



Prepared for: Margaree Salmon Association

Margaree Watershed Stream Health Report

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1.0 INTRODUCTION

Atlantic Salmon populations have declined significantly over the past several decades in the Maritime region (COSEWIC, 2010). Though the Gulf region is doing better compared to other areas of the Maritimes, declines have led to further restrictions on recreational salmon fishing (mandatory catch and release). According to a recent report by DFO, the estimated abundance of large (multi-sea winter) salmon has declined by approximately 25% and small (grilse) salmon by 62% in the Margaree (DFO, 2017). Indicators of juvenile salmon abundance were also documented, with declines of 70% and 74% estimated for fry and parr respectively over a 12 year period. Juvenile salmon spend up to four years in the Margaree until they are ready to migrate to sea. It is during this phase where the river and its tributaries play a critical role in the life cycle of Atlantic salmon. Optimal stream quality is essential for the preservation of salmon and must be considered in order to fully understand salmon habitat in the Margaree for future protection efforts.

Stream assessments have been conducted by several organizations in Cape Breton using the Canadian Aquatic Biomonitoring Program (CABIN) including Parks Canada, ACAP Cape Breton, Environment & Climate Change Canada (ECCC), and the Unama'ki Institute of Natural Resources (UINR). CABIN utilizes a group of organisms known as benthic macroinvertebrates that includes immature forms of aquatic insects, snails, crustaceans, worms, and mites. They are a commonly used indicator as they are widespread, abundant, and have long enough life cycles to reflect the pollution 'history' of a river (Rosenberg & Resh, 1993). They also play an important role in the food chain of aquatic organisms in rivers and streams as food for salmon fry and parr in both their immature (nymph) and adult stages (i.e., spinners, duns) and other fishes common to those habitats. The CABIN protocol incorporates other important elements of stream assessment such as water quality, substrate characteristics, and channel dimensions, thus making it an integrative method of ecological, chemical, and physical parameters for assessing streams for juvenile Atlantic salmon habitat.

CABIN assessments were conducted through collaboration between UINR and the Margaree Salmon Association (MSA). Both UINR and MSA have a mutual interest in protection of salmon. UINR works on behalf of the five Mi'kmaq communities of Unama'ki who have inherent rights to harvest salmon for food, social and ceremonial needs in the Margaree River that are critical for maintaining cultural practices, knowledge sharing, and providing a nutritional source of food to communities and community members. The MSA works to conserve salmon for the salmon recreational fishery that is central to the community culture and economy of Margaree. Sampling locations were selected with the goal of capturing stream health on a watershed scale while also targeting tributaries of interest to the MSA. Sites assessed in this report include the Northeast at Big Intervale Lodge, Ingram's Brook, Lake O'Law Brook, Big Brook, and Gallant's River. The use of CABIN's "network-of-network" approach allowed us to access data collected by ECCC on Mount Pleasant Brook in the Southwest Margaree and is included in this report.

2.0 PURPOSE & OBJECTIVES

This study aims to assess stream health on a broad level throughout the Margaree watershed and more specifically in the Northeast Branch. These assessments enhance our understanding of salmonid habitat conditions using benthic macroinvertebrates as an indicator of stream health, coupled with water chemistry testing and other stream characteristics including substrate measurements. By doing so, this study contributes to a formation of baseline for stream health to monitor changes in the future. Stream health was assessed by evaluating benthic macroinvertebrate community against standard metrics, comparing water quality results to federally established guidelines for the protection of aquatic life, and by examining substrate and other stream characteristics collected through CABIN to determine the presence of suitable habitat for benthic macroinvertebrates and juvenile salmon (fry and parr). By starting with a broad sampling approach, a large portion of the Northeast Margaree can be captured and serves as a first step in a more targeted stream assessment program to pin-point problem areas.

2.0 METHODS

2.1 Study Area

Six sites were sampled throughout the Margaree watershed; four in the Northeast led by UINR, one on a tributary below the Forks of the Margaree, and one in the Southwest sampled by ECCC (Figure 1). Sites were selected through discussions held between UINR and MSA. This guided sampling design, aimed to capture stream health and water quality on a watershed scale while also targeting tributaries of interest to the MSA (Table 1). Collectively these sites captured 537 km², covering roughly 46% of the 1,162 km² Margaree watershed.

Table 1. List of 2016 Margaree CABIN sampling locations, branch, site ID, and geographical coordinates.

Location	Branch	Site ID	Latitude	Longitude
Big Brook	NE	BIG01	46.31398	-61.03386
Northeast Margaree (Big Intervale)	NE	BIN01	46.42643	-60.94482
Gallants River	Main	GAL01	46.39011	-61.07067
Ingram's Brook	NE	ING01	46.40258	-60.92601
Lake O'Law Brook	NE	LOL01	46.31459	-60.97168
Mount Pleasant Brook	SW	NS01FB0011	46.22779	-61.1301

At the watershed level, the Northeast (NE) and Southwest (SW) branches of the Margaree are distinct systems. The Northeast drains the Highlands through the Margaree River valley; while the Southwest consists of foothills and low-lying areas draining Lake Ainslie, the largest freshwater lake in Nova Scotia (O'Neil et al., 2016). The physiography and geology within in the Northeast Branch is complex, best illustrated by the geologically diverse up-stream drainage area of Big Intervale, the headwaters of the Northeast Margaree. This area includes all major rock types, including Windsor group rocks often associated with gypsum and salt deposits, granite and other intrusive rocks, metamorphic

rocks such as gneiss and marble, and even volcanic rocks (Table 2). In contrast, Lake O'Law Brook drainage area is predominantly sedimentary (i.e., sandstones, shales) while Ingram's is primarily metamorphic (slates, marble, gneiss). These major geological differences combined with topography, vegetation, and soil characteristics result in distinct hydrological regions (Moreland, 2013). This diversity in the landscape is reflected in a variety of stream and river typologies throughout Cape Breton, and within the Margaree watershed.

Table 2. Bedrock geology composition and upstream drainage area derived from ARM modeling procedure.

Site ID	Intrusive	Metamorphic	Sedimentary	Volcanic	Area
	%	%	%	%	km ²
BIG01	51	0	49	0	48
BIN01	38	52	1	9	289
GAL01	0	2	36	61	62
ING01	28	72	0	0	21
LOL01	7	0	93	0	39
NS01FB0011	54	0	46	0	78

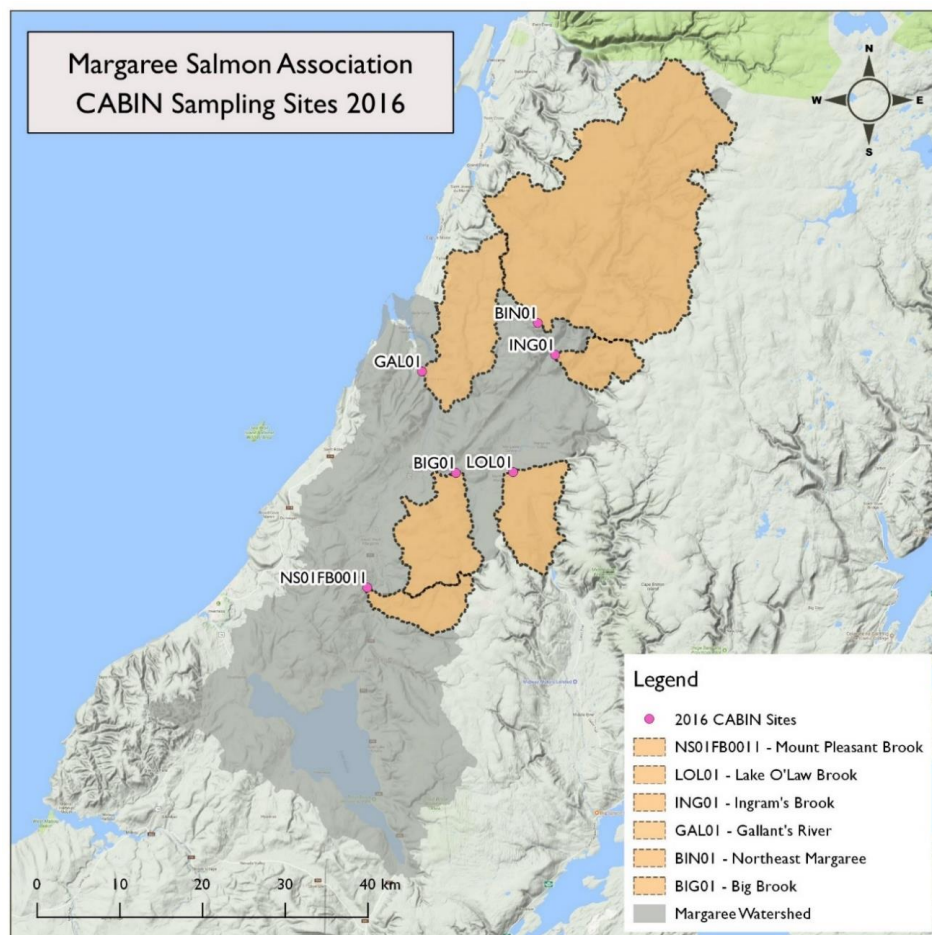


Figure 1. 2016 MSA CABIN site map with watersheds delineated using ARM model.

