservation Council established. The Council develops long-term and co-ordinated energy and fish conservation plans for the Columbia River. |
| 2008 | Federal Columbia River Power System (FCRPS) Biological Opinion. The FCRPS Biological Opinion describes a comprehensive set of actions to ensure the operational effects of the FCRPS on 13 listed salmon and steelhead complies with the Endangered Species Act. |
| 2008 | Columbia Basin Fish Accords |
| 2014 | Northwest Power Conservation Council Fish and Wildlife Program. The Council's program serves as a foundation for federal agencies working to mitigate impacts and recover species in the Basin. In October 2014, the Northwest Power and Conservation Council amended its Columbia River Basin Fish and Wildlife Program to investigate reintroducing anadromous fish back into the main stem Columbia River reaches and tributaries in the U.S.. In addition to salmon and steelhead, the program makes specific reference to the white sturgeon. |
| 2014 | Energy & Water Development Appropriation Act. This Act mandates the expenditure of funds for the design, testing, and construction of new or improved fish bypass facilities for Columbia River fish mitigation projects |

⁷¹ In 2001, the province of British Columbia made a policy decision that the magnitude of change it was willing to accept on the Columbia was smaller compared to other systems underdoing water use planning. Recognizing the value of the River for power generation, government policy set a cap on funding needed to support the implementation of water use plans (BC Hydro, n.d.).

In addition to examples of flexibility throughout Basin management, the Treaty enables flexibility in the operation of dams for maximum Canadian benefits, provided storage operations remain within the constraints of the Flood Control Operating Plan and flow across the U.S. border remains unchanged from the agreed flows. This flexibility allows BC Hydro to move water between various dams in response to power, social and environmental interests (CRTR, 2012). Moreover, the Treaty permits both entities to develop agreements that allow for mutually beneficial changes to baseline operations, including fisheries. Related agreements over the years include the Supplemental Operating Agreements, Non-Treaty Storage Agreement, Exchange of Notes, and the Libby Coordination Agreement.

In addition to plans specified within the formal Treaty,⁷² British Columbia and the United States may agree during the operating year to mutually beneficial arrangements referred to as supplemental operating agreements (SOAs) above or below the specified operating rules to meet power and non-power benefits (Bankes & Cosens, 2014). The SOAs tailor the operation of Treaty storage to address power and non-power objectives in relation to stream flows and operating conditions. An example of an action included in SOAs is the Canadian storage exchange at Libby Dam. This SOA provides exchange of storage between Libby and Canadian Treaty Storage to enhance both power and environmental objectives. SOAs can also be used to help meet requirements related to endangered listed fish species in the U.S. and minimum flows for Canadian resident fish (Bankes & Cosens, 2014).

The existence of non-treaty storage at Canadian facilities and the agreement of its storage operation provide additional flexibility in the management of the River. Because British Columbia designed Mica Dam with more storage capacity than was required by the Columbia River Treaty, this additional storage capacity referred to as the Non-Treaty Storage Agreement (NTSA) can be managed for power or non-power needs. For instance, the provision to release flows during dry seasons in the NTSA guarantees the United States a 0.5 million acre feet (MAF) release to support salmon migration in the lower Columbia River during the driest 20 percent runoff years (BC Ministry of Energy and Mines, June 25, 2013).

The Treaty contains provisions dealing with the elaboration of certain provisions by means of an Exchange of Notes. An exchange of notes occurs when one party proposes a particular agreement and the other responds by accepting the proposal (Bankes & Cosens, 2014). While the Treaty contains several examples of its use, these initiatives have all occurred within the confines of the Treaty's scope.⁷³ Yet, as it shows, an Exchange of Notes enables the Treaty to be adaptable and in doing so, suggests that parties are willing to accept a level of flexibility.

⁷² The Assured Operating Plans (AOPs) and Detailed Operating Plans (DOPs) are part of the formal Treaty apparatus. The AOP establishes rule curves, assured and variable refill curves and upper rule curves for each of the Canadian Treaty projects. The DOP is prepared annually for the next operating year and aims to evaluate proposed changes to the AOP.

⁷³ For a comprehensive list demonstrating the use of an Exchange of Notes in the Treaty, refer to: Bankes, N. & Cosens, B. (2014). *Protocols for adaptive water governance: The future of the Columbia River Treaty*. Munk School of Global Affairs: University of Toronto.

The most notable is the 2000 Libby Coordination Agreement (LCA).⁷⁴ This agreement between the British Columbia and the United States was created to resolve disputes about the operation of the Libby Dam and to provide flows to facilitate, protect, and enhance white sturgeon spawning downstream of the dam. The LCA can be terminated by either party with 30 days' notice and automatically ends on September 15, 2024 (Banks & Cosens, 2014). The LCA provides a significant example of how parties have coordinated and addressed ecological concerns under the Treaty regime.

