WaterShade

Implementation plan on the Restigouche River watershed (NB)

November 2023

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1. Context

Climate change and human activities have resulted in dramatic changes across all ecosystems that Atlantic salmon populations inhabit. causing drastic population declines. Changes in river temperature dynamics (e.g., daily variability, frequency, and duration of summer maximum, warmer thermal regimes) is one of the main concerns as it impacts growth rates, reproductive success, abundance of prey, timing of migration, and survival. During low flows and warmer conditions, thermal heterogeneity becomes essential to the resilience and survival of Atlantic salmon.

The past decade has produced scientific advances in thermal regime understanding and more specifically cold-water refuges (CWR) as key components of thermal heterogeneity, but policy development has not kept pace. The dynamic nature of CWRs makes identification, measurement, protection and management challenging and requires an interdisciplinary and collaborative approach between scientists, managers, stakeholders, land-use planners and policymakers that will: (1) include CWRs explicitly as a primary consideration for effective management, (2) implement dynamic spatial and temporal management practices, (3) leverage existing and new policies, and (4) improve coordination across jurisdictions as done for other ecosystem units.

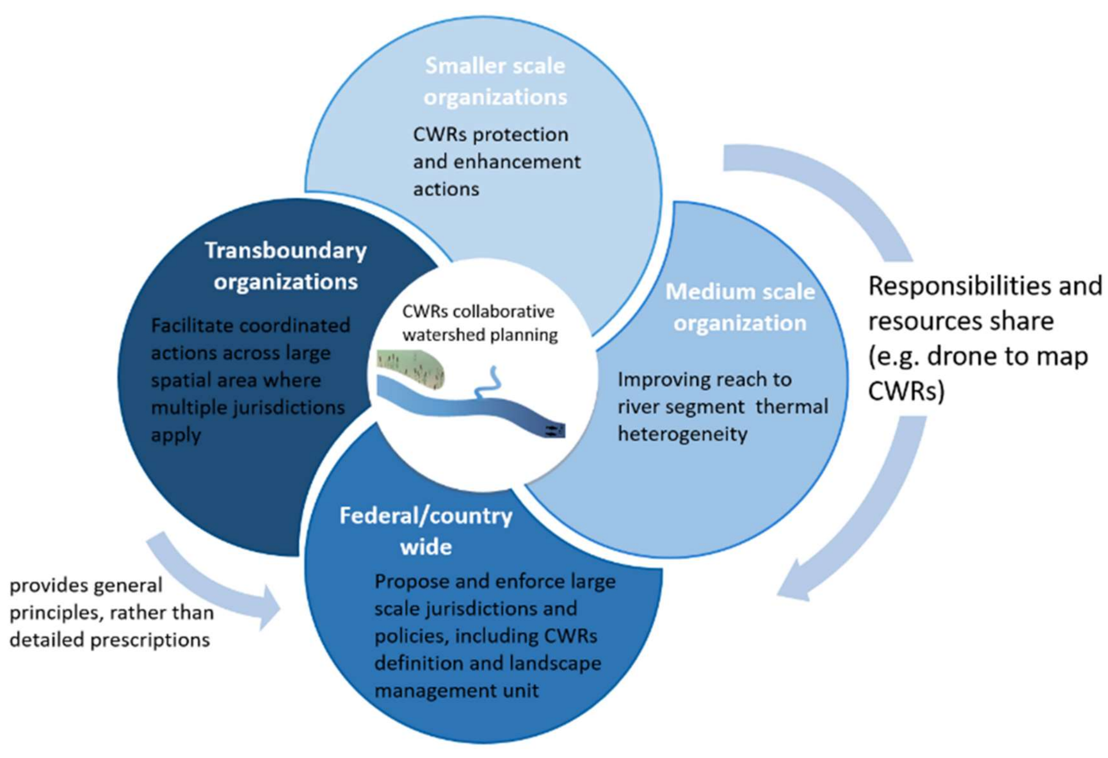


Figure 1: Scales of organization with corresponding management prioritization of cold-water refuges (source: Mejia et al., 2023)

2. The WaterShade project

The WaterShade project consists in developing a long-term and watershed-scale strategy for the management of CWRs in New Brunswick, targeting the headwater streams, ensuring that the riparian zones are adequately restored and protected in the long term while defining the maximum acceptable land use in the sub-watersheds. WaterShade would therefore become our preferred approach for the protection of CRWs in the face of climate change.

WaterShade has two components:

1) A general policy including a methodological framework for the selection, protection and enhancement of CWRs at the watershed scale
2) An implementation plan for the protection and enhancement of specific CWRs on the Restigouche River watershed.

The main partners in this project are:

- Working team
  - Gespe'gewa'gi Institute of Natural Understanding (GINU. formerly Gespe'gewaq Mi'gmaq Resource Council – GMRC)
  - Restigouche River Watershed Management Council (RRWMC)
  - LeBlanc MultiRessources
- Funding
  - Department of Fisheries and Ocean Canada (DFO) through the Aquatic Ecosystem Restoration Fund
  - The Atlantic Salmon Conservation Foundation
- Scientific support
  - University of New Brunswick
  - Institut National de Recherche Scientifique, centre Eau, Terre et Environnement (INRS-ETE)
- Governmental collaboration
  - Department of Natural Resources and Energy Development of New Brunswick (DNRED)
- Inter-provincial intra-watershed collaboration
  - Organisme de Bassin Versant Matapédia-Restigouche (OBVMR)
- Potential partners for future application
  - Licensees Owners on the Restigouche River watershed
  - Nepisiguit Salmon Association
  - Northeast Fisheries Science Center
  - Listuguj First Nation
  - Pabineau First Nation
  - Eel River Bar First Nation
  - Chaleur Bay Watershed

3. Objectives of the WaterShade implementation plan

The objectives of this implementation plan are to develop a framework and an action plan for the protection and enhancement of CWRs that are specific to the context of the New Brunswick part of the Restigouche River watershed (hereafter referred to as "Restigouche River watershed (NB)"). This action plan follows the principles, recommendations and decisions tools developed in the WaterShade Policy (hereafter referred to as "the Policy"). It includes actions to be taken in the context of the Policy implementation at a broader scale, that would apply to all Crown Lands in New Brunswick. The actions presented in the following sections are summarized in Table 2 at section 9.

