Mactaquac Aquatic Ecosystem Study
Report Series 2016-025

Contract Deliverable 3.1.1.1 – Developing environmental flows for Wolastoq / Saint John River / Fleuve Saint-Jean
Summary report Workshop 2: Developing flow-ecology hypotheses

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ACKNOWLEDGEMENTS

We would like to thank the participants at the second flow-ecology workshop held on the 27th and 28th October 2015 for their significant contributions to the break-out groups, wider discussions, and follow-up information.

We would also like to acknowledge the Nature Conservancy and WWF Canada for their continued support of the project. The Nature Conservancy provided example workshop materials in addition to sharing information on their previous environmental flow workshop experiences. Additionally, we would like to thank Dr. Colin Curry, Dr. Tommi Linnansaari (fish), Dr. Meghann Bruce (vegetation), and Dr. Jessica Orlofske (benthic macroinvertebrates) for contributing and reviewing workshop background materials.

We would like to acknowledge Dr. Colin Curry, Dr. Zacchaeus Compson, Dr. Meghann Bruce and Mr. Simon Mitchell for facilitating the break-out groups during the workshop.

LIST OF ACRONYMS

ASF	Atlantic Salmon Federation
CEQUEAU	Modèle de Simulation de Quantité et de Qualité de l'eau; Centre Québecois sur l'Eau
CRI	Canadian Rivers Institute
CRI SINLAB	Canadian Rivers Institute – Stable Isotopes in Nature Laboratory
DFO	Fisheries and Oceans Canada
DND	Department of National Defense
EC	Environment Canada
ELOHA	Ecological Limits Of Hydrologic Alteration
INRS	Institute National de la Recherche Scientifique
MAES	Mactaquac Aquatic Ecosystem Study
MGS	Mactaquac Generating Station
NB DELG	New Brunswick – Department of Environment and Local Government
NB DNR	New Brunswick – Department of Natural Resources
NBP	New Brunswick Power
OBV	Organisme de Bassin Versant
SJR	Saint John River
TNC	The Nature Conservancy
UNB	University of New Brunswick
WWF	World Wildlife Fund

WORKSHOP OBJECTIVES

With the proposed options of either repowering or rebuilding the MGS or components of the MGS, there is a clear opportunity to develop a sustainable environmental flows strategy for the future of the Wolastoq / Saint John River / Fleuve Saint-Jean. Building on the data, literature review, and discussion outputs from Workshop 1 (held in June 2015; Monk & Curry 2015), the second workshop (held in Fredericton, NB, on 27-28 October, 2015) focused on:

1. Using expert knowledge, workshop materials, and group discussion to draft flow-ecology and temperature-ecology hypotheses within target flow components for six major draft habitat types identified for the SJR during Workshop 1; and

2. Prioritising additional information and identifying further analyses to support the development of flow recommendations.

Appendices 1, 2 and 3 provide a summary of the workshop outline in addition to a list of participants.

Objective 1: Using expert knowledge, workshop materials, and group discussion to draft flow-ecology and temperature-ecology hypotheses within target flow components for six major draft habitat types identified for the SJR during Workshop 1

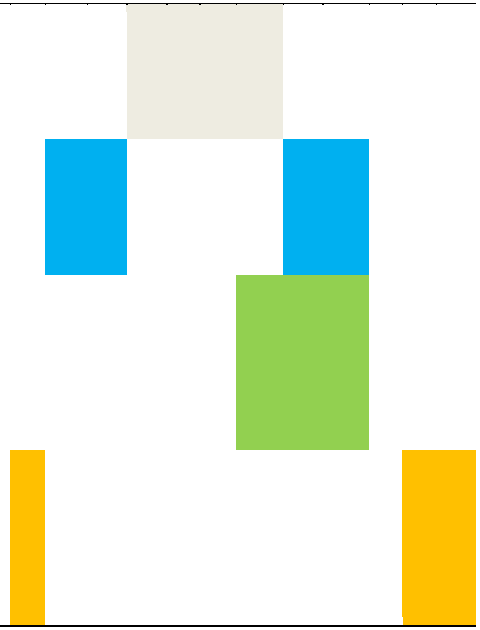
During the first part of the workshop Dr. Wendy Monk (UNB, CRI, MAES) introduced the project and the environmental flows approach for the SJR. She also presented the background material which included information gathered during Workshop 1 regarding the prioritised habitat types. These presentations were followed by presentations from Trout Unlimited (Jack Imhof) and Prothea Group (Dr. David Armanini) who highlighted the need for sustainable environmental flows and presented a follow-up on the current status of a literature review integrating the information given in Workshop 1. Finally, Dr. Steve Dugdale (UNB, CRI, MAES) presented the hydrological and thermal model (CEQUEAU hydrological model; Morin et al. 1995), which models the hydrology and thermal profiles of selected parts of the SJR basin, a key tool for the design of the flow recommendations for the SJR.

Developing hypotheses

Background materials were used to stimulate discussion during break-out group sessions to generate hypotheses for the direct or indirect associations between flow and temperature and ecosystem components (e.g. habitat structure, communities, individual species, etc.) in the SJR watershed. Structured by the major draft habitat types, the hypotheses represented all flow components with a focus on: (i) seasonal flows; (ii) low flows including extreme low flows; (iii) high flows including extreme high flows; and (iv) ice-affected conditions. These targeted, local- to watershed-scale hypotheses will form the basis of quantitative flow recommendations in the holistic environmental flows strategy for the SJR.

Table 1. Example of flow-ecology hypotheses developed during the Workshop 2.

Major draft habitat type	Ecosystem component	Hypothesis statement	Flow type	Timing
Medium tributaries	Habitat	Ice scour in the winter can create in-channel habitat diversity (e.g. through introduction of coarse woody debris)	Ice-affected	
Medium tributaries	Water quality	Magnitude, frequency and duration of high flows can increase variability in turbidity in water column	High flows	
Headwater and small tributary habitats	Fish	Spring flow variability affects habitat availability with key peak spring flows needed for spawning habitat creation and connectivity	Seasonal flows	
Headwater and small tributary habitats	Macroinvertebrates	Low flows (extended duration and magnitude) will shift structure of benthic macroinvertebrate communities with a decrease in diversity of grazers and shredders, increase in diversity of generalists	Low flows	



Objective 2: Prioritize additional information and identifying further analyses to support the development of flow recommendations

The remaining part of the workshop focused on identifying additional analyses to support the development of flow recommendations including hypothesis validation. The EcoEvidence approach (Webb et al. 2012), a systematic approach to evaluate causality in environmental science, was presented as a potential approach to identify consistent scientific support for the development of a series of flow recommendations from the hypotheses (Figure 1, Table 2).