2.2 CABIN Methodology

2.2.1 Overview

The Canadian Aquatic Bio-monitoring Network (CABIN) is an aquatic biological monitoring program for assessing the health of freshwater ecosystems in Canada. CABIN is based on the network of networks approach that promotes inter-agency collaboration and data-sharing to achieve consistent and comparable reporting on freshwater quality and aquatic ecosystem conditions in Canada. The program is maintained by ECCC to support the collection, assessment, reporting and distribution of biological monitoring information. CABIN allows partners to take their observations and make a formalized scientific assessment using nationally comparable standards. The program primarily uses the Reference Condition Approach (RCA) for study design and site assessment.

Many types of organisms can be used for biomonitoring, in particular invertebrates, macrophytes, algae, zooplankton and fish. These organisms are sensitive to a variety of disturbances and are recognized as environmental indicators. Currently, CABIN uses benthic invertebrate communities to assess aquatic ecosystem health. Benthic invertebrates live in all freshwater ecosystems. This group includes the larval stages of many insects such as mayflies, dragonflies, mosquitoes as well as other animals such as worms and mites. Using calculated measures of community composition, diversity, and pollutions tolerances to determine stream health, the data can be evaluated over time to determine trends, or compared to other sites as part of a reference condition approach.

2.2.2 Data Collection

CABIN assessments are typically conducted during the period of late summer to fall. At this time of year, most benthic macroinvertebrates are fully mature and easier to identify. Site selection depends on the purpose and objectives of a given project. As described earlier, the purpose of this project is to evaluate stream health in the Margaree focusing on the NE branch. UINR and MSA, assisted by ECCC, sampled five sites in 2016 (Figure 2). Both MSA and UINR had a common goal of developing a better understanding of Atlantic Salmon habitat in the Margaree. Prior to selecting a site, the national CABIN site map was consulted to determine if proposed sites were already sampled. One location on the Northeast Margaree (46.3665, -60.974) had been sampled in 2012.

The CABIN field collection protocol includes multiple elements of stream habitat assessments. The main steps in the CABIN procedure are *site inspection*, *general site description*, *reach characterization*, *water chemistry sampling*, *benthic macroinvertebrate sampling*, *substrate data collection*, and *channel measurements*. Parameters collected are provided in Table 3, and a full list of equipment required to complete a CABIN assessment is provided in Appendix 1. Following each CABIN assessment, water quality samples were sent to one of two labs for analyses. One site (Big Intervale) was funded by ECCC through their Atlantic CABIN monitoring project, and sent to ECCC's *Atlantic Laboratory for Environmental Testing (ALET)* in Moncton, New Brunswick. The remaining four samples were funded by the MSA, and sent to Maxxam Analytics in Sydney, NS for analyses. Benthic macroinvertebrates services (processing and family/genus level identification) were provided by *BioTech Taxonomy* in New

Brunswick for all samples. All data was entered upon completion of sampling in October 2016. Habitat, physical and water chemistry results were entered into the CABIN database by a UINR staff. *Note: Water chemistry samples were not available for Mount Pleasant Brook.*



Figure 2. UINR staff and MSA board member conducting CABIN sampling on Lake O'Law Brook in September 2016.

Table 3. CABIN procedure modified from CABIN manual (Environment Canada, 2011).

Procedure	Data Collection
<i>Site Inspection</i>	Inspection for site hazards, review of safety protocols
<i>General site description</i>	Site description, surrounding land-use, location data, site drawings, site photographs
<i>Reach characterization</i>	Stream habitat types, canopy coverage, macrophyte coverage, streamside vegetation, periphyton coverage
<i>Water Chemistry</i>	Physical parameters, nutrients, major ions, metals
<i>Benthic Macroinvertebrates</i>	Kick-net sample, sample transfer and preservation
<i>Substrate characteristics</i>	Pebble count, embeddedness, surrounding material
<i>Channel measurements</i>	Bankfull/wetted width, bankfull-wetted depth, depth, velocity, slope

3.0 DATA ANALYSIS

3.1 Habitat Suitability

The purpose of this section is to describe general habitat conditions to provide context for evaluation of habitat suitability (slope, substrate, depth, velocity) for juvenile salmon and benthic macroinvertebrates. Optimal ranges of habitat parameters are provided in Table 4 and is primarily based on information from the Recovery Assessment Potential document for Eastern Cape Breton (Gibson et al., 2014). Juvenile salmon can, however, occupy areas outside of these ranges especially where population densities are high. This section is meant to provide a general indication of the **presence (not quantity)** of habitat.

Table 4. Optimal physical habitat parameters for juvenile Atlantic salmon in the Eastern Cape Breton designable unit (Gibson et al., 2014). Optimal embeddedness from Chapman & MacLeod (1987), and optimal velocities for benthic macroinvertebrates from Biggs et al. (2002).

Habitat Parameter	Unit	Optimal range
Stream gradient	%	0.5-1.5
Spawning substrate	Type	Cobble, Gravel, Pebbles
Substrate (Age 0)	mm	16-256
Substrate (Age 1 and older)	mm	64-512
Fine sediments	%	<12
Embeddedness*	%	<50%
Depth (fry)	m	0.15-0.25
Depth (parr)	m	0.15-0.25 and greater
Velocity (fry)	m/s	>0.4
Velocity (parr)	m/s	0.2-0.4
Velocity (benthic macroinvertebrates)**	m/s	0.3-0.69

3.2 Benthic Macroinvertebrates

3.2.1 Indices

Benthic macroinvertebrate indices are a measure of stream health. Characteristics of the benthic invertebrate community that are associated with certain environmental conditions are calculated into a term that provides the indication of ecosystem health. In this report, indices include measures of richness, composition, diversity, and tolerance. Table 5 provides a list of the indices used and response to environmental stress.

Table 5. List of benthic macroinvertebrate indices used in this report and their response to stressors. Adapted from TRCA, 2008.

Indices	Response to Stressors
<i>Richness Measures</i>	
Family richness	Decrease
EPT family richness	Decrease
Ephemeroptera family richness	Decrease
Plecoptera family richness	Decrease
Trichoptera family richness	Decrease
<i>Compositional Measures</i>	
% EPT	Decrease
% Chironomidae	Increase
% Oligochaeta	Increase
% Dominant Family	Increase
<i>Diversity Measures</i>	
Simpson's Diversity	Decrease
<i>Tolerance Measures</i>	
Hilsenoff (Family) Biotic Index	Increase

3.2.2 Atlantic Reference Model (ARM)

Analysis through the CABIN online database supports a Reference Condition Model (RCA). Developing an RCA for a project requires many CABIN sampling sites to serve as the basis to compare against test sites. For those organizations who lack the resources to build a reference model, analysis is limited to basic composition and other community descriptors. Though this information is useful and informative, there is a need to provide a tool for groups to compare their sites to a reference condition. To fill this need the Atlantic Reference Model (ARM) was developed specifically for the Atlantic region (Armanini et al. 2013). Benthic data from CABIN and similar biomonitoring programs were collected from throughout Atlantic Canada and analyzed in relation to landscape level predictors. The analysis revealed four landscape level predictors that explained significant amounts of variation among benthic assemblages at the family level. These predictors, long term average air temperature and three bedrock geology types, were used as the basis of the model. Though valuable, the ARM is relatively new and has not been tested against results from local level reference condition models that incorporate a broader spectrum of parameters including water chemistry, or one that uses genus level taxonomic resolution. As such, 'normal' results in this study do not necessarily reflect what is normal on a smaller geographic scale (i.e., Cape Breton). This would require development of a more localized reference condition model.

3.3 Water Quality

As per the CABIN protocol, water quality data was collected using a multi-parameter sonde (*ProDSS*) and through the collection of water chemistry samples that were analyzed by the ALET laboratory in Moncton and Maxxam Analytics in Sydney. General water quality parameters were collected at the time of CABIN sampling (temperature, pH, dissolved oxygen and specific conductivity). Laboratory analyses provided more extensive data on various metals, ions, and nutrients. The results were analyzed against the values provided by the Canadian Council of Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life (POAL) (CCME, 2007). Provincial guidelines tailored specifically for Nova Scotia's freshwater characteristics (Environment Canada, 2015) were also used to supplement the CCME POAL guidelines. In cases where these guidelines differed, the value of the lower concentration was used. Additionally, a nutrient classification for rivers and streams developed by Dodds et al. (1998) was used to determine the trophic state at each site (Appendix 6). A full list of parameters and their corresponding guidelines can be found in Appendix 2, however only 15 out of 41 had established guidelines. These guidelines serve as a general indication of water quality for aquatic life, however, do not necessarily reflect naturally occurring variability at the local level. Therefore, parameters that approach or exceed guidelines should be interpreted with caution.

3.4 Integrated Analysis

This section is intended to provide an interpretation of stream health by integrating physical habitat, benthic macroinvertebrates, and water quality findings. Key outcomes include likelihood of stream health impairment, indication of possible stressors, and presence of suitable habitat for juvenile salmon. Due to limitations outlined previously, determination of stream health impairments or presence of stressors is not guaranteed.