4. The context of the Restigouche River watershed (NB)

4.1. Localization

The Restigouche River watershed has a drainage basin of 12,800 km², half of it being located in New Brunswick and the other half in Quebec (Figure 2). The New Brunswick part is essentially forested with a mixed coniferous and deciduous forest.

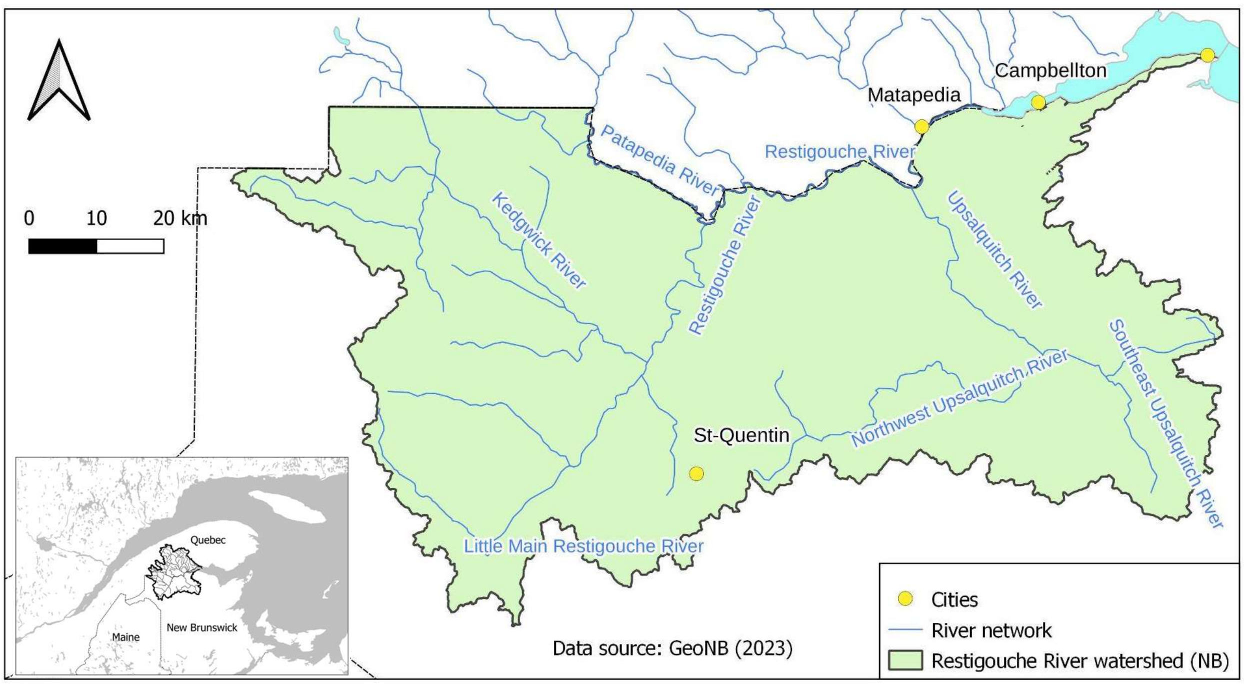
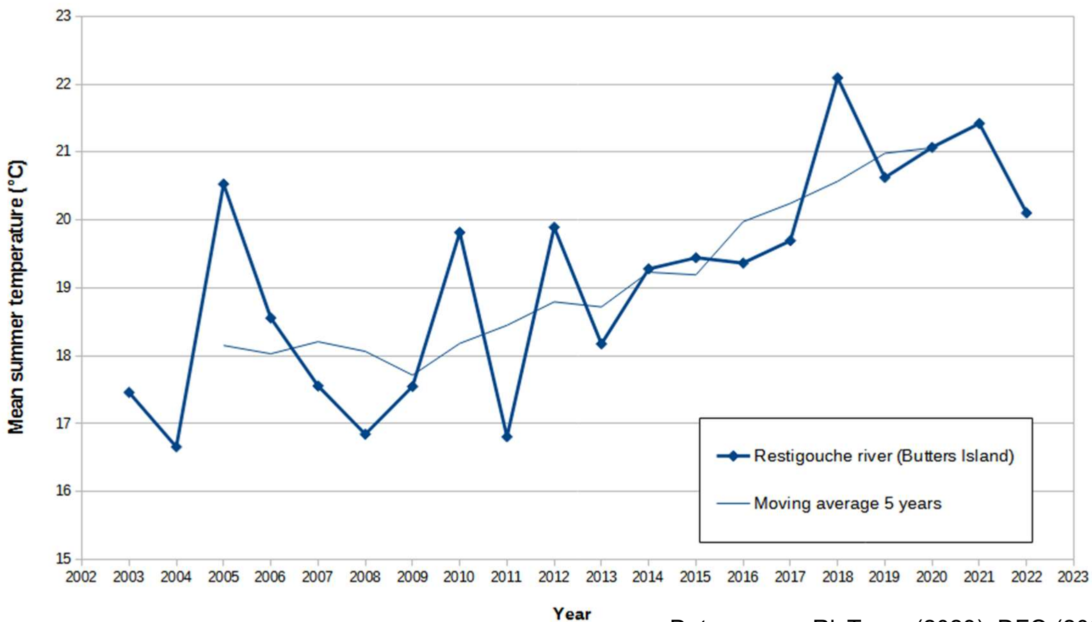