In addition to the LCA, the Columbia Basin tribes in the U.S. and First Nations in Canada participate in their respective countries' reconsiderations of the Columbia River Treaty and other forums from which to promote coordinated, bilateral fish reintroduction efforts. Through Treaty reconsideration, this group encourages their communities and governments to protect, enhance, and restore fish passage at Chief Joseph and Grand Coulee dams in the U.S. and at Hugh Keenleyside, Brilliant, Waneta, and Seven Mile dams in Canada (Columbia Basin Tribes and First Nations, 2014). Among its four objectives, the Columbia Basin Tribes and First Nations hope to restore access and population structure of resident fish including sturgeon and their historical habitats. Some preliminary planning has already occurred for Canadian projects and operations that legally must consider fish passage at Hugh Heenleyside, Brilliant and Waneta dams if anadromous fish are passed and restored above Chief Joseph and Grand Coulee dams in the United States.

The Lake Roosevelt White Sturgeon Recovery Project is a multi-agency venture that is responsible for assessing the white sturgeon population in Lake Roosevelt. For four years, the project has surveyed the white sturgeon population in the reservoir and free-flowing section of the Columbia River above Lake Roosevelt. Coordination between the U.S. and Canada is critical to the recovery of the upper Columbia River transboundary population and thus, the project has been working cooperatively with the transboundary Upper Columbia White Sturgeon Recovery Initiative and Team (UCWSRI/T).⁷⁵

⁷⁴ The LCA implements operational changes at Libby Dam such as improved temperature control, tiered sturgeon flow volumes, and Variable Flow (VARQ) flood control.

⁷⁵ The UCWSRI was formed in 2000 to aid the recovery of the Columbia River white sturgeon populations. The UCWSRI is comprised of U.S. and Canadian federal, state, provincial, First Nations and Tribal representatives. This includes biologists, researchers, and other sturgeon experts from provincial, federal and state governments, B.C. Hydro, Teck Metals, Columbia Power Corporation, Bonneville Power Administration, Spokane Tribe of Indians, Colville Confederated Tribes and other groups.

Appendix G.

Semi-Structured Interview Questions

Purpose of interview: The goal of this research is to provide a better understanding of the value of ecosystem goods and services within the Columbia River Basin, with specific consideration to the U.S. Columbia River White Sturgeon. In doing so, this research hopes to gain an understanding of how to incorporate ecosystem goods and services within Basin management or renegotiations of the Columbia River Treaty and explores policy options to better protect and enhance White Sturgeon within the Columbia River.

Sample questions (Information Round)

- What is your current understanding of White Sturgeon or the concept of ecosystem services within the Columbia River Basin?
- In your opinion, what market and non-market values are attached to White Sturgeon in the Columbia River Basin? Are any of these values represented in your daily life (i.e. recreation, fishing, culture, economic well-being, etc.)?
- What are some of the biggest stressors affecting the White Sturgeon in the Columbia River Basin?
- Over the past decade, do you believe that impacts to White Sturgeon have become worse, remained the same, or have improved?
- What do you think are the primary problems and challenges with how the Treaty has been framed in regards to White Sturgeon? Do you see any of these challenges interconnected?
- Do you see any direct links between basin management and the number of White Sturgeon? If so, how has basin management impacted White Sturgeon?

Ground-Truthing Questions: Feasibility of Implementation Round

- Because the Columbia River Treaty currently does not take into account White Sturgeon or other ecosystems, what could revisions to the treaty do to accommodate White Sturgeon/ecosystems? How?
- From your perspective, what are some of the transboundary policy options available to facilitate the protection of White Sturgeon? Or if you feel coordinated action is unlikely, what are other policy options that could protect this fish?

Of these policy options, what do you consider the most effective?

1. Please explain some of the key advantages with implementing this policy option.
2. Please explain some of the key challenges or obstacles with implementation.

- Specifically focusing on ecosystem goods and services, what do you think are the biggest barriers for incorporating this framework into the Treaty?
- Do you know of any interesting models, policies or approaches that have been used to address ecosystem services or fish that would be relevant to this research?
- From the list of policy instruments provided, do any stand out as being potentially feasible to implement, and why?

1. Transboundary watershed group
2. Treaty Modernization
3. Adaptive governance
4. Integrated water resources management committee

For the ones that would not be feasible, what do you see being the barriers?

Appendix H.

Quantitative Findings

Annual Value of Recreational Angling in the U.S. Columbia River Basin

To estimate the benefits of steelhead recreational angling in the United States portion of the Columbia River, the annual number of recreational steelhead anglers, number of trips made by steelhead anglers, average trip costs, and average permit costs from Idaho, Montana, Washington, and Oregon were used (see Table 7.1).⁷⁶

Table H.1. Recreational River Angling Expenditures

| Item | Definition |
|----------------------|--|
| Anglers | Number of river anglers |
| Trip Costs | Food, lodging, transportation, equipment rental, bait, and cooking fuel. |
| Trips | Trips per year |
| Permit & Other Costs | Membership dues, licenses, permits, stamps, and land leasing. |

Annual Value of Food provided by White Sturgeon

Female sturgeon produce thousands of eggs per kilogram. A literature scan indicates a range between 8-12 percent of female sturgeon bodyweight produces eggs (Logan et al., 1995).⁷⁷ From this, an 8 percent mark was used to calculate and define female white sturgeon as 48 kilogram fish. Moreover, scientific information pointed towards an estimated female to male sex ratio for white sturgeon (DeVore et al., n.d.). This information was used to base calculations of caviar against 45 percent of the target population.⁷⁸

⁷⁶ The four major states that the Columbia River runs through were included for estimation purposes.