Figure 1. EcoEvidence process (extracted from http://ewater.org.au/)

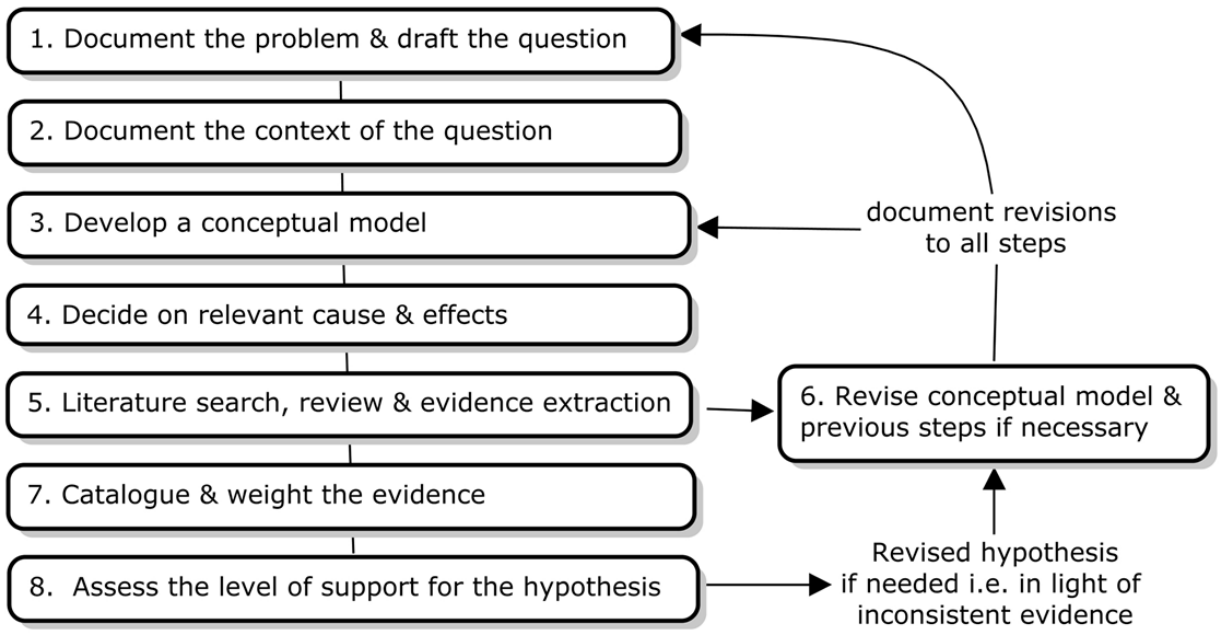


Table 2. Example of flow recommendations and statistics from Nature Conservancy workshop

	What are the major ecological functions during summer?	To preserve these functions, limit change to recommend:
High flows	• Support mussel spawning and growth • Maintain temperature and water quality	***High flow pulses (< bankfull)*** • <X% change to magnitude of **monthly Q10**
Seasonal flows	• Maintain habitats for resident and migratory fishes • Support mussel spawning and growth • Support development and growth of reptiles and amphibians • Maintain temperature and water quality	• Less than X% change to **monthly median**; and • Less than X% change to **seasonal flow range (Q50-Q75)**
Low flows	• Maintain habitats for resident and migratory fishes • Support mussel spawning and growth • Support development and growth of reptiles and amphibians • Promote macroinvertebrate growth and emergence • Maintain temperature and water quality	• Less than X% change to **monthly Q90**; and • Less than X% change to **low flow range (Q75 to Q99)**

CONCLUSIONS AND NEXT STEPS

The workshop was highly productive and resulted in a large amount of information that can be incorporated into the environmental flows strategy for the SJR. The hypotheses developed during the workshop will be further refined across habitats, flow components and seasons. These will form the basis of tailored flow recommendations and flow statistics.

The EcoEvidence approach will be explored to identify consistent scientific support for the development of flow recommendations from our hypotheses. A third workshop will be held in 2016 to review and refine the final flow recommendations.

REFERENCES

CRI. 2015. "Mactaquac Aquatic Ecosystem Study. http://canadianriversinstitute.com/research/mactaquac-aquatic-ecosystem-study/.

DePhilip, M., & Moberg, T. 2010. Ecosystem flow recommendations for the Susquehanna River basin. The Nature Conservancy, Harrisburg, Pennsylvania.

Monk, W.A. and Curry, R.A. 2015. Developing environmental flows for Wolastoq / Saint John River / Fleuve Saint-Jean. Summary report Workshop 1: Data resources, critical habitats, and target taxa. Mactaquac Aquatic Ecosystem Study Report Series 2015-027. Canadian Rivers Institute, University of New Brunswick. 71 p.

Morin, G., Paquet, P., Sochanski W. 1995. Le Modèle de Simulation de Quantité et de Qualité CEQUEAU, Manuel de Références, INRS-Eau Rapport de Recherche, no 433, 341 p.

NB Power. 2015. "Mactaquac Project." http://www.mactaquac.ca/.

Poff, N. L., Richter, B. D., Arthington, A. H., Bunn, S. E., Naiman, R. J., Kendy, E., Acreman, M., et al. 2010. "The Ecological Limits of Hydrologic Alteration (ELOHA): A new framework for developing regional environmental flow standards." Freshwater Biology 55: 147–70.

Webb, J. A., Nichols, S. J., Norris, R. H., Stewardson, M. J., Wealands, S. R., & Lea, P. 2012. Ecological responses to flow alteration: assessing causal relationships with Eco Evidence. Wetlands 32: 203-213.

Appendix 1. Workshop 2 agenda.

Day 1 (Tuesday 27th October):

8.30am - 9am	Coffee, tea, and juice served
9am - 9.20am	**Welcome, roundtable introductions, and review of agenda** *Wendy Monk (Canadian Rivers Institute / MAES)*
9.20am - 10am	**Review of first workshop outputs, recent progress and workshop goals** *Wendy Monk (Canadian Rivers Institute / MAES)*
10am - 10.30am	**Developing and applying environmental flows: Why the need? Why bother?** *Jack Imhof (Trout Unlimited)*
10.30am - 10.50am	Health break
10.50am - 11.25am	**Development of a coupled hydrological - water temperature model of the Saint John River watershed: Utility for environmental flow assessment** *Steve Dugdale (Canadian Rivers Institute / MAES)*
11.25am - 12pm	**A literature perspective linking flow and temperature with aquatic and riparian ecology** *David Armanini (Prothea)*
12pm - 1pm	Lunch provided
1pm - 1.15pm	**Introduction to break-out session activities** *Wendy Monk (Canadian Rivers Institute / MAES)*
1.15pm - 2.45pm	**Break-out session 1: Development of flow-ecology and temperature-ecology hypotheses**
2.45pm - 3pm	Health break
3pm - 4.20pm	**Break-out session 2: Development of flow-ecology and temperature-ecology hypotheses**
4.20pm - 4.30pm	**Final remarks for Day 1** *Wendy Monk (Canadian Rivers Institute / MAES)*
6pm	**Group dinner** (location TBA)

Day 2 (Wednesday 28th October)

8.30am - 9am	Coffee, tea, and juice served
9am - 10.15am	**Presentation and discussion of hypotheses developed on Day 1** *Wendy Monk (Canadian Rivers Institute / MAES) and group facilitators*
10.15 - 10.30am	Health break
10.30am - 12pm	**Break-out session 3: Development of flow-ecology and temperature-ecology hypotheses**
12pm - 1pm	Lunch provided
1pm - 2.30pm	**Break-out session 4: Development of flow-ecology and temperature-ecology hypotheses**
2.30pm - 2.50pm	Health break
2.50pm - 3.50pm	**Group discussion: Summarising hypotheses, prioritising information gaps, and identifying additional habitat types and further analyses to support development of flow recommendations**
3.30pm - 4pm	**Final remarks for workshop and next steps** *Wendy Monk (Canadian Rivers Institute / MAES)*