Figure 2: The Restigouche River watershed (NB)

4.2. Historical water temperature trends

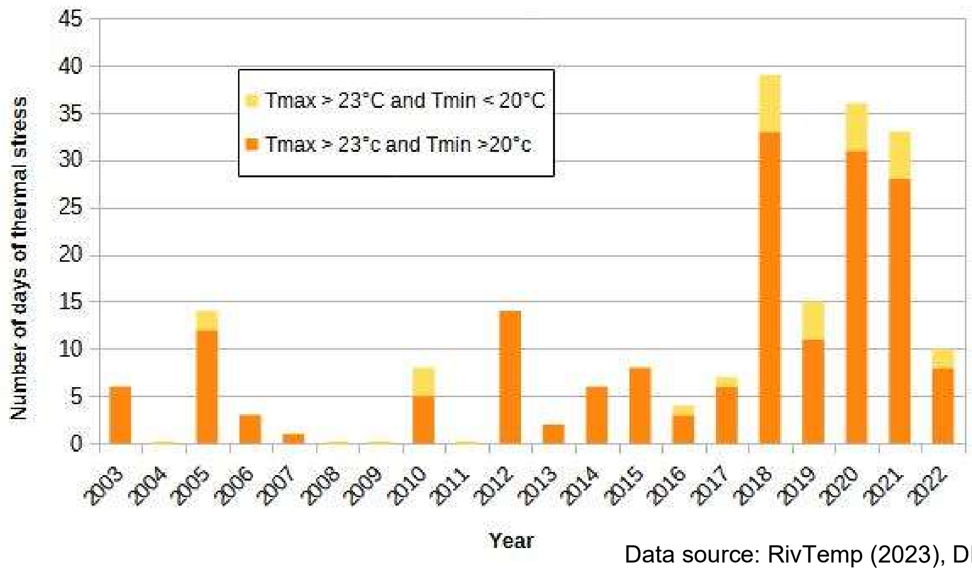
The historical evolution of mean summer temperature in the Restigouche River is depicted on Figure 3, showing an increasing trend, especially since 2013.



Data source: RivTemp (2023), DFO (2023)

Figure 3: Mean summer temperature (July-August) in the Restigouche River (Butters Island station) between 2003 and 2022

This recent tendency in water temperature can also be expressed in terms of thermal stress for cold-water fish. The annual number of days with thermal stress for the adult Atlantic salmon, i.e. with a daily water temperature higher than 23°C, has increased in the Restigouche River (at Butters Island station) since 2018, reaching more than 30 days in 2018, 2020 and 2021 while it was always less than 15 days between 2003 and 2017 (Figure 4). During these days with thermal stress, the minimum temperature has remained higher than 20°C most of the time. Note that the threshold of 23°C is used here for comparison, although it has been shown that thermoregulation behaviour of Atlantic Salmon was initiated earlier (i.e. at lower temperature) in relatively cool rivers than in warm rivers.



Data source: RivTemp (2023), DFO (2023)

Figure 4: Number of days with thermal stress for Atlantic salmon in the Restigouche River (Butters Island station) between 2003 and 2022

The water temperature trends in tributaries of the Restigouche River (in New-Brunswick and Quebec) are given in Appendix A, the warmest tributary being the Upsalquitch River.

5. Objective 1: Management and protection of cold-water refuges

5.1. WaterShade project management

The release of the WaterShade Policy and Implementation Plan is a first step of a long-term process that will need to evolve according to new data, issues and discussions with DNRED.

Actions:

- ➢ Develop a first version of the WaterShade Policy and Implementation Plan (2023)
- ➢ Create a WaterShade Committee for good management practices, funding securement and fostering relations, with a yearly meeting (2023-...)
- ➢ Collaborate with DNRED to agree on the WaterShade Policy objectives and guidelines (2024)
- ➢ Update the Policy and the Implementation Plan according to new data (2024-...)

5.2. Identification and classification of thermal anomalies

The identification and classification of thermal anomalies (step 1 of the framework) was done between 2011 and 2013: RRWMC, in collaboration with the Institut National de Recherche Scientifique, Centre Eau, Terre et Environnement (INRS-ETE), acquired high-resolution optical and thermal images on 862 km of river yielding a database of 1825 classified thermal anomalies throughout the whole Restigouche river watershed. This project was the first of its kind across the geographical range of Atlantic salmon (Dugdale et al., 2013; 2015).

In the Restigouche River watershed, cold-water patches are more numerous in river reaches with a sinuous channel and nearer tributary valleys. whereas patch clusters occur in moderately confined stream channels (Dugdale et al., 2013; 2015).

The thermal anomalies identified in the Restigouche River and its tributaries in New Brunswick are depicted on Figure 5. Note that the CWRs located in the Restigouche and the Patapedia River may be either on the Quebec or the New Brunswick side of these two rivers.

