Adapting the ELOHA Framework for Wolastoq | St. John River

Developing the Environmental and Social-Cultural Components

The St. John River Society | La Société du Fleuve Saint-Jean
Organisme de bassin versant du fleuve Saint-Jean
Canadian Rivers Institute
ACAP Saint John
WWF

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This project is a result of a huge collaborative effort from the different partners, individuals and contributors to the participatory mapping exercise and online survey, who all have one goal - to see a healthy Wolastoq | St. John River flowing through our region for both the people who live here and for the environment it supports.

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Executive Summary

Environmental flows describe the quantity, quality, and timing of water flows and levels required to sustain freshwater ecosystems and the human livelihood, culture, spirituality and well-being that is dependent upon these ecosystems. Recent developments in environmental flows have led to a framework at the watershed scale that considers both social-cultural values and environmental needs. One such approach is the Ecological Limits of Hydrologic Alteration (ELOHA) framework that combines data, modelling, and analysis with expert judgement and workshop discussion to develop a balanced, watershed-scale strategy that integrates an environmental and a social-cultural component. The environmental component of ELOHA includes several steps aimed at developing an understanding of flow dynamics and the effects of flow alteration on the hydrologic regime, including characterization of flow types, assessment of hydrology and water quality, and the creation and testing of relevant flow-ecology relationships that describe the ecosystem response to altered flows. The social-cultural component of ELOHA can be developed through the lens of Ecosystem Goods and Services (EGS), which describe the benefits that humans receive from nature, and are categorized as provisioning, regulating, supporting/habitat, and cultural.

Here we describe the development and adaptation of an ELOHA framework for the Wolastoq | St. John River. We outline the steps taken through this project and the Mactaquac Aquatic Ecosystem Study (MAES) to assess the environmental component of ELOHA and present the key findings of this work. We also present the results of one of the first applications in Canada of the EGS concept to the development of the social-cultural component of ELOHA. Through engagement with the community and stakeholders, EGS for the river were identified and prioritized to describe the importance of flows in a social-cultural context.

Our report builds upon existing components within the watershed framework by continuing to refine and support local- to watershed-scale pathways that connect environmental pressures (e.g., flow alteration) and stressors (e.g., water quality) with environmental and social-cultural responses (e.g., biodiversity) and impacts (e.g., ecosystem function and services). For the environmental component of the framework, we identify six key watershed habitats, summarise the assessment of flow alteration and water quality trends, and develop localised water quality triggers. For the social-cultural components, we introduce and explore our relationships with the river through a public survey and participatory mapping exercise supported by an extensive literature review. Our results highlight the primary social connections with the river through recreational opportunities and aesthetics, and these are also reflected in the use-based benefits (e.g., recreation) and intangible benefits (e.g., mental health, well-being). Our participatory mapping exercise highlighted locations where activities, such as recreation, aesthetics, hunting, and fishing, take place in the watershed. These results also show public and stakeholder concerns about the river including the importance of water quality and the interconnectedness of ecological services in supporting social benefit. A key output of the research has connected site substitutability to flow alteration to identify where changes could have a significant impact on social-cultural benefits and values.

Our work highlights the importance of connections between the environmental and social-cultural in developing sustainable environmental flows frameworks. There is a potential role of EGS in communicating the importance of services and benefits to governments, particularly if the relationship between management decisions and the impacts on cultural EGS can be defined. Furthermore, consideration of cultural EGS in watershed management at a local scale can support greater integration of these concepts into provincial and federal management priorities and approaches. Our next steps for the Wolastoq | St. John River includes testing of additional mechanistic pathways supporting the framework, expanding the social-cultural data developed through this project, and completing the integration of the framework to develop flow recommendations. We will also be collaborating with Wolastoqey communities through the Wolastoqey Nation in New Brunswick to incorporate Indigenous perspectives and values into the social and cultural component of the ELOHA framework, and to co-develop a decision support tool that can be used to inform future management action and regulatory decision making. Finally, we are continuing to identify and develop a long-term monitoring plan to support this work including the development of core metrics to support this assessment.

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1. Introduction

Global freshwater resources are under increasing threat from human activities, both in terms of consumptive and non-consumptive use (Poff et al. 2010, Richter et al. 2012). Increasing societal demands for water have led to substantial flow alterations in rivers, both in Canada and internationally. Flow alteration (e.g., altered regime timing, flow abstraction) can be directly linked to impacts on the physical and ecological attributes of rivers (Poff and Zimmerman 2010). Representing the largest source of electrical power generation (59.2% in 2015) in Canada (Statistics Canada 2021), hydropower facilities are managed at large spatial and temporal scales to balance water availability with demand for electricity. For example, hydropeaking meets diurnal consumer demand, and headpond storage maintains water levels for efficient turbine use. However, many components of the ecosystem can be impacted through the development of hydropower facilities and their operation schedules, including the shifting timing of the hydrological regime, significant thermal impacts on biota directly downstream of headponds, fragmentation, and altered ice regimes. The increasing recognition of the ecological, social, and cultural values of rivers paired with societal water demands has driven the development of environmental flow frameworks (Richter 2010).

Environmental flows describe the quantity, quality, and timing of water flows and levels required to sustain freshwater ecosystems and the human livelihood, culture, spirituality and well-being dependent upon these ecosystems (Arthington et al. 2018). The wider goal of environmental flow management within the watershed is to protect and restore the socially-valued benefits of healthy, resilient, biodiverse aquatic ecosystems and the vital ecological services, economies, sustainable livelihoods, and well-being they provide for people of all cultures (Arthington et al. 2018).

The concept of environmental flows is not new, and more than 200 individual environmental flow methods have been developed to manage and monitor river ecosystems for conservation and water resource protection (Tharme 2003). However, recent developments within environmental flows have allowed us to move beyond more simplistic hydrological approaches generally based on maintaining a minimum flow to now bringing together the wider watershed perspective that includes the linkages among environmental and social-cultural components. Indeed, these more recent developments represent a systematic shift from habitat-focused, species-specific approaches to a framework including direct and indirect linkages between flow and ecology at the watershed scale (Railsback 2016). By incorporating socio-cultural and governance components into the framework, these newer approaches pair the societal values with environmental needs (Pahl-Wostl et al. 2013, Poff and Matthews 2013, Matthews et al. 2014, Poff 2018). One such approach is the Ecological Limits of Hydrologic Alteration (ELOHA) framework that combines data, modelling, and analysis with expert judgement and workshop discussion to develop a balanced, watershed-scale strategy (Poff et al. 2010).

1.1 ELOHA Framework

The ELOHA framework builds towards a watershed-level environmental flows plan by combining a strong environmental foundation with the social-cultural process. The environmental foundation allows us to understand the historical, current, and projected future flow alterations while acknowledging the natural variation across broad habitat types within the watershed. These are combined with our working mechanistic understanding of the relationships among these critical pressures and stressors within the watershed to identify a series of flow-ecology hypotheses. The social-cultural piece of the framework seeks to understand the human and societal connection with the watershed and its relationship with flow. By bringing together these two critical pieces, we can identify areas of potential flow conflict within the watershed and seek to develop acceptable compromise. It is important to note that the final framework is not static; instead, it will evolve as new data and knowledge are brought into the space, allowing for a highly adaptive and responsive management plan.

1.1.1. Environmental foundation of ELOHA

In an effort to advance knowledge of environmental flows in Canada, WWF-Canada defined five components that can be used to understand and assess environmental flows at the river basin scale, including hydrology, geomorphology, biology, water quality and connectivity (WWF 2014). Together, these components describe the quantity and movement of water, the physical, biological and chemical attributes of the river ecosystem, and their interactions with flow. Each component is assessed as part of the environmental foundation of the ELOHA framework (Figure 1). First, they form the basis for the hydrologic foundation and the river classification step (Figure 1), which characterizes river type based on the hydrologic regime and geomorphology of the system. They can also be used to assess flow alteration by defining the normal range of variability and expected range of observations for future flows. Finally, they contribute to the description of flow-ecology relationships (Figure 1) through analysis of the response of each component to observed or predicted alterations in flow. Assessing environmental flows in a river system requires comprehensive analysis and understanding of each of the components identified by WWF to build the scientific foundation. This process requires collaboration between scientists, policy-makers, decision makers, local populations and Rights Holders to support the application of environmental flows into water management practices to protect, enhance, and restore healthy flow regimes in Canadian river systems.

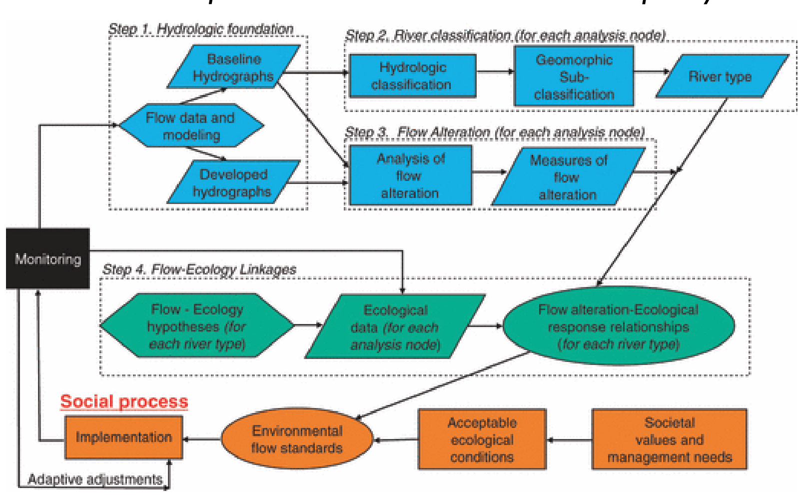


Figure 1. The ELOHA framework, with a focus on the environmental components of the scientific process, including the hydrologic foundation (blue), river classification (blue), flow alteration (blue), and flow-ecology relationships (green). Outputs of these steps are combined with outputs from the social-cultural process to develop environmental flow standards (orange). Figure reproduced from Poff et al. (2010).

1.1.1.1 River Classification

The ELOHA framework was developed based on the concept that the flow regime is one of the strongest drivers of ecosystem structure and function, and that knowledge of environmental flows is necessary for effective management of rivers (Poff et al. 2010). The framework has at its foundation the assessment of historical flows and characterization of rivers based on knowledge of the flow regime (Poff et al. 2010; Figure 1). This characterization of the flow regime is combined with geomorphological information to classify the river type. River classification can be applied to the entire river or to river segments to identify similarities and differences in hydrologic regimes and the physical habitat of the system. This step is necessary to evaluate the movement of water through the system and to develop system-wide expectations for flow variability. River classification allows for greater development of regional flow models and simplifies comparison among regions when assessment is standardized by hydro-geomorphic features, thus supporting large-scale application of ELOHA (Poff et al. 2010).

The hydrologic foundation for ELOHA is built through quantification of the magnitude, timing, duration, frequency, and rate of change of flow events. Historical flow data and baseline or reference flow data (in the absence of impact) are combined to develop models of observed and expected flows that can be used to determine hydrologic river type and to assess impacts of flow alteration on the system (Poff et al. 2010). Classification of rivers based on the hydrologic regime identifies river types that are expected to experience differences in the timing and magnitude of flows, for example, separating rivers fed by snowmelt from those primarily fed by rain or springs (Poff et al. 2010). Flow metrics that describe different aspects of the hydrologic regime are used in this characterization of flow conditions.

The geomorphology component of river classification is a sub-classification within river types that explores the composition and shape of river channels and floodplains, as well as the physical conditions required to maintain them. Geomorphic descriptors such as channel slope and streambed composition may have an effect on how water flows through the system, and how biota within the system experience flow (Poff et al. 2010). Applying this sub-classification to river types accounts for smaller-scale variation that may influence ecological response to flow alteration.

1.1.1.2 Estimating Alteration

Alteration of flow is a key driver in the ELOHA framework because of the potential for shifts in the hydrologic regime to impact all aspects of ecosystem structure and function (Poff et al. 2010). For impounded rivers, comparison of historical (pre-dam) and contemporary (post-dam) flows can be used to assess flow alteration in the system (Monk et al. 2018). The degree of flow alteration is evaluated by estimating deviations from expected or baseline flows, and this information can be used to support the development of flow-ecology relationships through creation of impact hypotheses and testing specific responses to alteration.

The ELOHA framework also recognizes the importance of other drivers of ecological structure and function in a system, and incorporates interactions between those drivers and flow (Poff et al. 2010). In particular, water quality is linked to the flow regime, and represents an important driver of ecological condition. The water quality component of environmental flows can describe the conditions required to support the health of river ecosystems and the array of services provided by them. Analysis of the current status and trends in water quality can be used to estimate the normal range of expected variability in water quality parameters. Hypotheses relating water quality parameters to the flow regime can predict how flow alteration may lead to deviations from the expected range for particular parameters. Furthermore, water quality can be related to ecological response variables as a potential driver of change.

1.1.1.3 Developing flow-ecology relationships

The ELOHA framework integrates the five components of environmental flows (WWF 2014) through the development and testing of flow-ecology relationships. These relationships describe the interactions between river flow, geomorphology, water quality, and biotic structure and function, expanding the analysis beyond the movement of water and offering a means to incorporate the ecological perspective into decision making.

Key to the development of flow-ecology relationships is the creation of impact hypotheses that describe the mechanisms by which alterations to the flow regime can affect different aspects of river ecology (Poff et al. 2010). For example, hypotheses may describe how reduced flow in the autumn restricts access to spawning grounds, thereby reducing spawning success in fish species, or how a shift towards a later spring freshet disrupts environmental cues for insect emergence. The development of flow-ecology hypotheses for a river system can elucidate the linkages between the five components of environmental flows, as well as the potential implications of flow alteration to the system.

Developing mechanistic pathways that link the components of environmental flows and describe their expected ecosystem response to flow alteration requires knowledge of driver-response relationships in river ecosystems. However, these general response relationships must be refined based on knowledge of local habitat conditions, regionally-specific pressures, and relevant components of ecological structure and function to ensure they accurately reflect the study system. Furthermore, if quantitative or directional predictions of change are developed, these flow-ecology relationships can be tested in the river system (Poff et al. 2010). These relationships and supporting data are used in concert with the social-cultural components of ELOHA (see section 1.1.2) to develop an integrated model of environmental flows to support management.

1.1.2. Social-cultural components of ELOHA

Traditionally, environmental and water management approaches have been informed by biophysical and economic values, while cultural and social values of the local community have been unknown or not considered (Raymond et al. 2009, Bark et al. 2016). However, environmental-cultural studies on rivers are slowly emerging, and this trend is introducing the importance of 'local' peoples' interpretations and expressions of their relationships to the river (Bark et al. 2016). The ELOHA framework presents an opportunity to include the social-cultural component into decision making and long-term management of water resources.

There are challenges associated with developing an understanding of the social component of flows, and while many completed ELOHA projects acknowledge the inclusion of social-cultural inputs, the implementation has largely been lacking (Anderson et al. 2019). The ecosystem goods and services (EGS) lens has been gaining ground as an approach to investigate the broad suite of ecosystem-human relationships (Murray-Rust et al. 2011, Chan et al. 2012a). Ecosystem goods and services result from environmental processes, sometimes with human interventions, that provide the benefits humans depend on to support life (e.g., water and food provision), security (e.g., mitigating flooding), and well-being (e.g., supporting cultural identity and spirituality; Value of Nature to Canadians Study Taskforce 2017). Understanding how the ecosystem provides benefits for human wellbeing is important for determining the effects of ecological change (Cowling et al. 2008), and can be a useful approach to characterize and summarize social and cultural components of flows for the ELOHA framework.

As rivers become impounded, changes within the ecosystem and the provision of EGS can affect people in different ways, making assessment of the social-cultural component essential for the future management of water resources (Cowling et al. 2008). Few studies have explored EGS in a flow management context and assessed policy changes to enhance or maintain these ecosystem goods and services (see Lejon et al. 2009, Fox et al. 2016, Brummer et al. 2017, Reilly et al. 2018).

1.1.2.1 Ecosystem Goods and Services Approach

Ecosystem Goods and Services are generally categorized as: provisioning, supporting/ habitat, regulating, and cultural (Millennium Ecosystem Assessment 2005). Definitions and examples from the 2017 Ecosystem Services Toolkit (Value of Nature to Canadians Study Taskforce 2017) were used throughout this project when applying the EGS framework (examples provided in Figure 2). Briefly, provisioning EGS includes goods that are produced by the ecosystem and upon which humans rely, or from which humans obtain some economic benefit. Supporting/habitat EGS includes the structural and functional ecological processes that are required for proper ecosystem function and that support the other EGS. Regulating EGS includes ecosystem feedback, controls, and regulations on ecosystem processes that contribute to the healthy environment on which humans rely. Finally, cultural services include the aspects of human social and cultural well-being that benefit from ecosystem processes. The links between these categories of EGS and the development of an environmental flows framework are clear, given that the definition of environmental flows specifically indicates that its goal is to support ecosystem health and social benefits derived from the ecosystem. In particular, provisioning, supporting and regulating EGS link strongly to aspects of the environmental component of ELOHA, including the assessment of *hydrologic alteration and flow-ecology relationships, whereas the cultural EGS component, in particular, supports the development of the social-cultural component of ELOHA. It is the latter category of EGS that is often neglected in environmental flows assessment, and that can be derived through discussion with the public, stakeholders, and Rights Holders about social benefits, values, and interactions with the ecosystem.*

Ecosystem Service (ES)
Provisioning services – ***the result of ecosystem processes and functions that provide goods or products that humans obtain and rely upon; often with some human inputs of labour, financial, and social capital***
Food (e.g., crops, livestock, capture fisheries, aquaculture, wild foods)
Timber and other wood products / fibres, resins, animal skins, and ornamental resources
Biomass fuel
Fresh water
Genetic material
Biochemical and medicinal resources
Regulating services – ***the result of ecosystem processes and functions that regulate all aspects of the environment, providing security and habitable conditions that humans rely upon***
Air-quality regulation
Climate regulation and carbon sequestration (e.g., global climate regulation, regional and local climate regulation)
Water-flow regulation
Erosion regulation
Water purification and waste treatment
Disease regulation
Pest regulation
Pollination
Natural hazard mitigation
Cultural services – ***the result of ecosystem processes and functions that inform human physiological, psychological and spiritual well-being, knowledge and creativity***
Cultural identity and heritage
Spirituality and religion
Knowledge systems and education
Cognitive development, psychological and physical health, and well-being
Aesthetic experience
Inspiration for human creative thought and work
Recreation, ecotourism
Sense of place
Supporting or habitat services – ***the underlying ecosystem processes and functions that are necessary for the production of all other ES, creating the biological environment***
Soil formation
Primary production
Nutrient cycling
Water cycling
Habitat

Figure 2. Definitions and examples from the 2017 ES Toolkit (Value of Nature to Canadians Study Taskforce 2017; page 15).

A person's definition of the benefits they receive from a given set of EGS has been found to vary between individuals according to their interest(s) (Casado-Arzuaga et al. 2013), level of scientific knowledge/expertise (Lamarque et al. 2011, Martín-López et al. 2012), degree of familiarity with the location (Fagerholm and Käyhkö 2009), and experiences in the area (Lamarque et al. 2011), among other factors (Darvill and Lindo 2015, García-Nieto et al. 2015). Social benefits derived from EGS also vary spatially and are affected by distance from the home or from roads, though the nature of the relationship varies among types of cultural EGS (Brown et al. 2002, Fagerholm et al. 2012, Plieninger et al. 2013, Potschin and Haines-Young 2013). For example, Brown et al. (2002) found that benefits derived from direct interaction with the ecosystem, such as recreation, tended to be greatest when the ecosystem was located near communities, while benefits derived indirectly from the ecosystem, such as intrinsic value, were obtained from ecosystems located further away. Even within a given spatial pattern of EGS, individuals vary in terms of the benefits they derive from an ecosystem based on where they live, how long they have been in the area, their values, and the stakeholder group to which they belong, among other factors (Fagerholm et al. 2012, Darvill and Lindo 2015).

One of the most powerful aspects of an EGS approach is that it focuses research and decision-making on ecosystem attributes, products, and functions that are of the greatest value to humans. Specifically, cultural EGS describe the "ecosystems' contribution to the nonmaterial benefits (e.g., experiences, capabilities) that people derive from human–ecological relations" (Chan et al. 2011, p. 206). As many EGS are linked to and depend upon healthy ecosystem function, cultural EGS can be used as a way of communicating the value of the whole ecosystem, and the range of services and benefits it provides. Cultural EGS are produced through direct interactions between people and ecosystems in a deeper sense than other services, and are directly experienced and intuitively appreciated (Chan et al. 2012a).

Methods for assessing and prioritising cultural EGS are limited; however there are a number of survey-based methods for collecting EGS data (e.g., Anthem et al. 2016, Bark et al. 2016). Surveys and questionnaires are highly useful as they collect structured data about variables directly from the user, and thus offer a promising approach for data collection that provides readily comparable data (Raymond et al. 2014). Surveys can be designed with a series of questions that probe and reveal respondents' perspectives that are deeply held and not obvious to the observer. They are also considered a financially viable option for collecting information across a large spatial scale.

In combination with surveys, spatially explicit assessment of the social benefits derived from EGS is a useful contribution to the decision-making process around water management decisions (Cowling et al. 2008). It allows individuals' or stakeholders' concerns and values about specific places to be taken into account (Darvill and Lindo 2015). It also can inform proposed adaptation or mitigation measures to restore or enhance EGS hotspots where multiple people experience benefits (Alessa et al. 2008, Bryan et al. 2010). Participatory mapping is a popular approach to determine the spatial distribution of social benefits from EGS to support decision making and/or engage stakeholders (Bryan et al. 2010, Brown and Fagerholm 2015, Brown et al. 2017). Mapping can be an effective way to gather localized, objective ecological and social knowledge, or to reveal stakeholders' personal perceptions and experiences (Fagerholm et al. 2012, Brown and Raymond 2014, de Vreese and Neijens 2016).

While the importance of cultural EGS has consistently been recognized in literature, they are difficult to assess given their characterization as being "intangible," or "subjective," (Millennium Ecosystem Assessment 2005, Chan and Satterfield 2020). Despite this challenge, ecosystem-based cultural benefits are clearly valuable to people, and neglecting these EGS values can produce unintended consequences and can impede the achievement of watershed goals (Chan et al. 2012a).