Appendix 2. List of Workshop 2 participants and their affiliation

Participants	Organisation	Participants	Organisation
David Armanini	Prothea Group, CRI	**Almudena Idígoras Chaumel**	Prothea Group
Donald Baird	EC, UNB, CRI, MAES	**Jack Imhof**	Trout Unlimited
Rod Bradford	Retired DFO	**Tommi Linnansaari**	UNB, CRI, MAES
Meghann Bruce	UNB, CRI, MAES	**Vincent Mercier**	EC
Daniel Caissie	DFO	**Wendy Monk**	UNB, CRI, MAES
Zacchaeus Compson	UNB, CRI, MAES	**Darek Moreau**	Stantec Canada
Dave Courtemanche	TNC	**Laura Noel**	UNB, CRI, MAES
Allen Curry	UNB, CRI, MAES	**Zoe O'Malley**	UNB, CRI, MAES
Colin Curry	EC, CRI	**Cara O'Donnell**	Houlton Band of Maliseet Indians
Daniele Demartini	Prothea Group	**Jessica Orlofske**	University of Wisconsin – Parkside
Annie Dietrich	NB DELG	**Daniel Peters**	EC
Rebecca Dolson	WWF Canada	**George Porter**	NBP
Steve Dugdale	UNB, CRI, MAES	**Andy Smith**	DND
Bronwyn Fleet-Pardy	CRI, MAES	**Andre St-Hilaire**	INRS, CRI, MAES
Mat Gorman	NBP	**Maureen Toner**	NB DNR
Michelle Gray	UNB, CRI, MAES	**Nathan Wilbur**	ASF
Michel Grégoire	OBV du fleuve St-Jean	**Gordon Yamazaki**	UNB, CRI, MAES
Brian Hayden	CRI SINLAB, UNB, CRI		

Appendix 3. Workshop 2 background materials provided to workshop participants (developed by Wendy Monk)

Brief workshop background

The Mactaquac Generating Station (MGS), a 672 MW run-of-the-river hydroelectric facility, was constructed in 1968 on the mainstem of the Saint John River (SJR) and is owned and operated by New Brunswick Power (NBP). The facility is expected to reach the end of its service life by 2030, when the powerhouse and spillway will no longer be viable because of an alkali-aggregate reaction with the concrete. Therefore, NBP (NB Power 2015) has initiated a process to explore three options: (i) repowering the station with a new powerhouse and spillway; (ii) rebuilding the spillway only; or (iii) removing all parts of the station. The decision will be based on a combination of economic, environmental, and social consequences.

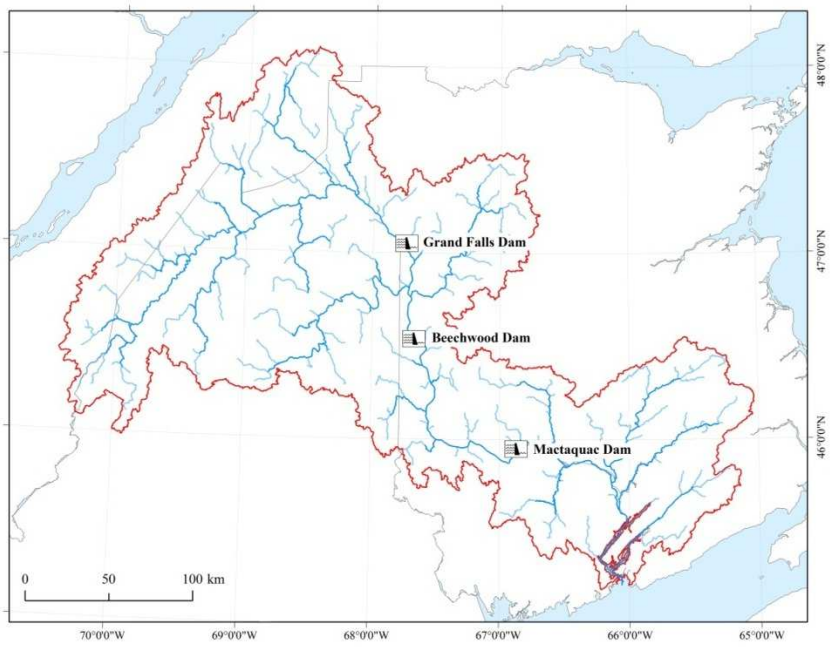


Figure 2: Location of mainstem dams on Saint John River

Mactaquac Aquatic Ecosystem Study (MAES)

Through the CRI (Canadian Rivers Institute 2015), the Mactaquac Aquatic Ecosystem Study (MAES; "Mactaquac Aquatic Ecosystem Study" 2015) is the scientific group conducting independent research in partnership with NBP in support of the pending MGS decision. MAES is providing highly integrated, multidisciplinary, scientific research for a multi-year assessment of the structure and function of the Wolastoq / Saint John River / Fleuve Saint-Jean including establishing baseline environmental conditions, designing appropriate metrics for biomonitoring, and modelling predictions about the water, sediment, thermal regimes, and future aquatic and riparian habitats. One of the key components is the development of a sustainable environmental flow regime for the Saint John River starting with the assessment of MGS.

Incorporating flow-ecology and temperature-ecology associations in environmental flows
Integrating an understanding of the natural variability in both intra- and inter-annual flow regimes into a management framework is critical for maintaining short- and long-term habitat complexity and connectivity, and ecosystem integrity. Developing testable hypothesised associations between flow and thermal regimes, aquatic and riparian habitats, and ecosystem components is a key step in the development of sustainable holistic environmental flow approaches (e.g. Poff et al. 2010). However, these associations of the direct and indirect mechanisms linking flow and temperature variability with key ecosystem components are often completed at a regional (or broader) scale leading to generalised statements. The holistic approach proposed through the Ecological Limits of Hydrologic Alteration (ELOHA) allows for the development of testable hypotheses focused on specific flow components within identified major habitat types targeted at a local or sub-regional scale (Poff et al. 2010).

Workshop goals
With the proposed options of either repowering or rebuilding the MGS or components of the MGS, there is a clear opportunity to develop a sustainable environmental flows strategy for the future of the Wolastoq / Saint John River / Fleuve Saint-Jean. Building on the data, literature review, and discussion outputs from Workshop 1 (held in June 2015), the second workshop will focus on:

1. Using expert knowledge, workshop materials, and group discussion to draft flow-ecology and temperature-ecology hypotheses within target flow components for six major draft habitat types identified for the Saint John River during Workshop 1; and

2. Prioritise additional information and identifying further analyses to support the development of flow recommendations.

Background material
The background material for the Saint John River draws upon published scientific and grey literature, regional datasets, and consultation with expert groups and managers. The information will be used during the group break-out sessions and provides local and regional examples of flow and temperature associations with trait information for groups of fish, benthic macroinvertebrates, freshwater mussels, and aquatic and riparian vegetation. These will be further expanded based on the result of this workshop and additional follow-up work.