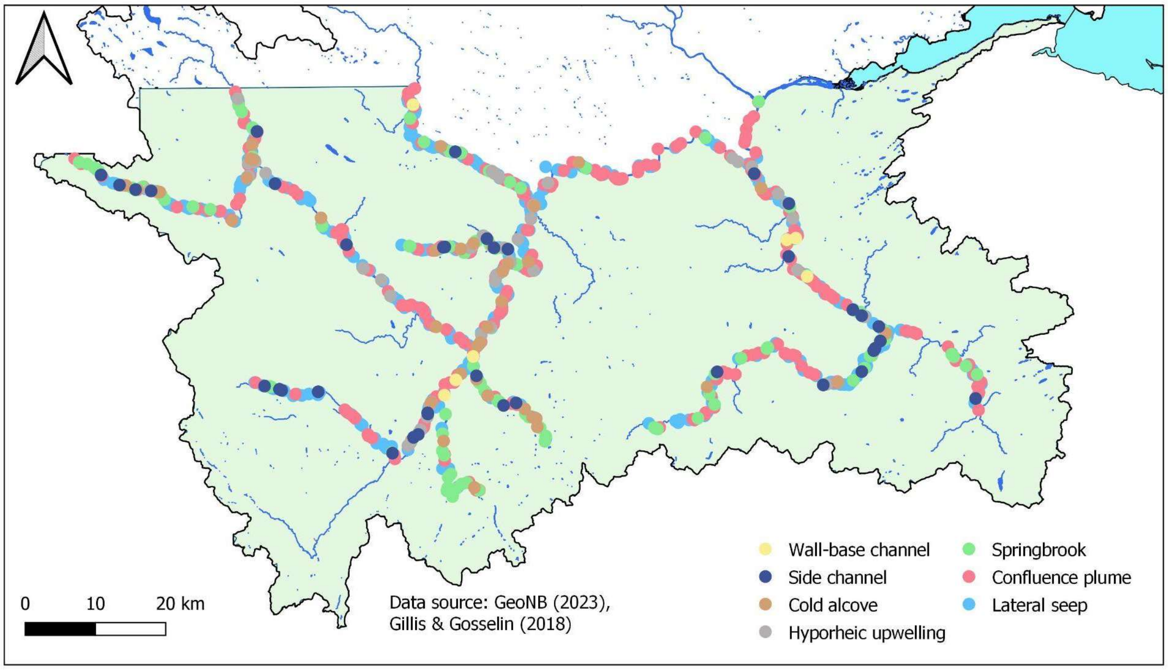


Figure 5: Cold-water anomalies in the Restigouche River watershed (NB)

5.3. Update governmental inventory of cold-water inputs and refuges

As stated in the WaterShade Policy (section 5.1), streams located on Crown Land and upstream of cold-water inputs and refuges, which are defined by DNRED in the FMM, are supposed to be protected by a 30 m buffer without any harvesting. In the Restigouche River watershed, this governmental database contains 7 cold-water inputs and refuges, all located in the Kedgwick River and the Little Main Restigouche River (Figure 6), on Licence 9 territory. No such cold-water input is identified in the eastern part of the watershed (Licence 1 territory).

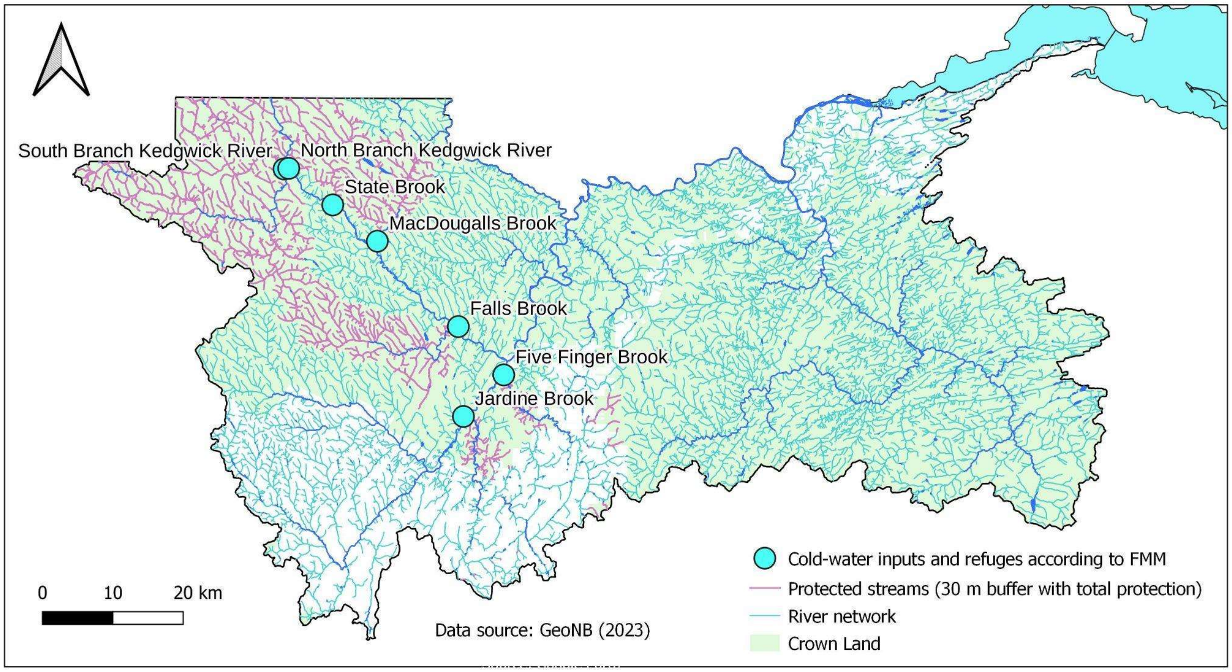


Figure 6: Current cold-water inputs and refuges and their corresponding protected streams in the Restigouche River watershed (NB), as considered in the Forest Management Manual

According to DNRED, this identification was made several years ago by DNRED with help from regional biologists. In most cases, it was based on biologists' knowledge of the territory. DNRED does not have any formal process to update this database.

When considering the progress in the last decade about cold-water refuges identification in the watershed (section 5.1), this highlights the need for updating this governmental database to be able to adequately apply the FMM requirements regarding buffer zones and cold-water refuges protection.

Actions:

➢ Discuss with DNRED to find an agreement to upgrade their database according to coherent CWR protection standards (2023-2024)

This issue was presented and discussed during three meetings with different representatives of DNRED, in Spring and Summer 2023. Further discussion will be needed regarding this issue in 2024.