1.1.3. Linking ecological and social-cultural components for the environmental flows framework

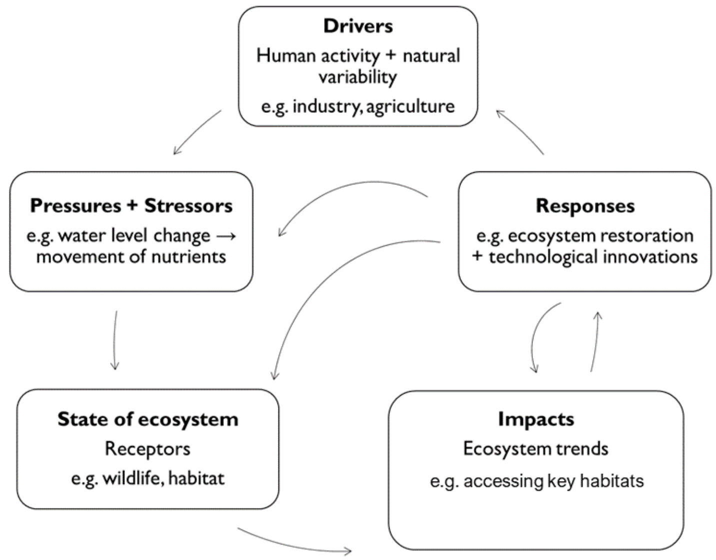


Figure 3. Example of a Driver-Pressure-State-Impact-Response (DPSIR) framework adapted for an environmental flows framework application.

Bringing the ecological and social-cultural components together for a comprehensive environmental flows framework requires a structure that can help visualise the connections among the different components. The Driver-Pressure-State-Impacts-Response (DPSIR) approach (Figure 3) developed by Smeets and Weterings (1999) has been widely adopted in environmental management and policy development, and has been modified for use in multiple stressor scenarios by Baird et al. (2016). While the use of DPSIR in environmental flows frameworks is a new approach, it allows multiple drivers (e.g. hydroelectricity production, agriculture, forestry, urbanisation, climate change, and natural weather variability) to be assessed via their pressures (e.g., flow regulation, landscape disturbance) and stressors (e.g., modified flow regime components, water quality) to explore their effects on key environmental and social-cultural states (e.g., biodiversity, ecosystem goods and services) (Figure 3). The definitions proposed by Oesterwind et al. (2016) allow us to clearly separate between drivers and pressures, where drivers are natural or anthropogenic processes that drive ecosystem change, while pressures and their secondary stressors alter the environmental and social-cultural state of the watershed as a result of this driver-initiated mechanism. Impacts have substantial environmental and social-cultural effects; these effects can be positive or negative. A response is an action by management that seeks to reduce or prevent an unwanted change, or to develop a desirable change in the ecosystem.

1.2 Adapting the ELOHA framework for the Wolastoq | St. John River

In this report, we develop and adapt the ELOHA framework for the Wolastoq | St. John River. The Wolastoq | St. John River is one of the largest rivers in Atlantic Canada, with its headwaters in Maine, USA. The river basin lies over Maine (36% of the basin), Quebec (13%), and New Brunswick (51%), and flows 673 km to the Bay of Fundy in Saint John, New Brunswick. The mainstem river and several tributaries are regulated for hydropower generation with three mainstem hydropower facilities at Grand Falls (66 MW), Beechwood (112 MW) and Mactaquac (668 MW) and tributary facilities at Hargrove on Monquart River (3 MW), Madawaska on Madawaska River (5.3 MW), Second Falls on Green River (3.2 MW), Sisson on Tobique River (9 MW), Tinker on Aroostook River (34.5 MW) and Tobique Narrows on Tobique River (20 MW). Further, there are several tributary-based hydrological controls for storage, for example Trousers, Long and Serpentine storage lakes. Research on environmental flows in the Wolastoq | St. John River contributes to the Mactaquac Aquatic Ecosystem Study (MAES; https://www.canadianriversinstitute.com/maes), a research project supported by NB Power to provide the scientific foundation for decisions related to dam renewal at the Mactaquac Generating Station (Curry et al. 2020).

We adapted the original ELOHA framework to meet the needs of the Wolastoq | St. John River watershed. For example, we have included components that address ice processes, given that the watershed experiences significant ice and snow conditions for four to six months of the year. Additionally, we made a concerted effort throughout the model adaptation to include ecosystem processes that were both data- and workshop-led, thus allowing us to identify key drivers, pressures, stressors, and responses specific to our watershed.

Given NB Power's priorities and the research focus of the MAES program, our initial focus has been on the Mactaquac Generating Station. However, by adopting an adapted ELOHA framework, we were able to develop one of the first watershed-level ELOHA applications in Canada. We can also link an adapted ELOHA framework to our five watershed priorities: (i) understanding of water quality and quantity; (ii) building towards reconciliation through water; (iii) understanding of climate change impacts and mitigation; (iv) quantifying biodiversity loss and invasive species; and (v) developing respectful and inclusive governance within the watershed. This adaptation of an ELOHA model framework for the Wolastoq | St. John River also supports the development of sustainable flow thresholds as part of a wider watershed management approach.

In this report, we highlight the work that has been completed as part of the adaptation and development of an ELOHA framework for the Wolastoq | St. John River, including the environmental foundation and the social-cultural components. Results from the workshop- and analysis-based approach to developing the environmental foundation (including work completed through MAES) are summarized. Further, we present the results of an assessment of social benefits derived from EGS that was designed to develop the social-cultural components of ELOHA. Though the aim of the social-cultural component was to assess all forms of EGS, we present the results with particular emphasis on cultural EGS, which have received less focus in previous assessments. We summarize the key findings for each component of the ELOHA framework and provide guidance for the integration of these components through the development of a DPSIR framework.

2. Developing the environmental foundation of ELOHA

The development of the environmental foundation for ELOHA in the Wolastoq | St. John River has been ongoing since 2014 as part of MAES. The MAES research group worked to characterize flows and physical habitat within the Wolastoq | St. John River, providing a hydrologic and geomorphic foundation for river classification as part of ELOHA. Variability in the hydrologic regime of the river was explored, including a focus on seasonal flows, low flows (including extreme low flows), high flows (including extreme high flows), and ice-affected conditions (Monk et al. 2018, Holder 2020). Comparison of the hydrologic regime before and after dam construction was used to evaluate the degree of flow alteration in the system (Monk et al. 2018, Holder 2020). Estimates of alteration in the Wolastoq | St. John River have also focused on water quality. Analysis of status and trends in water quality was completed (CRI 2019), leading to the development of triggers that identify water quality levels of management concern based on normal or expected ranges of water quality parameters (Arciszewski and Gray 2019). Finally, work has begun to identify and test flow-ecology relationships within the Wolastoq | St. John River, relating changes in flow to ecosystem structure and function. In this section, we outline the steps that have been taken to develop the environmental foundation for the ELOHA model in the Wolastoq | St. John River and summarize the main findings.

2.1 River Classification

River classification of the Wolastoq | St. John River was completed through a combination of data collection and extensive workshop discussions held with hydrologic experts and local stakeholders and Rights Holders (Monk et al. 2018). Through this process of engagement and data analysis, the MAES team identified six river types that represent the key habitats within the watershed, namely mainstem and large tributaries (e.g. mainstem Wolastoq), medium tributaries (e.g. Aroostook, Nashwaak Rivers), small tributaries and headwater systems (e.g., Nashwaaksis Stream), island habitats (e.g., islands found throughout the lower mainstem of the Wolastoq), and riparian wetlands and floodplain habitats (e.g., Grand Lake Meadows) (Figure 4; Monk et al. 2018). The importance of cold- and cool-water refugia was also identified through expert workshop discussions as being part of critical habitat throughout the watershed, and these were highlighted separately from the habitat types (Figure 4; Monk et al. 2018).

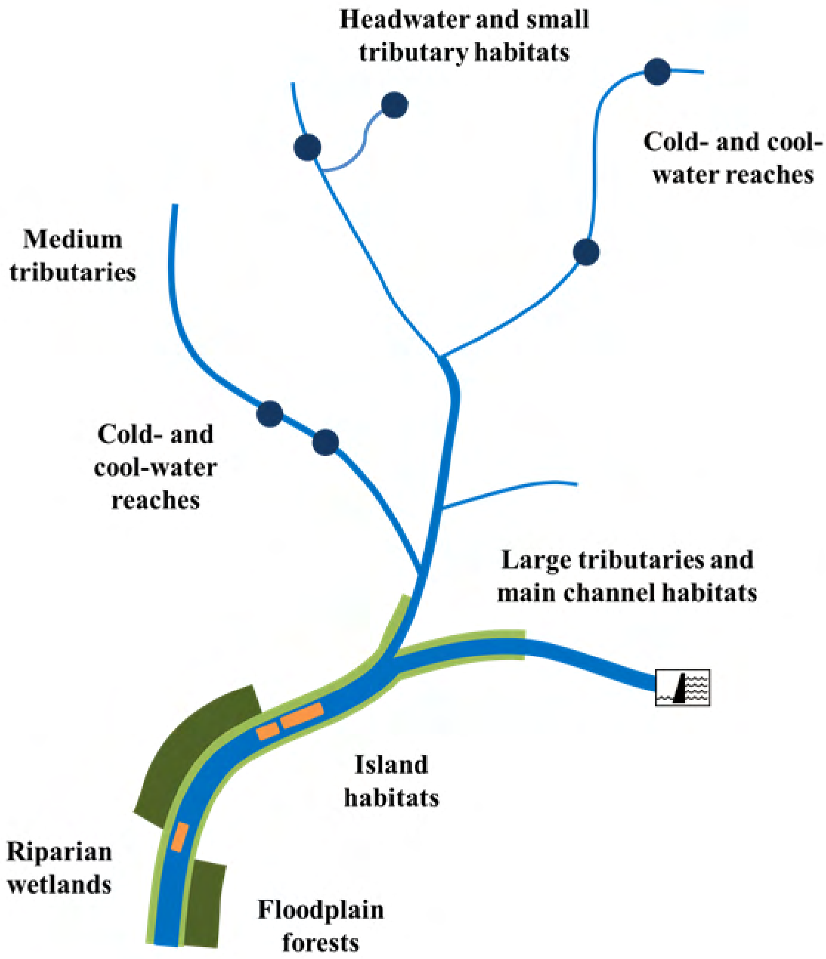


Figure 4. Schematic representing the six different habitat types identified within the Wolastoq | St. John river watershed.

2.2 Estimating Alteration

Status and trends in hydrology and water quality were assessed for the Wolastoq | St. John River to provide information to support the development of flow-ecology relationships and environmental flow standards. As part of this process, alteration of flow due to river regulation was examined by comparing flow metrics pre- and post-dam construction. In addition, the normal range of variability was estimated for water quality parameters to quantify the expected range of future values and identify trigger levels at which values may be of concern.

2.2.1. Hydrology

2.2.1.1. Flow alteration

Changes to hydrologic regimes through flow alteration, including shifts in the magnitude, duration, and timing of peak flows, have the potential to affect multiple aspects of ecosystem structure and function. Here we provide a short summary of the core flow alteration assessment completed as part of the ELOHA framework development for the watershed (see Monk et al. 2018 for additional detail). Assessment of the mainstem alteration was completed using paired Water of Survey gauges (01AD002 Fort Kent and 01AK003 Fredericton) from their extensive records (1929 - present). The Fort Kent gauge represents upstream conditions, as it is located above the three mainstem generating stations, while the Fredericton gauge is downstream of all impoundments. Core components of the hydrological regime were explored across three different timeframes reflecting changes to flow regulation in the system: (i) post-Grand Falls Generating Station but pre-Beechwood and Mactaquac Generating Stations, (ii) post-Grand Falls and Beechwood Generating Stations but pre-Mactaquac Generating Station, and (iii) post-Grand Falls, Beechwood and Mactaquac Generating Stations. Comparison across these three time frames allowed for both spatial (reference vs. impacted) and temporal (pre- vs. post-developments) assessments of flow alteration.

Thirty-three hydroecological variables, known as the Indicators of Hydrologic Alteration (IHA), were identified by Richter et al. (1996) and represent ecologically important flow regime components. The IHA variables quantify five ecological facets of the hydrological regime: (i) magnitude of monthly water conditions; (ii) magnitude and duration of extreme water conditions; (iii) timing of annual extreme water conditions; (iv) frequency and timing of high and low pulses; and (v) rate and frequency of flow reversals. The degree of flow alteration was quantified via the Range of Variability Approach (RVA) across identified groups (e.g. pre- vs. post-construction) (Richter et al. 1998).

The RVA analysis assesses whether different flow variables for the post-impact period attain the targeted range at the same frequency that occurred in the pre-impact flow regime. For example, attainment in a range defined by the 25th and 75th percentile values would be expected in only 50% of the years. The degree to which a RVA target range is not attained is a measure of flow alteration (Richter et al. 1998). Hydrological alteration is equal to 0 when the observed frequency of post-impact values match the expected frequency of the target. A positive deviation indicates that the annual parameter frequency occurred more often than *expected, while a negative deviation indicates that the annual parameter frequency occurred less often than expected (Richter et al. 1998).*

The RVA approach was applied to compare the post-Grand Falls Generating Station, pre-Beechwood and pre-Mactaquac Generating Stations period (T1) with the post-all Generating Stations (T2) between the reference gauge (e.g. Fort Kent, WSC 01AD002) and the impacted gauge (e.g. Fredericton, WSC 01AK003). For the Fredericton gauge, twenty-six variables demonstrated increased frequency of occurrence in the high category between T1 and T2, representing an increase in these variables. For example, there was evidence of increases in the magnitude of minimum water levels and increased water level variability (number of reversals; Figure 5) likely linked to operational activities at the downstream Mactaquac Generating Station. These results reflect hydropeaking during non-peak water levels and increased minimum flows during summer, as mandated by the NB Power-DFO protocol agreement. Five variables demonstrated an increase in the frequency of occurrence in the low category, representing the count and duration of flow pulses. Twenty-two of the available variables for the T2 period were significantly higher (hydrologic alteration value >1) than T1. By comparison, the Fort Kent gauge presented minimal flow alteration with similar (but muted) patterns in the monthly median flows between T1 and T2, and had limited variation in both minimum and maximum flows. None of the variable categories were significantly altered at the Fort Kent gauge (all hydrologic alteration values <1).

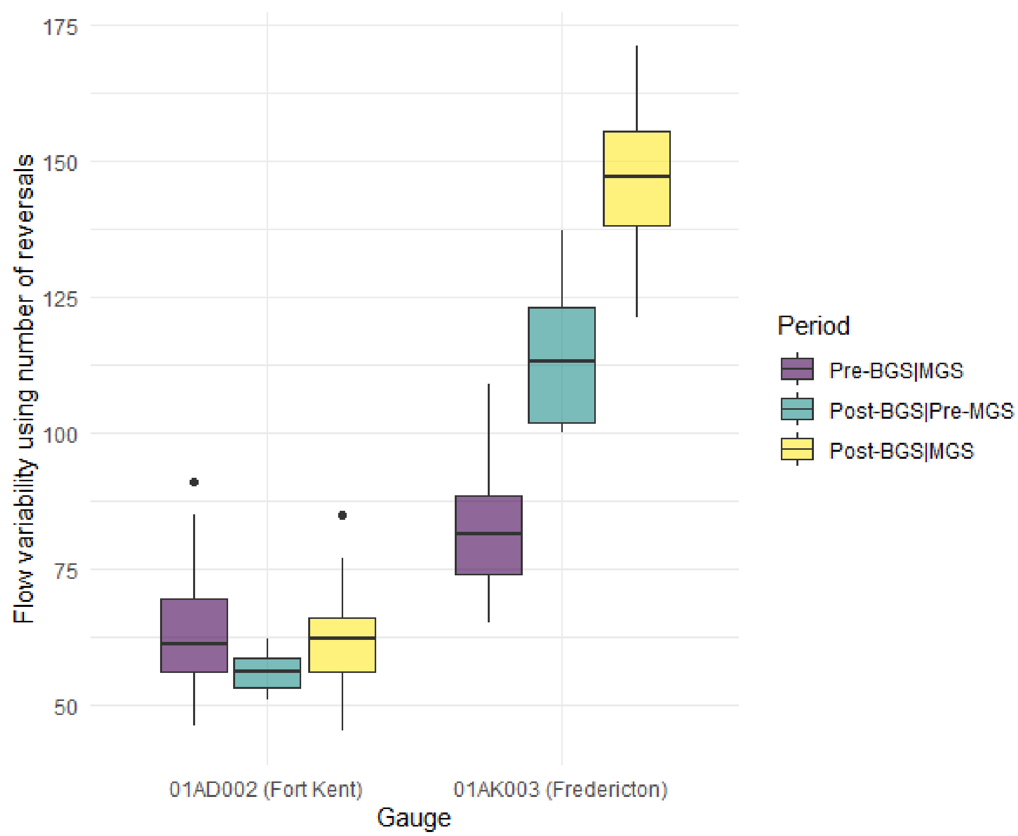


Figure 5. Comparison of flow variability as quantified by the number of reversals in either flow or water level between the Fort Kent Water Survey of Canada gauge (01AD002) upstream of all hydropower generation stations and the Fredericton Water Survey of Canada gauge (01AK003) downstream of all hydropower generation stations. BGS = Beechwood Generating Station; MGS = Mactaquac Generating Station.

Assessment of flow alteration was completed for additional gauging stations upstream and downstream of the Mactaquac Generating Station by Holder (2020). The Grand Falls gauge (01AF002) is located downstream of the Grand Falls generating station, but upstream of the larger Beechwood and Mactaquac hydropower facilities. Comparison of IHA variables for hydrologic data pre- and post-dam construction indicated low hydrologic alteration values at Grand Falls, similar to results found at Fort Kent (Holder 2020). For the Grand Falls gauge, the highest variation between time periods was observed for the number of flow reversals, which is a measure of the rate and frequency of change in flow and water level (Holder 2020). There was generally strong similarity between the two time periods for other flow measures, and variation between Grand Falls and Fort Kent was low when just the later time period was considered, likely due to the operation schedule for the Grand Falls generating station.

Overall, the results of the pre-and post-dam flow assessment indicate that variation in flow measures between time periods was low at gauging stations located in the upstream reaches of the river thus accounting for general climatic trends, but strong differences in flow were evident post-construction in the lower reaches of the river where there is a higher influence of dams. The IHA variables and the measure of hydrologic alteration provide valuable information to support the development of flow-ecology relationships in the Wolastoq | St. John River.

2.2.2. Water quality

2.2.2.1. Status and trends

Long-term trends in water quality parameters were analyzed to update an earlier report on the the Canadian portion of the mainstem Wolastoq | St. John River (Kidd et al. 2011), and to expand the assessment to examine water quality and primary productivity for the full watershed (CRI 2020). Water quality data from 283 stations in the watershed, including mainstem and tributary stations, were obtained from the New Brunswick Surface Water Monitoring Network, Atlantic DataStream, State of Maine and Quebec provincial datasets, and the ECCC Chemicals Management Program. The status of parameters was assessed using data collected from 2015 to 2019. In addition, temporal trends were assessed by (1) comparing decadal data summaries (2000-2009 compared with 2010-2019), and (2) conducting trend analysis on 24 stations with at least 4 samples per year over the period 2005-2019 (CRI 2020). The parameters analyzed included pH, dissolved oxygen, metals (aluminum, iron, manganese, copper, zinc), coliform bacteria (E. coli), nutrients (total nitrogen, total phosphorus, chlorophyll-a), dissolved and total carbon, road salts (inorganic chloride salts), polyaromatic hydrocarbons (PAHs) and pesticides, priority chemicals (ECCC Chemicals Management Program), as well as supplementary information gathered from automatic sampling stations including temperature, specific conductance, and automatic dissolved oxygen and turbidity.

The status of water quality parameters was assessed for this analysis by comparing with national guidelines (Canadian Council for Ministers of the Environment (CCME) guidelines for the protection of life) and provisional chemical thresholds, where they were available (CRI 2020). In the 2011 report on the Wolastoq | St. John River mainstem (Kidd et al. 2011), water quality was shown to have improved compared to previous decades due to increased environmental pollution regulations and improvements to wastewater treatment, but exceedances of water quality guidelines remained evident for some parameters. Basin-wide analysis of data from 2015-2019 (CRI 2020) also identified exceedances of water quality guidelines and provisional thresholds throughout the watershed. For example, there were few water quality stations in the basin that were below the dissolved oxygen guidelines for warm-water life stages, but 27 of 28 stations had samples below the guideline for cold early life stages. Aluminum exceeded CCME guidelines in samples collected at 41 of the 58 stations with data for this parameter, but median concentrations of aluminum were below the guideline level for most sub-sub-basins, with the exception of Nashwaak, Oromocto, and Salmon (CRI 2020). Median levels of iron were also above the CCME guideline in the Oromocto and Salmon sub-sub-basins, though the same patterns were not evident for other metals (manganese, copper, or zinc). Levels of E. coli were generally below recreational guidelines, with few samples showing elevated concentrations. Nutrient levels were compared with provisional guidelines derived from the scientific literature to assess current status. Total nitrogen was highest in the sub-sub-basins affected by agriculture, and median levels in the Aroostook sub-sub-basin were above provisional guidelines (CRI 2020). Exceedances of provisional guidelines for total phosphorus were more frequent, with 92% of stations and 55% of individual samples exceeding the guidelines (Figure 6), and the highest concentrations were found in sub-sub-basins affected by agriculture (CRI 2020).

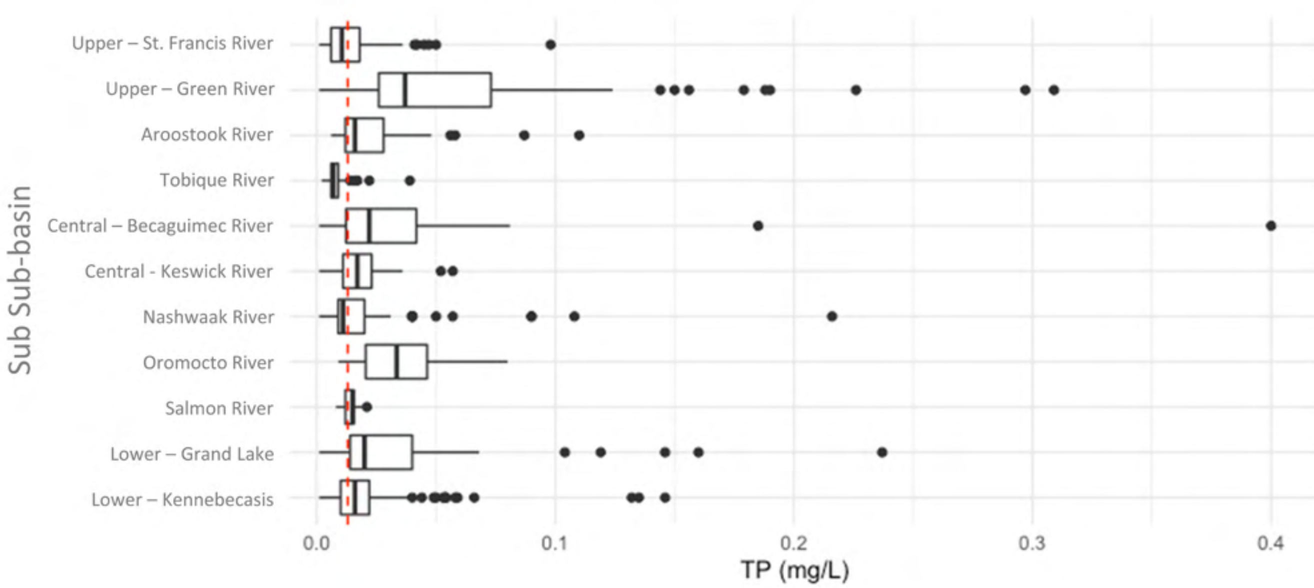


Figure 6. Status of total phosphorus (mg/L) in the Wolastoq | St. John River (2015-2019) across sub-sub-basins. The vertical red line represents a provisional chemically-derived threshold (TP = 0.013 mg/L) Figure from CRI (2020).