- **Background material A**: Figure 2 provides a schematic of the latitudinal and longitudinal connectivity among the major draft habitat types identified for the Saint John River during Workshop 1. Figures 3 - 6 provides examples of the features of the major draft habitat types. Figure 3 presents a spatial example of the distribution of Silver Maple floodplain forests, riparian wetlands, and delineated wetlands in addition to island habitats within the channel. Figures 4 - 6 are example hydrographs for the major draft habitat types summarising key hydrological components including seasonal and long-term flow variability.

- **Background material B**: Tables 1 - 4 summarises the vegetation, benthic macroinvertebrates, fish and mussel taxa groups, their shared traits, and example taxa within each group. Note that not all of the taxa within the Saint John River demonstrate sensitivities to flow and temperature but can be discussed in the context of the wider ecological community.
- **Background material C**: Tables 5 - 8 summarise the trait groups of vegetation, benthic macroinvertebrates, fish and freshwater mussel groups and indicate where they likely occur within each major draft habitat type.

Developing hypotheses

In combination with your expertise and knowledge, these background materials will be used to stimulate discussion during break-out group sessions to generate hypotheses for the direct or indirect associations between flow and temperature and ecosystem components (e.g. habitat structure, communities, individual species, etc.) in the Saint John River watershed. These targeted, local- to watershed-scale hypotheses will form the basis of quantitative flow recommendations in the holistic environmental flows strategy for the Saint John River

Structured by the major draft habitat types, the hypotheses will represent all flow components with a focus on: (i) **seasonal flows**; (ii) **low flows including extreme low flows**; (iii) **high flows including extreme high flows**; and (iv) **ice-affected conditions**. The hypotheses can be either *positive* (i.e. needs-based) and/or *negative* (i.e. threshold-based). For example:

a) During spring, the magnitude, duration or frequency of high flows are needed to minimise deposition of fines to maintain interstitial habitat structure within coarser substrates for riffle/run benthic macroinvertebrates.

b) If flow magnitudes decrease during glochidia release (late Spring and Summer depending on species), water clarity and depth may also decrease, reducing the potential for host fish to reach mussels and for successful glochidia transfer.

A complete hypothesis will address *who* (taxa, group, or habitat component), *what* (flow or temperature component), *when* (month or season), *where* (habitat type or unit), and *why/how* (ecological response and hypothesised/known mechanism).

Background material A: Major draft habitat types

The classification of aquatic and riparian habitats within the ELOHA framework helps to broaden the application of the developed flow-ecological and temperature-ecology response associations to streams and rivers across a wider geographical area (Poff et al. 2010). Extensive discussion during break-out group sessions during Workshop 1 identified six major draft habitat types within the Saint John River watershed (Figure 3):

1. **Headwater (<20km^2) and small tributary (<250km^2) habitats [including cold- and cool-water reaches]**: Typically perennial conditions; few mussels; high macroinvertebrate diversity; withdrawals could lead to seasonal flow depletion in dry seasons/years; cold- and cool- water habitats critical for spawning and rearing habitats for key taxa, and provide refuge during high temperature events.

2. **Medium tributaries (<1500km^2) [including cold- and cool-water reaches]**: Perennial conditions; well-defined stream channels with high morphological complexity; high fish and mussel diversity; some floodplain development in lower reaches; cold- and cool- water habitats critical for spawning and rearing habitats for key taxa, and provide refuge during high temperature events.

3. **Large tributaries (<2500km^2) and main channel habitat**: Provide important habitat diversity for rare taxa; perennial conditions; high fish and mussel diversity; complex stream channel structure and morphology including margins, islands and backwater habitats; expansive floodplains and riparian habitats; often influenced by flood control and hydropower operations.

4. **Mainstem island habitats**: Unique habitats with direct linkages to flow regime variability; provide refugia for both aquatic and terrestrial taxa; important for edge rearing habitat for key taxa; hydrologically-complex habitat mosaic within channel; susceptible to loss of habitat with development of hydropower and flood control.

5. **Riparian wetlands**: Refugia during high water events; critical feeding, spawning and rearing habitat for key taxa; important lateral connection between riparian and aquatic habitats; relatively high biodiversity; sinks/sources for sediments, nutrients, etc. depending on connectivity; can help attenuate flood pulse.

6. **Floodplain forests**: Unique highly diverse ecosystem; stable habitat containing rare taxa; key linkage between terrestrial, riparian and aquatic habitats; periodically connected at higher flows to main channel; limited occurrence in Atlantic Canada; susceptible to invasions by non-native species due to high edge:interior ratio.

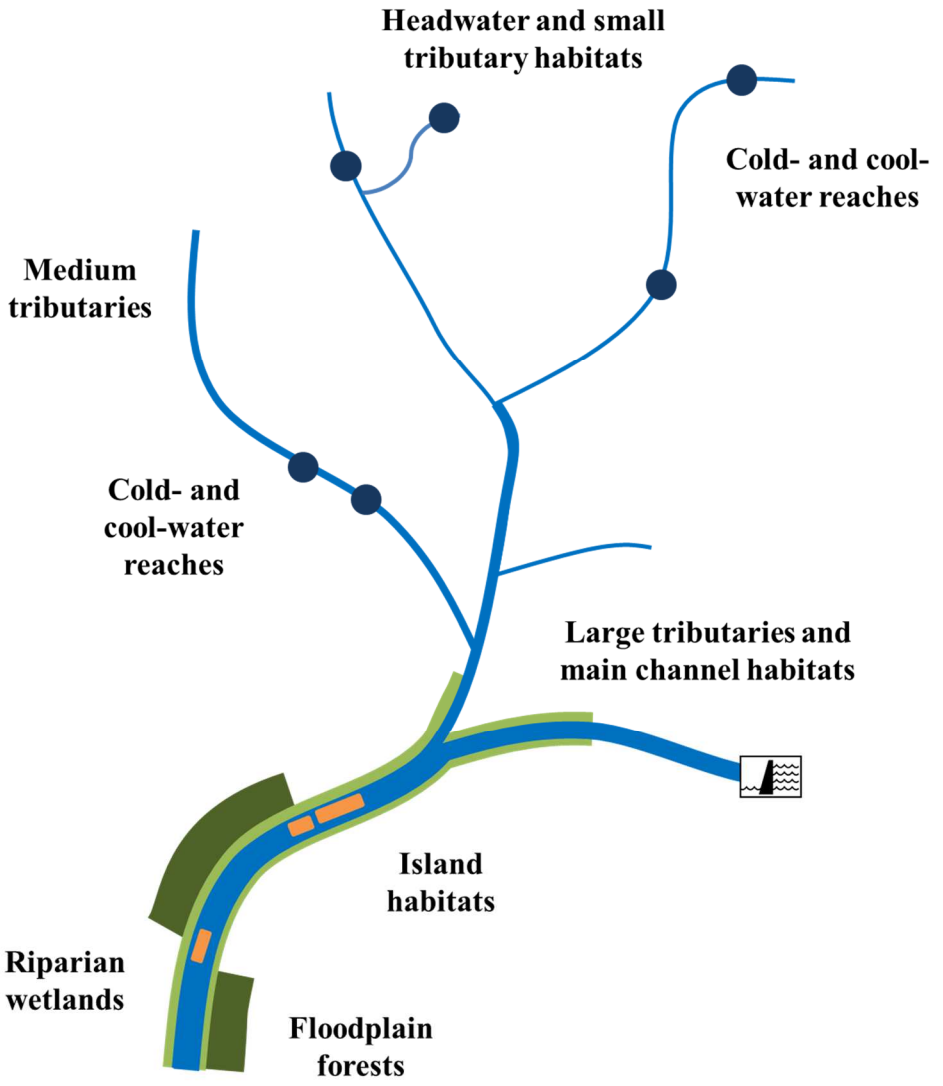


Figure 3: Schematic identifying the longitudinal and lateral connections among the major draft habitat types identified during Workshop 1