5.4. Gather cold-water refuge data in a shared platform

As stated in the Policy (section 5.2), a web platform is being developed on GeoNode by GINU with the collaboration of OBVMR to gather information regarding salmon habitat information in the Restigouche River watershed. However, the management of cold-water refuges localization is still an issue due to their high sensitivity and the need for confidentiality.

Actions:

- ➢ Investigate the way to include cold-water refuges data of the Restigouche River watershed in the GeoNode platform (2024)

5.5. Adopt land use management strategies in CWR drainage basin

In 2018, RRWMC elaborated a first CWR strategic management plan in collaboration with GMRC and Listuguj Fisheries (Gillis & Gosselin, 2018). The goal of this study was to build a decision matrix in order to prioritize CWRs that can be enhanced and protected in the face of climate change and warming water temperatures. To do so, the following steps were conducted on the whole Restigouche River watershed (Quebec and New-Brunswick):

1. From the cold-water patches identified in the thermal image database. create a list of refuges to target for field characterization based on their potential to create persistent and/or large cold-water plumes
2. Conduct field-characterization of these targeted patches to determine their size. shape. temperature and source
3. Create a GIS database containing the physical characteristics of each of these CWRs
4. Create a decision matrix to prioritize CWRs to be enhanced
5. Create a list of future enhancement sites
6. Prioritize CWR types for protection actions

This work enabled to initially target:

- 15 confluence plumes for potential enhancement. These CWRs are located in the Restigouche River and the Upsalquitch River, since these two rivers are the ones that show the highest temperatures in summer.
- 3 types of groundwater-driven CWRs for future protection efforts by controlling land use change in drainage basin: springbrooks, cold alcoves and wall-based channels.
- 4 potential sites to study the use of thermal refuges by juvenile Atlantic salmon, 2 of them being located in New Brunswick.

Selection of cold-water refuges is a continuous process. For instance, in 2018, 27 thermal anomalies along the Matapedia River including 24 confluence plumes and 3 springbrooks were pre-selected in the context of a CWR protection strategy (Gillis et al., 2020).

In this context, the framework presented in the Policy for the selection and protection of CWRs will be used to update and further this process on the Restigouche River watershed (NB), as depicted on Figure 7.

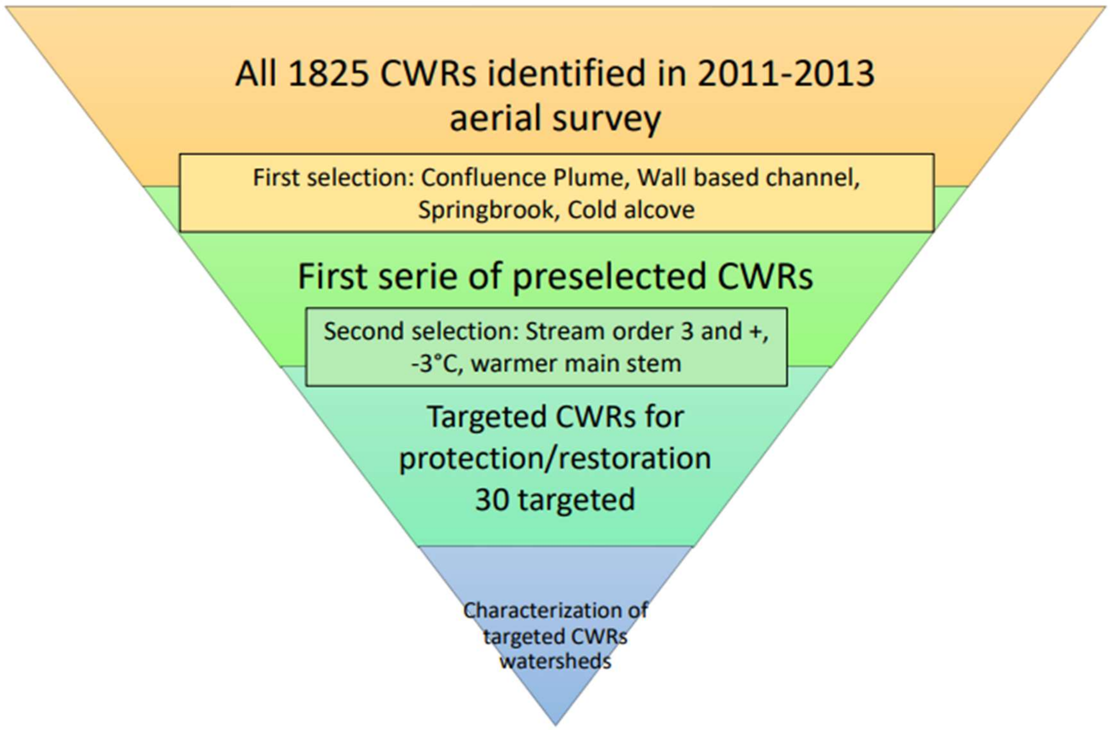


Figure 7: CWR selection and prioritization process on the Restigouche River watershed (NB)

Actions:

➢ Gather existing data and information regarding CWR inventory, protection and enhancement projects on the Restigouche River watershed (2023)

➢ Specify the location of CWRs identified by thermal imagery in 2013 (2023-2024)

Based on GIS and thermal imagery analysis.

➢ Characterize the river mainstem temperature pattern and target warm water reaches (2024)

Based on GIS, derived LIDAR data and thermal imagery analysis.

➢ Identify and map potential surface flow based on LIDAR data to localize intermittent headwater streams so that they can be adequately integrated in the forest management plans (2024)

➢ Create the CWR prioritization score method for site selection based on Policy criteria (2024)

➢ Select the 30 drainage basins for CWR protection and create maps (2024)

Based on the work that was done in 2018 and on the proposed framework in the Policy. The *a priori* objective is to select 30 CWRs with 5 priority ones.