⁷⁷ An estimated average weight of 600kg was used for white sturgeon. Based on Logan et al. (1995). 8 percent of 600kg was calculated to use 48kg as the weight to multiply the price of caviar by. Caviar benefits may represent an overestimate or underestimate of annual benefits due to variability in time of harvest and bodyweight.

⁷⁸ Of the targeted 10,000 white sturgeon population size, an estimated 4,500 were designated as female and used for caviar benefit calculations.

Appendix I.

Interview Summaries

Impacts to White Sturgeon

When discussing the various stressors affecting white sturgeon and ecosystems within the Columbia River Basin, a similar explanation emerged across all interviewees. All participants identified the following pressures on white sturgeon: urbanization, pollution, overharvesting and fishing practices, environmental degradation (i.e. forestry projects), large scale water diversion projects, predation, climate change, water flow issues, and hydropower dams. Participants' stated that most of these stressors are a result of human changes and modifications to the River and also because white sturgeon are slow to mature.

The majority of participants expressed that stressors are complicated to address because their level of impact varies across the River. This implies that while there is consensus on the various impacts affecting white sturgeon, stressors will be difficult to address given regional variations in environmental degradation and sources of threats.

All interviewees discussed how dams along the Columbia River restrict upstream movement of white sturgeon and as a result, created isolated subpopulations that are no longer genetically connected. The participants stated that operations of the hydro system have dramatically decreased the conditions needed to promote successful spawning and a strong age class of white sturgeon, limiting their reproductive potential. This view is reinforced in the literature. As discussed in Chapter four, the change in water flow and quantity from hydropower operations have produced harmful effects on white sturgeon. One participant indicated that while fish ladders were installed on dams along the River, a lack of focus and knowledge of how white sturgeon move through the system has amounted to passages that fail to readily facilitate sturgeon migration. This participant later noted that although fish ladders were built with consideration to salmon, even with these efforts they failed to provide favourable conditions for salmon passage. Thus, any actions taken to enable sturgeon to move freely through the Columbia system must involve foresight to all fish species, including the white sturgeon.

Participants also emphasized the effects of climate change on the Basin. One participant stated:

It's clear that climate change will mean less water stored as snow and ice and scientists say we will have the same amount of water but that flows will come at a time when we don't need it. Water will come earlier than during the dry summer. So water will come down the Columbia at the wrong time for fish. We are changing the ecosystem really quickly and species, especially fish are not able to adjust as fast. As the River starts to flow more heavily in the winter and early spring, you'll see more competition as the water becomes shorter and shorter for farmers, cities, and fish that need more water in the summer.

Another participant supported this comment by pointing towards the unequal effects climate change could have on the River. This participant noted that while Canada will experience an increase in annual water flows, less water will be available to the United States portion of the Basin, especially during summer months. Yet despite concerns of water volumes, this participant asserted that the warming of water was more acute in the near term. This is particularly concerning because warmer waters could be threatening to species and ecosystems such as sturgeon who thrive in cooler water temperatures.

In responding to stressors, interviewees discussed the merits of supplementation and hatchery programs. Interviewees' saw these programs as short-term strategies used to keep populations alive but thought to solve the problem natural ecosystems needed to be restored for white sturgeon to survive on their own. One participant noted that if we fail to do this, the risk of extinction for the white sturgeon increases.

White Sturgeon Ecosystem Goods and Services

While the term 'ecosystem goods and services' and its relation to white sturgeon was recognized by all interviewees, the consensus is that valuation of the white sturgeon is necessary for the concept of ecosystem function to be recognized in Basin management. When asked what he/she thought of ecosystem goods and services with respect to the Columbia River, one participant stated:

Those concepts represent a major shift in the approach that people are taking to restoration in the Columbia River and it's a real recognition that fish and wildlife use the whole system and not just one piece of it. A lot of agencies and people in the United States understand and depend on white sturgeon as not only a sport fish and food fish but also as a significant tribal fish.

Multiple participants indicated that white sturgeon occupy strong cultural values that cannot be replaced. While all participants realized that the white sturgeon had economic value, participants stated their cultural values were significantly higher. The majority of interviewees stated that white sturgeon are historic, iconic, and spiritual species that are fundamental to residents' well-being. One participant stated:

We value [white sturgeon] inherently for the diversity that they bring to the river. [White sturgeon] have a unique lifecycle; they resemble dinosaurs in some ways. Sturgeon are archaic and ancient, they are a very early form of fish that are slow to reproduce and grow to enormous size and for those reasons, they are historic, valuable, and clearly at risk.