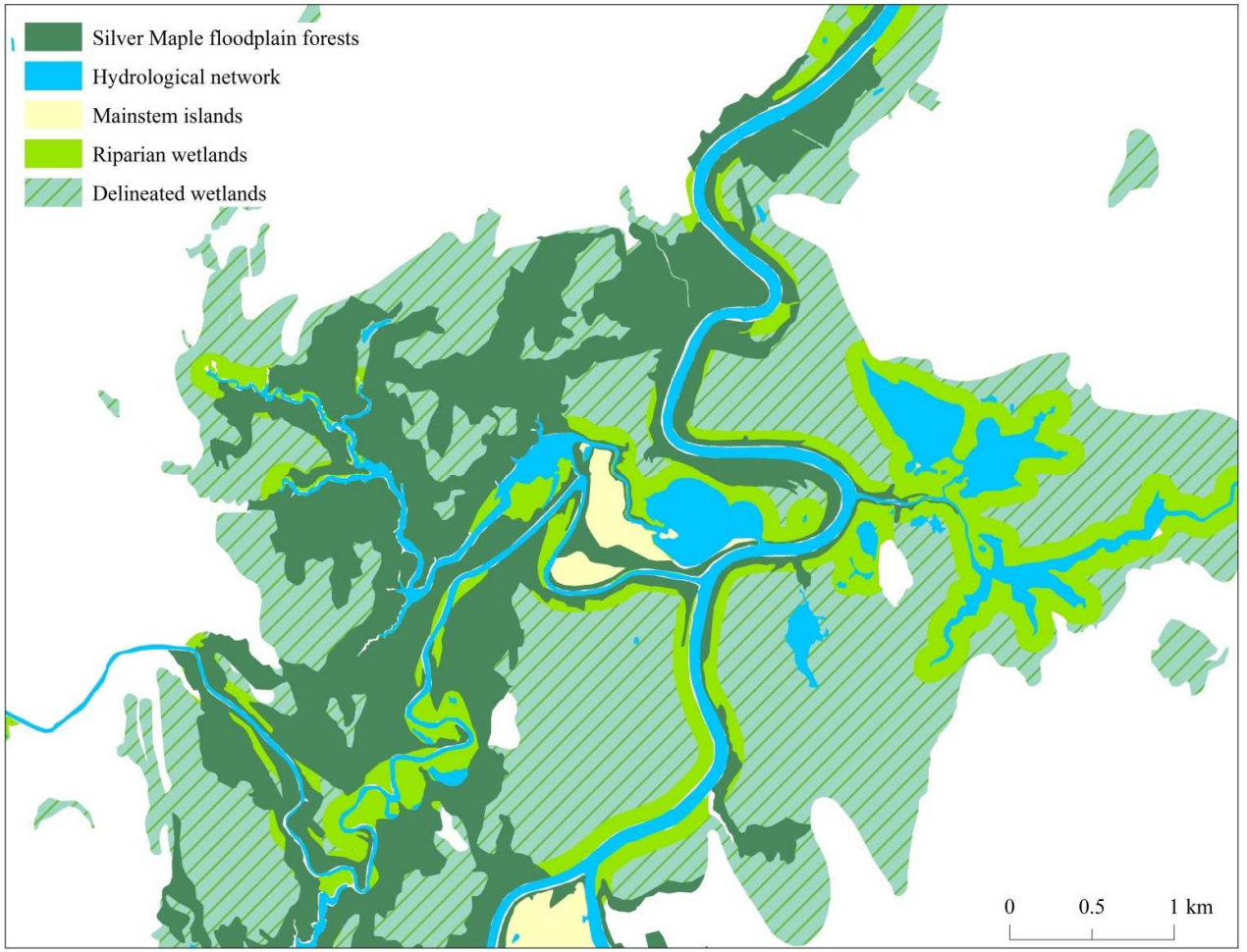


Figure 4: Example of island, riparian and floodplain habitat distribution within the Saint John River (data provided through GeoNB and New Brunswick Department of Environment and Local Government)

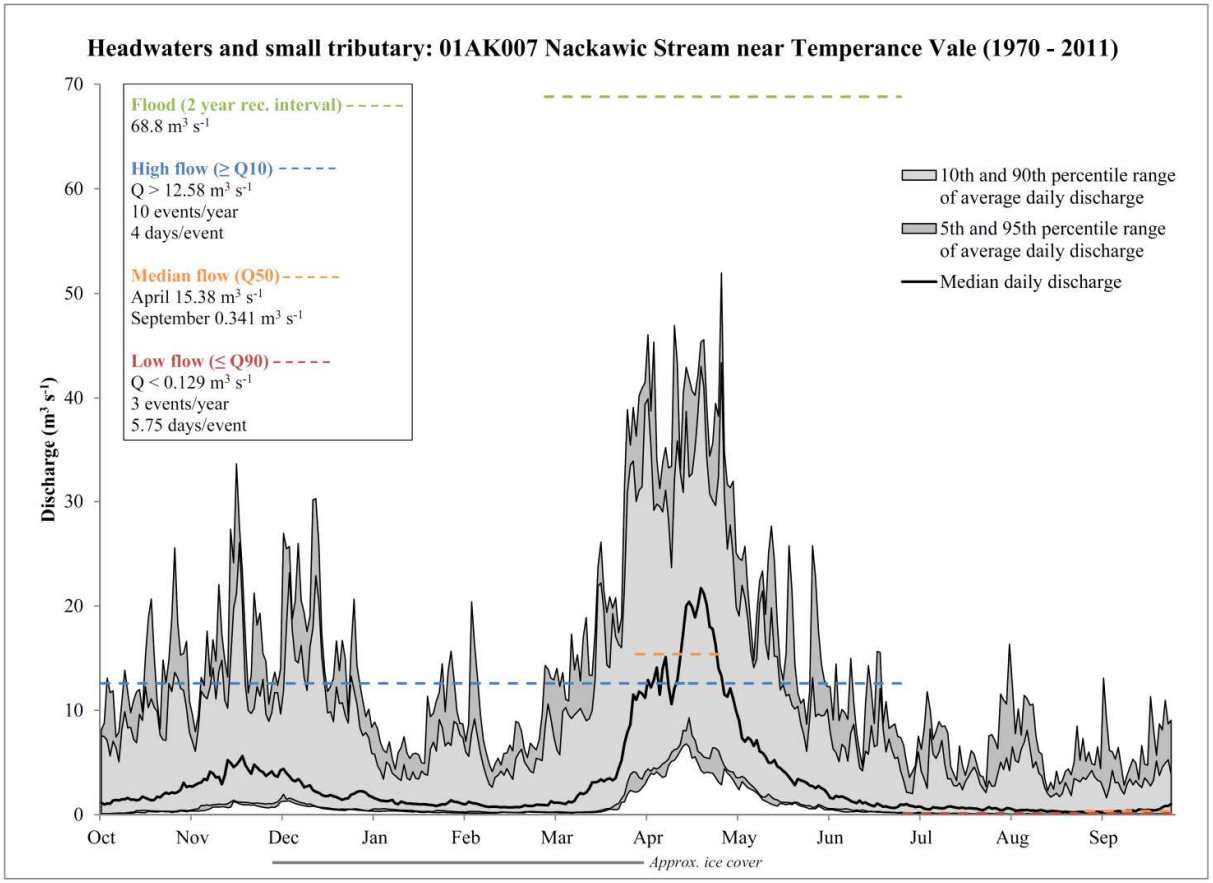


Figure 5: Example of hydrograph for headwaters and small tributary habitat (01AK007 Nackawic Stream near Temperance Vale, 1970 - 2011)