➢ Use LIDAR to detect riparian zones protection status among selected sub-watershed and create maps

➢ Characterize and map the drainage catchment of selected CWRs (2024)

This will be based on GIS analysis and will lead to site-specific information layers regarding the river network, buffer zones, geology, topography, land use, land ownership and fishing regime, wetlands, salmon habitat, etc., as shown in appendix B. This will lead also to the identification of unvegetated riparian zones along streams and thermally sensitive areas upstream of selected CWRs.

➢ Drone flight for in-river CWR characterization of selected sub-watersheds (2024)

➢ Field validation of selected sites (location, spatial configuration, riparian zone, drainage areas and fish presence) (2024-2026)

A field characterization will be done to validate the CWRs characteristics (localization, spatial configuration, vegetation cover, fish frequentation, etc.) as well as key elements of drainage basins that were identified by GIS analysis (state of buffer zone, recent harvesting, drainage, groundwater pattern, etc.)

➢ Temperature monitoring: installation and retrieval of in-river loggers (2024-2026)

➢ Do the final selection of 5 priority CWRs and areas to be protected/restored (2025)

➢ Prepare site-specific action plans for selected areas (2024-2026)

These action plans will be developed following the methodological framework proposed in the Policy for protection of CWRs. They will include a monitoring plan, be adapted to land ownership, and include a communication component.

➢ Assess the impact of the action plans on forest harvesting for each selected CWR (2026)

The resulting loss in merchantable forest area and wood volume will be calculated.

➢ Create vegetated riparian buffers on unvegetated zones along main rivers of the watershed on private lands (2024)

To initiate short-term restoration projects, consultation with riparian landowners (fishing camps) through the Restigouche River Camp Owners Association to target voluntary initiatives to revegetate riparian strips located near main stretches. Tree-planting work will follow the presentation of a plan developed for fishing camps and other riparian land managers, such as the Kedgwick Forks Pool or Northwest Upsalquitch 10 Miles pool.

➢ Create vegetated riparian buffers on unvegetated zones along main rivers of the watershed on Crown Lands (2024)

➢ Create a new vegetal cover with permanent protection on specific areas in selected CWRs drainage basin (2024-2025)

A LIDAR analysis will be done to identify sites devoid of tree cover: landing, former logging jetty, former river channel, erosion zone, cottage bed, roadsides, abandoned roads, former stream crossing site, proximity to bridges and culverts. Analysis must integrate two CWR approaches to avoid planting trees that may be harvested: (1) sites within CWR drainage basins in Protected Natural Areas (PNAs), and (2) sites outside PNAs, but within 30 m of permanent stream protected as cold-water input.

Consultation will also be held with DNRED to be informed of their current approach to the 2BT program and map of potential sites.

5.6. Improve the current protection of buffer zones in Crown Lands

Actions:

- ➢ Ensure education and awareness of licensees, workers, and government employees regarding buffer zone protection (on going, to be continued)

- ➢ Advocate and perpetuate the practice of full 30 m buffer zone along all permanent watercourses on license 9 (2024)

The License 9 holders (Acadian Timber), on their own initiative, do not harvest within the 30 m buffer zone along all permanent watercourses, even where they are not recognized as cold-water inputs and refuges. This practice takes into consideration soil type and forest stands vulnerable to blowdown and rutting. It leads to a better protection of CWRs, although it may be perceived as a loss of volume in the forest harvesting possibilities. In this way, it is an example that may be highlighted and reproduced elsewhere in the watershed. This issue will be addressed with DNRED representatives in 2024.

5.7. Improve legislation regarding forest management in Crown Lands

Actions:

- ➢ Discuss with DNRED and find an agreement to have the chance to comment on the new Forestry Goals & Objectives Manuals to harmonize with Restigouche CWR protection objectives

- ➢ Discuss with DNRED on opportunities regarding land protection within the Restigouche River Watershed (i.e. enhanced intermittent streams protection or equivalent cut areas application)

5.8. Create new protected areas targeting CWRs

Identification of new areas to be protected in the watershed will be done after characterization and mapping of CWRs drainage basins.

In the context of a federal strategy to increase the size of protected areas by 2030, it is planned that other territories could be candidates for permanent protection. In a climate change resilience approach, it is therefore conceivable to propose thermal refuge drainage basins to be protected in the next call for candidate territories.

In consideration of the importance of the salmon in First Nation culture, CWRs drainage should also be considered in indigenous programs involved in protection and conservation.

Actions:

- ➢ Advocate for the increase of New Brunswick PNAs beyond 10% (2024)

- ➢ Propose areas to be included within a potential next round of PNAs of the Natural Legacy Initiative (2025)

- ➢ Propose areas to be protected through the Indigenous Protected and Conserved Area (IPCA) program (2025)

5.9. Promote best management practices on private lands

This will be done after selection and characterization of CWRs for selected CWRs whose drainage basin include private woodlots, farmed lands or urban areas, and be integrated in site-specific action plans

Actions:

- ➢ Prepare site-specific conservation agreements adapted to land use and ownership (woodlots, farmed lands, urban areas) (2024)

This could be based on the voluntary-based protection plan developed in 2020 on the Matapedia River watershed (see section 5.11). It could also be merged with the current actions for sediment control on farmed lands.

5.10. Integrate cold-water refuges protection in municipal plans and policies

This will be done after selection and characterization of CWRs and be integrated in site-specific action plans.

Actions:

- ➢ Discuss with municipality representatives about the possibilities for a legal protection of CWRs (2025)

5.11. Ensure coordination with other jurisdictions at the watershed scale

In the Quebec part of the Restigouche River watershed, a protection strategy was developed in 2020 by GINU and OBVMR (Gillis et al., 2020) to protect 10 selected CWRs, including:

- A voluntary-based protection plan which focused on information, awareness, and involvement of landowners in the CWR drainage basins. This process led to the signing of voluntary conservation agreements by landowners.
- The inclusion of cold-water refuges in the Plan régional des milieux humides et hydriques (PRMHH) of Avignon and Matapedia regional county municipalities (RCM). These plans aim to integrate the conservation of wetlands and bodies of water into land use planning, by promoting sustainable and structuring development. Selected cold-water refuges will therefore be legally protected by limiting land use in their drainage basins in a proactive way. These PRMHHs are currently in the final process to be approved by the ministry.