While other interviewees supported the spirituality attached to white sturgeon, some mentioned how this created intergenerational concerns. As a resident on the Columbia River for over 15 years, a participant noted:

The value I place on white sturgeon enables me to understand the importance in seeing fish again especially because when I pass away, I want my children and grandchildren to experience this value too.

This applies significant value to the existence and preservation of white sturgeon. Participants placed emphasis on the availability of white sturgeon for present and future generations. One participant discussed the relationship between humans and wildlife and how this connection is taken for granted when deciding basic questions about how many dams to create, how much electricity to produce, and how much money can be produced. This participant stated that while the construction of a dam may be easier to estimate, the spiritual and cultural value of species is not and as a result, decision makers make little effort to include or understand its significance. Another participant believes there is a critical lack of knowledge among policymakers regarding these services provided by fish and wildlife and the value they have upon human life. This presents an opportunity for ecosystem valuation within the policy process and decision making framework. With a heightened level of awareness of ecosystem services and its relation to the Columbia River, substantive policy changes could occur.

Interviewees also commented on the recreational value held by white sturgeon to tribal harvesters, fishermen, and sportsmen. Participants indicated that white sturgeon represent a high value to a broad level of fisheries. Some participants described why sturgeon are 'fun to catch' and unlike any other species from a recreational standpoint. One participant mentioned that in his/her own experience, no other substitute existed for white sturgeon. In this discussion, the participant notes:

From a marketing standpoint you could look to other white fish such as halibut but from a recreational angler standpoint there is no substitute. When you get a sturgeon, they almost dance out of the water and there is no substitute for that experience in the Pacific Northwest.

Thus, if white sturgeon have few or no substitutes then very high levels of compensation would be required to make up for their loss. Multiple interviewees also mentioned how the role white sturgeon play in the ecosystem has not been well explored or researched. One participant mentioned that any species as long lived, large, and in similar abundance to historic numbers of white sturgeon plays an important role in the ecosystem but because few studies capture this, we fail to truly understand this role. Another interviewee stated that there was a lack of investment being made in research on what could be done to improve habitat conditions for white sturgeon and ecosystems more generally. This highlights an area for policy intervention. Research and data gaps impede policy development for white sturgeon protection and population remediation. In light of this research gap, participants commented that the best approach in the interim is to exercise as much precaution in order to conserve as best as possible the species and their role within the broader river ecosystem.

Treaty Framework Barriers

Consensus across all interviewees' confirmed that the Columbia River Treaty was created in focus of flood control and hydropower generation with larger ecological issues not addressed. As one participant noted:

Going back 50, 60 years, the concern of the time was power generation and economic development, which was completely understandable in terms of the periods of flooding that people experienced but there was not adequate consideration for the damage that the [hydropower] facilities created. Yes, [hydropower dams] helped flood reduction and safety but the whole discussion for fish and streamflow did not receive any attention.

In our discussion, one interviewee pointed toward how the Treaty had shifted the River's hydrograph through its emphasis on flood control and risk aversion. This participant stated that the United States alone did not have the storage capacity to shift the hydrograph and instead, reservoirs in British Columbia were to blame. Without reservoirs in British Columbia, the participant stated that the hydrograph would have remained in its natural state. This participant states:

In addition to the effects of additional dams, Treaty operated reservoirs and its emphasis on risk aversion through flood control provisions have been key elements in reducing sturgeon productivity.

These arguments reinforce previously discussed challenges with the Columbia River Treaty. As the evidence suggests, a clear barrier toward addressing white sturgeon health through the Treaty is its narrow focus on flood control and hydropower generation. With a broadening of scope or flexibility built within the Treaty, perhaps then policy change could occur to accommodate white sturgeon needs.

Another challenge brought up by participants concerned the scope of the Columbia River Treaty and the number of Treaty dams versus non-Treaty dams along the Columbia River. While most participants were hesitant to accept that because the Treaty deals with fewer dams that broader ecosystem needs should be left out of Treaty discussions, this topic was concerning among participants. Participants discussed hearing Energy Minister Bill Bennett state that the reintroduction of salmon was not a Treaty issue. According to participants, this means that because some non-Treaty dams in the United States are responsible for halting salmon migration, Minister Bennett would rather the issue of salmon remediation to be left outside the Treaty. Most participants noted that while non-Treaty dams have affected the migration of various fish, the operation of these dams affects fish runs in both countries and thus, should be addressed collaboratively. While components of the River experience different impacts, this participant noted that the threat of fish migration resonates throughout the River. One participant stated that because dams located in the United States are reliant on water released from Treaty dams in British Columbia, how Treaty dams operate will significantly affect flows for fish migrating up and down the River. In this regard, the majority of participants felt that collaborative and consistent operations across all dams

would work best to address fishery needs. With the possible threat of future dam impoundments on the Columbia River, these reactions could help to create focus around the cumulative effects of dams and in doing so, provide foresight to renegotiations of the Treaty.