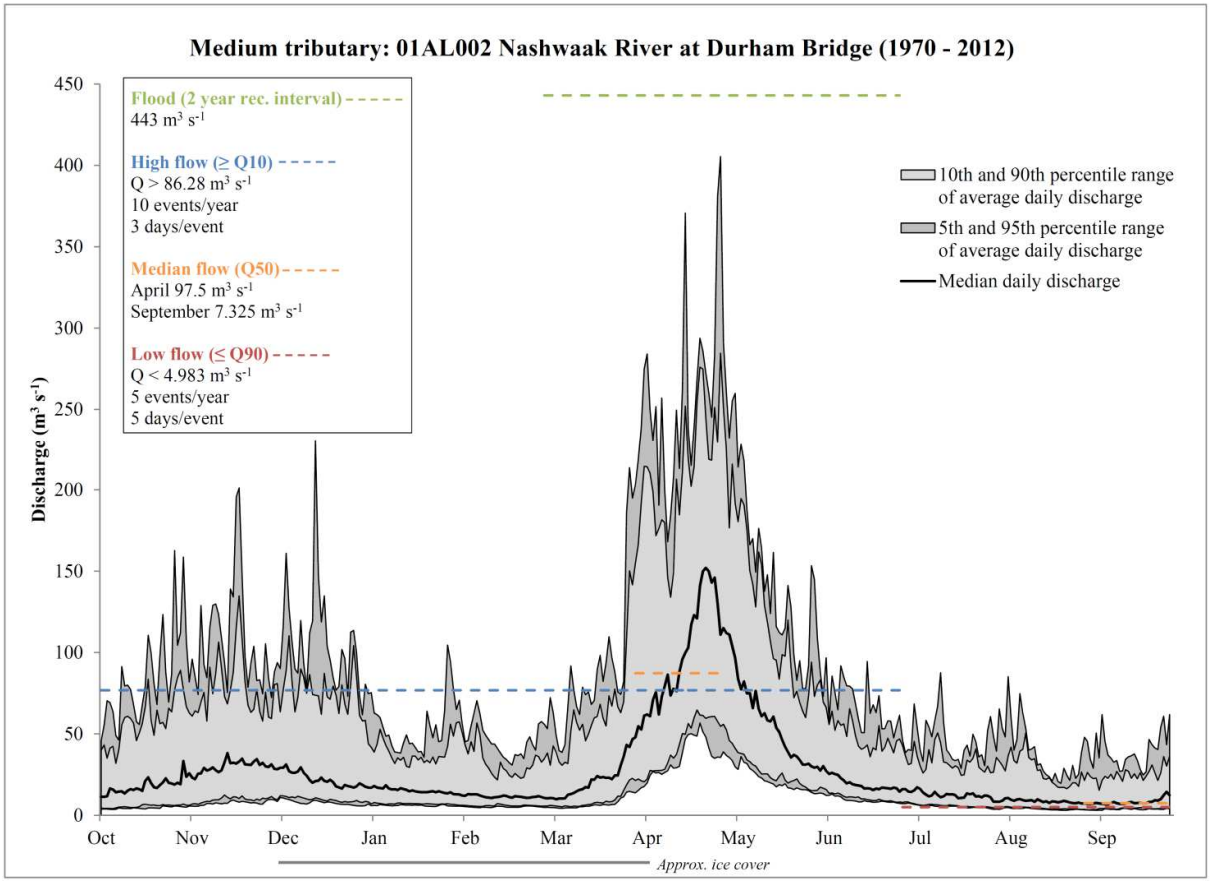


Figure 6: Example of hydrograph for medium tributary habitat (01AL002 Nashwaak River at Durham Bridge, 1970 - 2012)

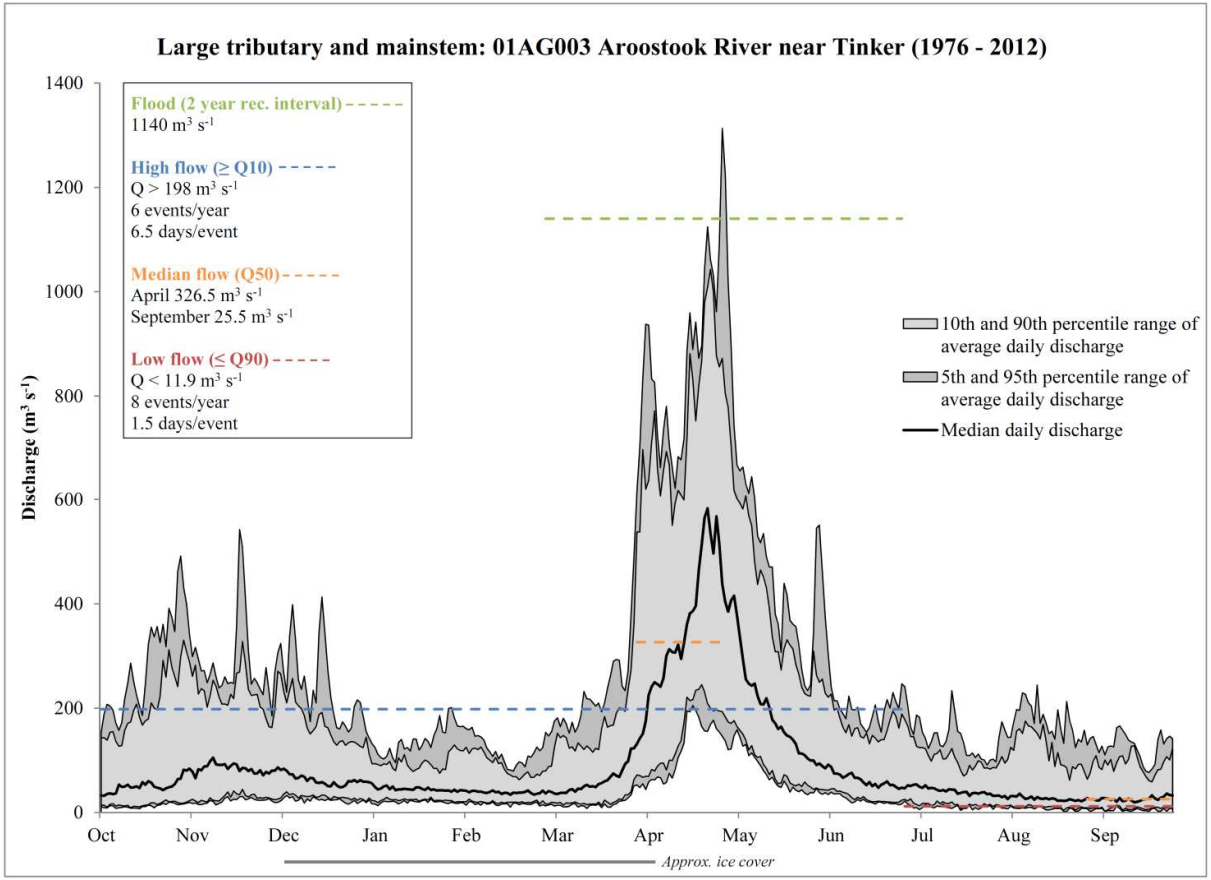


Figure 7: Example of hydrograph for large tributary and mainstem habitat (01AG003 Aroostook River near Tinker, 1976 - 2012)