Likely unimpaired stream health is based on a combination of %EPT (>50%), intolerant dominant family (i.e., sensitive EPT taxa), and FBI scores of 'Excellent' or lower range of 'Very Good'; whereas possibly impaired stream health is determined by <50% EPT, a more tolerant dominant family, and a FBI score of 'Very Good' or higher. Sites with likely impaired stream health have strong evidence of impairment including less than 40% EPT, a highly tolerant dominant family, and FBI scores of 'Good' or less. Indication of a potential water quality and/or physical habitat stressor is also noted, based on evidence including notable presence of periphyton and/or bryophyte coverage, water quality parameters close to or exceeding Protection of Aquatic Life guidelines, mesotrophic state according to total phosphorus, presence of certain pollution tolerant taxa, low percentage of EPT taxa, and visual indicators of stream processes associated with instability. Finally, the presence of suitable habitat conditions for each juvenile life stage (fry and parr) is determined based on substrate size, stream gradient, embeddedness, and hydraulic parameters (depth and velocity) conditions at the time of sampling. Whether a site falls within the optimal range of habitat parameters identified by Gibson et al. (2013) is also noted.

4.0 RESULTS & ANALYSIS

4.1 Physical Habitat

Overall, the Margaree CABIN sites in this study can be characterized as mild to moderately sloping rivers and streams (<4%, Rosgen (1994)) consisting of varying proportions of cobble and pebble material, surrounded by gravel and some cases sand. Though sites were not classified by river or stream type (i.e., stream order), clear differences in stream characteristics could be observed (Appendix 5). The Northeast Margaree at Big Intervale and Mount Pleasant Brook were relatively wide, low gradient sites lacking canopy coverage; while Ingram's Brook and Lake O'Law brook sites' were relatively narrow and moderately sloped with plenty of cover from the adjacent riparian zone. These differences are important to keep in mind when evaluating stream habitat, as what may be normal for one type may be abnormal



Figure 3. Left) Low gradient stream with 1-25% canopy coverage (Big Brook) and Right) moderately sloped stream with 76-100% canopy coverage (Ingram's). Photos are taken in the upstream direction.

for another.

Only one of the six sites examined in this study fell within the optimal stream slope range of 0.5-1.5% (Lake O'Law Brook). Stream slope at Ingram's Brook was only slightly higher than the recommended range at 1.59%, whereas Gallant's River was higher gradient at 2.23% indicating a moderate stream slope. The NE at Big Intervale, Big Brook, and Mount Pleasant Brook (SW) fell below the optimal range with very mild gradients. Ingram's, Lake O'Law, and Gallant's were the only locations with higher canopy coverage, whereas all other sites were relatively 'open' with little cover provided by riparian vegetation (Figure 3). Though quantifying stream geomorphological processes is not the intent of this study, common visual indicators of degradation (erosion) were observed at five of six sites. Big Brook and Gallant's River both had leaning trees, Ingram's and Lake O'Law had exposed tree roots, and Mount Pleasant Brook had leaning vegetation and some areas of exposed stream bank. Big Intervale was the only location where indicators of bank erosion were not observed, however, it is worth noting it was considerably wider than other locations. Erosion and deposition are natural channel processes, and observation of these indicators does not necessarily imply that a stream is functioning outside its natural state. For example,

riprap installed at Lake O'Law to protect property is limiting channel migration and may have led to erosion of the bank downstream of the riprap.

Study locations were dominated by 25% embedded pebble to cobble sized substrate surrounded by gravel (Table 6). Cobble, pebble, and gravel serve an important function as in-stream cover for juvenile salmon and spawning substrate for adult salmon. Based on median particle size (D50) alone, substrate appeared more optimal for fry than parr at Big Brook, Big Intervale, Lake O'Law, and Mount Pleasant due to the dominance of pebble-sized rocks. When looking at the substrate composition, however, substantial cobble sized rocks were present and provide habitat for parr at these sites (except Mount Pleasant Brook). Substrate was optimal for both fry and parr at Gallant's and Ingram's where cobble made up the majority of bed material. Though CABIN does not specifically target spawning habitat, all riffles and runs sampled had spawning substrate (cobble, pebble, and gravel). Though Mount Pleasant lacked cobble, the presence of pebble and gravel would be adequate for spawning.

Lack of embedded substrate and fines (<2 mm; sand, silt, clay) indicate good overall availability of interstitial spaces (spaces between larger rocks) for developing salmon and benthic macroinvertebrates. However sand was noted at some sites despite being absent from 5/6 pebble counts (Table 6), and was visually identified as the surrounding material at Mount Pleasant Brook though not documented in the pebble count. It is likely that interstitial spaces are filled with gravel and coarse sand (Figure 4). One site, Lake O'Law, had a higher degree of embeddedness (50%) which could lead to declines in salmon density and benthic macroinvertebrate abundance (Chapman & MacLeod, 1987).

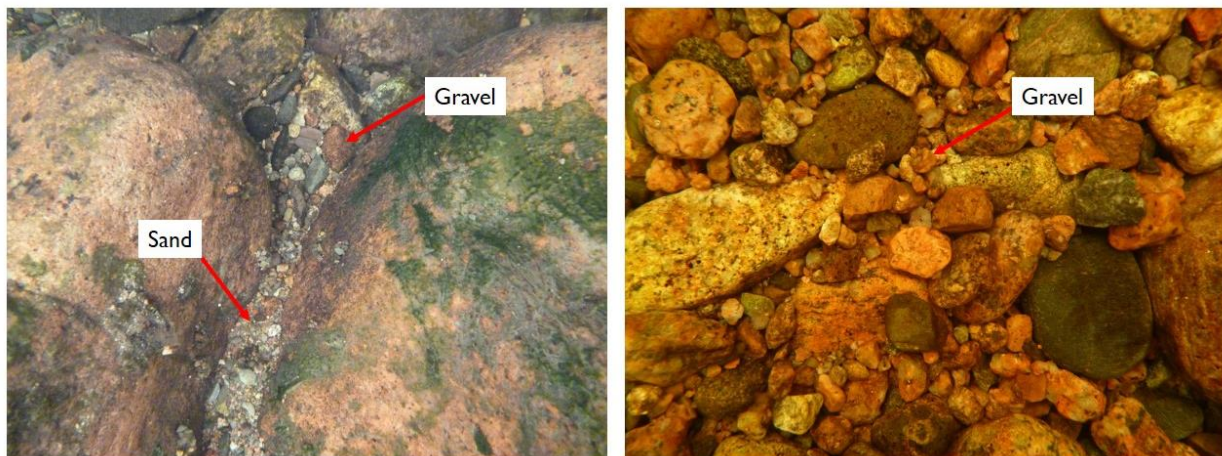


Figure 4. Left) Substrate with periphyton growth and mixture of gravel and sand in interstitial spaces (Big Brook), and Right) substrate with minimal periphyton and gravel as surrounding substrate (Big Intervale).

Depth and velocity data were instantaneous measurements taken at only one cross-section in the sampling site, and therefore do not fully reflect habitat suitability throughout the entire reach or range of flows. However they can be used to provide a general idea of overall habitat conditions with respect to preferred velocity and depth for juvenile salmon and benthic macroinvertebrates at the time of sampling. Fry and parr have similar depth preferences ranging from 0.15-0.25m, though parr can move into deeper areas 0.25 m. Fry prefer faster moving water (>0.4 m/s) compared to parr that prefer slower velocities

(0.2-0.4 m/s). Ideal velocities for a healthy benthic macroinvertebrate community range from 0.3 to 0.69 m/s according to Biggs et al., 2002.

Depth measurements ranged from 0.07-0.75m and velocities from 0.26-0.86 m/s overall. This indicates suitable depth and velocity conditions were present among sites at the time of sampling, with some areas more favourable for either fry or parr. Most velocities were in the ideal range for benthic macroinvertebrates, though some areas falling outside that range could support slightly different taxa. Velocity measurements collected in CABIN are taken approximately mid-way through the water column, and do not capture near-bed velocities. In fast flowing areas such as riffles, larger substrate materials like cobbles provide important microhabitat for parr that use slower areas behind rocks as flow refuges (Figure 5). This underscores the need for substrate heterogeneity for juvenile Atlantic Salmon, and a mixture of substrate sizes including cobble, pebble, and gravel to provide habitat for both fry and parr life stages.