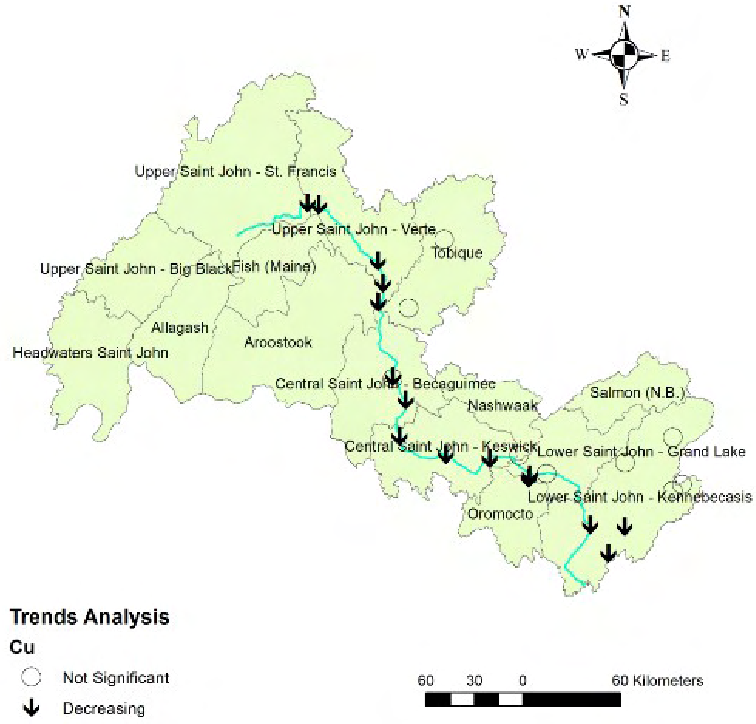


Figure 7. Long-term trend analysis for copper (Cu) at select stations with sufficient data (May-Nov, 2005-2019). The downward arrow indicates a statistically significant decreasing trend (Mann-Kendall trend test, $p < 0.05$) and the circle indicates no statistically significant trend (Mann-Kendall trend test, $p > 0.05$) Figure from CRI (2020).

Decadal comparisons of water quality parameters and trend analysis indicated temporal shifts in water quality parameters in the Wolastoq | St. John River basin, with the strongest trends evident for metals and nutrients. Most metal concentrations decreased significantly over time across much of the basin. For example, aluminum showed a significantly decreasing long-term trend across 10 stations, iron decreased significantly in 8 stations, copper decreased significantly over time in 15 stations (Figure 7), and a significant decreasing trend in zinc was found for 22 of the 24 stations with long-term data (CRI 2020). A significant decreasing trend in E. coli was also evident across several stations in the upper, middle, and lower reaches of the basin. Long-term data for nutrients showed the opposite trend, with a significant increase in total nitrogen at 4 stations and a significant increasing trend in total phosphorus at 9 stations. Few significant trends were observed for pH, dissolved oxygen, or organic carbon (dissolved or total; CRI 2020).

An understanding of water quality can be used to identify areas of concern and specifically to assign a Watershed Stressor Index, a parameter developed by the Nature Conservancy of Canada and ECCC, to provide an assessment of watershed health. Watershed Stressor Index values were calculated for each sub-sub-basin, and the top stressors for each area were identified from the 17 stressors used to calculate the index. For the St. John River, the most prominent stressors included climate change, unpaved road density, clear-cut harvesting, and non-native fish species. The predominant water quality stressors shifted across the basin from the upstream reaches to the lower reaches of the river, supported by the changing land-use patterns in the lower watershed and emphasizing the influence of flow alteration on water quality and watershed health (CRI 2020).

2.2.2.2. Triggers

Assessment of historical and contemporary water quality data can be used to estimate the normal range of variability, which is the degree to which water quality can be altered in the system with minimal ecological impact (Munkittrick et al. 2009, Kilgour et al. 2017, Munkittrick and Arciszewski 2017). In this process, the range of expected variability in water quality parameters is used to define triggers, or levels outside of which additional monitoring or management action may be necessary (Munkittrick et al. 2009, Arciszewski and Munkittrick 2015, Munkittrick and Arciszewski 2017). The benefit of such an approach is that water quality guidelines are defined based on site-specific historical conditions and reflect local flow and geologic conditions, both of which can affect water quality. Furthermore, trigger levels can be adjusted over time as more data are collected and estimates of natural variability are refined (Arciszewski and Munkittrick 2015). These defined limits provide information to managers regarding acceptable limits of alteration, and act as guidelines to trigger management action if measurements for any parameters fall outside of what is determined to be necessary for the ecosystem to function (Arciszewski and Munkittrick 2015, Munkittrick and Arciszewski 2017). Furthermore, these triggers can feed into the development and testing of flow-ecology relationships for the river system.

Expected ranges were developed for nutrient parameters in the Wolastoq | St. John River basin using data from 2003 to 2018 (Arciszewski and Gray 2019). The focus of this assessment was on total ammonia, total nitrogen, and total phosphorus, with total aluminum also examined due to its strong response to flow conditions (total aluminum is positively correlated with flow). Expected ranges for each parameter were estimated by determining the statistical distribution with the best fit to each parameter and using that distribution to estimate the normal range (range containing 95% of the data) and the 25th, 50th, and 75th percentiles of the data (Arciszewski and Gray 2019). Though the purpose of this analysis was primarily to define the expected range for nutrients at each station, rather than to interpret and assess water quality, there were some patterns evident in the data. In particular, the expected range for nutrients was high for St. Basile, which is downstream of sewage and pulp mill effluent discharge into the river (Arciszewski and Gray 2019). The expected ranges developed and reported by Arciszewski and Gray (2019) for all long-term monitoring stations in the basin can be used as trigger levels at each water quality station, and future data can be compared with these triggers to identify additional monitoring or management needs within the basin. The approach can also be extended to additional water quality parameters in the future.

2.3 Flow-ecology Relationships

The ELOHA framework is supported by our mechanistic understanding of the relationships between flow variability and environmental or social-cultural responses. The initial focus during the MAES project was on the environmental component. Through MAES-led workshops, flow-ecology and temperature-ecology hypotheses were developed and refined to support the identification of targeted flow needs. The hypotheses were either positive (i.e., needs-based) or negative (i.e., threshold-based). More than 500 hypotheses were initially developed and were then condensed to 69 testable hypotheses through a process of discussion and expert judgement. The final hypothesis selection targeted local-to-watershed-scale responses structured by both major habitat type and core flow components (i.e. seasonal flows, low flows including extreme low flows, high flows including extreme high flows, and ice-affected conditions) for general ecosystem and target taxa group responses. Each of the hypotheses was represented through the DPSIR approach by identifying the individual components associated with each hypothesis and then the mechanistic pathway among these components.

The final environmental flows framework is built upon ten core flow needs, which directly integrate the 69 flow-ecology and temperature-ecology hypotheses (Monk et al. 2018). These flow needs reflect the broad ecosystem needs of the river, for example flow required to maintain channel morphology and sediment distribution, ice processes, and key ecological components, such as ecological cues or habitat connectivity. Flow components of supporting hypotheses varied depending on the core flow need but reflected low flows, seasonal flows, high flows, and ice-affected flow. Core flow needs are temporally dynamic; for example, some needs are associated with key flow events, such as the spring freshet or summer stable low flows, while others require these flow events and variability throughout the year. Flow needs also vary spatially; for example, certain flow needs are more important for large rivers and mainstem habitats, but they may not be significant for riparian wetlands or small tributary habitats. For the mainstem habitat type, ten flow needs were identified, representing different ecosystem components (e.g., geomorphology and channel processes, reproduction cues, spawning and emergence, nutrient and sediment distribution, connectivity to key habitats, thermal habitats, and ice processes).

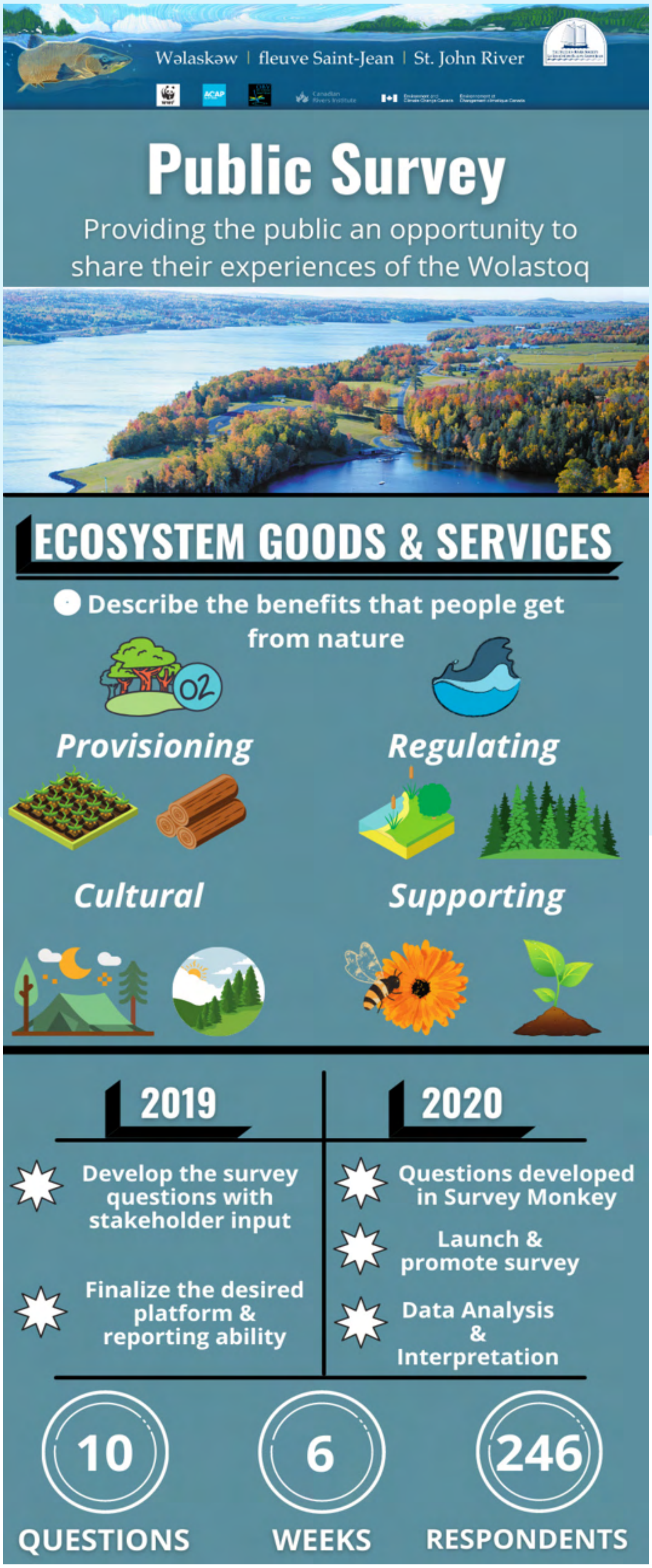
Research on developing flow-ecology relationships for the Wolastoq | St. John River is ongoing, with a current focus on investigating the mechanistic connections between flow components and the ecological response. A systematic published literature can be used to identify support for flow-ecology and temperature-ecology relationships from other systems and assess the range of expected responses to alteration in flow or temperature Monk et al. (2019). To examine these relationships in the context of the Wolastoq | St. John River system, empirical studies can be used to directly test mechanistic relationships and provide support for described hypotheses. This work is ongoing through MAES and will contribute to the next steps in the development of an adaptation of the ELOHA framework for this system (see section 4).

3. Developing social-cultural linkages for ELOHA

This project represents the first step in understanding the human and societal connection with the watershed and its relationship to flow. Through research and data collection, this work reveals the ecosystem goods and services (EGS) within the Wolastoq | St. John River basin. The project undertook a socio-ecological systems approach using the EGS framework to elicit the benefits and values citizens have in relation to the watershed. EGS are multifaceted, and while values can be associated with EGS and benefits, the results do not lead to a one-to-one relationship between a service and a value (Millennium Ecosystem Assessment 2005, Kareiva and Marvier 2011, Chan and Satterfield 2020). These relationships are complex, interrelated, and interdependent. The goal of this work was to begin to identify the pathways through which EGS within the Wolastoq | St. John River leads to social benefits, values, and interactions. This project recognizes that developing an understanding of human values and activities in relation to the watershed and predicting how they will be impacted by changes in the flow regime is essential for informing management decisions in the watershed.

In this project, we used surveys and participatory mapping to identify human values and activities related to the EGS provided by the river and its watershed. Responses to survey questions by the public can provide information about the personal values associated with the river and ecosystem services. It is important to understand what people value in the environment in order to inform management choices and understand tradeoffs between the ecosystem and human needs. Participatory mapping of watershed-based activities was targeted to organizations, to view EGS through the lens of stakeholders who manage, use, and protect the watershed. Through this lens, the spatial relationships between human well-being and watershed characteristics such as land use can be identified (de Groot et al. 2010). Questions developed for the survey and mapping exercise were not directed towards a particular category of EGS; however, the responses in both cases most strongly reflected cultural services. Results from the two data collection methods were categorized into themes that reflected human values and activities in the watershed. The public survey was focused on values, and the survey responses addressed three themes: relationships, benefits, and concerns. The stakeholder mapping exercise was focused on activities, and its results addressed the themes of interaction and concerns. Together, these results provide novel insight into the social-cultural perspective of the watershed and the EGS that it provides.

3.1 Public Survey



The objective of the public survey was to try to understand the values that citizens have for the Wolastoq | St. John River. There were a number of considerations that were to be part of the survey design and implementation:

- *The survey has to be short, with a 10-question maximum.*
- *The tone of questions should be light to make it easy and enjoyable to complete.*
- *The survey was to focus on cultural EGS, benefits, and values associated with the river.*
- *The target audiences were residents in New Brunswick and Quebec living near the river.*
- *The survey questions should allow for both positive and negative perspectives in order to get a holistic reflection of the river.*
- *Respondents should be directed to think about the full year cycle on the river, not only the season during which the survey was active.*

The survey was developed through Survey Monkey (see Appendix 1 for English survey), an online system commonly used in studies about the human relationship to the environment (Chan and Satterfield 2020), and was launched on July 25, 2020 and closed on September 25, 2020 (see infographic). The survey was promoted in English and French through Facebook on the St. John River Society's public Facebook page.

The survey was completed by a total of 246 respondents, including 237 responses to the English version and 9 completed French surveys. The majority of the responses were from Fredericton (41) and Saint John (29). Not all of the survey questions were completed by the 246 respondents, providing insight into which topics were more engaging, and which questions were beyond the scope of public knowledge. Overall, most of the survey questions had a good response rate (greater than 95%) from those who took the survey (though two questions had lower response rates of 84% and 55%).

3.1.1. Relationships

Individual experiences with the river lead to differing personal relationships with the watershed, which are challenging to define. The public survey was designed to gain insight into the individual relationships that respondents have with the river, and to understand how natural variability has an impact on these relationships.

The first of the questions aimed at understanding the public's relationship with the river asked participants to name the top three things they love most about the Wolastoq | St. John River. This open response question allowed respondents the maximum creativity and freedom to choose the most appropriate words to describe what they love about the river. A word cloud was created from the English and French responses, with the size of the words proportional to the frequency in which they occurred in survey responses (i.e., larger words appeared more frequently and small words less frequently; Figure 8). The responses indicated in Figure 8 reflect the values that respondents have for the river and the EGS they receive.

The most commonly used descriptions of the river included 'beauty', 'fishing', 'boating', 'scenery', 'swimming', 'recreation opportunities', 'beautiful', 'wildlife', and 'peaceful'. The responses to this survey question most commonly represented cultural EGS. For example, responses such as 'fishing', 'boating', 'swimming', and 'recreation opportunities' reflect the recreation and ecotourism categories of cultural services. Furthermore, words like 'beauty', 'scenery', 'beautiful', and 'peaceful' reflect the aesthetic experience category of cultural EGS. These and other similar responses speak to the importance of cultural EGS in defining respondents' relationships with the river, and suggest that changes to such cultural services would have a negative impact on social benefits received from the river. However, other common responses such as 'habitat', 'wildlife', and 'diversity' indicated that other types of EGS (e.g., supporting/habitat services) were also considered important to respondents, indicating that cultural services alone are not sufficient to characterize human benefits derived from the river.

Figure 8. A word cloud listing the words used by survey respondents to answer the question, "What do you love the most about the Wolastoq | St. John River?" Size of the word is proportional to the number of times the word was encountered in survey results.

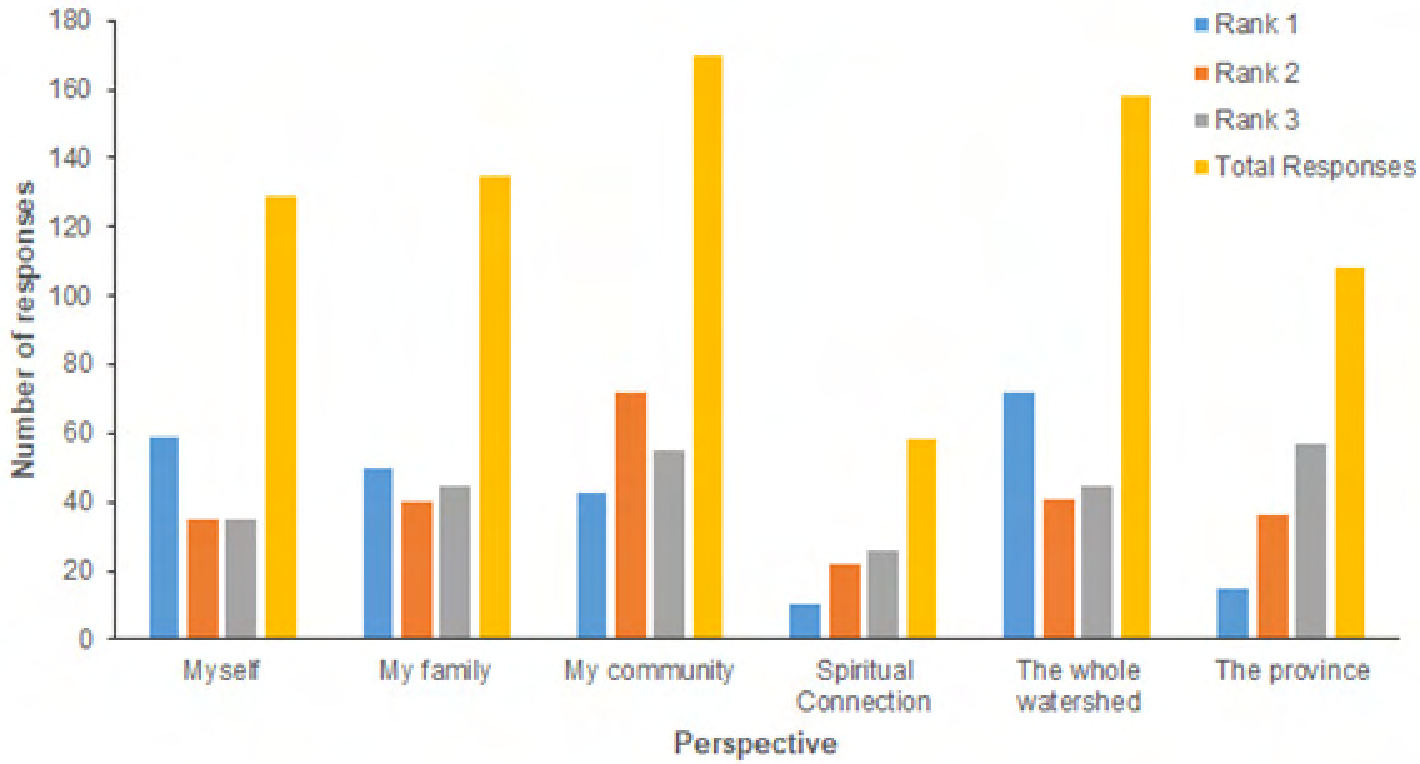


Figure 9. Responses to the survey question, "When I think of the river, I think of it from the perspective of...", indicating the number of times each response was chosen as the respondent's first, second, or third choice rank, as well as the total number of times each response was selected as one of the three ranks. Plotted frequencies include responses to English and French surveys.

Survey respondents were asked to indicate the perspectives they use when thinking of the river. The purpose of this question was to reveal how respondents perceive themselves in relation to the Wolastoq | St. John River by suggesting various key perspectives ranging from the individual scale to the province as a whole. Respondents were asked to rank the top three ways they perceive the river, demonstrating the dynamic nature of social connections with the river. The community scale and watershed scale perspectives were chosen most often by respondents as one of their top 3 choices (selected 166 times and 151 times, respectively; Figure 9). The personal and family perspectives were also important to respondents, and were selected as one of the top three ranked choices 125 and 132 times, respectively (Figure 9). In contrast, the spiritual connection was chosen the least often by respondents (selected less than 60 times), indicating that it did not rank as one of the top 3 perspectives that most respondents used when thinking about the river. The watershed scale was the perspective most often ranked as the first choice by respondents, followed by the perspective of the self and the family (Figure 9). The community scale, which was also highly ranked by respondents, was the most commonly chosen as the second ranked choice for the perspective with which respondents viewed the river.

The results indicate that a holistic and larger-scale perspective of the river basin is most commonly used by respondents, as the watershed and community perspectives were the most popular selections overall, and they were the most commonly chosen as the first and second ranks, respectively. However, this larger perspective extended to the provincial scale less frequently, indicating that fewer respondents considered the perspective of how the river influences and is important to the province as a whole. The results also highlight the importance of the self and family perspectives in respondents' relationship with the river, indicating the strength of the personal connection in determining how the river is viewed. Although these results do not provide details on why respondents selected the three perspectives in the order that they did, it provides an example of the variety of perspectives held and considered by those who live within the watershed.