Bringing Ecosystems into the Framework

When asked how Treaty revisions could accommodate white sturgeon and broader ecosystem needs, participants gave varying replies. Two participants discussed the Treaty's focus on flood control and risk aversion. Based on modelling in the United States, one of these participants stated the following:

If we took a less risk averse approach to flood control and maintained somewhat higher reservoir levels as opposed to emptying all the reservoir as low as the operating curves allow every spring prior to runoff, we would pass more water in the spring more often for sturgeon populations to build up again. The primary possibility for introducing ecosystems into the Treaty and benefiting sturgeon is to change flood control rules enough to increase refill probability and experience higher spring time flows in greater percentage years.

This suggests a technical way for the Treaty to reorient its operations towards ecosystem needs within its existing framework. Another participant indicated that in order for ecosystem values to be taken into account, Treaty renegotiations must make environmental issues an explicit component of the Treaty. In addition to flood control and hydropower generation, this would create a third environmental objective into the Treaty. One participant reinforced this view by stating there was significant potential to discuss ecosystem issues in a more system wide approach relative to flows and hydropower generation.

In our discussion, a participant suggested that perhaps the scope of the Treaty needed to be broadened to include the governance of additional dams or future dams along the River. This participant stated that the Treaty was the best option available to the Pacific Northwest to holistically and cooperatively govern the Columbia River. The participant noted:

If we maintain governance of the river through a limited lens, the River's capacity will continue to be negatively impacted because as you start tweaking one dam, this upsets the entire River system. You have to coordinate all the dams together and that is tremendously complex.

Following this suggestion to expand the Treaty's coverage along the River would involve both nations undertaking a wider range of powers and a higher level of governance. In this way, to work efficiently, policy must find a way for both parties to speak with one clear voice. This will be a tall order.

Other participants' felt including ecosystems into the Treaty was not necessary and instead proposed outside mechanisms for addressing sturgeon needs. One participant

suggested the Northwest Power Conservation Council's Columbia River Basin Fish and Wildlife program as an avenue from which to address ecosystem needs in the lower half of the Basin.⁷⁹ Another interviewee pointed towards the use of the U.S. Endangered Species Act (ESA) to respond to ecosystems under threat. This participant described how white sturgeon in the Kootenai River are designated under the ESA and how this listing affects their management. Without ESA restrictions, one participant stated that hydropower companies are able to get by on technicalities instead of stepping back and viewing the River as a system. In spite of these examples, the limited scope of the ESA makes it difficult to protect broader ecosystem needs along the River. While the ESA may work well to protect listed species, species and ecosystems under threat that fail to meet the ESA threshold are left out.

Ultimately, this question elicited various reactions and views. Decisions on how policy can best address ecosystem needs within the Basin will require a robust assessment of the trade-offs amongst alternatives and options.

Challenges to an Ecosystem Based Treaty

In discussing barriers towards incorporating ecosystem health and white sturgeon needs into the Treaty, most participants indicated institutional, political, and stakeholder inclusion as the main bottlenecks. One interviewee mentioned that there may be reluctance at the U.S. federal level to mess with what has been pointed to as a great example of how good neighbours should get along. Because of this, the participant stated ecosystem health might have to be addressed outside of the Treaty at a regional level. This participant voiced:

And obviously building structures to do this are very difficult and they tend to be more temporary and dependent upon circumstances and regional leaders at the time. Yet, the Treaty shows better promise as regional strategies won't have the same durability as the Treaty.

This is an important consideration mentioned earlier in the literature. If the Treaty were unable to address ecosystem needs, domestic and regional strategies would become called upon. Yet, the extent to which regional agendas include ecosystem needs will be heavily dependent upon regional leaders holding short term positions. One participant characterized this barrier as short term self-interest. He/she pointed out that while regional decision makers may want to think in broader terms, the day-to-day reality of the job inhibits them from doing so. As another participant notes:

I think with the Columbia River Treaty you take a swath of area and if you just relied on regional efforts you wouldn't get the full depth and scale of the Columbia River itself.

⁷⁹ The Council's 2014 revised program addresses all species affected by hydropower dams along the River. A component of this program specifically deals with white sturgeon as a species of concern.

Another participant supported this by noting that regional strategies are dependent on regional vision and efforts by politicians, tribal nations and chiefs that are all intertwined to the initiative. Other participants added that while political will is lacking on both sides of the border, the provincial government in British Columbia places no value on ecosystems and instead is cutting back resources in that area, creating a huge barrier towards addressing ecosystem needs. Other interviewees' brought up the need to broaden representation of interests in Treaty decision making. One participant stated:

The other barrier is who is actually engaged in the decision making. On the U.S. side it's the federal government on behalf of the states and tribes and on the Canadian side it's BC Hydro trying to act on behalf of the provincial government and first nations. Until there is a somewhat broader representation of interest in the actual decision making it will be harder to do more than the gradual change that we have been seeing.

Conversely, one participant felt the inclusions of additional stakeholders, voices, and needs within the Treaty could further complexities to renegotiations. Yet, for many participants, the representation of each entity in the U.S. and Canada remains a big question and challenge towards incorporating ecosystem objectives more broadly into the Treaty.