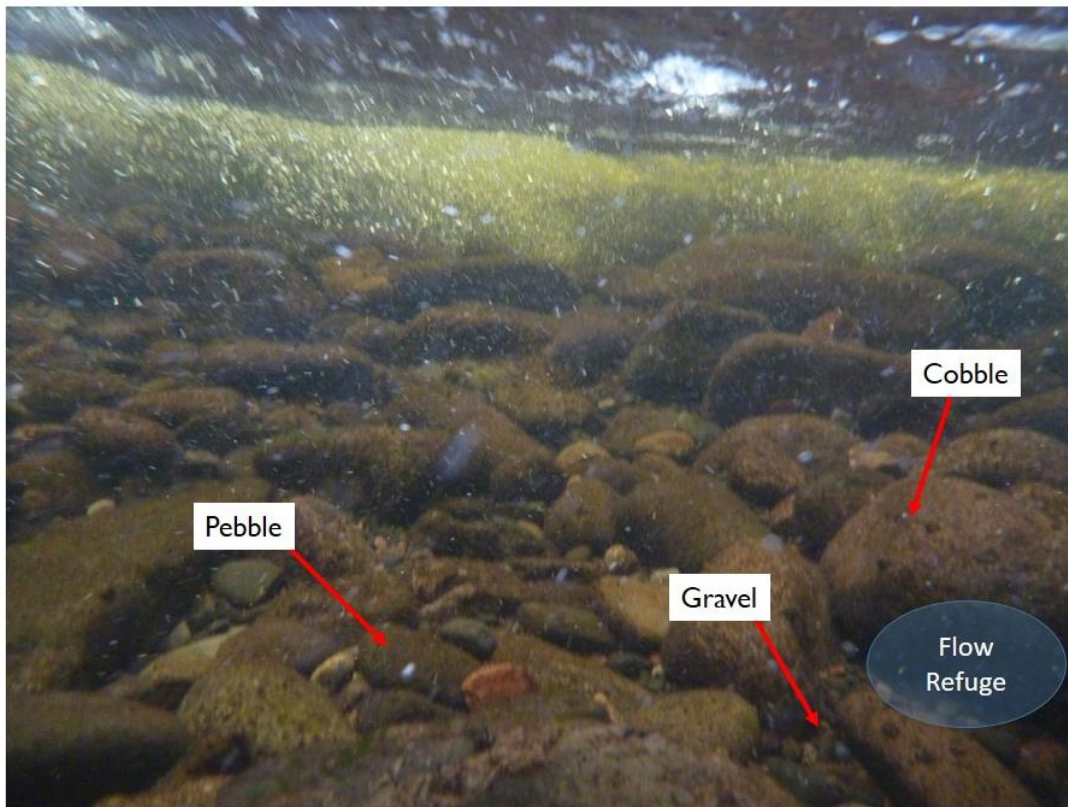


Figure 5. Underwater view of riffle habitat in Gallant's River of cobble, pebble, and gravel substrate, and an example of flow refuge.

Table 6. Physical habitat parameters calculated for each CABIN site.

Habitat Parameter	Channel		Substrate (100 Rock Count)								Hydraulics		
	Stream gradient	Canopy Coverage	D50 (Median Size)	Substrate Composition (100 Rock Count)					Fry Suitability	Parr Suitability	Embeddedness	Average Depth	Average Velocity
				Cobble (64-256 mm)	Pebble (16-64 cm)	Gravel (2-16 mm)	Sand (1-2 mm)	Silt+Clay (<1 mm)					
Optimal range	0.5-1.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	16-256	64-512	<50	Fry: 0.15-0.25 Parr: 0.15-0.25 or >	Fry: >0.4 Parr: 0.2-0.4 Benthics: 0.3-0.69
Unit	%	%	mm	%	%	%	%	%	mm	mm	%	m	m/s
BIG01	0.30	1-25	60	43	47	10	0	0	Optimal	Sub-optimal	25%	0.31 (0.14-0.45)	0.55 (0.34-0.75)
BIN01	0.41	1-25	52.5	34	59	5	1	0	Optimal	Sub-optimal	25%	0.43 (0.2-0.75)	0.58 (0.48-0.76)
GAL01	2.23	26-50	87.5	76	20	4	0	0	Optimal	Optimal	25%	0.29 (0.16-0.38)	0.63 (0.26-0.86)
ING01	1.59	76-100	87.5	62	35	3	0	0	Optimal	Optimal	25%	0.28 (0.24-0.31)	0.57 (0.51-0.80)
LOL01	1.23	26-50	45	28	64	8	0	0	Optimal	Sub-optimal	50%	0.27 (0.07-0.45)	0.53 (0.33-0.83)
NS01FB0011	0.16	1-25	20	0	81	19	0	0	Optimal	Sub-optimal	25%	0.38 (0.21-0.59)	0.36 (0.3-0.5)

4.2 Benthic Macroinvertebrates

Overall, sites supported sensitive benthic macroinvertebrates with community composition reflecting **very good** to **excellent** stream health (Table 7). A total of 55 *families* were confirmed among sites and consisted of mostly insects (Appendix 3). Quantities of benthic macroinvertebrates varied from 1192 at Ingram's, to as many as 5433 at Mount Pleasant Brook. The most common families found among sites (in order of abundance) were Lepidostomatidae, Elmidae, Chironomidae, and Heptageniidae, with taxa ranging from very sensitive Rhithrogena (mayfly) to more tolerant genera of Chironomidae (midge). While all sites had good representation of EPT taxa, there was indication of poorer water quality.

Table 7. Calculated benthic macroinvertebrate for 2016 CABIN sites. EPT=Ephemeroptera, Plecoptera, Trichoptera. DF=Dominant Family. FBI= Modified Family Biotic Index (Hilsenhoff), Diversity=Simpson's Index of Diversity. Values highlighted in **orange** suggest possible impairment.

Index	BIG01	BIN01	GAL01	ING01	LOL01	NS01FB0011
# Individuals	3838	4343	4543	1192	5100	5433
Family Richness	27	19	16	26	20	21
# EPT* Families	14	11	12	13	12	12
# E* Families	5	5	4	4	3	4
# P* Families	2	3	3	4	4	3
# T* Families	7	3	5	5	5	5
% EPT*	69.7	78.3	77.4	76.1	48.4	36.5
% Chironomidae	16.0	10.9	20.1	17.4	35.3	24.5
% Oligochaeta	4.23	0.99	0.00	0.00	0.98	2.45
% DF*	16.6	29.6	21.4	21.9	35.3	31.6
DF*	Lepidostomatidae	Lepidostomatidae	Lepidostomatidae	Baetidae	Chironomidae	Elmidae
FBI*	3.46	2.98	3.21	3.60	4.01	3.92
Diversity*	0.95	0.87	0.90	0.93	0.92	0.89
FBI Assessment	Excellent	Excellent	Excellent	Very Good	Very Good	Very Good

The average family richness among sites was 21, with a minimum of 16 at Gallant's and maximum of 27 at Big Brook. EPT families contributed roughly half of the family richness at all sites, ranging from 11 at Big Intervale to 14 at Big Brook. According to Barbour et al. (1992) streams with EPT diversity of more than 10 suggests excellent quality. The most abundant EPT taxa include genera from the caddisfly families' Lepidostomatidae (*Lepidostoma*) and Hydropsychidae (*Ceratopsyche*), and mayflies from the Ephemerellidae (*Ephemerella*), Heptageniidae (*Rhithrogena*), and Leptophlebiidae (*Paraleptophlebia*) families (Table 8). All of these EPT taxa (except for *Ceratopsyche*, a more tolerant net-spinning caddisfly) are very sensitive to pollution that depend on leaves and other organic matter as a food source. The high abundance of *Lepidostoma*, a leaf shredding caddisfly, suggests ample leaf litter entering from surrounding forests and riparian areas.

Table 8. List of families of Ephemeroptera, Plecoptera, and Trichoptera found among MSA 2016 CABIN samples. Highlighted families indicate EPT taxa are most abundant among samples.

Ephemeroptera	Plecoptera	Trichoptera
Ameletidae	Capniidae	Brachycentridae
Baetidae	Chloroperlidae	Glossosomatidae
Ephemerellidae	Leuctridae	Helicopsychidae
Heptageniidae	Perlidae	Hydropsychidae
Leptohyphidae	Perlodidae	Hydroptilidae
Leptophlebiidae	Pteronarcyidae	Lepidostomatidae
	Taeniopterygidae	Leptoceridae
		Philopotamidae
		Polycentropodidae
		Rhyacophilidae

The proportion of pollution tolerant and intolerant organisms within a sample provides an indication of stream quality. High relative abundance of EPT families is a useful metric with greater than 50 percent EPT (% EPT) indicating healthy streams (University of Puget Sound, n/a). Big Intervale, Big Brook, Ingram's and Gallant's River were predominantly EPT taxa (~70%), while Lake O'Law and Mount Pleasant Brook were below 50%. Mount Pleasant Brook had the lowest %EPT, the second highest percentage of chironomidae (midges), and the moderately tolerant Elmidae (riffle beetle) as the dominant family. This site also had the highest number of uncommon taxa (only found at one site). These include the unusually abundant and sensitive chironomid *Stempellina* that constructs its case out of sand, and several periphyton-grazing taxa such as *Stenelmis*, *Psephenus*, and *Helicopsyche* (also makes sand case). Lake O'Law Brook had a better %EPT at 48.4%, but the dominant family was chironomidae suggesting a potential stressor upstream of this location. It is also worth noting that Big Brook and Mount Pleasant Brook had slightly more worms than other sites, and that Big Brook was the only site that had the highly tolerant worm family Enchytraeidae. Furthermore, the taxa that contributed to the higher EPT richness at Big Brook were from more tolerant caddisfly (Polycentropodidae) and mayfly (Leptohyphidae) families.