Background material B: Taxa groups, shared traits, and example taxa within each group for the Saint John River

Table 3: Examples of shared traits and example taxa for vegetation groups in the Saint John River watershed

Taxa (traits)		Groups and examples
Vegetation (inundation tolerance, frequency and severity of flood scour, seed dispersal, disturbance regime)	**Submerged aquatic vegetation**	**Submerged aquatic vegetation associated with riffles**: submerged aquatic vegetation occurring in the relatively shallow, fast moving waters of medium to large rivers e.g. Fountain moss *(Fontinalis sp.)*
		Submerged aquatic vegetation associated with runs: submerged aquatic vegetation occurring in moderately deep, moderate currents of medium to large rivers. Diverse vegetation community e.g. Water stargrass (*Heteranthera dubia*)
		Submerged aquatic vegetation associated with pools: submerged aquatic vegetation occurring in the relatively deep slow moving water of medium to large rivers. Diversity may be low, while abundance can be high e.g. Waterweed (*Elodea nuttallii*, *Elodea canadensis*), Eel grass (*Vallisneria americana*), some water milfoils (e.g. *Myriophyllum farwellii*)
	Emergent aquatic vegetation	**Emergent vegetation**: emergent vegetation occurring in slow moving areas of medium to large rivers. These areas include shorelines, side and back channels areas, and the confluence areas of major tributaries. Water levels may fluctuate seasonally, but the substrate is seldom dry. Typically a mixture of submerged and free-floating aquatic species e.g. Spatterdock (*Nuphar variegata*), Common bladderwort (*Utricularia macrorhiza*), some water milfoils (eg. *Myriophyllum alterniflorum* and *M. sibericum*)
	Floodplain and riparian vegetation	**Shoreline and scour vegetation**: periodically exposed shorelines and stream margins maintained by severe flooding and scour e.g. Furbish's lousewort (*Pedicularis furbishiae*)
		Floodplain vegetation: annual spring flooding and prolonged inundation by flood waters, highly fertile floodplain soils which host characteristic plant assemblages of flood-tolerant trees and shrubs and emergent and submerged plants e.g. Speckled alder (*Alnus incana*), Black willow (*Salix nigra*), Silver maple (*Acer saccharinum*), Butternut (*Juglans cinerea*)
		Wetland vegetation: occurring within the riparian corridor along the stream networks, unique array of wetland habitats including swamps, marshes, fens, flooded meadows, shallow lakes and marsh islands, high number of priority taxa associated with wetland habitat e.g. Arrowhead (*Sagittaria latifolia*) Willow spp. (*Salix spp.*), Meadowsweet (*Spiraea alba*)

Table 4: Examples of shared traits and example taxa for benthic macroinvertebrate groups in the Saint John River watershed

Taxa (traits)	Groups and examples
Benthic macroinvertebrates (energy environment, substrate, habitat association, velocity and thermal niche)	**Benthic macroinvertebrate taxa associated with high energy, flowing waters**: occurring in high energy, dynamic substrates consisting of cobbles and boulders of streams and rivers e.g. Sallflies (Chloroperlidae), Net-spinning caddisfly (Hydropsychidae), Golden stonefly (Perlidae), Winter stoneflies (Taeniopterygidae), Blue-winged Olives (Baetidae), Apple caddisfly (Brachycentridae)
	Benthic macroinvertebrate taxa associated with moderate to low energy, stable substrate, flowing waters: occurring in moderate to low energy, stable substrates consisting of gravels and cobbles in flowing waters. Found in the downstream reaches of small rivers and the stable back channel, low gradient areas of large rivers e.g. Spiketails (Cordulegastridae), Tube-making caddisfly (Polycentropodidae), Clubtail (Gomphidae), Fingernet caddisfly (Philopotamidae)
	Benthic macroinvertebrate taxa associated with slow flow areas, vegetated backwaters: low gradient backwater, backchannel, sloughs of medium to large rivers as well as lakes and ponds. Usually confined to slow-moving portions of riverine environments in sandy or muddy substrates with a tolerance for heavy detritus, aquatic vegetation, and warmer water e.g. Angler's Curse (Caenidae), Long-horned caddisfly (Leptoceridae), Ramshorn snail (Planorbidae), Northern caddisfly (Limnephilidae)

Table 5: Examples of shared traits and example taxa for fish groups in the Saint John River watershed

Taxa (traits)	Groups and examples
Fish (body size, home range, habitat association, feeding habit, velocity and thermal niche)	**Cold- and cool-water fish**: Presence limited by low temperature thresholds e.g. Brook trout (*Salvelinus fontinalis*), Brown trout (*Salmo trutta*), Slimy sculpin (*Cottus cognatus*)
	Riffle obligate fish: Small bodied, flow velocity specialists, riffle/run habitat e.g. juvenile Atlantic salmon (*Salmo salar*) and Blacknose dace (*Rhinichthys atratulus*)
	Nest building fish: Sensitivity to flow conditions (esp. stranding) during nest building, spawning and egg and larval development; diverse nesting strategies e.g. Creek chub (*Semotilus atromaculatus*), Redbreast sunfish (*Lepomis auritus*), Smallmouth bass (*Micropterus dolomieui*)
	Resident fish with defined spawning migrations: : large home range species, requiring connectivity between mainstem and small river habitats during spawning migrations e.g. White sucker (*Catostomus commersonii*)
	Pool associate species: Large bodied fish that occupy deep, slow moving bodies of water e.g. adult Atlantic salmon (*S. salar*), adult White sucker (*C. commersonii*)
	Diadromous fish: large-bodied fish that require connectivity between mainstem and tributary habitats for spawning and nursery habitat e.g. American shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), Atlantic salmon (*Salmo salar*), or require specific flow conditions to ensure successful egg development e.g. Shortnose sturgeon (*Acipenser brevirostrum*), Striped bass (*Morone saxatilis*)
	River margin or backchannel species: Juvenile life stages of various species requiring shallow, slow moving habitats with adequate macrophyte cover for refugia e.g. cyprinid family (shiner spp., dace spp.) and pike family.
	Vegetation spawners: Fish that rely on either spring flows to flood emergent vegetation for spawning e.g. Yellow perch (*Perca flavescens*), Chain pickerel (*Esox niger*), Muskellunge (*Esox masquinongy*) or require inundated macrophytes or filamentous algae for spawning in summer months e.g. Golden shiner (*Notemigonus crysoleucas*)