In the continuity of this project, information booklets on CWRs are being prepared specifically for the RCMs (Avignon and Matapedia) and will be published in 2024.

Actions:

- ➢ Coordinate the development of tools and strategies for CWR protection and enhancement and share experiences with the OBVMR (on going, to be continued)

6. Objective 2: Enhancement of cold-water refuges

6.1. Selection of CWRs for enhancement

The first site that was chosen for CWR enhancement in the Restigouche River watershed (NB) was the 10 Mile Pool, located in the Northwest Upsalquitch River. A barrier is used to maintain Atlantic salmon in place under constant surveillance against poaching activities between June 15th and October 19th every summer. This location is defined as a sanctuary of critical importance for the Atlantic salmon conservation efforts in the watershed. It had been operated by DNRED for decades but nowadays, the contract is held by the RRWMC. A cold underground water stream feeds the resting pool. The 10 Miles Pool refuge was classified as a lateral seep in the 2012 CWR inventory.

This CWR was selected for enhancement because the three main factors indicated in the framework presented in the Policy for CWR enhancement were met:

1. It is located in the tributary where water temperature reaches the highest values of the whole Restigouche River watershed (see appendix A)
2. It constitutes an important sanctuary for the salmon with a high density of juveniles
3. The access for machinery was already available due the barrier management activities
4. This site has been recognized for long as a sanctuary of critical importance for the Atlantic salmon conservation efforts in the Restigouche River watershed, which ensures a good acceptability by stakeholders. local people and First nations.

In 2018, site visits were conducted to characterize the 15 confluence plumes that had been pre-selected specifically for enhancement in the whole Restigouche River watershed (see section 5.1). Perpendicular temperature gradient transects were done from the shoreline towards the mainstem to measure the width and length of each cold-water plume. A total of five sites were finally selected for enhancement in the Restigouche River and the Upsalquitch River, four of them being in New Brunswick (Gillis & Gosselin, 2018).

Since then, two other confluence plumes have been added: the England Brook (tributary of the Restigouche River, Quebec) and the Coxs Brook (tributary of the Upsalquitch River, New Brunswick). The latter was considered as a potential site for enhancement following changes in stream dynamics due to culvert replacement (see section 6.3).

A total of 5 sites have been selected to date in New Brunswick for enhancement in addition to the existing one at 10 Mile Pool (Figure 8).

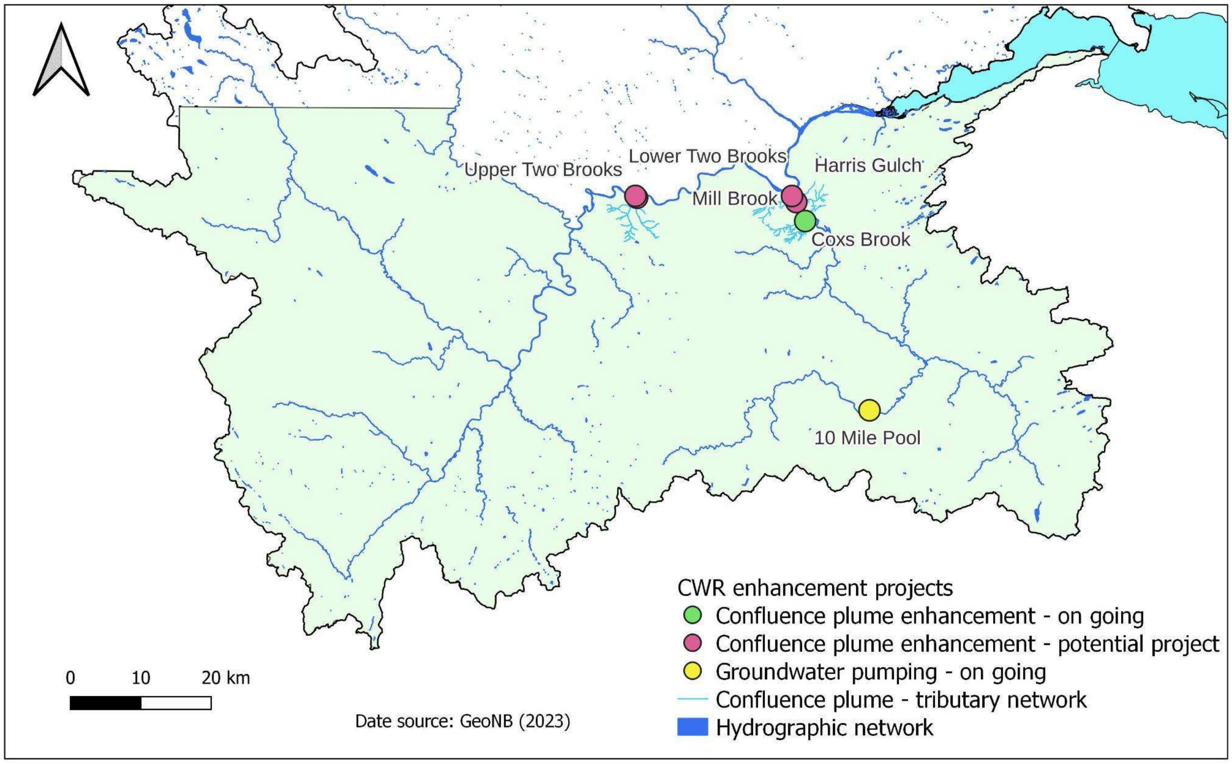


Figure 8: On going and potential CWR enhancement projects in the Restigouche River watershed (NB)

Actions

- ➢ Update the selection of potential sites for CWR enhancement (2024-...)
- ➢ For each selected site, develop an enhancement action plan based on the framework presented in the Policy (2024-...)
- ➢ Select enhancement methods, do the technical design, permitting and field works (2024-...)
- ➢ Monitor and evaluate the effects of the projects on water temperature and salmonid behaviour (2025-...)
- ➢ Communicate about the projects (2024-...)