The overall diversity of benthic assemblages was determined using the Simpson's Index, with zero indicating low diversity and one indicating high diversity (Table 7). Simpson's index values were found to be above 0.87 for all sites, indicating a high level of diversity among samples. The highest diversity scores were found at Big Brook (0.95), Ingram's (0.93), and Lake O'Law (0.92). This may be related to the presence of several uncommon taxa at each of these locations and the presence of bryophytes (mosses) and/or periphyton. Though not part of the CABIN protocol, submerged bryophytes were observed growing on rocks in Ingram's and Lake O'Law brooks (Figure 6). At these sites, uncommon moss-preferring insects were found including the net-spinner caddisfly *Parapsyche*, *Pericoma* moth fly, and *Chelifera* dance fly at Ingram's Brook, and the giant stonefly *Pteronarcys* at Lake O'Law. Aquatic mosses are a qualitative indicator of stream stability (Michigan Department of Environmental Quality, 2008), however, they are also able to take up significant amounts of nutrients (Alan & Castillo, 2007). Aquatic

periphyton (a mix of algae, bacteria, microbes, and detritus) provides habitat and a food source for certain benthic macroinvertebrate feeding groups, however can also be an indication of nutrient pollution (Biggs et al., 2002). Periphyton was identified as more abundant at Big Brook (Figure 4), Lake O'Law, Mount Pleasant, and Ingram's.



Figure 6. Aquatic bryophytes (moss) coverage on rocks at Lake O'Law (left) and Ingram's Brook (right).

Another important measure of stream health is the modified Hilsenhoff family Biotic Index (FBI). It provides an indication of organic pollution based on established tolerance values of benthic macroinvertebrate families (Mandaville, 2002). The resulting values are classified into groups indicating varying degrees of water quality and degrees of organic pollution (Table 9). Lower values indicate less pollution, whereas higher values are associated with organic pollution. The FBI values ranged between 'Very Good' and 'Excellent' in the 2016 samples. Based on the FBI index Big Intervale, Big Brook, and Gallant's River were all considered 'Excellent' with no apparent organic pollution. Sampling sites in Ingram's, Lake O'Law, and Mount Pleasant Brook were determined to be 'Very Good' with possible slight organic pollution, suggesting nutrients may be present.

Table 9. Modified Family Hilsenhoff Biotic Index (FBI) values ranges and corresponding water quality and organic pollution levels.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

4.2.6 Atlantic Reference Model (ARM)

Through the ARM modeling process, MSA CABIN sites were compared to five different benthic macroinvertebrate indices (Table 10). By comparing sites from this study with the benthic community of reference sites of similar landscape characteristics, the ARM model can determine whether sites are normal, divergent or highly divergent based on a statistical model (see Appendix 4). The only metric with divergent results was richness, indicating Big Intervale and Mount Pleasant Brook had lower richness values than expected and a possible stressor.

Table 10. ARM modeling results for select indices for MSA's 2016 sites. Shaded orange values indicate metrics falling into divergent category.

Site	Metric Observed/Expected (O/E)				
	Richness	Berger_Parker	Simpson	Pielou	Shannon
BIG01	1.093884461	1.481745351	1.237330831	1.303519376	1.328715734
BIN01	0.838190009	1.103105545	1.072345652	1.119389888	1.052781639
GAL01	0.976528819	1.253948949	1.101204533	1.144899245	1.043165477
ING01	1.158548615	1.200838267	1.11435433	1.173554709	1.15757539
LOL01	0.982842662	1.20943193	1.130994471	1.116864428	1.095940562
NS01FB0011	0.763093636	1.222287715	1.096774098	1.030313657	1.024286392
Normal	>0.95	>0.77	>0.96	>0.92	>0.91

4.3 Water Quality

4.3.1 In-situ Sonde Measurements

Water quality measurements were collected using a multi-parameter sonde (*ProDSS*) at the upstream end of each site prior to entering the water. Water (and air) temperature, pH, specific conductance, and dissolved oxygen (DO) were collected (Table 11). Water temperatures were 10.4 °C on average, ranging from 8.1 °C at Ingram's to 11.9 °C at Big Brook. Dissolved oxygen concentrations averaged 11.0 mg/L with all sites measuring above the 9.5 mg/L threshold for juvenile cold water fishes (CCME, 2007). Specific conductivity was below 100 µS/cm at Big Intervale, Ingram's, and Gallant's, and above 100 µS/cm at Big Brook, Lake O'Law, and Mount Pleasant Brook. The latter are underlain by roughly 50% or more sedimentary rocks which are more prone to weathering and may contribute to higher conductivity values.

Table 11. In-situ water quality measurements collected with ProDSS sonde at 2016 Margaree CABIN sites. pH measurements from ProDSS not included (except for Mount Pleasant Brook) due to issues with UINR's pH sensor.

Site ID	Date	Time	Air Temperature	Water Temperature	pH	Specific Conductance	Dissolved Oxygen
			°C	°C	units	µS/cm	mg/L
BIG01	27/09/2016	13:46	15.0	11.9	-	105.1	10.3
BIN01	27/09/2016	10:46	12.0	9.3	-	50.8	11.6
GAL01	28/09/2016	10:49	14.0	9.9		74.3	11.6
ING01	27/09/2016	12:06	12.0	8.1	-	69.1	11.5
LOL01	27/09/2016	14:37	12.0	11.6	-	117.2	10.7
NS01FB0011	18/10/2016	n/a	12.0	11.7	7.20	123.1	10.6

4.3.2 Water Chemistry

Water chemistry was determined to be neutral to slightly basic among sites. Values ranged from 7.0 to 7.5 and fell within the recommended guidelines for protection of aquatic life (6.5-9.5) (CCME, 2007). The majority of parameters and sites did not exceed any of the available guidelines, with the exception of Lake O'Law Brook where total phosphorus slightly exceeded the 0.03 mg/L guideline (Table 12). Though no metals exceeded guidelines, concentrations did vary among sites likely reflecting the geological, soil, and vegetation diversity of the upstream drainage areas in this study.

All sites had varying concentrations of Aluminum, Barium, Calcium, Iron, Manganese, Magnesium, Potassium, Sodium, and Strontium. Overall, metals were low among sites with the exception of Calcium and Sodium, which are common and abundant in the Earth's crust and higher with certain sedimentary rock types (Windsor group especially). Due to lower detection limits used by the ALET laboratory, several additional metals were found in low concentrations at Big Intervale including Antimony, Arsenic, Beryllium, Chromium, Copper, Lead, Molybdenum, Nickel, Selenium, Vanadium, and Zinc. Though not found at other sites, it is possible that these metals could have been present but below the detection

limits used by the Maxxam laboratory. Other notable metals include Boron at Big Brook and Big Intervale, Cadmium at Big Intervale, Ingram's Brook, and Lake O'Law, Silver at Ingram's, and Titanium at Lake O'Law.

Big Brook and Big Intervale were the only sites with Windsor group geology in their upstream watersheds (in small amounts). Windsor group and other carboniferous sedimentary rock types (e.g. Horton group) are easily weathered and often associated with higher levels of ions, metals, and sulphates. Water samples from these sites were not strongly indicative of these characteristics, although Big Brook did have the highest concentrations of Calcium and Magnesium. In general, sulphates were only detected at sites with sedimentary rocks (all except Ingram's), and the sites with the highest proportion of sedimentary rocks also had the highest concentrations of sulphate.

Measured nutrients were nitrate and total phosphorus. The maximum nitrate concentration at the time of sampling was 0.13 mg/L at Lake O'Law, which is still far below the guideline of 3 mg/L. However Lake O'Law slightly exceeded the total phosphorus guideline (0.03 mg/L) at a concentration of 0.31 mg/L, and Big Brook and Ingram's came close to exceeding it (0.025 and 0.028 respectively). Based on total phosphorus, Big Brook, Ingram's, and Lake O'Law Brook are considered mesotrophic (moderately productive), while Big Intervale and Gallant's are considered oligotrophic (nutrient-poor) (Dodds et al., 1998). Sources of phosphorus include agriculture, stream bank and soil erosion, atmospheric deposition, certain rock types (apatite), storm water runoff, wastewater, and seepage from septic systems (MPCA, 2017). As a limiting source of nutrients, excessive phosphorus loading may lead to eutrophication (i.e., excessive algae and periphyton growth). However, streams may experience a period of increased productivity due to increased food availability. Determining whether the levels observed in this study are naturally occurring or from anthropogenic sources would require further research.

Table 12. Lab results for water samples taken during CABIN assessments. Parameters shaded in dark grey do not have established guidelines. Columns shaded in light grey indicate parameter detection limits for each respective laboratory. Values highlighted in **red** indicate guideline exceeded. Values highlighted in yellow indicate metals.