Respondents were further asked to think about the river from their community's perspective, and indicate what the river means to the community. There were no instructions on what constituted a community, and respondents were expected to use their own definition for this term. Respondents were asked to select their first, second, and third choice of community perceptions of the river, including perceptions about the river's importance, meaning, and concerns about the river.

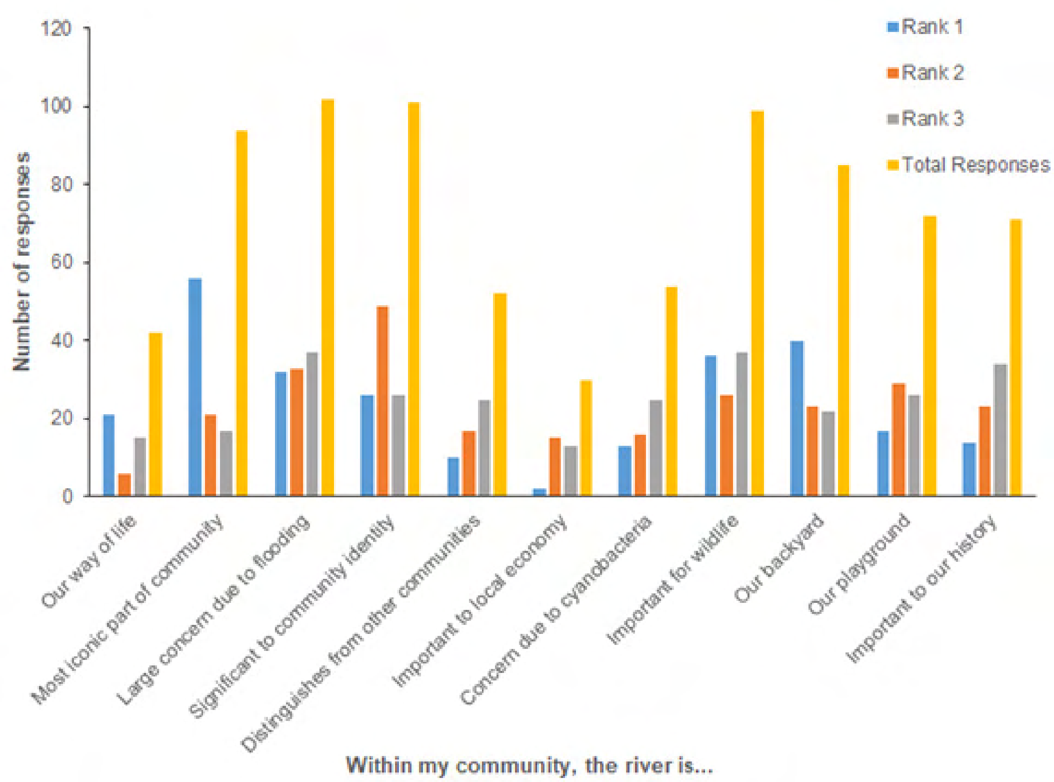
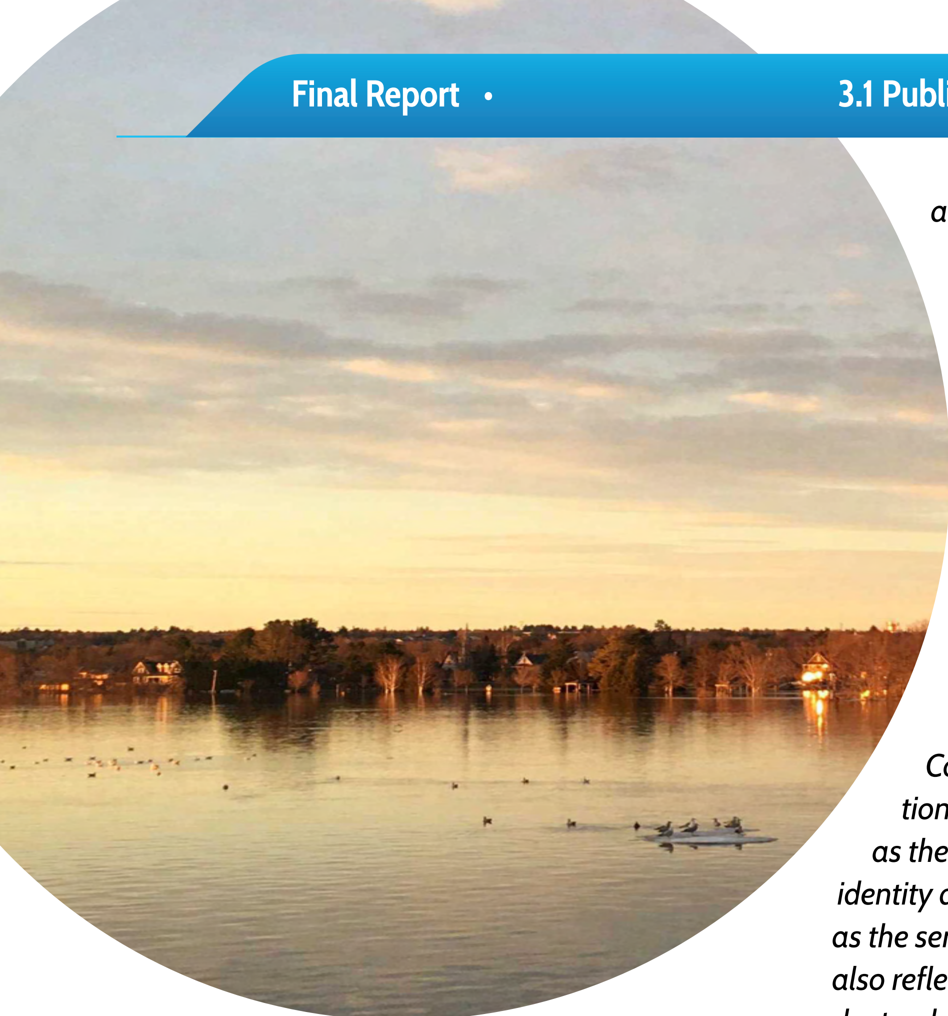


Figure 10. Responses to the survey question, "Within my community, the river is...", indicating the number of times each response was chosen as the respondent's first, second, or third choice rank, as well as the total number of times each response was selected as one of the three ranks. Plotted frequencies include responses to English and French surveys.



Overall, the most commonly selected community-level perceptions of the river included: the river is a large concern because of flooding (selected 102 times), is significant to our community identity (selected 101 times), is important for wildlife (selected 99 times), and is the most iconic part of our community (selected 94 times; Figure 10). The perceptions of the river as 'our backyard', 'our playground', and 'important to our history' were also commonly selected among the top ranked choices by a large number of respondents. In contrast, there were far fewer respondents who indicated that the community views the river as 'a concern due to cyanobacteria', 'distinguishes us from other communities', 'our way of life', or 'important to the local economy' (Figure 10). In part, the perception of the river as a distinguishing feature may have been reflected in the selection of the river as the 'most iconic part of our community', which was the perception most commonly selected as the first ranked choice by respondents. However, other less common selections, such as the river's importance to the economy and concerns about cyanobacteria, were unique among the options provided to respondents. Though the low response to these concerns may have reflected the composition of survey respondents (i.e., there may have been a higher frequency for these options had different people completed the survey), the low frequency with which they were selected as one of the top three community-level perceptions indicates that respondents did not feel that economic value or threats due to cyanobacteria were the most important perceptions within the community.

Commonly selected community-level perceptions and those that were most commonly ranked as the first or second choice reflected the cultural identity and heritage category of cultural EGS, as well as the sense of place. Supporting or habitat EGS were also reflected in the answers by a number of respondents who selected the importance of the river for wildlife, and its importance as 'our backyard'. But the selection of concerns, notably the concerns regarding flooding, offered some insight into the importance of regulating services (e.g., water flow regulation) in the relationship between the community and the river.

To determine how individual relationships are impacted by seasonality, the survey presented questions regarding the respondents' favourite time of year, special occasions, as well as seasonal limitations. Not surprisingly, summer was the most popular season among respondents (60% of respondents), followed by the fall (31% of respondents). Less than 10% of respondents selected winter or spring as their favourite time of year on the river. With the occurrence of flooding in the spring due to the freshet and lack of access in the winter, these findings were logical and expected.

Table 1. Summary of respondents' key words describing why they chose a particular season as their favourite.

Season	Total Comments	Keywords
Summer	65	*water-based recreation activities (e.g., boating, swimming, fishing), land-based activities (e.g., picnics, camping, gardening), sheer beauty, cottage life, community and people, warm, accessible.*
Fall	51	*scenery and colours, hunting and fishing, less activity on river, migrating birds, peaceful, less bugs.*
Winter	4	*close to home, recreation (e.g., skating, skiing, walking), scenery, ice.*
Spring	11	*less people, limited boat use, scary, powerful, renewal, new life, flooding.*
No Preference	8	*Enjoy the river all year around.*

A subset of those who answered the survey question about seasonality provided details regarding why they chose a particular season (Table 1). Respondents indicated that summer on the Wolastoq | St. John River is represented by its sheer beauty, cottage life, the weather, and various water and land-based recreational activities (Table 1). The fall was most associated with scenery and colours of the trees, hunting and fishing, and less activity on the river, allowing people to enjoy the peace and wildlife. The winter comments reflected winter recreational activities and the scenery. Spring also included some comments about recreation, along with concerns about the freshet and flooding. Most of these comments reflected cultural EGS categories, including recreation and aesthetic experience, though the concerns about the spring season supported the importance of regulating EGS in the participants' relationship with the river.

Respondents were also asked about specific events or occasions that they enjoy or participate in within the watershed or on the river. The results are presented by season and many respondents provided full sentences or stories which were summarized into key words for analysis (Table 2). As might be expected, Summer (73) garnered the most respondent feedback, which is consistent with the results in question three above, followed by Spring (18), Fall (16) and Winter (4). There were 25 respondents that simply said they did not know of any specific events or that they enjoyed the river all year. There were a number of special occasions listed in the responses, including Canada Day, festivals (art, music, and beer festivals, as well as region-specific festival celebrations; Table 2). However, a large number of people did not provide a specific event or occasion, but instead listed activities such as boating or picking fiddleheads. While most of these results did not include locations in a specific part of the watershed, it can be anticipated that these are annual events that are influenced by weather, river flow and other phenomena like COVID-19. Seven respondents noted that events had been cancelled in 2020 due to the COVID-19 pandemic. This provides an example of how the social benefits that people receive from cultural EGS or other services provided by the river can be disrupted.

Table 2. Responses to the question, "Are there specific events or occasions that you associate with the river?", with responses grouped by season, occasion and key words. Respondents were not required to provide a response to this question, and the total number of responses was 136.

Season	Keywords
Spring (18)	*Picking Fiddleheads, freshet, flooding (years: 2017, 2018, 2019), Gagetown ferry*
Summer (73)	*Canada Day (fireworks), sweat lodge, water-based recreation, (fishing, kayaking, sailing, boating, wildlife watching), festivals (Riverjam, Big Axe Beer, Gagetown Fair, St. John River Day), markets (Gagetown), long weekends, sunsets, biodiversity, Wolastoq pow-wow, picking fiddleheads*
Fall (16)	*Fall festivals (Harvest Jazz and Blues, Dooryard Art), hunting, fishing general and for specific fish (trout, Woodstock bass tournament, Muskie), potato harvest, markets (Hartland)*
Winter (4)	*ice fishing, snow mobile, ice*
Didn't Pick (25)	*Nothing specific or enjoy all seasons*

Table 3. Comments on why respondents selected a particular season in which they are prevented from enjoying the river. Number of responses is indicated in parentheses.

Spring (78)	Summer (25)	Fall (3)	Winter (62)
Flood/ing (63)	Cyanobacteria (11)	Cyanobacteria and dog risk (2)	Ice danger (17)
Too cold (3)	Boaters - speed, noise, rude, wakes of jet boaters (5)	Duck hunting (1)	Don't like winter or winter recreation (13)
Freshets (3)	Pollution (5)		Can't do preferred recreation (10)
Water too high (3)	High temperature (2)		River frozen (7)
Ice break up (3)	Blocked view by trees (1)		Unsafe (6) (not attributed)
Dangerous (1)	Too busy (1)		Lack of access (4)
Safety - Not safe to go on it (1)			Not frozen enough (3)
Too wet (1)			Low water (1)
			Wheelchair access (1)

Respondents were also provided with an opportunity to focus on barriers to their relationship with the river, based on the typical characteristics of the season and limitations that may occur (i.e., the floods in spring or the inaccessibility in winter). The results demonstrate that spring (41% of responses) and winter (42% of responses) were almost equally representative of the season in which respondents felt they were prevented from enjoying the river, whereas summer (15% of responses) and fall (2% of responses) posed fewer barriers.

When asked about the reasons why they were prevented from enjoying the river in a particular season, respondents provided the greatest number of comments for spring and winter (Table 3). Flooding in the spring was the most commonly named barrier to enjoying the river, contributing 63 of the 78 comments about spring (Table 3). The frequency of this comment speaks to the importance of regulating EGS, but likely also reflects the interconnectedness of different categories of EGS, for example, while the major dams on the river are operated as run-of-the-river systems with limited storage in headwater and tributary storage lakes, the increased water levels during the spring freshet may prevent people from deriving benefit from some cultural EGS, such as recreation services. Respondents' comments about winter generally focused on danger/safety and lack of access to or recreation on the river. Together, the spring freshet and winter ice cover predominated as the most common barriers to enjoyment of the river, indicating how natural seasonal variability in flow conditions and ice can influence the degree to which humans can gain benefit from the EGS offered by the river.

The survey questions discussed on the previous page were able to provide novel details regarding the relationship that individuals have with the river. The results confirm a strong love for the beauty and recreation that the river offers, and that most people think of the river from a watershed and community perspective first, and from a personal perspective second. These perspectives define the identity associated with the river and with the EGS that are provided and enjoyed. Furthermore, the results demonstrate that communities along the watershed have a relationship based on the iconic scenery that defines their way of life and that is important to wildlife. However, concern around flooding is also recognized as a significant part of the community relationship with the river, and one that impedes personal enjoyment of the river during the spring. The relationship characteristics identified through the survey questions can help emphasize the importance of the river as a personal and community entity, and make connections to the provision of EGS.

3.1.2 Benefits

The relationship with the river is a starting point for understanding the total benefits that the river provides to individuals and communities. There are a wide range of social benefits that may be derived from the river, and several survey questions were designed to collect information about these benefits from the viewpoint of residents of the Wolastoq | St. John River watershed.

The survey asked respondents to choose why the river is important to them. The question provided eight choices in a list and encouraged respondents to select all applicable choices, while also offering the option to add their own answers to the list.The beauty of the river and a personal connection with nature were both selected by approximately 90% of respondents, and were the most popular responses, followed by recreation (78% of respondents; Table 4).

Table 4. Respondents' choices for why they consider the river important, presented as the total number of responses and the percent of respondents who selected each choice. Respondents were allowed to pick all choices that applied.

Choices	% of Respondents	Total Responses
It's beauty	90%	222
Connecting with nature	89%	212
Recreation	78%	184
Social interactions	55%	130
Inspiration	47%	111
Cultural or heritage connections	46%	109
Spiritual fulfillment	45%	107
Employment	15%	35
Other (please specify below)	7%	16
	Answered	246

Recreation was not broken down into water or land-based recreational activities in the question, and thus encompassed both types. Social interactions (55%), inspiration (47%), cultural or heritage connections (46%) and spiritual fulfillment (45%) were all selected by a similar number of respondents, whereas employment was only selected by a small number of respondents (Table 4). In addition, other responses added to the list by participants included: feeds my soul, fishing (5), supports wildlife (4), research, healthy ecosystem (2), and tourism (2). These results provide information about the importance of the aesthetic experience and recreation as cultural services from which humans benefit. However, they also speak to the intangible social benefits and values derived from EGS, including the connection with nature, social interactions, and inspiration that may be harder to attribute to specific cultural services.

Respondents were also directly asked to identify what benefits they receive from the river. A list of benefits was provided and respondents were asked to choose all that apply. More than 83% of respondents indicated that the river contributed to their mental health (Figure 11). Mental health benefits are difficult to measure, and this quantifiable, direct linkage between the river and mental health therefore provides vital information about intangible social benefits. Recreation (76% of respondents) was the second most commonly selected benefit, representing a use-based cultural EGS that was highlighted by respondents in many of the questions about their relationship with the river. Other intangible benefits that were chosen by a large percentage of respondents included peace of mind (70%), sense of place (61%) and community identity (58%), which were the third, fourth and fifth most commonly selected benefits (Figure 11). Given that many cultural EGS are non-use and intangible, these results provide evidence that just because we cannot see the values and benefits that people associate with the river, does not mean they are not there. Further, these are important considerations that should be included in management discussions.

The results from this section emphasize the wide range of benefits that are received from the Wolastoq | St. John River, and the complexity and individuality of experiences. The outputs suggest that mental health, sense of place, and recreation are the most recognized benefits in the watershed, all of which can be derived from cultural EGS. These data provide support for including cultural EGS in decision-making by placing emphasis on the significance of social values that are often intangible and non-quantifiable.

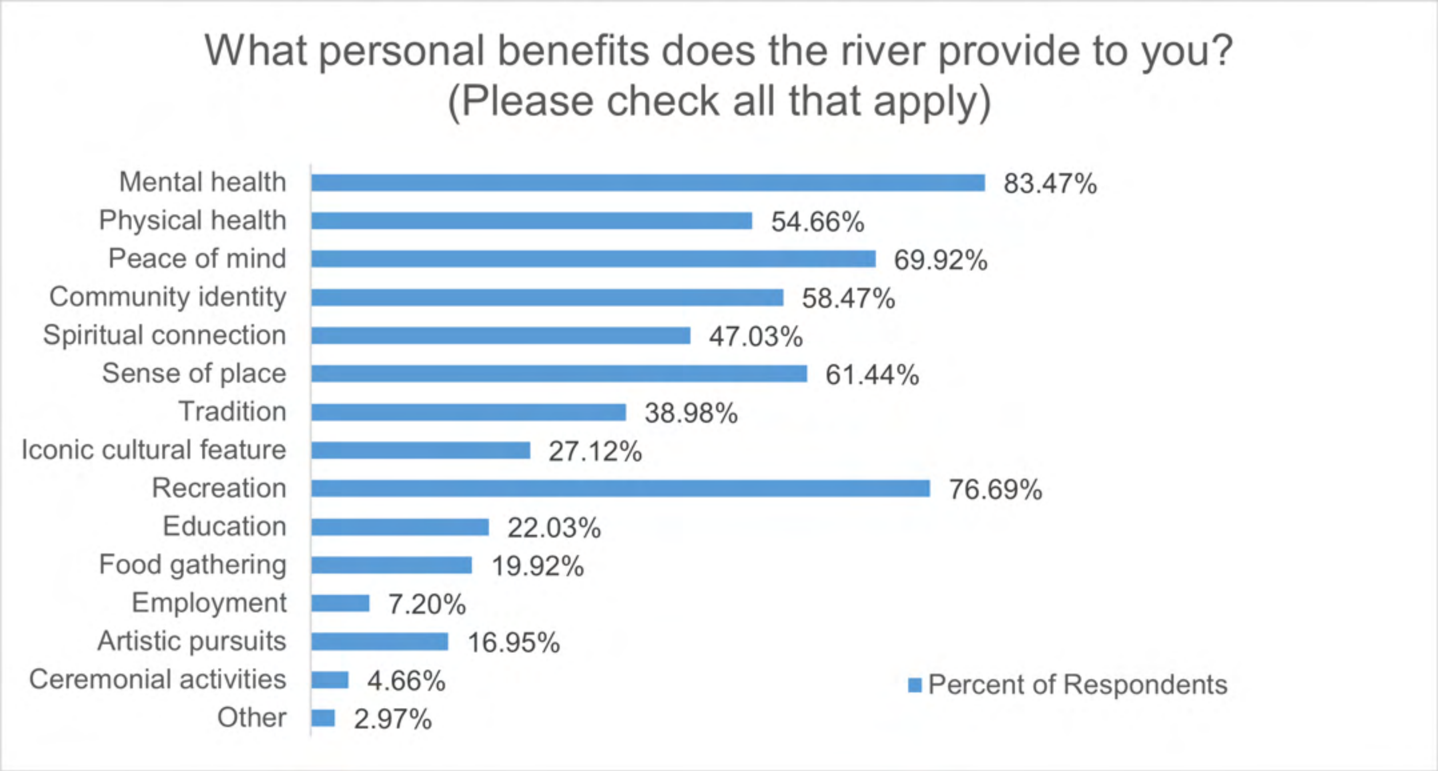


Figure 11. The benefits that respondents receive from the river, presented as the percent of respondents who selected each benefit. Respondents were allowed to select multiple benefits.

3.1.3 Concerns

While the EGS approach has a focus on the benefits provided by the ecosystem, it also acknowledges that the production of EGS is directly affected by environmental processes (Chan et al. 2011). In conjunction, changes to the environment have a direct impact on the provision of EGS and can be useful to inform watershed management priorities. In the survey, respondents were asked to provide information about their concerns related to the river to address the social impact of such changes.