One participant brought up the level of ecological literacy among populations as a barrier towards incorporating ecosystem health into the Treaty. This participant stated:

I don't think people in general really have a good knowledge of how river systems are dependent on seasonal flows of water or how they are built and developed so once you change the river system there are all kinds of diverse effects that we don't understand.

This revealed how an insufficient understanding of the River as an ecosystem can become translated into a lack of foresight amongst decisions makers. Moreover, because most individuals tend to look at the bottom line in simplistic and immediate terms, this can become an impediment towards researching and fully understanding environmental needs, health, and repercussions to the River. Without a sufficient understanding of ecosystem needs and various effects on the River, Treaty renegotiations will fall short of protecting the ecosystem needs.

Monetary compensation and economic loss were also cited as potential challenges to including ecosystems and white sturgeon needs into the Treaty. A few participants indicated how parties in British Columbia and the United states were more concerned about the amount of money paid and received than restoring fish runs or remediating ecosystem health in the Basin. Similarly, economic losses achieved from changes to hydropower operations to better facilitate white sturgeon and ecosystem needs was expressed as a barrier. In this discussion, the participant stated:

Hydropower dams are engineered such that they maximize power production and revenue and as soon as you start proposing we change operations to benefit fish they don't want to talk about it so it's basically a clash against interests and a really big challenge to overcome.

Because hydropower production and flood protection are major issues for Treaty signatories, requests to reduce the capacity of these objectives may not be received favourably. Under this scenario, the participant stated it would be important to show all relevant research on ecosystems and the monetary value of ecosystem goods and services when weighing the pros and cons of proposed actions. This could be difficult though if decision makers are unable to acquire all necessary information. Throughout our discussions, many participants explained how due to a lack of research, we are unaware of the number of white sturgeon in certain areas of the River and also how well they are responding to supplementation efforts. Consequently, without this information, decision makers are unsure of the total loss of white sturgeon and negative effects to its populations. This would also follow for all other ecosystems distributed throughout the River. Obtaining baseline data and monitoring updates would aid policymakers in assessing what initiatives and actions are working to improve ecosystem health in the River. Participants supported this by indicating a lack of research and funding towards research. One participant stated that while the United States has placed significant efforts into this area, Canada lags behind exponentially. Thus, without adequate research and information being relayed to decision makers, it will be difficult to create effective policy.

Policy Considerations

When discussing policy considerations to address white sturgeon protection and ecosystem health within the River, responses differed among participants. The main policies considered by interviewees included: Treaty modernization, transboundary watershed group, integrated water resources management committee, and adaptive governance. The majority of participants asserted that policymakers should both modernize the Treaty to include ecological considerations and implement adaptive governance within its framework. Based on his/her experience, one participant expressed that the most durable and resilient way to address white sturgeon and ecosystem value is through options that include renegotiations or modernization of the Treaty. This participant discussed the benefit of responding to white sturgeon through transboundary cooperation and noted:

The response should be a joint effort between Canada and the United States. Sturgeon were initially transboundary so it's important that policy also be. Transboundary governance provides a wonderful learning experience with information and knowledge flowing back and forth over the border, which is great.

This relates to the lack of research identified as a barrier in the previous section. Including environmental objectives within the Treaty may help to facilitate information

sharing, increase research efforts, and fill gaps in understanding on ecosystems and white sturgeon populations. Participants also explained the importance of establishing mechanisms for adaptive management within the Treaty. In reflecting on change since the Treaty was signed, one participant discussed the importance of continually having new dialogue and science brought forward to assess and respond to changing conditions. This participant pointed towards the Pacific Salmon Treaty (PST) as a model from which the Columbia River Treaty could learn from.⁸⁰ By increasing research and monitoring efforts in defined areas by the Treaty, obtained data can be used to inform further decisions for protecting and enhancing white sturgeon and ecosystem health within the Basin. Through adaptive governance, the treaty could enhance its flexibility and adaptive capacity in transboundary water management. In some ways, adaptive governance could serve to bridge identified differences between Canada and the United States on the treatment of ecosystem values. This concept is explored further in Chapter 11.

While the discussion of an outside transboundary watershed group was discussed by most participants, not all participants felt favourable about it. One participant suggested that having an outside group would work only if there was strong leadership that provided a common function and long term vision to people. Other participants felt this approach was unnecessary and unlikely, with one participant expressing that he/she didn't feel either party of the Treaty would be willing to include recommendations made by an outside transboundary group.

The above findings and remaining policy considerations expressed by interviewees are used in Chapter 10 to help guide the determination of which policy is most effective for addressing this policy problem.

⁸⁰ The PST is comprised of a commission, panels, and various technical committees and working groups. The PST emphasizes flexibility and adaptation in relation to the Pacific salmon fishery through the use of an umbrella treaty accompanied by detailed annexes open to amendments (Banks and Cosens, 2014).

Appendix J.