Parameter	Guidelines(s)		Units	MSA CABIN SITES 2016					
				Maxxam				ALET	
	Short Term	Long Term		Detection Limit	BIG01	GAL01	ING01	LOLO1	Detection Limit
Alkalinity	n/a		mg/L	5.0	25	19	10	21	20.0
Aluminum	n/a		mg/L	0.005	0.076	0.07	0.14	0.12	0.0015
Antimony	n/a		mg/L	0.001	ND	ND	ND	ND	0.00002
Arsenic	0.005		mg/L	0.001	ND	ND	ND	ND	0.00002
Barium	n/a		mg/L	0.001	0.026	0.0049	0.004	0.018	0.0001
Beryllium	n/a		mg/L	0.001	ND	ND	ND	ND	0.000005
Boron	n/a		mg/L	0.05	0.025	ND	ND	ND	0.001
Cadmium	1	0.09	mg/L	0.00001	ND	ND	0.000013	0.000038	0.00001
Calcium	n/a		mg/L	0.1	12	5.4	4.8	10	0.01
Chromium	n/a		mg/L	0.001	ND	ND	ND	ND	0.00002
Cobalt	n/a		mg/L	0.0004	ND	ND	ND	ND	0.00002
Colour	narrative		Colour Units	10.0	41	28	52	19	5.0
Conductivity	n/a		µS/cm	1.0	100	70	66	110	0.5
Copper	0.002		mg/L	0.002	ND	ND	ND	ND	0.0001
Dissolved Chloride	640	120	mg/L	1.0	8.6	10	14	15	0.04
Hardness	n/a		mg/L	1.0	38	19	16	32	-
Iron	0.3		mg/L	0.05	0.097	0.055	0.088	0.2	0.0005
Lead	$(e^{1.272 \cdot \ln[\text{hardness}] - 4.705}) \times 0.001$		mg/L	0.0005	ND	ND	ND	ND	0.00003
Magnesium	n/a		mg/L	0.1	1.9	1.2	0.85	1.5	0.002
Manganese	n/a		mg/L	0.002	0.012	0.039	0.002	0.021	0.0002
Molybdenum	n/a		mg/L	0.002	ND	ND	ND	ND	0.00002
Nickel	$(e^{0.76 \cdot \ln[\text{hardness}] + 1.06}) \times 0.001$		mg/L	0.002	ND	ND	ND	ND	0.00005
Nitrate	3		mg/L	0.05	0.053	0.11	0.1	0.13	0.02
Nitrogen*	n/a		mg/L	0.05	ND	ND	ND	ND	0.02
pH	6.5-9.0		pH units	0.0	7.3	7.5	7	7.4	0.0
Phosphorus -Total	0.03		mg/L	0.02	0.025	ND	0.028	0.031	0.002
Potassium	n/a		mg/L	0.1	0.48	0.42	0.39	0.65	0.05
Selenium	0.001		mg/L	0.001	ND	ND	ND	ND	0.00003
Silver	0.25		mg/L	0.0001	ND	ND	0.0001	ND	0.000005
Sodium	n/a		mg/L	0.1	7	6.7	6.3	8.9	0.02
Strontium	n/a		mg/L	0.002	0.053	0.024	0.059	0.076	0.00015
Sulphate	n/a		mg/L	2.0	17	2.1	ND	16	0.2
Thallium	0.8		mg/L	0.0001	ND	ND	ND	ND	0.00002
Tin	n/a		mg/L	0.002	ND	ND	ND	ND	0.00002
Titanium	n/a		mg/L	0.002	ND	ND	ND	0.005	-
Total Dissolved Solids	n/a		mg/L	1.0	68	44	42	71	-
Total Organic Carbon	n/a		mg/L	0.5	5.4	4	5.2	2	0.25
Turbidity	narrative		NTU	0.1	0.71	0.26	0.19	2.6	0.1
Uranium	0.033	0.015	mg/L	0.0001	0.0001	ND	0.00011	0.00013	0.000005
Vanadium	n/a		mg/L	0.002	ND	ND	ND	ND	0.00002
Zinc	0.0075**		mg/L	0.005	ND	ND	ND	ND	0.0002

(-) indicates parameters not analyzed by laboratory.

(n/a) no guideline available for parameter.

(ND) indicates parameter not detected (i.e., below reportable detection limit).

() Calculated site specific guideline

*Nitrogen measured as Ammonia Nitrogen for Maxxam, Total Nitrogen for ALET

**Zinc guideline for hardness <90 mg [CaCO₃]/L

***Hardness not provided by laboratory, calculated using equation Hardness =Ca(mg/L)×2.497 + Mg(mg/L)×4.118

5.0 Integrated Analysis

5.1 Big Brook

Big Brook fell in the Excellent FBI category, indicating a lack of organic (nutrient) pollution. Nitrate concentrations were among the lowest observed among sites, but total phosphorus approached the guideline at 0.025 mg/L falling on the border of oligotrophic and mesotrophic, indicating poor to moderate productivity. High %EPT and diversity suggest a healthy stream. The dominant sensitive leaf-shredding caddisfly, Lepidostomatidae, suggests adequate leaf litter coming from upstream forests and riparian areas. Periphyton was noticeable at this site, which is consistent with phosphorus concentrations. Though otherwise healthy, some taxa suggest a stressor is present at the site. These include the observed higher proportion of worms than other sites, including the highly tolerant family Enchytraeidae. Less sensitive EPT taxa including the net spinning caddisfly Polycentropodidae and the Tricorythodes (trico) mayfly were also exclusive to this site. Lack of canopy coverage and leaning trees along banks may be an indication of impairment (bank erosion), and can also be a source of phosphorus. Low stream gradient may be natural given the topography of this area or may be an indication of a physical habitat stressor. Pebble was the dominant substrate (47%) indicating more optimal substrate is available for fry than parr, however there is still significant cobble present for parr (43%). Substrate was minimally embedded (25%), however fine material (sand) was visually observed in interstitial spaces which could affect habitat availability. Suitable depths were present for both fry and parr, though some deeper areas are more suitable for parr. Velocities were more optimal for fry, though cobble could provide habitat for parr. Velocities ideal for benthic macroinvertebrates.

Overall Assessment: **Possibly impaired stream health**, some indication of potential water quality and/or physical habitat stressors. Suitable juvenile salmon habitat present for both life stages and benthic macroinvertebrates, though not 100% optimal. Although stream health is overall excellent, there is evidence suggesting mild impairment.

5.2 The Northeast at Big Intervale

The Northeast at Big Intervale scored excellent having the lowest FBI score of all sites, suggesting a lack of organic (nutrient) pollution. This result is consistent with oligotrophic conditions indicated by low levels of nutrients and minimal periphyton. Lower laboratory detection limits for water samples analyzed by ALET revealed diverse metals, but none exceeded any available guidelines. The dominant leaf-shredding and sensitive caddisfly suggests ample leaf supply coming from upstream forest and riparian areas. Though still high, this site had the lowest diversity score (0.87) which is consistent with the divergent ARM result for richness suggesting a possible stressor. Substrate was optimal for fry, and sub-optimal for parr with pebble being the dominant substrate (59%), though cobble was present (34%). Depths were suitable for both fry and parr, though some deeper areas more suitable for parr. Velocities were more optimal for fry than parr though cobble substrate could provide refuge for parr, and were in the ideal range for benthic macroinvertebrates. Substrate was only 25% embedded on average suggesting good availability of interstitial habitat, although sand was present which could limit habitat availability for

benthic macroinvertebrates. Low gradient, lack of canopy coverage, and a wide channel may be natural to this stream type, though could be an indication of a physical habitat stressor.

Overall Assessment: **Likely unimpaired stream health**, some indication of possible physical habitat stressor(s). Suitable juvenile salmon habitat present for both life stages and benthic macroinvertebrates, though not 100% optimal.

5.3 Gallant's River

Gallant's River scored in the Excellent FBI category, suggesting a lack of organic (nutrient) pollution. Low nutrient concentrations and minimal periphyton indicate oligotrophic conditions, consistent with the FBI score. There were no apparent water quality issues according to the water chemistry results. %EPT value was among highest of all sites, and dominant family was the sensitive leaf-shredding caddisfly *Lepidostoma* suggesting good amounts of leaf litter from upstream forest and riparian areas. Substrate was predominantly cobble (76%), optimal for both fry and parr. Substrate was relatively unembedded (25%) indicating availability of habitat for benthics and salmon fry. Stream gradient was highest at this site (outside optimal range for salmon) which may be normal for this stream type given the topography of the upstream watershed, although could be an indication of physical habitat stressor. Canopy coverage was in the 25-50% range, however leaning trees may indicate stream bank erosion. Depths were suitable for both fry and parr and velocities more suitable to fry. Velocities fell into ideal range for benthic macroinvertebrates, with some areas slightly above and below ideal range, and could support different taxa.

Overall Assessment: **Likely unimpaired stream health**, some indication of possible physical habitat stressor(s). Suitable juvenile habitat present for both life stages and benthic macroinvertebrates. The site had among the most optimal parameters for salmon, though not 100 % optimal.

5.4 Ingram's Brook

Ingram's Brook scored in the lower range of the Very Good category, indicating possible slight organic pollution at this site. Nitrate levels were low, however phosphorus approached Protection of Aquatic Life guideline (0.03 mg/L) at 0.028 mg/L. Total phosphorus concentrations and significant periphyton coverage on rocks indicate mesotrophic conditions that are consistent with the FBI finding. No other water parameters exceeded available guidelines. %EPT was high, however the dominant family was the minnow mayfly (*Baetidae*), a comparatively less sensitive family of mayfly (ranging from 4-6 tolerance score). The genus *Baetis* was present, a collector-gatherer mayfly that feed off fine particulate organic matter on the stream bed, or in the aquatic mosses observed throughout the site. Significant canopy coverage from the adjacent riparian zone provides shade and cover for fish, and may contribute to the cool water at this site (lowest of all sites, 8.1°C). Substrate was predominantly cobble (62%) followed by pebble and gravel, indicating optimal habitat for both fry and parr. Substrate was minimally embedded (25%) indicating good availability of interstitial habitat for benthics and fry. Depths were suitable for both fry and parr, but velocities more optimal for fry though abundant cobble would provide habitat for parr. Velocities fall within ideal range, though some areas are above and may support different taxa that prefer that habitat. Presence of moss may indicate stream stability and/or mesotrophic conditions.