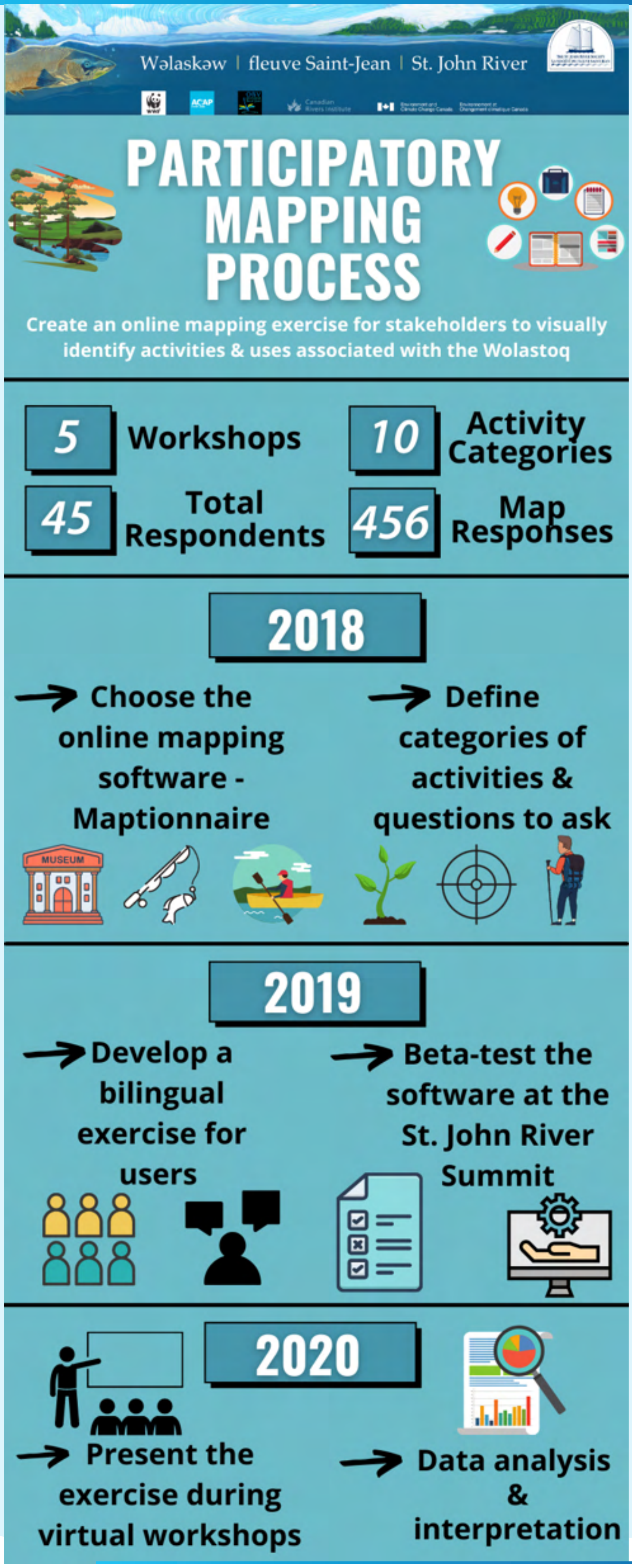
Respondents were asked to indicate their most significant concerns about the river in an open question format, with no limit placed on the number of concerns that each respondent could provide. Concerns provided by respondents were grouped into 9 categories, including water quality, water quantity, management practices, development, erosion, habitat and wildlife change or loss, climate change, water-based recreational activities, and access (Table 5).

The results from the survey demonstrated that water quality issues, including pollution, cyanobacteria, and pesticide use, were a significant concern for respondents throughout the watershed (Table 5). Water quantity was also a frequent concern in the survey question responses, consistent with other questions that noted the importance of flooding to the community perception of the river. Concerns categorized as development included urbanization and residential development, but also included development of dams and hydroelectric on the river. Each of these categories of respondents' concerns is closely linked with regulating EGS, which includes water flow regulation, water purification and waste treatment, and natural hazard mitigation. Concerns around habitat changes, invasive species, and biodiversity loss were also common among respondents, and these concerns are primarily linked with supporting and habitat EGS. Interestingly, these results demonstrate that the respondents' primary concerns were generally focused on the broad EGS categories as opposed to cultural EGS. These results highlight both the significant interconnectedness of the different categories of EGS and their supporting role in creating cultural EGS, and also reinforce the importance of scale of perspective whereby participants tended to connect with the river from the larger scales of watershed or community, rather than from the personal scale. The categories of concerns that were more directly related to cultural EGS, including water-based recreational activities and access to the river, were among the least common concerns provided by respondents. This category helps to emphasize the growing concern around development, forestry practises, climate change and habitat loss, and how these issues may directly or indirectly affect the social benefits derived from EGS.

Table 5. Respondents' most significant concerns about the river, with key words from respondent comments coded by category.

Code Categories	Definition	Response Numbers	Key Words
Water Quality	*This category bundled all the responses that were principally about an issue or observation relating to the water quality in the Wolastoq | St. John River*	139	*blue green + algae, pollution, cyanobacteria, boating dumping stations, quality, clean, excessive runoff, sedimentation, agriculture impacts, temperature and litter.*
Water quantity	*This category bundled all the responses that were principally about an issue or observation of water quantity relating to the Wolastoq | St. John River.*	57	*flooding, dam levels, flow modification, drought, diversion, low water levels, changing water levels, head ponds, ice flows.*
Management Practices	*This category is for any concerns that mentioned management practices of any type.*	18	*dredging, funding, improper practices, legislation, regulations, government, engineering, capacity loss.*
Development	*This category contains any comments relating to human development activities that are current or proposed.*	33	*residential, dams, hydroelectric, population growth, loss of wharfs/ lighthouses, need marinas, poor land use, sustainable use, clear cutting.*
Erosion	*Given the number of unique comments about erosion, it was deemed an appropriate sub-category affecting water quality.*	11	*erosion, silting*
Habitat and wildlife change or loss	*This category bundles comments relating to both habitat or wildlife change or loss.*	29	*habitat loss, preservation, wildlife, fish (loss + Muskie + Salmon), invasive species, rip rap.*
Climate Change	*This category bundles all concerns relating primarily to climate change, or related terms.*	8	*climate change, global warming*
Water-Based Recreational Activities	*This category bundles all responses that link significant concern about the river relating to human activities regarding water based recreation activities.*	17	*Boating (motorised + boat + traffic + congestion + boat dumping + litter + safety + loud + exhaust), few marinas, navigation issues, ferry, swimming, fishing.*
Access	*This category presents the comments related to access on or near the river. Generally, these comments relate to a lack of access for people to the Wolastoq | St. John River.*	8	

3.2 Stakeholder Participatory Mapping Exercise



Participatory mapping was conducted to identify the activities and uses that stakeholder groups associate with the watershed (see infographic for an overview of the process). In total, 97 stakeholder groups were invited to participate in the exercise, including watershed associations, hunting/trapping and fishing associations, recreational groups, academia, government departments, parks, and historical and multicultural associations. The participatory mapping component was completed using Maptionnaire, an online community engagement platform that provides a set of map-based tools for designing questionnaires, data collection, and presenting information (https://maptionnaire.com/).

The questionnaire included eight categories of activities that align with an EGS framework, including provisioning EGS (e.g., fishing, hunting and trapping) and cultural EGS (e.g., recreational activities, cultural sites; Table 6). Participating stakeholders were offered an opportunity to indicate locations within the basin in which their organization operates or interacts with the ecosystem, or which are deemed important to their organization, with locations indicated as exact points on the map or as a general area. Respondents were asked to provide answers from the perspective of their organization, rather than personal perspectives. Additionally, respondents were asked to choose any threats (provided in a list) that negatively impact the Wolastoq | St. John River and watershed. These responses provided an informative overview of critical concerns; however, they were not geolocated nor were they linked directly to the activities.

To aid in completion of the exercise, a total of five workshops were hosted with the goal to provide instructions and support for participants while they completed the exercise. Upon closing the participatory mapping exercise, 456 data points were collected from a total of 45 participants, including watershed groups and river—

Table 6. Participatory mapping categories and definitions.

Maptionnaire Mapping Categories and Definitions

Fishing	*This activity is defined as fishing for any species, both from boats and shore.*		
Hunting & Trapping	*This activity is defined as hunting or trapping birds and mammals for food, recreation, or economic purposes.*		
Land-Based Recreation	*This activity is defined as any other land-based recreational activities not included in the hunting & trapping category (e.g., hiking, snowmobiling, ATV, skiing on land, camping, picnicking and cycling).*		
Water-Based Recreation	*This activity is defined as water-based recreation activities including when the river is both open and frozen (e.g., canoe/kayak, sailing, motorized boating, swimming, water-skiing, boat-towed tubing, skating, etc.). Infrastructure needed to access the water, such as boat launches and wharves are also included.*		
Site of Cultural Significance	*Sites of cultural significance are considered worthy of preservation for the future, and may include areas significant to the archaeology, science, or technology of a specific culture.*		
Plants that Humans Use	*This category can be defined as either:*		
	Food gathering is defined as individuals directly collecting food from nature for food supply (e.g., fiddlehead, wild rice gathering, or mushroom foraging). This does not include farming or fishing.		
	And/ or Non-food materials are defined as directly gathered non-food materials and resources from nature. Examples include plants for medicinal, ceremonial, basket making and furniture making purposes.		
Aesthetics	*Think about the areas you appreciate for their aesthetics such as lookouts, spots where you take people, and favourite photography locations.*		
Protected Areas	*Think about the designated natural protected areas within the watershed (outlined in green on the map), are there any areas you think should be added?*		
Threats	*Understanding the threats along the Wolastoq | fleuve Saint-Jean | St. John River is part of managing a healthy and resilient waterway from both ecological and human health perspectives. Which threats are a factor for your group? Check all that apply.*		
	Non-point source pollution	*Point source pollution*	*Invasive Species*
	Flooding	*Ice jams*	*Cyanobacteria*
	Climate Change	*Dams*	*Urbanization/Development*
	Other (list as many as needed) If other, please specify:	*Climate Change*	*Dams*
Other Activities We've Missed?		*Please list any activities here that were not captured in the categories above.*	

associations, NGOs, government organizations (municipal, provincial, federal), fishing associations, industry, tourism organizations, and historical societies (for full list, see Appendix 2). The results provided specific locations, general areas, and comments about activities and uses within the watershed. Results of the participatory mapping exercise were broadly categorized as interactions with the river or concerns about the river. It is important to note that the maps developed from this exercise are not comprehensive for all areas of the watershed or river, as less than half of the invited stakeholder groups participated in the mapping exercise. Furthermore, although the questions for the participatory mapping exercise were reviewed by Indigenous representatives facilitated by the Wolastoqey Nation in New Brunswick, there were no direct results collected from Indigneous Peoples and Rights Holder organizations through this exercise. This omission was not by design, however, Indigenous peoples access resources in the context of constitutionally protected Aboriginal and Treaty Rights. Appreciation for the sensitivity of any information provided is paramount to developing trust-based relationships with Indigenous communities, and we chose not to move forward with collecting this information until these relationships could be better developed. Therefore, results for categories such as "sites of cultural significance" must be interpreted with caution, as they do not include the perspectives of Indigenous peoples residing in the Wolastoq|St. John River catchment.

3.2.1 Interactions

While the public survey data provided novel information regarding the personal relationship with the river, the participatory mapping exercise explored the interactions that stakeholders have with the river, including activities and uses. These data are essential for developing an understanding of how people use the river, and what interactions are significant to them. By plotting the activities spatially, a story can be revealed about how and where people are using the river, and further connections to EGS can be defined.

The density of mapped activities along the river was greatest close to the largest populations (Figure 12). Literature suggests that the use of cultural EGS is affected by distance from the home or from roads (Brown et al. 2002, Fagerholm et al. 2012) and the results provide support for this idea. As might be predicted based on the understanding of EGS and accessibility, the majority of the activities mapped were clustered around Saint John, Fredericton and Edmundston, the most populated municipalities in the watershed. The distribution of activities may in part be a reflection of the geographic coverage of respondent stakeholder groups, but this likely does not fully account for the pattern.

The largest polygons in Figure 12 represent land-based activities (in variations of green), including people (e.g., hiking) and machine powered (e.g., all-terrain vehicles, snowmobiles). Land-based recreation included polygons and corridors that overlapped with parks, wildlife areas, nature preserves, and trailways, speaking to the importance of these designated areas in contributing to cultural EGS. Hunting areas included a polygon in the northern watershed and corridors along the river in the Fredericton region, whereas locations where fishing takes place included a large area centred around Saint John (Figure 12). Even though these polygons represent large areas, they provide information about the importance of the Saint John region for provisional EGS including fishing activities (recreational or commercial) and hunting. In the case of recreational fishing and hunting, respondents may not have wanted to provide their exact fishing or hunting locations, and therefore provided the larger polygon area.

Specific geographic locations (mapped as points) were provided for a number of activities, particularly in the vicinity of larger municipalities (Figure 12), demonstrating patterns of activities along the river and tributaries. In particular, these points indicated locations of water-based activities (representing 72% of the recreational activities that were mapped) and aesthetic locations (e.g., photography locations, tourism locations, and locations where one feels connected), both contributing to cultural EGS in the watershed. These specific locations can be used to understand how changes to environmental flows will potentially impact these activities, EGS, and the values that stakeholders have revealed.

The results of the participatory mapping exercise provide valuable information about stakeholder use and interaction with the watershed, with identification of specific locations and regions that are meaningful from an activity perspective. Further mapping is required to complete a full data set with a more comprehensive set of views and usage history included; however, these results advance the consideration of stakeholder uses and activities into watershed management. By understanding where and how stakeholders use the river, and making connections to flow regime, the river can be managed in such a way that enhances both the diverse ecosystems and social values that exist.

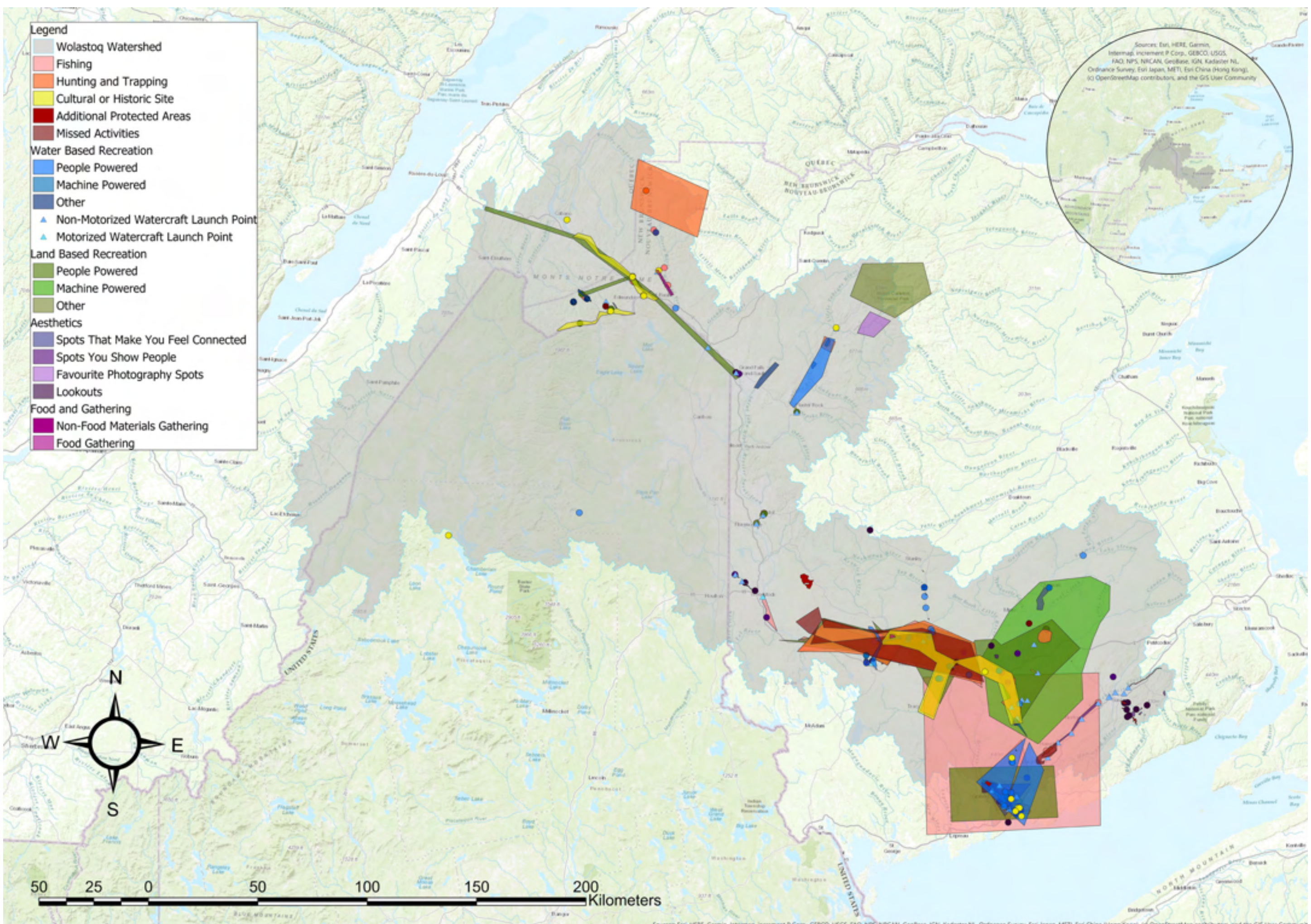


Figure 12. Results of the participatory mapping with all stakeholder activities mapped as points (specific locations) or polygons (areas), depending on information provided by the 45 stakeholder groups that contributed to the exercise. Points and polygons are coloured by category. See appendices for maps separated by category.

3.2.2 Concerns

As in the public survey, stakeholder participants in the mapping exercise were asked to select threats to the river from a list, and were allowed to add "other" concerns. Participant responses ranged from zero to eight identified threats. Whereas the concerns indicated in the public survey were primarily focused on water quality and water quantity, with habitat and wildlife change or loss being selected by fewer participants, stakeholder feedback appeared to have a greater emphasis on wildlife change. Invasive species was selected most often as a concern by stakeholders (24 participants), followed by point-source pollution (19 participants; Table 7). A number of other concerns were selected by a similar, but slightly lower number of stakeholders, including biodiversity loss (17 participants), non-point pollution (17), the effects of dams (17), flooding (17), and climate change (16). In these stakeholder responses, there was a greater balance in the number of participants who viewed water quality, water quantity, and wildlife change as prominent threats to the river than was evident in the public survey responses.

The participatory mapping exercise also offered participants an opportunity to identify areas of the watershed that they would like to see protected. While the geographic indicators showed a low response rate, the comments on this category suggested that many more areas should be designated as protected, and some suggested that the entire watershed be included within this designation. This information helps to emphasize the growing concern around development, forestry practises, climate change and habitat loss.

Understanding local concerns is essential for creating a sustainable watershed where humans and ecosystems thrive. The production of cultural EGS is affected by environmental processes that affect the river ecosystem, other EGS, and biodiversity (Chan et al. 2011). Accordingly, environmental threats to EGS production such as water use (e.g., changes to the flow regime) and land-use change (e.g., fragmentation and habitat), pollution, climate change, and invasive species can alter the flow and timing of important cultural EGS. Overall, the data collected provide support for the growing concerns along the river and place emphasis on areas where management practices that incorporate a social and cultural component can contribute to improving watershed health and sustaining the provision of EGS.

Table 7. Threats to the Wolastoq | St. John River as selected by the stakeholder groups that contributed to the participatory mapping exercise. There was no limit to the number of concerns stakeholders were allowed to select.

Threat	# of stakeholders who selected
Invasive Species	*24*
Point source pollution	*19*
Biodiversity loss	*17*
Dams	*17*
Flooding	*17*
Ice Jams	*17*
Non-point source pollution	*17*
Climate change	*16*
Urbanization/Development	*14*
Cyanobacteria	*8*
Other (added below)	
Clear-cutting/forestry operations	*1*
Berms along the river	*1*
Low water levels	*1*
Silting	*1*
Climate change specific to ice fishing depth and target fish density	*1*
Use of pesticides use by the agricultural industry	*1*
Soil mining along the river (Nashwaak Watershed)	*1*
Lack of enforcement of existing regulations (fisheries and water quality/quantity)	*1*
Rural Plan Implementation - Lack of oversight	*1*

3.3 Additional feedback

Throughout the public survey and participatory mapping exercise, participants were able to provide explanations and anecdotal comments to accompany the locations and activities they identified. This resulted in a wide range of comments that described public and stakeholder interactions with the river in the context of cultural EGS, regulating EGS, and threats to the river, specifically contributing to information about historical and cultural heritage, and local perceptions.

The additional feedback received from participants in the survey and participatory mapping exercise was combined and categorized as human/ biophysical river issues, pollution and clean-up, government and science, lifestyle and beauty, tourism and promotion, recreation, spiritual and inspiration, and acknowledgement of heritage (Table 8). The comments included specific concerns regarding threats and suggestions for actions to safeguard the river, as well as comments related to the governance and management of the river (Table 8). These comments relate directly to the importance of regulating EGS to safeguard access to provisioning and cultural services. A number of comments also related directly to different aspects of cultural EGS, including the aesthetic experience (descriptors of lifestyle and beauty interactions with the river), recreation and tourism (activities and suggestions to increase interaction with the river), and spiritual and mental health (including ways that interaction with the river contributes to human well-being). Together, these comments indicate ways in which respondents have directly interacted with the river to derive social and cultural benefits, and ways in which their ability to interact with the river could be protected.

Table 8. Participatory mapping exercise respondents' additional comments about their experiences with the River.

Code Categories	Definition	Key words and Phrases	Connection to the river
Human/ Biophysical River Issues	*Issues on the river that are caused by the relationship and settlement of humans including individual behaviour.*	*Powerboats ruin visits, too much boat traffic, need launch areas, killing Muskies, development, noise issues, infilling, hydro dams, forestry, rethinking our modern uses*	*Threats*
Pollution and Clean-up	*Specific comments about pollution issues in the river and comments about cleaning and conserving the river.*	*Long term river health, more pollution now, clean it up, preserve, conserve, algae issues, afraid to swim, agricultural runoff, spraying, sawmill waste, more protection needed*	*Threats*
Government and Science	*Specific comments about science and any government or government actions mentioned.*	*Federal and provincial government - funding, regulations, environmental protection, firmer laws, dam removal, flood controls, net-zero runoff , carbon offset projects*	*Governance*
Lifestyle and Beauty	*This collection of comments lists the love, connection and beauty respondents had, including the contribution to their lifestyle.*	*Beautiful, home, watching the river, views, calming, need to see it daily, personal, community connection, great for raising families and creating memories, fiddleheading, chaga, raspberry and blueberry harvest, covered bridges, wildlife neighbours (fish and moose as familiar species*	*Cultural EGS - Aesthetic*
Tourism and Promotion	*Comments about the promotion of the river and specific tourism ideas.*	*Promote tourism, a treasure, market, recreational opportunities, historic, undervalued, underutilised, fishing tournaments, moonshine festival in Saint-Hilaire, provincial parks, geological sites, ziplining, NB Botanical Garden*	*Cultural EGS - Recreation and Tourism*
Recreation	*References to specific recreational activities within the watershed.*	*Picnics, visits, river recreation (e.g., boating, kayaking, fishing, fly fishing, ice fishing), skating, boat docks and infrastructure, camping, horseback riding, cycling*	*Cultural EGS - Recreation and Tourism*
Spiritual and Inspiration	*The concepts of spiritual connection and inspiration.*	*Stress relief, the river is my anchor, inspiring, spiritual connection, peaceful, place of relaxation, intrinsic connection*	*Cultural EGS - Spiritual and Mental Health*
Acknowledge-ment of Heritage	*Comments about the heritage and cultural legacy of the river.*	*Transportation route, entire watershed significant for First Nations, Plaster Rock, historic settlements, rename to the Wolastoq River, affirm the heritage, cultural identity and aboriginal presence*	*Governance*

Table 9. Public comments on the Facebook survey advertisement, grouped by category, number of respondents and key words. Several comments included multiple codes and descriptors, and these comments are therefore represented in multiple rows.