Table 6: Examples of shared traits and example taxa for mussel groups in the Saint John River watershed

Taxa (traits)	Groups and examples
Mussels (energy environment, substrate, habitat association, velocity and thermal niche, silt tolerance)	**Freshwater mussel associated with very high energy, cold, clear, flowing waters**: mussel habitat specialist, occurring in very high energy, stable boulder substrates of cold water streams and rivers. Often co-occurs with trout habitat e.g. Eastern Pearlshell (*Margaritifera margaritifera*)
	Freshwater mussels associated with high energy, dynamic substrate, flowing waters: mussel species occurring in high energy, dynamic cobbles and boulders substrates of streams and rivers e.g. Alewife Floater (*Anodonta implicata*), Eastern Elliptio (*Elliptio complanata*)
	Freshwater mussels associated with moderate to low energy, stable substrate, flowing waters: Freshwater mussels occurring in moderate to low energy, stable substrates consisting of gravels and cobbles, in flowing waters. Found in the downstream reaches of small rivers and the stable back channel, low gradient areas of large rivers e.g. Brook Floater (*Alasmidonta varicose*), Triangle Floater (*Alasmidonta undulata*)
	Freshwater mussel associated with stagnant, vegetated backwaters: mussel preferring low gradient backwater, backchannel, sloughs of medium to large rivers as well as lakes, ponds, and marshes. Usually confined to slow-moving portions of riverine environments, in sandy or muddy substrates, with a tolerance for heavy detritus, aquatic vegetation, and warmer water e.g. Eastern Floater (*Pyganodon cataracta*)

Background material C: Trait groups and associated habitat types within the Saint John River

Table 7: Draft vegetation groups, example species, and associated habitat types for the Saint John River

Taxa group		Headwater and small tributaries	Medium tributaries		Large tributaries and main channel	Island habitats	Riparian wetlands	Floodplain forests
		Cold-and cool-water reaches	*Cold-and cool-water reaches*	*Typical reach*				
Submerged aquatic vegetation	**Submerged aquatic vegetation associated with riffles**: e.g. Fountain moss *(Fontinalis sp.)*	●	●	●	●	●		
	Submerged aquatic vegetation associated with runs: e.g. Water stargrass (*Heteranthera dubia*)		●	●	●	●		
	Submerged aquatic vegetation associated with pools: e.g. Waterweed (*Elodea nuttallii*, *Elodea canadensis*), Eel grass (*Vallisneria americana*), some water milfoils (e.g. *Myriophyllum farwellii*)			●	●	●	●	
Emergent aquatic vegetation	**Emergent vegetation**: e.g. Spatterdock (*Nuphar variegata*), Common bladderwort (*Utricularia macrorhiza*), some water milfoils (eg. *Myriophyllum alterniflorum* and *Myriophyllum sibericum*)	●	●	●	●	●		
Floodplain and riparian vegetation	**Shoreline and scour vegetation**: e.g. Furbish's lousewort (*Pedicularis furbishiae*)				●	●		
	Floodplain vegetation: e.g. Speckled alder (*Alnus incana*), Black willow (*Salix nigra*), Silver maple (*Acer saccharinum*), Butternut (*Juglans cinerea*)			●	●		●	●
	Wetland vegetation: e.g. Arrowhead (*Sagittaria latifolia*) Willow spp. (*Salix spp.*), Meadowsweet (*Spiraea alba*)			●	●	●	●	

Table 8: Draft benthic macroinvertebrate groups, example species, and associated habitat types for the Saint John River

Taxa group	Headwater and small tributaries	Medium tributaries		Large tributaries and main channel	Island habitats	Riparian wetlands	Floodplain forests
	Cold-and cool-water reaches	*Cold-and cool-water reaches*	*Typical reach*				
Benthic macroinvertebrate taxa associated with high energy, flowing waters e.g. Sallflies (Chloroperlidae), Net-spinning caddisfly (Hydropsychidae), Golden stonefly (Perlidae), Winter stoneflies (Taeniopterygidae), Blue-winged Olives (Baetidae), Apple caddisfly (Brachycentridae)	•	•	•	•	•		
Benthic macroinvertebrate taxa associated with moderate to low energy, stable substrate, flowing waters e.g. Spiketails (Cordulegastridae), Tube-making caddisfly (Polycentropodidae), Clubtail (Gomphidae), Fingernet caddisfly (Philopotamidae)		•	•	•	•		
Benthic macroinvertebrate taxa associated with slow flow areas, vegetated backwaters e.g. Angler's Curse (Caenidae), Long-horned caddisfly (Leptoceridae), Ramshorn snail (Planorbidae), Northern caddisfly (Limnephilidae)			•	•	•	•	•

Table 9: Draft fish groups, example species, and associated habitat types for the Saint John River

Taxa group	Headwater and small tributaries	Medium tributaries		Large tributaries and main channel	Island habitats	Riparian wetlands	Floodplain forests
	Cold-and cool-water reaches	*Cold-and cool-water reaches*	*Typical reach*				
Cold- and cool-water fish e.g. Brook trout (*Salvelinus fontinalis*), Brown trout (*Salmo trutta*), Slimy sculpin (*Cottus cognatus*)	●	●					
Riffle obligate fish e.g. juvenile Atlantic salmon (*Salmo salar*) and Blacknose dace (*Rhinichthys atratulus*)	●	●	●	●	●		
Nest building fish e.g. Creek chub (*Semotilus atromaculatus*), Redbreast sunfish (*Lepomis auritus*), Smallmouth bass (*Micropterus dolomieui*)		●	●	●	●		
Resident fish with defined spawning migrations e.g. White sucker (*Catostomus commersonii*)		●	●	●			
Pool associate species e.g. adult Atlantic salmon (*Salmo salar*), White sucker (*Catostomus commersonii*)		●		●			
Diadromous fish e.g. American shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), Atlantic salmon (*Salmo salar*), Shortnose sturgeon (*Acipenser brevirostrum*), Striped bass (*Morone saxatilis*)		●	●	●	●		
River margin or backchannel species e.g. juvenile Cyprinidae spp.		●		●	●	●	
Vegetation spawners e.g. Yellow perch (*Perca flavescens*), Chain pickerel (*Esox niger*), Muskellunge (*Esox masquinongy*)				●	●	●	●

Table 10: Draft mussel groups, example species, and associated habitat types for the Saint John River

Taxa group	Headwater and small tributaries	Medium tributaries		Large tributaries and main channel	Island habitats	Riparian wetlands	Floodplain forests
	Cold-and cool-water reaches	*Cold-and cool-water reaches*	*Typical reach*				
Freshwater mussel associated with very high energy, cold, clear, flowing waters e.g. Eastern Pearlshell (*Margaritifera margaritifera*)	●	●	●	●	●		
Freshwater mussels associated with high energy, dynamic substrate, flowing waters e.g. Alewife Floater (*Anodonta implicata*), Eastern Elliptio (*Elliptio complanata*)		●	●	●	●		
Freshwater mussels associated with moderate to low energy, stable substrate, flowing waters e.g. Brook Floater (*Alasmidonta varicose*), Triangle Floater (*Alasmidonta undulata*)			●	●	●		
Freshwater mussel associated with stagnant, vegetated backwaters e.g. Eastern Floater (*Pyganodon cataracta*)			●	●	●	●	