Description of Criteria and Measures

Flexibility

Flexibility is used as a guiding objective to address the complexity of ecosystems. Science is continually improving to better understand the structures, functions, and uncertainty of ecosystems. Policy options are assessed on their ability to respond to and integrate new information, data, and decisions. Given this objective, governing bodies of the Basin will be able to address environmental issues as they develop. In doing so, authorities can ascertain the most effective intervention and easily alter policy approaches as information and science develops.

Given the identified research gaps on the impacts to white sturgeon and its population decline, policies that promote the flexibility to address white sturgeon decline with better and evolving information is prudent. As the hydrograph of the River and its ecosystems change, policy approaches with a greater degree of flexibility are increasingly desirable. Ultimately, a flexible policy provides maximal room to adapt ecosystem function and health. This criterion is assessed using information obtained from the literature.

Ease of Implementation

Ease of implementation considers the likelihood of the policy option facing political resistance, and whether the option can be implemented under the current Treaty. Competing priorities of governments can impact the likelihood of policy being implemented. With anticipated population growth in the Basin, what uses of the River takes priority? Increasing hydroelectricity demands could push Treaty entities to focus more on power generation. To evaluate this, official statements released from provincial and federal bodies in both jurisdictions expressing opinion on the policy will be used as primary comparison, with supplementary information from stakeholder interviews.

The level of stakeholder acceptability is also critical. Water in the Basin is claimed by governments, agencies, and private entities, and regulated by international, federal, tribal and state agencies with different scopes of authority, regulatory interests, and purposes (Osborn, 2012). Stakeholder acceptability considers whether alternative governance involves engagement with stakeholders of the Columbia River Basin and

their approval levels for each policy.⁸¹ This criterion is evaluated on the most recent benchmark of public statements expressed by stakeholders, complemented with stakeholder interviews, to determine the expected level of stakeholder acceptability for each option.

Lastly, ease of implementation considers the administrative complexity of each policy option. As it stands, Treaty objectives limit the role and scope of operations. Policies that propose changes to these operations for the benefit of white sturgeon and ecosystems in the River will require changes to Treaty operations, experts from various areas outside the treaty, and the modification of goals, objectives, and operating plans. For options operating outside of the Treaty, the creation and implementation of these policies becomes even more burdensome, costly, and complex to manage. Some policies may involve upfront costs that require immediate implementation in order to realize any future benefits. All of this increases the amount of change and costs required by each policy option. A policy option scores high on this criterion for requiring minimal change in its implementation, or if resources can be easily reallocated to achieve the policy.

Equity

The distribution of impacts to both Canada and the United States is critical for cooperation. For example, if water flows were increasingly allocated toward white sturgeon, this could impact hydroelectricity generation costs in both regions. Costs to both nations could range between \$14 to \$76 per acre-foot of additional water being lost to ecosystem needs (National Research Council, 2004).⁸² As a result, in the U.S. Pacific Northwest, the per-kilowatt-hour costs of power supply have increased over time because of fish and wildlife expenditures (Northwest Power Conservation Council, 2014). Moreover, while the direct capital costs of required re-engineering to allow fish passage is uncertain, these costs will undoubtedly be high. For example, new fish passage facilities at the Waneta Expansion Project are calculated at capital costs of \$30-40 million U.S. (Nelitz et al., 2007). In a preliminary evaluation of passage options at Chief Joseph dam, capital costs are estimated at \$7-71 million (Nelitz et al., 2007). Demonstrated in both of these cases, foregone revenues need to be considered. In the future, as carbon emission regulations become more stringent, impacts from

⁸¹ A number of major stakeholders are involved with this policy issue: the United States Army Corps of Engineers, Bonneville Power Administration, BC Hydro, non-profit organizations, tribal nations along the River, community members and industries, United States Department of Fish and Wildlife, Department of Fisheries and Oceans, BC Ministry of Environment, Lands, and Parks, National Marine Fisheries Service, and Northwest Power Planning Council, Powerex, Fortis, BC Utilities Commission, the Comptroller of Water Rights, Natural Resources Canada, Environment Canada, the Columbia Basin Trust, Canadian Columbia River Inter-Tribal Fisheries Commission, the private sector, municipalities and regional districts, the Bureau of Land Reclamation, National Marine Fisheries, Bureau of Land Management, the Federal Energy Regulatory Commission, the Natural Resource Conservation Service, the Environmental Protection Agency, the Columbia Basin Fish and Wildlife Authority.

⁸² The higher values correspond to loss of water further upriver in British Columbia, while the lower values are based on water located in the mid-stem of the Columbia River (National Research Council, 2004).

hydroelectric generation may be valued higher than today. Overall, reductions or alterations in streamflow and storage for sturgeon could have significant implications for hydropower production, revenues, and system reliability in both countries.