Codes and Descriptors	Number of Comments	Descriptor	Keywords
Love for the river	*99*	*These comments were all positive and emphasised what people love about the river or experiences on and with the river.*	*Peaceful, tranquil, many recreation options, best kept secret in NB, born and raised, happy place, spending time, mighty St. John, scenery, inspiring, growing up, beautiful sunsets.*
Threats, loss and issues with the river	*38*	*These comments specifically mentioned a specific threat to the river, a loss over time and anger or sadness about the state of the river and actions on the river.*	*The river is dry, dirty, stinky, algae issues. River health impacted by clear cutting, development, dams, sewage, being taken for granted.*
The name of the St. John River	*17*	*These comments were specifically about the name and perspectives on changing or not changing the name.*	*Call it by its name - Wolastoq, the original name, leave the name alone, First Nation history, spell Saint John River properly.*
Historic connection	*12*	*If the comments provided an historic context or connection with the river.*	*Songs about the river, place as Amazon of the North, history and changes on the river, fishing areas, riverboat, working on the river, settling along the river, dam history.*
Governance and Government comments	*3*	*If the comment was specifically about a government action or inaction was*	*NB government: doing little, not promoting, under utilised, recognise the value, fishing issues, tourism promotion.*

Additional public comments outside of those received from the survey were obtained through promotion of the survey on Facebook. In total, there were 139 comments on the Facebook post in response to the question "Tell us about your river" in the survey advertisement (Table 9). The majority of comments were about respondents' love for the river, including many of the same terms that were found in Figure 8. Threats and concerns about the river were the second most frequent comments, reflecting similar ideas to those found in the survey responses. Although the degree of overlap between respondents to the survey and the Facebook advertisement is unknown, the most frequent comments on the advertisement were overall very similar to the results of the survey.

In relation to watershed management and the future of the Wolastoq | St. John River, the connections identified through the feedback provided by respondents demonstrate support for our wider watershed priorities to (i) understand water quality and quantity; (ii) build towards reconciliation through water; (iii) understand climate change impacts and mitigation; (iv) quantify biodiversity loss and invasive species; and (v) develop respectful and inclusive governance within the watershed.

3.4 Activities, Ecosystem Goods and Services, and Benefits

One of the most powerful aspects of an EGS approach is that it focuses decision making on what people care about, and although they are unquestionably difficult to measure, cultural EGS and the social benefits that can be derived from those EGS are clearly valuable to people (Chan et al. 2012a, Chan et al. 2012b). This research can provide important inputs to contribute to water management decisions that are both ecologically based and connected to important EGS.

Research into cultural EGS in New Brunswick, particularly relating to water management, is limited; however, there are a few resources that provide related information about water-based activities, benefits, and threats to aquatic ecosystems in the province. Specifically, the 2017 Conservation Council of New Brunswick report (Comeau 2017) presents the findings of an online survey in which participants were asked to share what they love about their favourite lake, river or stream. The results support the findings of this research with the most cited words being "clean" followed by "beauty." While not specific to the Wolastoq | St. John River, the Conservation Council of New Brunswick report provides some of the earliest work revealing what New Brunswickers love about their favourite water body and making connections to several EGS and benefits, although not using this terminology. The Conservation Council of New Brunswick survey also provided an opportunity for New Brunswickers to voice their concerns about aquatic/ river health. In alignment with this analysis, when asked to indicate what worries them about their favourite lake, river or stream, the most cited word was "pollution" followed by other associated words like "contamination" (Comeau 2017).

To further the application of EGS into water management in New Brunswick, the social-cultural data collected through the public survey and participatory mapping exercise was examined following the work of Klain et al. (2014). Through this analysis, benefits provided by respondents were linked to cultural EGS categories following the definitions in Table 10. This analysis emphasizes that an individual service can provide multiple benefits. While it would simplify the process to map one service to one benefit, Klain et al. (2014) do not see this being possible with cultural EGS since "spiritual, inspiration, and place values are not products of single kinds of experiences; rather these benefits are products of all manner of experiences associated with ecosystems (including metaphysical contemplation)" (Chan et al. 2011). This is a powerful tool for interpreting the often intangible benefits of interaction with the environment, and begins to illustrate the connectivity and cross over when describing the numerous benefits an individual can receive from cultural EGS. The results of our research support this idea of complexity, whereby individual descriptions of relationships, benefits, concerns, or interactions with the Wolastoq | St. John River are diverse and unique.

Table 10. EGS and benefits categories and definitions.

Ecosystem Category	Definition
Cultural EGS	*Contribution from ecosystems to the non-material benefits to humans from human-ecological relations, such as experiences and capabilities*
Subsistence	*Use of renewable wild resources for food, shelter, fuel, clothing, tools or transportation*
Outdoor recreation	*Activities in natural or semi-natural settings for the purpose of relaxation or amusement, e.g., kayaking, recreational fishing*
Education & Research	*Activities associated with learning about the natural world or research related to a natural or semi-natural landscape/waterscape*
Artistic	*Associated with the creation and appreciation of beauty from nature*
Ceremonial	*Set of actions performed on a special occasion for symbolic value and linked to biotic features of land/water*
Benefits	**Valued goods, experiences, and conditions**
Place/heritage	*Meaning or importance associated with a location; locations that serve as reminders of past events for people and communities*
Activity	*Intangible benefits associated with an action, e.g., satisfaction from collecting wild food*
Spiritual	*Related to metaphysical forces that exist beyond the individual*
Inspiration	*Mental stimulation to do or feel something*
Knowledge	*theoretical as well as practical information and/or skills*
Existence/be-quest	*Intangible non-use benefits associated with knowing that something exists or satisfaction in preserving a natural landscape for future generations*
Option	*The predicted benefit of future use of a natural resource*
Social capital & cohesion	*Contributing to enhancing relationships among people*
Aesthetic	*Relating to beauty or appreciation of beauty*
Employment	*Contribution to work that provides monetary income*
Identity	*Ideas, relationships and sense of belonging that shape people*
Mental Health	*Physiological and emotional well-being*

The relationship between EGS categories (from Table 10) and perceived benefits was explored by identifying the potential benefits that might be obtained from each EGS (Table 11). Multiple benefits were clearly associated with each cultural EGS. For example, recreation as a cultural EGS does not simply provide activity benefits but also inspiration, knowledge, and identity (Table 11). From the public survey and the participatory mapping exercise, it was clear that recreation is a large component of the EGS provided by the Wolastoq | St. John River, and the comments shared through these exercises allow for deeper connections to be made beyond the role of recreation as an activity. Respondents' comments suggest that recreation is a way for residents to stay physically active, providing health benefits, but that it also provides a sense of cultural identity through historic events and traditions. These data are consistent with the suggestion that cultural EGS and the associated benefits are multi-faceted and interwoven, and that results do not necessarily lead to a one-to-one relationship (Millennium Ecosystem Assessment 2005, Kareiva and Marvier 2011, Chan and Satterfield 2020).

Table 11. EGS Categories, Benefits and the Benefit Substitutability.

CES Categories (Chan et al. 2011; 2014)	Connections to this Research	Benefits												Site Sustainability
		Place / Heritage	Activity	Spiritual	Inspiration	Knowledge	Existence, Bequest	Option	Social capital / cohesion	Aesthetic	Employment	Identity	Mental Health	
Subsistence	*food gathering, employment, fishing, hunting, trapping, plants for human use*	x	x	x	x	x			x	x	x	x	x	*varies*
Recreation	*physical health, land-based recreation, water-based recreation, fishing, hunting, and trapping*	x	x	x	x	x			x	x	x	x	x	*depends*
Education & Research	*education, protected areas, site of cultural significance, fishing*	x	x	x	x	x		x	x	x	x	x	x	*depends*
Artistic	*sense of place, artistic pursuits, iconic cultural feature, aesthetic*	x		x	x	x				x	x	x	x	*varies*
'Ceremonial'	*peace of mind, community identity, tradition, ceremonial activities, spiritual connection, site of cultural significance, fishing, hunting, trapping, plants for human use*	x		x	x	x			x	x		x	x	*varies*
*** Site Sustainability**		*low*	*high*		*varies*		*depends*		*high*	*low*	*high*	*varies*	*varies*	

** Site substitutability is low if the service or benefit is linked directly to particular places, and high if not; it depends on whether there are clearly identifiable and understandable differences in instances within a category (e.g., existence value may be site-substitutable for valued species, but not for sacred sites); or it varies if the logic of the variation is more complex (e.g., the provision of ubsistence opportunities is not site-specific for activity values, but it may be for place values) (Chan et al., 2012a; Chan et al, 2011)*

Site substitutability refers to whether a value can be provided by an alternative site, and provides a score that measures the direct to indirect nature of the service's link to a particular place. Site substitutability falls into four categories: low, high, depends or varies. If the service or value is directly linked to a particular place, the relationship is 'low' (i.e., the value cannot be easily received from another site). If the value is not directly site specific, its site substitutability is 'high,' (i.e., the site can be substituted by another location to provide the same value). If there are clearly identifiable and understood qualitative variations within a category, it is deemed 'depends'. For example, if the value is provided based on site conditions, the site substitutability will depend on the presence of the qualitative characteristics. The relationship can also 'vary' if the logic of the variation is more complex (e.g., the provision of subsistence opportunities is not site-specific for activity values, but it may be specific for place values). This provides useful information to understand the potential impacts of changes in the flow regimes and recommendations to minimise the loss of EGS benefits and values.

For the purposes of this research, the site substitutability for benefits associated with place/heritage and aesthetics is low, meaning that if the site is lost, these benefits cannot be easily replaced. Alternatively, the substitutability for benefits related to activities, social capital, and employment is high, since new sites can be used to provide similar benefits. In the Wolastoq | St. John River watershed, the site substitutability of cultural EGS are less easily determined. The provision of these EGS depends on various factors, and is variable to changing social and environmental situations. In this analysis, the site substitutability can be a useful measure to provide an understanding of the value of specific sites, and the irreplaceable aspects that exist within the watershed.

The results of this work highlight the importance of cultural EGS within the Wolastoq | St. John River watershed. Further, identifying the activities, benefits and cultural EGS helps to emphasize the importance of the river as part of the social identity of the community, and to the values held by those who live in the watershed. This research provides an opportunity to evaluate the cultural EGS and benefits that are experienced through the watershed along with specifics regarding the activities, timing, and locations that can be directly related to water flows at various times of the year. The results of this assessment demonstrate the value associated with the Wolastoq |St. John River and the range of benefits that although intangible, have a significant role in the future of the watershed. By providing insight into the types of uses and values that stakeholders identify with, this research provides an essential contribution for watershed management moving forward. The importance of combining an understanding of human values with the science of river management, as in this adaptation of ELOHA, is intended to provide a more holistic and powerful input into best practices and river management and policy in New Brunswick.

4. Next Steps: Integration of ecological and social-cultural components

4.1 Bringing our Results Together

Our goal for environmental flows within the Wolastoq | St. John River watershed is to meet the definition laid out by Arthington et al. (2018) where we aim to, "protect and restore the socially valued benefits of healthy, resilient, biodiverse aquatic ecosystems and the vital ecological services, economies, sustainable livelihoods, and well-being they provide for people." In this context, the work undertaken in this project has included the assessment of both ecological flow needs, through the environmental component of the ELOHA model, and social benefits, through the assessment of EGS with a particular focus on the often intangible cultural EGS. Our work is starting to explore the interconnectedness of the environmental and social-cultural components, and we are clearly seeing the importance of these connections. For example, all of the 69 flow-ecology hypotheses developed through the environmental component of ELOHA have a link to supporting and regulating EGS (Figure 13). Perhaps this is not surprising given their roles, e.g., links to flow control or nutrient cycling, but we also see that 46 of the hypotheses have connections to cultural EGS, which are less tangible than the other categories, and 41 are linked to provisioning EGS (Figure 13). By tailoring the ELOHA framework to our watershed, we have the opportunity to combine the environmental and social-cultural components to inform wider watershed flow management. Combining these data in the next phase of this process will require fully elucidating the connections between these two components, striking a balance between the needs of the ecosystem and the people who reside within the watershed, while acknowledging necessary trade-offs.

SUPPORTING EGS: 100%
REGULATING EGS: 100%
CULTURAL EGS: 67%
PROVISIONING EGS: 61%

Figure 13. Percentage of the ELOHA hypotheses developed for the Wolastoq | St. John River that are linked to the four EGS categories, where word size is proportional to those percentages.

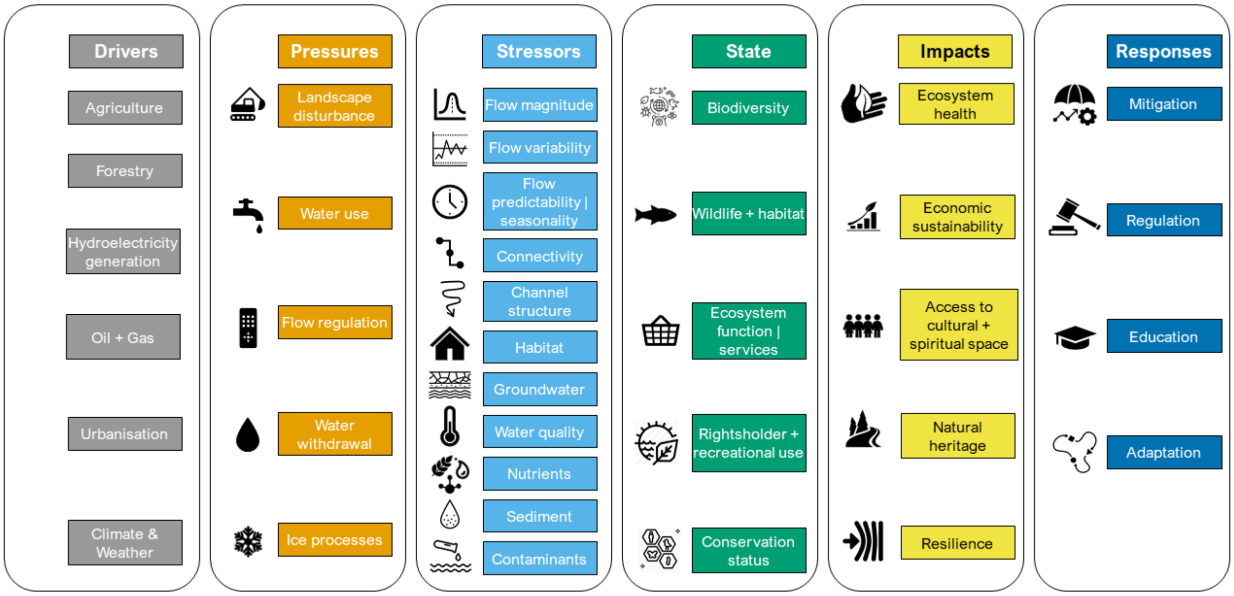


Figure 14. Adapted DPSIR framework to support the Wolastoq | St. John River environmental flows process, indicating drivers, pressures, stressors, states, impacts, and responses relevant to the watershed.

Here we have explored a novel approach to understand the connections between the watershed drivers that can affect flows, ecosystem integrity, and EGS and benefits received, and the resulting changes to our environmental and social-cultural pressures (and stressors), state and impacts. We can build upon our results to start to synthesise these two components and visualise their interconnectedness. We developed a DPSIR-based framework to support this process and to allow us to visualise the highly complicated connections between the different components (Figure 14). The adapted DPSIR for our environmental flows framework represents the wider watershed drivers (e.g., agriculture, forestry, urbanisation, hydroelectricity generation, and weather and climate) and their subsequent pressures (e.g., flow regulation, water use, ice pressures), the stressors that reflect changes in drivers and pressures (e.g., water chemistry, flow magnitude, flow variability, and flow seasonality and predictability), the ecosystem and service states that are affected by changes in stressors (e.g., biodiversity, ecosystem goods and services, Rights Holder and recreational use), the resultant ecological and social impacts (e.g., ecosystem health and resilience, natural heritage), and the management responses (e.g., mitigation and technological development) (Figure 14).

While not all of the drivers and subsequent pressures are directly linked to hydroelectricity generation, it is important to understand the other potential mechanistic pathways across this complex landscape (e.g., impacts from forestry, agriculture, climate change) to have a more comprehensive understanding to apply to our adapted environmental flows framework. Within this project, we have focused our assessment of the environmental and social-cultural components only on those associated with hydroelectricity generation.

As most of the hydro facilities and supporting facilities on the Wolastoq | St. John River are operated through a run-of-the-river management approach with limited storage capacity beyond smaller tributary storage facilities, the resulting hydrograph is fairly similar to its historical shape in terms of peak flow timing, duration and frequency of high flows.

However, there are parts of the flow regime that are clearly modified, for example increased minimum flows during summer months as mandated by the NB Power-DFO protocol agreement and the intra-daily effects of hydropeaking at non-peak flows (Figure 15). In Figure 15, the wider watershed drivers (e.g., climate change, hydroelectricity generation) are linked to pressures and stressors in a conceptual model of the Wolastoq | St. John River system. Changes to flow magnitude (for example, through increased minimum flows during summer through the NB Power-DFO Protocol agreement) or through longer-term climate change-induced shifts lead to habitat loss and shifts in connectivity, changes to water quality, sediment movement and channel structure. Increased flow variability at non-peak flows due to hydropeaking affects sediment, connectivity, and leads to habitat loss. The conceptual model also highlights that the natural range of flow predictability and seasonality is important to provide cues for fish migration and key ecosystem processes including access to key habitats.

Each of these stressors in turn can affect the state of the ecosystem for both environmental, for example wildlife and wider biodiversity both in the river and in the adjacent wetland and floodplain habitats, and social-cultural components as seen via EGS, for example access to EGS, Rights Holder and recreational use of the river system (Figure 15). The end result of such alterations is changes to ecosystem function and services, loss of aesthetic properties, and reduced capacity for fishing and recreational space, leading to impacts such as reduced resilience and natural heritage, general declines in ecosystem health, and reduced access to cultural and spiritual space.

By identifying the key pathways through this mechanistic understanding (Figure 14), we can start to highlight areas of potential concern and work with flow regulators and watershed users to address these concerns to benefit the ecosystem, social-cultural needs, while meeting the needs for hydropower generation. The results of the social-cultural assessment have allowed us to identify the core receptors (e.g., ecosystem goods and services, fishing health, flooding concerns and recreation) and impacts (e.g., access to cultural space, and ecosystem resilience) in the watershed (Figure 14).

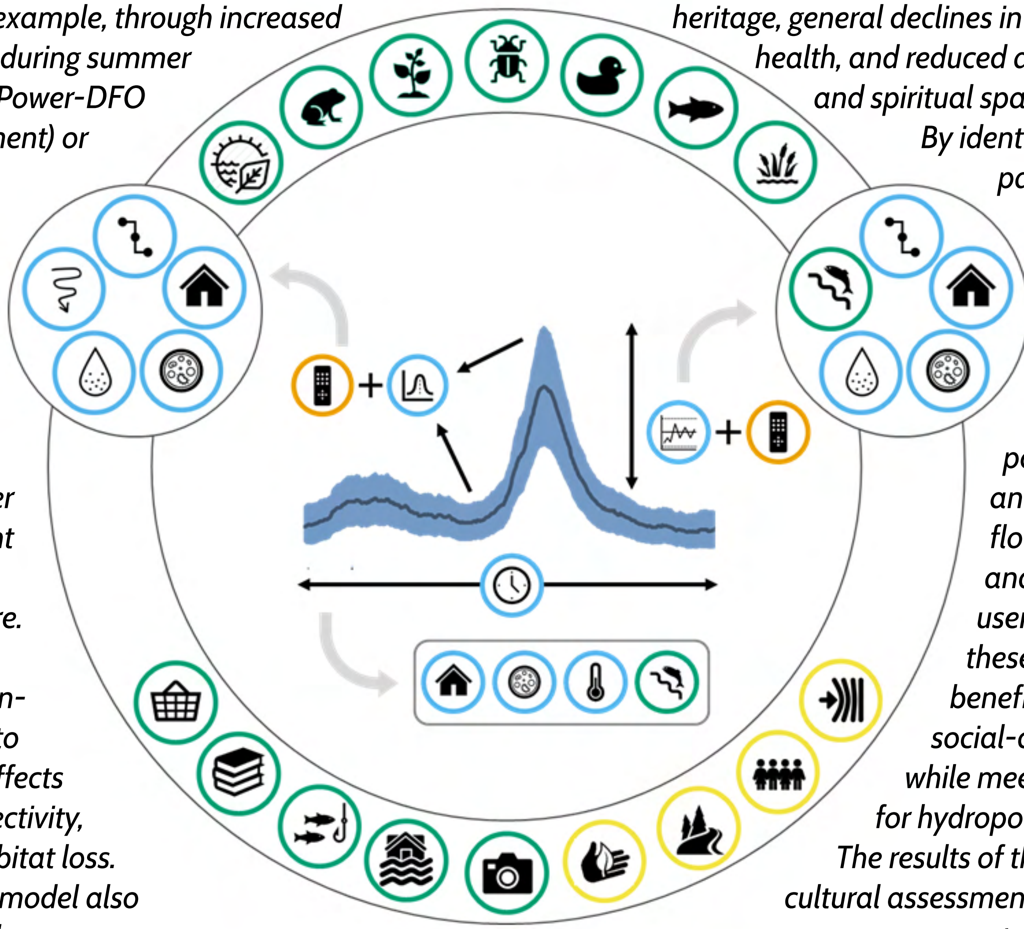


Figure 15. Understanding the components and connections to flow management. Note that the colours and most icons can be linked to Figure 14 (orange = pressures, blue = stressors, green = state or receptors; and yellow = impacts). The conceptual framework highlights the linkages among flow components, both natural and modified, as shown by the hydrograph in the centre, and their connection to wider pressures and stressors, as shown by the smaller circles, in addition to the impacts on ecosystem and social-cultural state and impact, as shown in the outer circles.