Overall Assessment: **Likely unimpaired stream health**, some indication of possible water quality and/or physical habitat stressor. Suitable juvenile habitat present for both life stages and benthic macroinvertebrates. The site had among the most optimal parameters for salmon, though not 100%.

5.4 Lake O'Law Brook

Lake O'Law scored in the Very Good category and had the highest FBI score (4.01), indicating possible slight organic pollution. Nitrate levels were low, but phosphorus exceeded the Protection of Aquatic life guideline (0.03 mg/L) at 0.031 mg/L and periphyton was also very noticeable. These findings are consistent with the FBI score suggesting mesotrophic conditions. No other water parameters exceeded guidelines. % EPT was the second lowest of all sites at 48.4%, with chironomidae as the dominant family at 35.3%. Chironomidae are an overall pollution tolerant group that are usually indicators of poorer water quality. However the site does support sensitive EPT taxa, including the giant stonefly *Pteronarcys* that was only found at this location. This could have been related to abundant moss coverage, which provides habitat and feeding opportunities for some EPT and chironomidae taxa. Though beneficial to certain taxa and is an indicator of stream stability, abundant moss could indicate incoming nutrients from Lake O'Law (natural and/or anthropogenic). Furthermore, flows at this site may be naturally regulated to an extent by Lake O'Law and could influence substrate embeddedness. The site had a good amount of canopy coverage from the riparian area, however riprap had been installed for adjacent property protection likely leading to erosion of the bank downstream. Dominant substrate was pebble and was more optimal for fry than parr, though there was a good amount (28%) of cobble present that would be suitable for parr. Depths fell in the optimal range for both fry and parr, though some areas of the stream were shallow for both life stages, and some deeper areas more optimal for parr. Velocities were more suitable for fry than parr, with some areas having higher velocities more suitable to fry. Velocities were in the ideal range for benthic macroinvertebrates, with some areas having higher velocity that could support different taxa.

Overall Assessment: **Possibly impaired stream health**, some indication of possible water quality and/or physical habitat stressors. Suitable salmon habitat was present for both life stages and benthic macroinvertebrates, though not 100% optimal.

5.4 Mount Pleasant Brook (Southwest)

Mount Pleasant Brook FBI score fell in the Very Good category indicating possible slight organic pollution. Water chemistry data was not available for this site, though the water quality probe measurements indicate similar conductivity values to Big Brook and Lake O'Law. Although periphyton was identified as minimal by ECCC, photographs indicate it was present to a greater extent. This section of stream lacked canopy coverage and was below the optimal stream gradient for salmon (0.16%). The reach also had a substantially larger floodplain and different riparian vegetation characteristics than other locations, which could be consistent with the low-lying physiography of the Southwest Margaree. The %EPT was the lowest of all sites at 36.5%. The moderately tolerant scraping beetle Elmidae was the dominant family which is consistent with the noticeable presence of periphyton in site photos. Taxa unique to this site include two insects that use sand to construct their cases (*Helicospyche* and

Stempellina), and several taxa typical of somewhat larger slower moving sites including *Stenelmis*, *Psephenus*, *Helicopsyche*, *Ophiogomphus* and *Paragnetina*. This site was determined to be divergent for richness according to the ARM model indicating a possible stressor. Substrate was comparatively small, dominated by pebble sized material, with the dominant surrounding material coarse sand. Substrate is within the optimal range for fry (though on the lower end) and was not optimal for parr due to lack of larger rocks. Substrate was determined to be 25% embedded, though coarse sand surrounding the pebbles may limit available habitat space. Depths were optimal for both fry and parr, though some areas were too deep for fry. Velocities were slightly more suitable for parr (slower), though there were areas with higher velocities more preferable for fry. Velocities fell within the lower end of the ideal range for benthic macroinvertebrates, and possibly support taxa that live in slower moving habitats which is consistent with the unique community observed at this location.

Overall Assessment: **Possibly impaired stream health**, some indication of possible water quality and/or physical habitat stressors. Overall sub-optimal habitat for salmon, lower end of suitable range for fry, and not optimal for parr. The benthic macroinvertebrate community reflects different habitat characteristics than found at other sites in the Margaree.

5.0 SUMMARY & CONCLUSIONS

Stream health was evaluated at six locations throughout the Margaree watershed using benthic macroinvertebrates, water chemistry, and physical habitat as parameters. Although this study did not include all variables that drive aquatic ecosystems (for example, land-use), the data collected provides valuable information to contribute to a current understanding of habitat in the Margaree watershed. Stream health was determined to be likely unimpaired at three sites, and varying degrees of possible impairment at the remaining three sites. All locations had some indication of possible water quality and/or physical habitat stressors. Juvenile salmon habitat was available for both life fry and parr life stages at the majority of sites, though no one site had completely optimal habitat.

Sites in this study varied in their characteristics ranging from higher gradient shaded tributaries to mildly sloping low-lying reaches, illustrating the diverse landscape of the Margaree watershed. Though there were differences, common themes emerged through this assessment. Streams were largely a mix of relatively unembedded cobble and pebble sized substrate, surrounded by gravel and to some extent sand. This suggests that, though not 100% optimal according to Gibson et al. (2013), the physical habitat space required for both juvenile life stages and benthic macroinvertebrates is present at most sites. The exception was at Mount Pleasant Brook, which lacked cobble required for parr and supported a distinct benthic community despite being very similar geologically to the adjacent Big Brook. Though CABIN can help determine the **presence** of suitable substrate conditions, the data does not fully reflect the quantity, quality, or distribution of micro-habitat at these locations. This would require a more targeted habitat assessment.

Overall, there was some indication of possible water quality and/or physical habitat stressors at all locations. Indicators of possible water quality stressors included abundance of periphyton and submerged bryophytes, somewhat elevated levels of total phosphorus, presence of pollution tolerant organisms, and low proportions of EPT taxa. Evidence of possible physical habitat stressors observed included slightly embedded substrate, and indicators of potentially accelerated stream bank erosion rates such as leaning trees, exposed roots and banks, and widening. However, presence of these indicators does not necessarily imply impairment or severe habitat degradation. The Northeast at Big Intervale, Ingram's, and Gallant's River support a healthy benthic macroinvertebrate community reflecting clean water, adequate food supply, and good substrate, though Big Intervale was slightly divergent for richness in the reference model. This suggests that the effects of stressors (if present) exerted on these locations have not yet reached a threshold where significant impacts to the aforementioned qualities have occurred. Conversely, Big Brook, Lake O'Law Brook, and Mount Pleasant Brook demonstrated multiple lines of evidence that suggest water quality, food sources, and substrate conditions have been impacted to a certain degree. Though Big Brook had a high percentage of healthy EPT organisms, other more tolerant taxa were present that were not found at likely unimpaired sites. Further investigation into upstream land use (past and present) and additional CABIN sampling could help determine whether these sites are impaired relative to reference sites, and understand natural variability of phosphorus in the area.

Based on the integrated assessment of CABIN sampling presented in this report, stream health was determined to be **very good** to **excellent** with some indication of stressors at all sites. The Northeast

Margaree at Big Intervale, Gallant's River, Ingram's Brook were determined to be **likely unimpaired**; while results of Big Brook, Lake O'Law Brook and Mount Pleasant Brook suggest **possible impairment**. Upstream land-use and other possible stressors should be considered at all sites, regardless of impairment status determined in this study. As pressure on watersheds is expected to increase with climate change, focusing on limiting anthropogenic stressors will be critical to facilitating resiliency in these rivers and streams.

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APPENDICES

Appendix 1. CABIN field gear equipment list.

CABIN FIELD GEAR
General Equipment
Field sheets and clipboard
Pencils and markers
Gloves (rubber, neoprene)
Waterproof labels
Labelling tape
Ziploc bags
Duct tape and tool kit
Location and Reach data
GPS
Camera
Densimeter
Channel and Substrate characteristics
Velocity metre OR Meter stick
Measuring Tape
15 or 30cm ruler
Hand Level
Calculator
Tent pegs
Water chemistry sampling
Water quality metres (Temp, pH, DO, Conductivity, turbidity)
Cooler with sample bottles and ice pack
Extra batteries
Benthic Sampling
Kicknet
Stopwatch
Sieve
White tray
Squeeze Bottle
Spoon/tweezers
Bucket
Sample jars
Formalin with MSDS, gloves and glasses
Cooler for sample jars & Formalin
Safety equipment
Lifejackets
First aid kits (field and vehicle)
Cell phone or Satellite phone
Swift water helmet
Throw bags
Waders, boots, raingear
Sunscreen, hat, bug spray

Appendix 2. Water quality/chemistry parameters and guidelines.