Reallocation of flows and water volumes to benefit fish passage also pose financial implications to other water users. Policies that increase water flow or volume for sturgeon may pose adverse impacts on navigation and specific communities that depend on shipments. Additionally, if less water is diverted toward irrigation needs, agriculture in Washington and Oregon could experience annual costs ranging from \$465 million to \$2.4 billion, depending on the amount of water lost (Goodstein & Matson, 2007). For example, in 2001, low snowpack in the Klamath Basin led authorities to shut off irrigation channels, affecting 12,000 farms (34 percent of irrigated land in the basin) to maintain water levels for endangered species (Erickson & Gowdy, 2007). As a result, gross farm incomes fell between \$48 and \$64 million, in a region that generated average revenues of \$97 million the previous three years (Erickson & Gowdy, 2007).

Thus, the implications of each policy varies across agricultural, navigational⁸³, hydropower, municipal, and recreational uses and create difficult trade-offs. Moreover, while the distribution of impacts between Treaty entities is significantly important to including EGS in Basin management, impacts from any given level of EGS are expected to be shared unequally between water users in Canada and the United States.⁸⁴ Although the distribution of impacts will be similar across policy options, specific management efforts may be more apt to create equity. Thus, in keeping align with the Treaty's founding principles of creating and sharing benefits equally, policy options aim to incorporate EGS in Basin management by finding mechanisms for equity. Impacts are determined by the timing and magnitude of changes in flow and storage for EGS. To assess distributional impacts, each policy option is evaluated against its level of impact to water users across the River. If the policy option includes mechanisms for equity (i.e. compensation), the policy scores favourably. In this case, policy should evaluate whether processes are in place to compensate disproportionately affected parties and whether compensation matches the level of impact created by policy. Literature from case studies, academic reports, state reports, and information from stakeholder interviews is used to predict and evaluate equity concerns.

Community conservation funds developed through willingness to pay (WTP) measures represents one avenue from which compensation to impacted water users could be derived.⁸⁵ For instance, the WTP acquired through benefit transfer in my study (see Chapter 7) serves as an indicator of how much money households in the United States portion of the Basin could be willing to forego to preserve and restore white sturgeon

⁸³ The marginal value of water for navigational purposes on the Columbia River has been estimated at \$5.60/acre-foot (Nelitz et al., 2007).

⁸⁴ As it stands, the U.S. receives the majority of Treaty benefits, while B.C. bears a disproportionate amount of the costs (BC Ministry of Energy and Mines, June 25, 2013). For further information refer to Section 5.

⁸⁵ The purpose of the conservation fund is to provide local financial support to projects that will protect and enhance natural areas. For example, the East Kootenay Columbia Valley Local Conservation Fund receives dedicated funds for conservation projects from property owners' willingness to pay a parcel tax of \$20 per year.

populations. Using this money to compensate industry for the preservation of white sturgeon would serve well to better ensure equitable impacts. Equity, in this sense, relates to how well policy addresses white sturgeon, while also ensuring that no communities are made worse-off.

Equity also considers intergenerational impacts. Policy approaches should be evaluated based on its ability to ensure that generations in the future are not made worse off than current generations. If policy fails to address white sturgeon health in the River, this could inflict costs and repercussions to future white sturgeon anglers and consumers, and also significantly impact the cultural heritage of future residents in the Pacific Northwest.

Effectiveness

Ultimately, the goal for any policy option is to address the decline of white sturgeon populations and facilitate the protection of natural capital in the Columbia River. To be effective, the policy option must respond to impacts on the white sturgeon and demonstrate whether the various landlocked subpopulations of white sturgeon can be protected, enhanced, and remediated to allow for safe natural migratory patterns. To measure resiliency, stock assessments can be used to measure the impacts of policy management on sturgeon population size in the River.⁸⁶ Stock assessments can be used to indicate whether identified populations experience no net loss of reproductive potential, reach or exceed population and distribution targets for conservation, and overall, meet a healthy population target. If sturgeon fall under the sustainable population target, Basin management should be assessed according to how it interacts with biological and habitat needs of white sturgeon (see Chapter 4), how it addresses impacts to sturgeon populations, or look to new stressors impacting repopulation and population size.

This criterion also considers the sustainability of white sturgeon populations. Given the challenges faced by white sturgeon, the environmental implications of each option represent a significant role within the analysis. Options should be evaluated in terms of how they affect sturgeon in the long-term and the level of risk to white sturgeon survival. Specifically, options should be assessed on their ability to respond to a variety of impacts affecting sturgeon. If options are limited in scope on what they can identify and respond to, the option scores poorly in its ability to provide long-term security to white sturgeon in the Basin.

Lastly, the benefits of protection and conservation of white sturgeon should be measured and used to assess options. Policy options should be assessed on whether they increase or decrease ecosystem goods and services provided by white sturgeon. To do this, a natural capital inventory could be developed to show the quantity and quality of ecosystems in the Basin. This inventory could be routinely assessed and updated to indicate impacts and changes to natural capital in the Basin. Options are evaluated

⁸⁶ Stock assessments for fish in the U.S. are conducted by scientists from the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) (National Academy Press, 1998).

against quantitative results achieved, outcomes from other case studies, academic reports, and supplemented by interviews with stakeholders.