4.2 Conclusions and Recommendations

The adaptation of an ELOHA framework for the Wolastoq | St. John River followed the approach laid out by Poff et al. (2010) with separate processes for the environmental and social-cultural components. However, we have found that this has led to difficulties in bringing these two critical pieces together for the final environmental flows framework. Moving forward, we would strongly recommend developing the environmental and social-cultural pieces in tandem as they are closely linked. To facilitate this process, we have adapted the original ELOHA framework to meet these proposed changes (Figure 16). We identified six core processes that draw upon workshop-, data- and knowledge-led processes, namely: (A) knowledge and ecosystem connectivity to understand the historical, current and future status of the watershed including identifying the different environmental and social-cultural pieces and their connections within the watershed; (B) identification of core habitat types that can be linked to existing data and local observation of the space; (C) assessment of historical, recent and future flow alteration; (D) assessment of individual ecosystem and social-cultural components and their pathways via the DPSIR approach; (E) identifying water needs and objectives, supported by data and knowledge, that can form the core of the final environmental flows framework; and (F) development of an adaptive watershed framework with paired monitoring plan (Figure 16).

Figure 16. Adapted ELOHA framework for the Wolastoq | St. John River.

This project builds on previous work completed through the MAES research (Monk et al. 2018) to develop the environmental component of an adapted ELOHA model, in addition to quantifying the social values and citizen perspectives that contribute to the social-cultural component of ELOHA. The social-cultural component, in particular, represents an often unrepresented aspect of determining environmental flows, but one that clearly highlights the importance of cultural EGS within the watershed. Those who participated in the public survey and participatory mapping exercise identified the importance of use-based benefits, such as recreation, hunting, and fishing, but they also revealed the many intangible benefits of their interactions with the ecosystem, such as its contributions to mental health and well-being. Although the findings of the project do not capture all viewpoints within the watershed, they do represent an important first step in the process. Making values, benefits and cultural EGS evident provides the necessary inputs to integrate the social and cultural elements of environmental flows with the environmental needs, and highlights the importance of the river and how it is managed to those who live within its watershed. There is a potential role of EGS in communicating the importance of services and benefits to governments, particularly if the relationship between management decisions and the impacts on cultural EGS can be defined. Furthermore, consideration of cultural EGS in watershed management at a local scale can support greater integration of these concepts into provincial and federal management priorities and approaches. Incorporating such knowledge can help to determine multi-functional, feasible and acceptable solutions to water-related issues. This approach has been proven to increase acceptance and success of environmental planning, natural resource management and nature conservation (European Union 2018). A better understanding of flow needs from the ecological and human perspectives can support the development of policies that promote resilience and adaptation. We will continue to build upon this work by quantifying some of the hypotheses that form the core of the framework through the MAES project. We will also be collaborating with Wolastoqey communities and the Wolastoqey Nation in New Brunswick to incorporate Indigenous perspectives and values into the social and cultural component of the ELOHA framework, and to co-develop a decision support tool that can be used to inform future management action and regulatory decision making. Finally, we are continuing to identify and develop a long-term monitoring plan to support this work including the development of core metrics to support this assessment.

References

Alessa, L., Kliskey, A., Lammers, R., Arp, C., White, D., Hinzman, L., and Busey, R. 2008. The Arctic Water Resource Vulnerability Index: An Integrated Assessment Tool for Community Resilience and Vulnerability with Respect to Freshwater. Environmental Management 42(3): 523. doi: 10.1007/s00267-008-9152-0.

Anderson, E.P., Jackson, S., Tharme, R.E., Douglas, M., Flotemersch, J.E., Zwarteveen, M., Lokgariwar, C., Montoya, M., Wali, A., and Tipa, G.T. 2019. Understanding rivers and their social relations: A critical step to advance environmental water management. Wiley Interdisciplinary Reviews: Water 6(6): e1381.

Anthem, H., Infield, M., and Morse-Jones, S. 2016. Guidance for the rapid assessment of cultural ecosystem services. Oryx 50(1): 13.

Arciszewski, T.J., and Gray, M.A. 2019. Expected ranges of water quality variables in New Brunswick surface waters sampled between 2003 and 2018. Canadian Rivers Institute, Fredericton, New Brunswick. 61 p.

Arciszewski, T.J., and Munkittrick, K.R. 2015. Development of an adaptive monitoring framework for long-term programs: An example using indicators of fish health. Integrated environmental assessment and management 11(4): 701-718.

Arthington, A.H., Bhaduri, A., Bunn, S.E., Jackson, S.E., Tharme, R.E., Tickner, D., Young, B., Acreman, M., Baker, N., Capon, S., Horne, A.C., Kendy, E., McClain, M.E., Poff, N.L., Richter, B.D., and Ward, S. 2018. The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018). Frontiers in Environmental Science 6. doi: 10.3389/fenvs.2018.00045.

Baird, D., Van den Brink, P., Chariton, A., Dafforn, K., and Johnston, E. 2016. New diagnostics for multiply stressed marine and freshwater ecosystems: integrating models, ecoinformatics and big data. Mar. Freshwater Res. 67(4): 391-392.

Bark, R.H., Robinson, C.J., and Flessa, K.W. 2016. Tracking cultural ecosystem services: water chasing the Colorado River restoration pulse flow. Ecological Economics 127: 165-172.

Brown, G., and Fagerholm, N. 2015. Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosystem Services 13: 119-133. doi: https://doi.org/10.1016/j.ecoser.2014.10.007.

Brown, G., and Raymond, C.M. 2014. Methods for identifying land use conflict potential using participatory mapping. Landscape and Urban Planning 122: 196-208.

Brown, G., Reed, P., and Harris, C. 2002. Testing a place-based theory for environmental evaluation: an Alaska case study. Applied geography 22(1): 49-76.

Brown, G., Strickland-Munro, J., Kobryn, H., and Moore, S.A. 2017. Mixed methods participatory GIS: An evaluation of the validity of qualitative and quantitative mapping methods. Applied geography 79: 153-166.

Brummer, M., Rodríguez-Labajos, B., Nguyen, T.T., and Jorda-Capdevila, D. 2017. "They have kidnapped our river": Dam removal conflicts in catalonia and their relation to ecosystem services perceptions. Water Alternatives 10 (2017), Nr. 3 10(3): 744-768.

Bryan, B.A., King, D., and Wang, E. 2010. Biofuels agriculture: landscape-scale trade-offs between fuel, economics, carbon, energy, food, and fiber. GCB Bioenergy 2(6): 330-345. doi: 10.1111/j.1757-1707.2010.01056.x.

Casado-Arzuaga, I., Madariaga, I., and Onaindia, M. 2013. Perception, demand and user contribution to ecosystem services in the Bilbao Metropolitan Greenbelt. Journal of Environmental Management 129: 33-43.

Chan, K.M., Goldstein, J., Satterfield, T., Hannahs, N., Kikiloi, K., Naidoo, R., Vadeboncoeur, N., and Woodside, U. 2011. Cultural services and non-use values. In Natural capital: Theory and practice of mapping ecosystem services. Edited by P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky. Oxford University Press, New York. pp. 206-228.

Chan, K.M., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J., and Woodside, U. 2012a. Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. BioScience 62(8): 744-756. doi: 10.1525/bio.2012.62.8.7.

Chan, K.M., and Satterfield, T. 2020. The maturation of ecosystem services: Social and policy research expands, but whither biophysically informed valuation? People and Nature 2(4): 1021-1060.

Chan, K.M., Satterfield, T., and Goldstein, J. 2012b. Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics 74: 8-18.

Comeau, L. 2017. Healthy Water Healthy People. Conservation Council of New Brunswick, Fredericton, New Brunswick. 97 p.

Cowling, R.M., Egoh, B., Knight, A.T., O'Farrell, P.J., Reyers, B., Rouget, M., Roux, D.J., Welz, A., and Wilhelm-Rechman, A. 2008. An operational model for mainstreaming ecosystem services for implementation. Proceedings of the National Academy of Sciences 105(28): 9483-9488.

CRI. 2020. State of water quality in the Wolastoq | Saint John River watershed. Canadian Rivers Institute, Fredericton, New Brunswick. 131 p.

Curry, R.A., Yamazaki, G., Linnansaari, T., Monk, W., Samways, K.M., Dolson, R., Munkittrick, K.R., and Bielecki, A. 2020. Large dam renewals and removals—Part 1: Building a science framework to support a decision-making process. River Res. Applic. 36(8): 1460-1471.

Darvill, R., and Lindo, Z. 2015. Quantifying and mapping ecosystem service use across stakeholder groups: Implications for conservation with priorities for cultural values. Ecosystem Services 13: 153-161.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., and Willemen, L. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7(3): 260-272. doi: https://doi.org/10.1016/j.ecocom.2009.10.006.

de Vreese, C.H., and Neijens, P. 2016. Measuring Media Exposure in a Changing Communications Environment. Communication Methods and Measures 10(2-3): 69-80. doi: 10.1080/19312458.2016.1150441.

European Union. 2018. How do you include non-monetary values in decision making? Available from https://operas-project.eu/sites/default/files/resources/operas-a4-4pp-policybrief03-nonmonetaryvaluesdecisionmaking-april2018.pdf.

Fagerholm, N., and Käyhkö, N. 2009. Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. Fennia-International Journal of Geography 187(1): 43-60.

Fagerholm, N., Käyhkö, N., Ndumbaro, F., and Khamis, M. 2012. Community stakeholders' knowledge in landscape assessments—Mapping indicators for landscape services. Ecological Indicators 18: 421-433.

Fox, C.A., Magilligan, F.J., and Sneddon, C.S. 2016. "You kill the dam, you are killing a part of me": Dam removal and the environmental politics of river restoration. Geoforum 70: 93-104.

García-Nieto, A.P., Quintas-Soriano, C., García-Llorente, M., Palomo, I., Montes, C., and Martín-López, B. 2015. Collaborative mapping of ecosystem services: The role of stakeholders` profiles. Ecosystem Services 13: 141-152.

Holder, K. 2020. Defining "normal" ranges for flows and water temperature: setting monitoring triggers for the Wolastoq | Saint John River. Master of Environmental Management (MEM) FInal Report, Forestry and Environmental Management, University of New Brunswick, Fredericton, NB, Canada.

Kareiva, P.M., and Marvier, M. 2011. Conservation Science. Balancing the Needs of People and Nature. Roberts and Company, Colorado.

Kidd, S.D., Curry, R.A., and Munkittrick, K.R. (eds.) 2011. The Saint John River: A State of the Environment Report. Canadian Rivers Institute, Fredericton, NB.

Kilgour, B.W., Somers, K.M., Barrett, T.J., Munkittrick, K.R., and Francis, A.P. 2017. Testing against "normal" with environmental data. Integrated environmental assessment and management 13(1): 188-197.

Klain, S.C., Satterfield, T.A., and Chan, K.M. 2014. What matters and why? Ecosystem services and their bundled qualities. Ecological Economics 107: 310-320.

Lamarque, P., Tappeiner, U., Turner, C., Steinbacher, M., Bardgett, R.D., Szukics, U., Schermer, M., and Lavorel, S. 2011. Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. Regional Environmental Change 11(4): 791-804.

Lejon, A.G., Renöfält, B.M., and Nilsson, C. 2009. Conflicts associated with dam removal in Sweden. Ecol. Soc. 14(2).

Martín-López, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I., Amo, D.G.D., Gómez-Baggethun, E., Oteros-Rozas, E., Palacios-Agundez, I., Willaarts, B., González, J.A., Santos-Martín, F., Onaindia, M., López-Santiago, C., and Montes, C. 2012. Uncovering Ecosystem Service Bundles through Social Preferences. PLoS ONE 7(6): e38970. doi: 10.1371/journal.pone.0038970.

Matthews, J., Forslund, A., McClain, M., and Tharme, R. 2014. More than the fish: environmental flows for good policy and governance, poverty alleviation and climate adaptation. Aquatic Procedia 2: 16-23.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being. World Health Organization, Geneva, Switzerland. 64 p.

Monk, W.A., Compson, Z.G., Armanini, D.G., and Idigoras Chaumel, A. 2018. Proposed holistic environmental flows framework for the Saint John River with a focus on operations at the Mactaquac Generating Station. Mactaquac Aquatic Ecosystem Study Report Series 2017-035, Canadian Rivers Institute, University of New Brunswick. 115 p.

Monk, W.A., Compson, Z.G., Choung, C.B., Korbel, K.L., Rideout, N.K., and Baird, D.J. 2019. Urbanisation of floodplain ecosystems: Weight-of-evidence and network meta-analysis elucidate multiple stressor pathways. Science of the total environment 684: 741-752.

Munkittrick, K.R., and Arciszewski, T.J. 2017. Using normal ranges for interpreting results of monitoring and tiering to guide future work: A case study of increasing polycyclic aromatic compounds in lake sediments from the Cold Lake oil sands (Alberta, Canada) described in Korosi et al.(2016). Environ. Pollut. 231: 1215-1222.

Munkittrick, K.R., Arens, C.J., Lowell, R.B., and Kaminski, G.P. 2009. A review of potential methods of determining critical effect size for designing environmental monitoring programs. Environmental Toxicology and Chemistry 28(7): 1361-1371.

Murray-Rust, D., Dendoncker, N., Dawson, T.P., Acosta-Michlik, L., Karali, E., Guillem, E., and Rounsevell, M. 2011. Conceptualising the analysis of socio-ecological systems through ecosystem services and agent-based modelling. Journal of Land Use Science 6(2-3): 83-99. doi: 10.1080/1747423X.2011.558600.

Oesterwind, D., Rau, A., and Zaiko, A. 2016. Drivers and pressures—untangling the terms commonly used in marine science and policy. Journal of Environmental Management 181: 8-15.

Pahl-Wostl, C., Arthington, A., Bogardi, J., Bunn, S.E., Hoff, H., Lebel, L., Nikitina, E., Palmer, M., Poff, L.N., Richards, K., Schlüter, M., Schulze, R., St-Hilaire, A., Tharme, R., Tockner, K., and Tsegai, D. 2013. Environmental flows and water governance: managing sustainable water uses. Current Opinion in Environmental Sustainability 5(3): 341-351. doi: https://doi.org/10.1016/j.cosust.2013.06.009.

Plieninger, T., Dijks, S., Oteros-Rozas, E., and Bieling, C. 2013. Assessing, mapping, and quantifying cultural ecosystem services at community level. Land use policy 33: 118-129.

Poff, N.L. 2018. Beyond the natural flow regime? Broadening the hydro-ecological foundation to meet environmental flows challenges in a non-stationary world. Freshwater Biol. 63(8): 1011-1021.

Poff, N.L., and Matthews, J.H. 2013. Environmental flows in the Anthropocene: past progress and future prospects. Current Opinion in Environmental Sustainability 5(6): 667-675.

Poff, N.L., Richter, B.D., Arthington, A.H., Bunn, S.E., Naiman, R.J., Kendy, E., Acreman, M., Apse, C., Bledsoe, B.P., Freeman, M.C., Henriksen, J., Jacobson, R.B., Kennen, J.G., Merritt, D.M., O'Keeffe, J.H., Olden, J.D., Rogers, K., Tharme, R.E., and Warner, A. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biol. 55(1): 147-170. doi: https://doi.org/10.1111/j.1365-2427.2009.02204.x.

Poff, N.L., and Zimmerman, J.K. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biol. 55(1): 194-205.

Potschin, M., and Haines-Young, R. 2013. Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecol. 28(6): 1053-1065.

Railsback, S.F. 2016. Why it is time to put PHABSIM out to pasture. Fisheries 41(12): 720-725.

Raymond, C.M., Bryan, B.A., MacDonald, D.H., Cast, A., Strathearn, S., Grandgirard, A., and Kalivas, T. 2009. Mapping community values for natural capital and ecosystem services. Ecological economics 68(5): 1301-1315.

Raymond, C.M., Kenter, J.O., Plieninger, T., Turner, N.J., and Alexander, K.A. 2014. Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services. Ecological Economics 107: 145-156.

Reilly, K., Adamowski, J., and John, K. 2018. Participatory mapping of ecosystem services to understand stakeholders' perceptions of the future of the Mactaquac Dam, Canada. Ecosystem Services 30: 107-123.

Richter, B.D. 2010. Re-thinking environmental flows: from allocations and reserves to sustainability boundaries. River Res. Applic. 26(8): 1052-1063.

Richter, B.D., Baumgartner, J.V., Braun, D.P., and Powell, J. 1998. A spatial assessment of hydrologic alteration within a river network. Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management 14(4): 329-340.

Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.P. 1996. A method for assessing hydrologic alteration *within ecosystems. Conserv. Biol. 10(4): 1163-1174.*

Richter, B.D., Davis, M., Apse, C., and Konrad, C. 2012. A presumptive standard for environmental flow protection. River Res. Applic. 28(8): 1312-1321.

Smeets, E., and Weterings, R. 1999. Environmental indicators: Typology and overview. Report No. 25, European Environment Agency, Copenhagen. 19 p.

Statistics Canada. 2021. Table 25-10-0015-01 Electric power generation, monthly generation by type of electricity. doi: https://doi.org/10.25318/2510001501-eng.

Tharme, R.E. 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Res. Applic. 19(5-6): 397-441.

Value of Nature to Canadians Study Taskforce. 2017. Completing and Using Ecosystem Services Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts. Federal, Provincial, and Territorial Governments of Canada, Ottawa, ON. 284 p.

WWF. 2014. Environmental Flows: Orchestrating Healthy Waters. WWF Factsheet. Available from http://awsassets.wwf.ca/downloads/factsheet_eflows_final_030914.pdf.

Appendices

Appendix 1: Survey Questions

ELOHA - Facebook-Survey Monkey Survey Questions

Question 1: What are the top three things that you love most about the St. John River?

1. ____________________

____

2. ____________________

____

3. ____________________

____

Question 2: What personal benefits does the river provide to you?

(Please check all that apply from the list. To do this please pick your first choice and submit, then the list again for you to choose the next option. You can pick as many as you want to.)

- ☐ *Mental Health*
- ☐ *Physical Health*
- ☐ *Peace of Mind*
- ☐ *Community Identity*
- ☐ *Spiritual Connection*
- ☐ *Sense of Place*
- ☐ *Tradition*
- ☐ *Iconic cultural feature*
- ☐ *Recreation*
- ☐ *Education*
- ☐ *Food gathering*
- ☐ *Employment*
- ☐ *Artistic Pursuits*
- ☐ *Ceremonial Activities*
- ☐ *Other:* ____________

Do you have more to say about the choices you made?

____

____

____

Question 3: What is your favorite time of year on the river? (Please pick one)

- ☐ *Summer*
- ☐ *Fall*
- ☐ *Winter*
- ☐ *Spring*

Would you like to tell us why?

____

____

Question 4: I consider the river important for...

(Please check all those that apply from the list. To do this please pick your first choice and submit, then the list again for you to choose the next option. You can pick as many as you want to.)

- ☐ *It's beauty*
- ☐ *Social interactions*
- ☐ *Inspiration*
- ☐ *Connect with nature*
- ☐ *Cultural or Heritage connections*
- ☐ *Spiritual fulfillment*
- ☐ *Employment*
- ☐ *Recreation*
- ☐ *Other:* ____________________

If you'd like to, please provice more on why the river is important:

____

____

____

Question 5: What are your most significant concerns about the river?

____

____

____

____

____

____

Question 6: When I think of the river, I think about it from the perspective of:

(Please select your top three choices. To do this please pick your top choice and submit, then the list will come back for your second choice and then third choice.)

- ☐ *Myself*
- ☐ *My family*
- ☐ *My community*
- ☐ *Spiritual connection*
- ☐ *A specific part of the river (Please say where:________________________)*
- ☐ *The whole watershed*
- ☐ *The province*
- *Other: ____________________*

Would you like to say more about why you chose that option?:

Question 7: Are there specific events or occasions that you associate with the river?

(Please provide the name, date, and location)

Question 8: Within the community, the river is...

(Please select your top three choices. To do this please pick your top choice and submit, then the list will come back for your second choice and then third choice.)

- ☐ *Our way of life*
- ☐ *The most iconic part of our community*
- ☐ *A large concern because of flooding*
- ☐ *Significant to our community identity*
- ☐ *What distinguishes us from other communities*
- ☐ *Important to our local economy*
- ☐ *A concern because of cyanobacteria*
- ☐ *Important for wildlife*
- ☐ *Our backyard*
- ☐ *Our playground*
- ☐ *Important to our history*
- ☐ *Other:* ____________

Question 9: Are you prevented from enjoying the river at a specific time of year? If so, when?

(Please select the season)

- ☐ *Summer*
- ☐ *Fall*
- ☐ *Winter*
- ☐ *Spring*

Would you like to tell us why?

____

____

Question 10: Now that you have taken the survey, do you have any other suggestions to enhance the health of the river?

Do you have anything else you would like to add about your relationship with the Wolastoq | St. John River?

End of Survey

Thank you for your participation!
Please like or follow the St. John River Society!

Appendix 2: List of Stakeholders

Stakeholders who completed the paricipatory mapping exercise*:

ACAP Saint John

Commission de services régionaux Nord-Ouest

Community Forests International

Department of National Defence

Discover Saint John

Dominion Park Ice Fishing Association

Environment Canada and Climate Change (ECCC)

Fredericton Region Museum / York Sunbury Historical Society, Ltd.

Friends of White's Bluff Wharf, St. John River Society

Fundy North Fishermen's Association

Government of New Brunswick – Dept. of Environment and Local Government

Jardin botanique du Nouveau-Brunswick

Kennebecasis Watershed Restoration Committee (2 members)

Lower St. John River Hydro (Mactaquac) Community Liaison Committee (5 members)

Local Service District Bright

Martinon Yacht Club (2 members)

Meduxnekeag River Association

Nashwaak Watershed Association (2 members)

Nature Trust of New Brunswick

NB Power

Oromocto River Watershed Association Inc.

Saint John Marina Ltd

Saint John Naturalists Club

Société d'aménagement de la rivière Madawaska

Southern New Brunswick (SNB) Forest Products Marketing Board

The St. John River Society

Tobique Watershed Association

Town of Florenceville-Bristol

Town of Nackawic

Town of Oromocto- Recreation Dept

Université TÉLUQ - Projet environnement et santé au Madawaska

Valley Yacht Club, Woodstock, NB

* 6 Stakeholders that completed the mapping provided no organisational information provided.

Appendix 3: Participatory Mapping Results

Additional maps from participatory mapping activity categories will be included in this section.