*Canadian Council of the Ministers of the Environment guidelines for the Protection of Aquatic Life

**Canadian Environmental Sustainability Indicators

Parameter	Guidelines(s)		Units	Notes	Source
	Short Term	Long Term			
Alkalinity	n/a		mg/L		
Aluminum	n/a		mg/L		
Antimony	n/a		mg/L		
Arsenic	0.005		mg/L		CCME-POAL*
Barium	n/a		mg/L		
Beryllium	n/a		mg/L		
Boron	n/a		mg/L		
Cadmium	1	0.09	mg/L	Short term, long term	CCME-POAL*
Calcium	n/a		mg/L		
Chromium	n/a		mg/L		
Cobalt	n/a		mg/L		
Colour	narrative		Colour Units		
Conductivity	n/a		µS/cm		
Copper	0.002		mg/L	< 90 mg [CaCO ₃]	CESI**
Dissolved Chloride	640	120	mg/L		CCME-POAL*
Hardness	n/a		mg/L		
Iron	0.3		mg/L		CESI**
Lead	e1.273*ln[hardness]-4.705		mg/L	Site specific	CESI**
Magnesium	n/a		mg/L		
Manganese	n/a		mg/L		
Molybdenum	n/a		mg/L		
Nickel	e0.76*ln[hardness]+1.06		mg/L	Site specific	CESI**
Nitrate	3		mg/L		CESI**
Nitrogen Total	n/a		mg/L		
pH	6.5-9.0		pH units		CCME-POAL*
Phosphorus -Total	0.03		mg/L		CESI**
Potassium	n/a		mg/L		
Selenium	0.001		mg/L		CCME-POAL*
Silver	0.25		mg/L	Long term	CCME-POAL*
Sodium	n/a		mg/L		
Strontium	n/a		mg/L		
Sulphate	n/a		mg/L		
Thallium	0.8		mg/L		CCME-POAL*
Tin	n/a		mg/L		
Titanium	n/a		mg/L		
Total Dissolved Solids	n/a		mg/L		
Total Organic Carbon	n/a		mg/L		
Turbidity	narrative		NTU		
Uranium	0.033	0.015	mg/L	Short term, long term	CCME-POAL*
Vanadium	n/a		mg/L		
Zinc	0.0075		mg/L	< 90 mg [CaCO ₃]	CESI**

Appendix 3. Benthic macroinvertebrates identified and their FBI tolerance values (Mandaville, 2002).

Class	Order	Family	Tolerance Value
Bivalvia	Veneroida	Pisidiidae	8
Arachnida	Sarcoptiformes	Sarcoptiformes	n/a
Arachnida	Trombidiformes	Aturidae	6
Arachnida	Trombidiformes	Feltriidae	6
Arachnida	Trombidiformes	Hydryphantidae	6
Arachnida	Trombidiformes	Hygrobatidae	6
Arachnida	Trombidiformes	Lebertiidae	8
Arachnida	Trombidiformes	Sperchontidae	8
Arachnida	Trombidiformes	Torrenticolidae	6
Gastropoda	Basommatophora	Physidae	8
Gastropoda	Basommatophora	Lymnaeidae	6
Gastropoda	Heterostrophia	Valvatidae	8
Insecta	Coleoptera	Elmidae	4
Insecta	Coleoptera	Psephenidae	4
Insecta	Diptera	Athericidae	2
Insecta	Diptera	Ceratopogonidae	6
Insecta	Diptera	Chironomidae	7
Insecta	Diptera	Empididae	6
Insecta	Diptera	Simuliidae	6
Insecta	Diptera	Tipulidae	3
Insecta	Diptera	Psychodidae	10
Insecta	Ephemeroptera	Ameletidae	0
Insecta	Ephemeroptera	Baetidae	4
Insecta	Ephemeroptera	Caenidae	6
Insecta	Ephemeroptera	Ephemerellidae	1
Insecta	Ephemeroptera	Heptageniidae	4
Insecta	Ephemeroptera	Leptophlebiidae	2
Insecta	Ephemeroptera	Leptohyphidae	4
Insecta	Megaloptera	Corydalidae	0
Insecta	Odonata	Gomphidae	1
Insecta	Odonata	Calopterygidae	5
Insecta	Plecoptera	Capniidae	1
Insecta	Plecoptera	Chloroperlidae	1
Insecta	Plecoptera	Leuctridae	0
Insecta	Plecoptera	Perlidae	1
Insecta	Plecoptera	Perlodidae	2
Insecta	Plecoptera	Pteronarcyidae	0
Insecta	Plecoptera	Taeniopterygidae	2
Insecta	Trichoptera	Apataniidae	3
Insecta	Trichoptera	Brachycentridae	1
Insecta	Trichoptera	Glossosomatidae	0
Insecta	Trichoptera	Goeridae	3
Insecta	Trichoptera	Helicopsychidae	3
Insecta	Trichoptera	Hydropsychidae	4
Insecta	Trichoptera	Hydroptilidae	4
Insecta	Trichoptera	Lepidostomatidae	1
Insecta	Trichoptera	Leptoceridae	4
Insecta	Trichoptera	Limnephilidae	4
Insecta	Trichoptera	Philopotamidae	3
Insecta	Trichoptera	Polycentropodidae	6
Insecta	Trichoptera	Rhyacophilidae	0
Insecta	Trichoptera	Uenoidae	3
Oligochaeta	Haplotaxida	Enchytraeidae	10
Oligochaeta	Haplotaxida	Naididae	8
Oligochaeta	Lumbriculida	Lumbriculidae	5

Appendix 4. ARM model metrics and categories.

Metric (O/E = Observed vs Expected ratio)	Normal	Divergent	Highly divergent
O/E Taxon Richness (R)	>0.95	0.95-0.47	<0.47
O/E Shannon-Wiener diversity index (H)	>0.91	0.91-0.45	<0.45
O/E Simpson Diversity Index (S)	>0.96	0.96-0.48	<0.48
O/E Pielou's Evenness Index	>0.92	0.92-0.46	<0.46
O/E Berger-Parker dominance (D)	>0.77	0.77-0.38	<0.38
O/E Canadian Ecological Index (CEFI)	>0.97	0.97-0.48	<0.48
O/E Hilsenhoff Benthic Index (HBI)	>0.96	0.96-0.48	<0.48

Appendix 5. CABIN site photos, taken looking in the upstream direction.



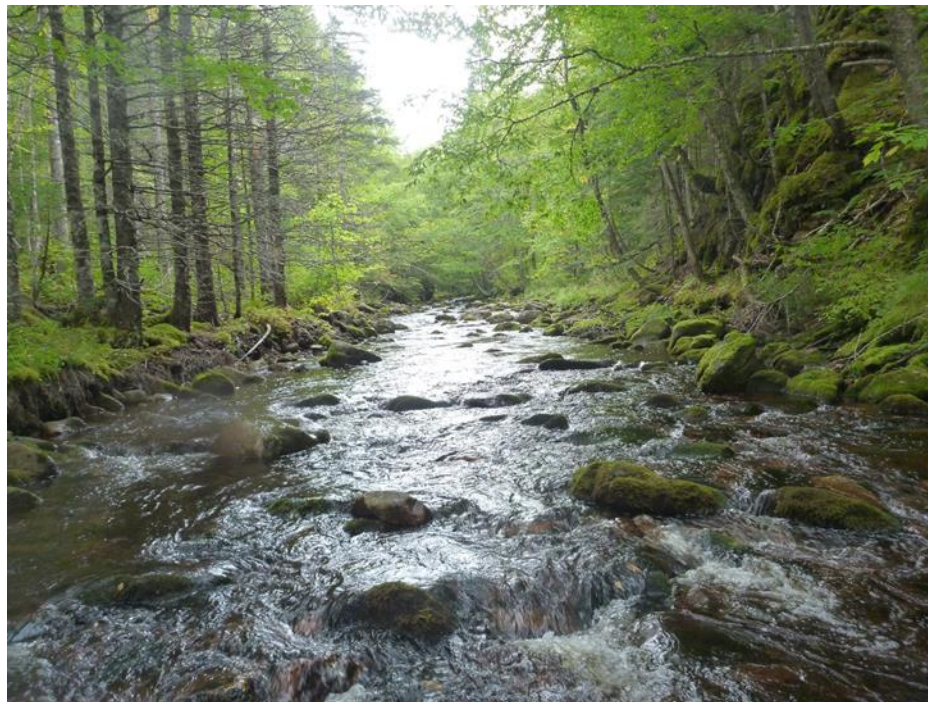
Big Brook (BIG01)



Northeast at Big Intervale (BIN01)



Gallant's River (GAL01)



Ingram's Brook (ING01)



Lake O'Law Brook (LOL01)



Mount Pleasant Brook (NS01FB0011)

Appendix 6. Proposed trophic state classification of rivers and streams (Dodds et al. 1998)

Parameter	Units	Oligotrophic	Mesotrophic	Eutrophic
Mean benthic chlorophyll <i>a</i>	(mg/m ²)	< 20	20-70	> 70
Maximum benthic chlorophyll <i>a</i>	(mg/m ²)	< 60	60-200	> 200
Sestonic chlorophyll <i>a</i>	(µg/L)	< 10	10-30	> 30
TN	(mg/L)	< 0.7	0.7-1.5	> 1.5
TP	(mg/L)	< 0.025	0.025-0.075	> 0.075