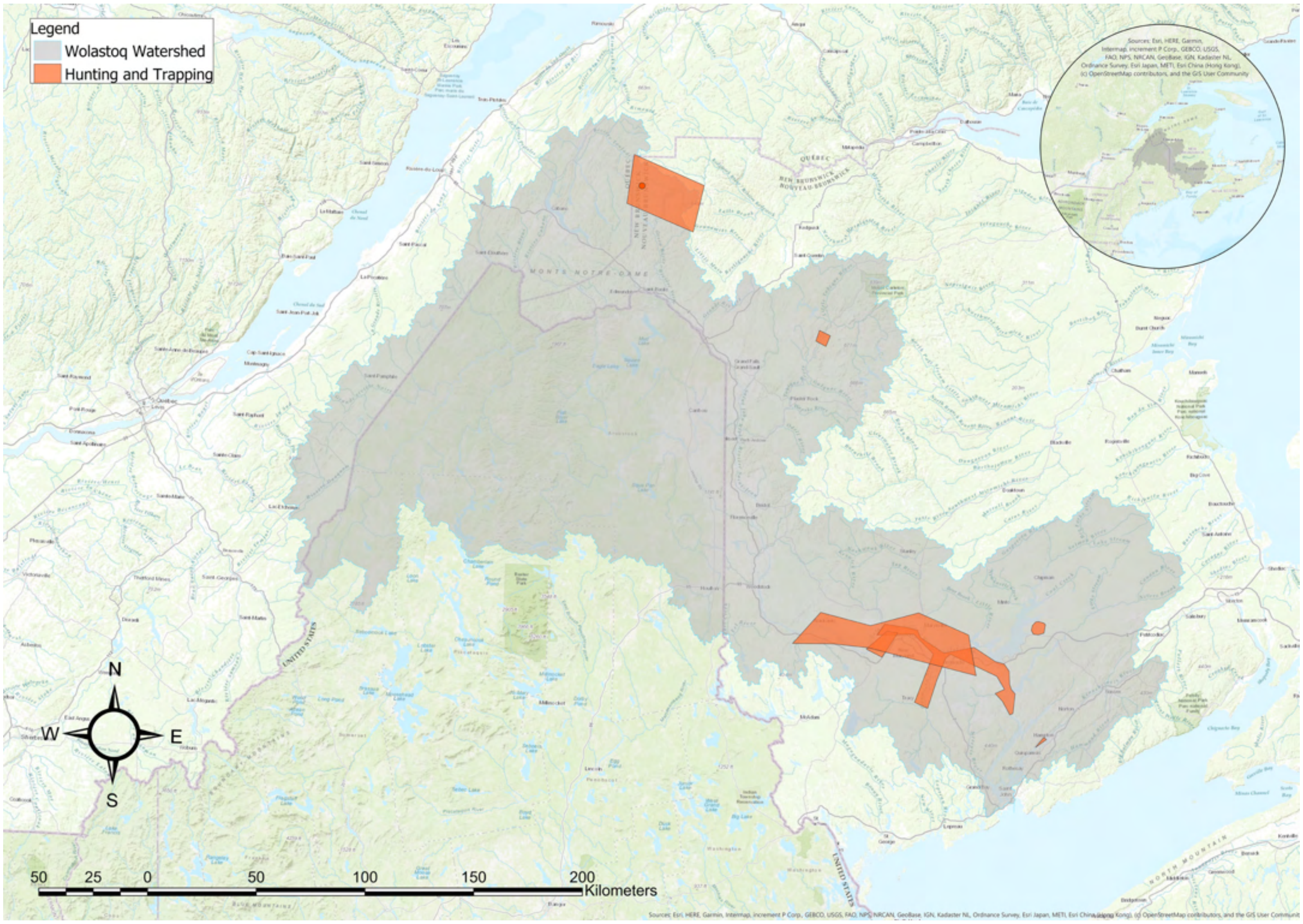


Figure: Results of the participatory mapping with all hunting and trapping activities mapped.

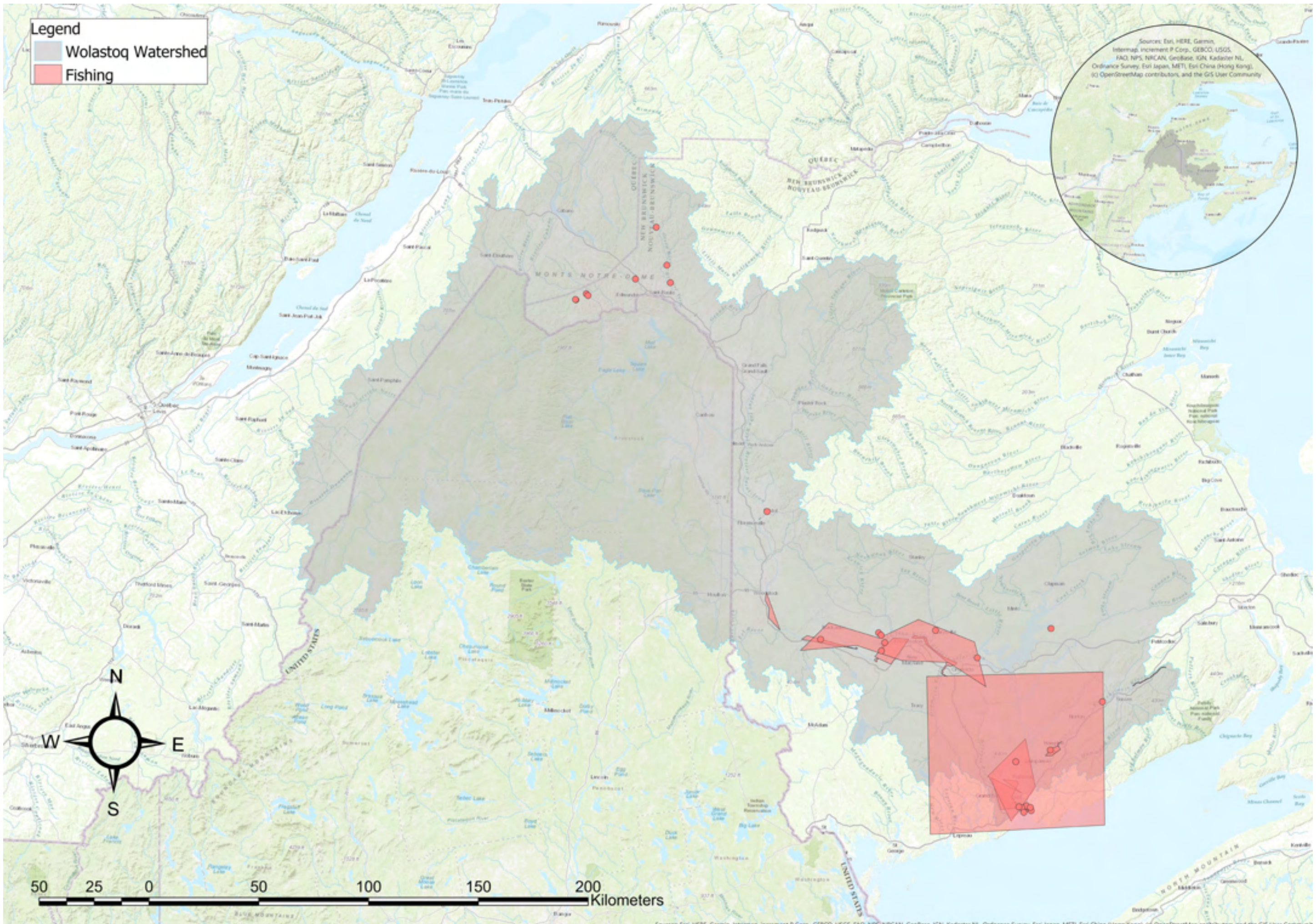


Figure: Results of the participatory mapping with all fishing activities mapped.

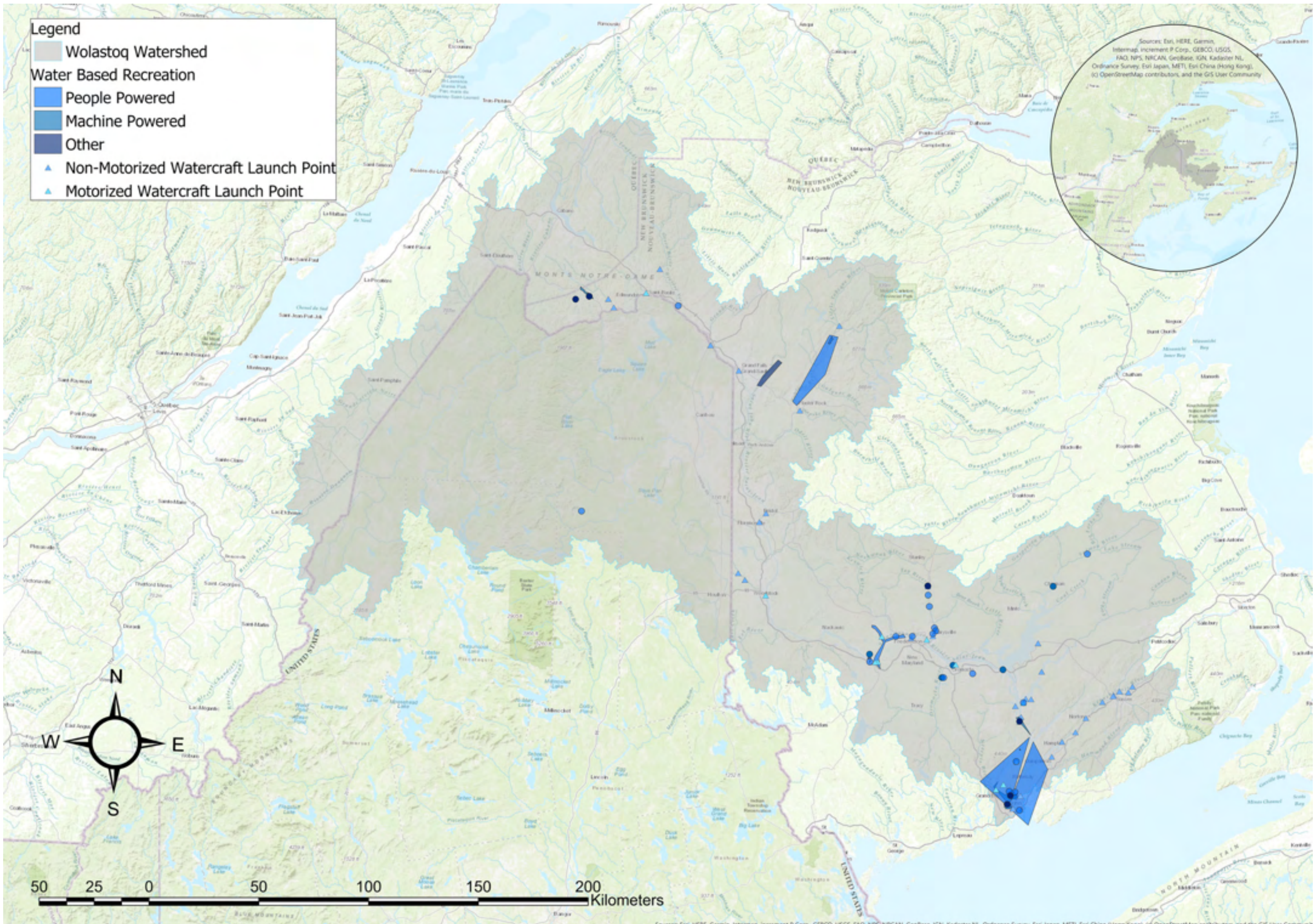


Figure: Results of the participatory mapping with all water-based recreation activities mapped.

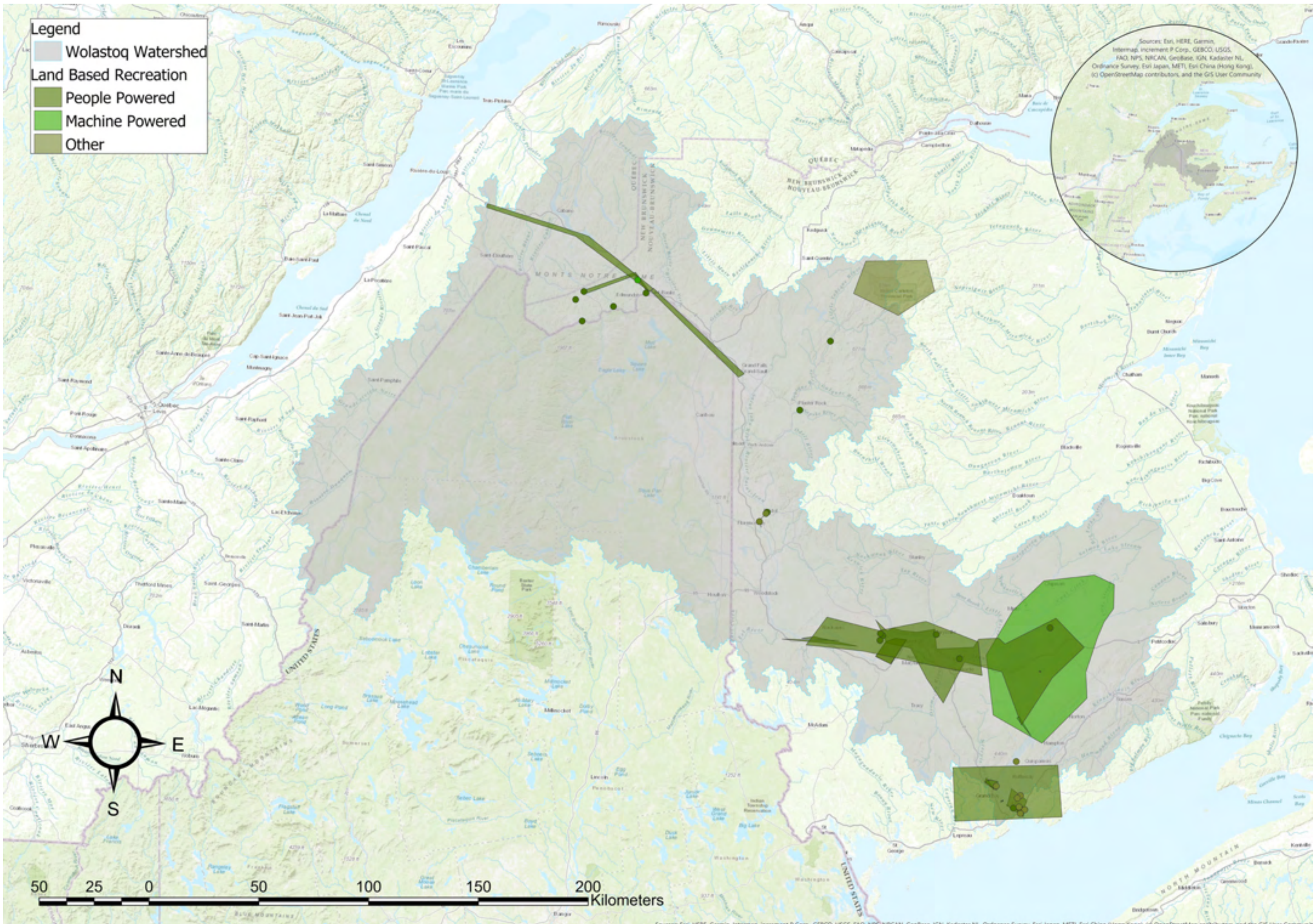


Figure: Results of the participatory mapping with all land-based recreation activities mapped

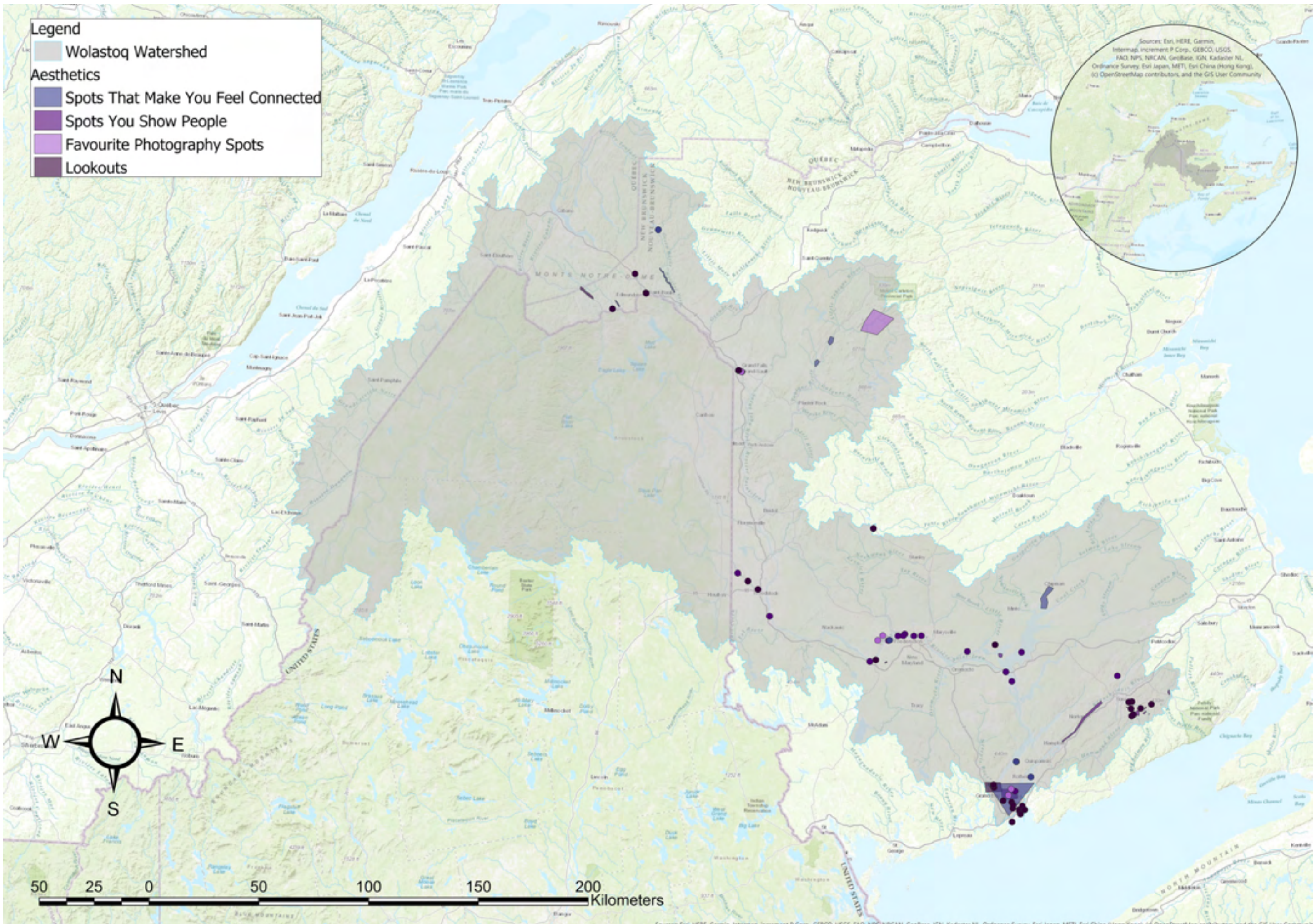


Figure: Results of the participatory mapping with all aesthetic activities mapped.

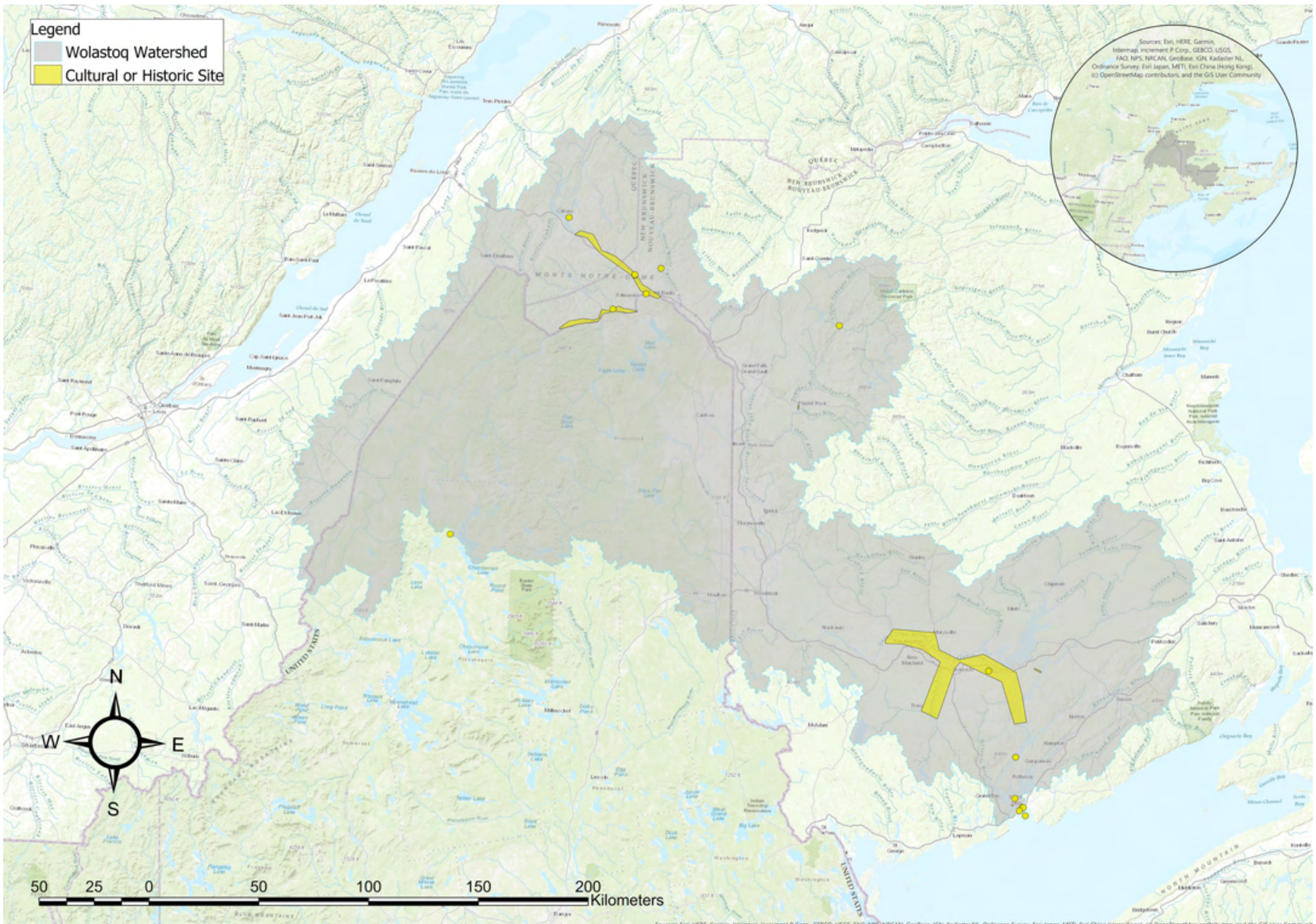


Figure: Results of the participatory mapping with all cultural or historic sites mapped.

The St. John River Society
La Société du Fleuve Saint-Jean

Organisme
de bassin versant
du fleuve Saint-Jean

Canadian
Rivers Institute

ACAP
Saint John

WWF