6.2. The 10 Mile Pool

An active enhancement method was chosen to provide additional cold water to the salmons in the pool. It consists in pumping underground water from a surface well located in the vicinity of the pool (Figure 9) when temperature reaches an elevated threshold during warm water episodes in summer. The works were done and pumping started at the end of the 1980s.

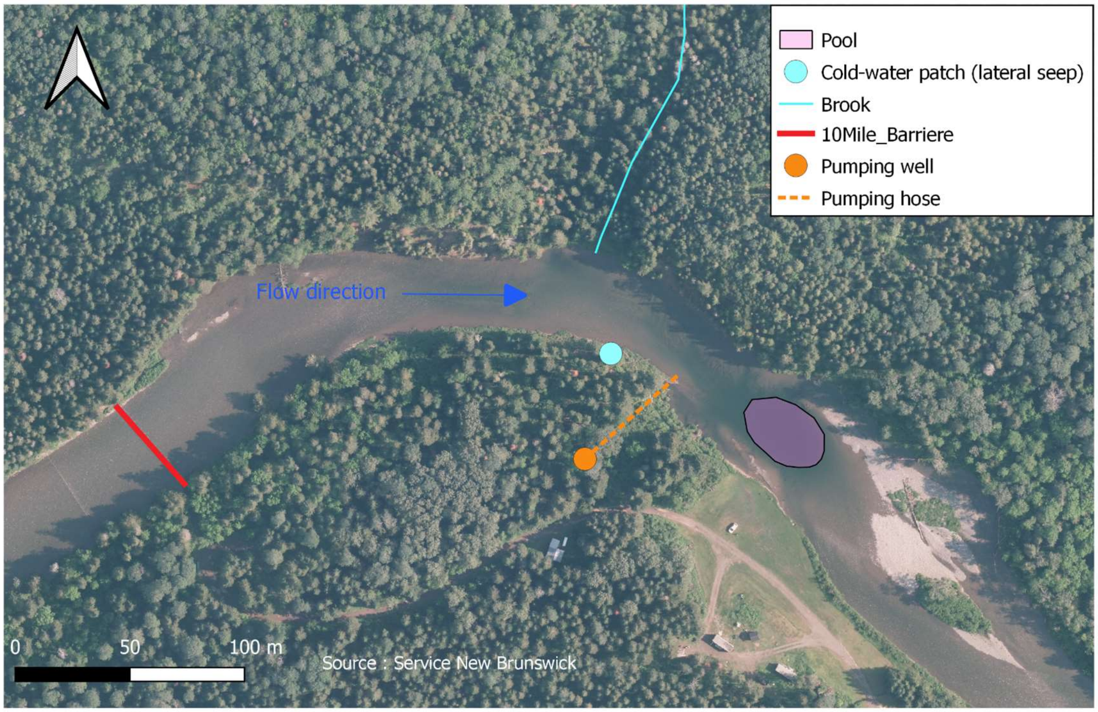


Figure 9: The 10 Mile Pool site

During the summers 2022 and 2023, a series of tests were performed to assess the efficiency of the pumping on water temperature. A standard pumping test was performed to verify the general behaviour and the capacity of the well. The river temperature was also monitored using thermographs installed in the river. Finally, thermal imagery data were acquired by drone flight under pumping and non-pumping conditions.

The results showed that:

- The groundwater recharge rate in the well is adequate to maintain the groundwater table during pumping.
- According to thermal imagery data acquired in September 2022, the spatial range of water temperature in the river is 4°C in natural conditions and becomes 8°C when pumping water from the well.
- According to water temperature monitoring in Summer 2023, pumping has a clear effect on water temperature in the vicinity of the hose outlet, with a drop (reaching -1°C at hose outlet) as soon as the pumping starts and rises back when the pumping stops.
- During warm water events, the cooler zone of the river is the lateral seep as identified in 2012 where water is shallow, but salmons and trouts gather in the pool located downstream.

These results confirm that groundwater pumping has a cooling effect in addition to the cold-water coming from the lateral seep located upstream, but that this effect remains mainly localised along the right bank of the river. This increases the temperature gradient between the left side (warm) and the right side (cool) of the river reach, both mixing in the pool located downstream. Further temperature monitoring will be performed to assess the efficiency of this project.

Actions

- ➢ Continue temperature monitoring and field observations to better assess the effect of groundwater pumping on thermal heterogeneity and fish behaviour during warm temperature events (2024-2025)
- ➢ If this site is included in the 30 selected ones, ensure a long-term protection of the drainage basin of the CWR from intensive harvest (for instance by adding it in to the surrounding PNA) (2025)

6.3. The Coxs Brook

The Coxs Brook was identified as a thermal refuge and the culvert near the confluence was also picked up as a barrier to fish passage in 2019. Since then, the Department of Transport and Infrastructures of New Brunswick replaced the culvert, but this caused some changes in stream dynamics upstream. The section directly above the riprap is very unstable and is starting to gouge a new branch that would cut around the newly replaced culvert. Stream enhancement and stabilization work is therefore urgently needed to keep the thermal refuge functional for fish at the confluence.

A detailed survey of the site was performed in 2022, resulting in the production of a detailed elevation map and the elaboration of a stream enhancement design by a specialized consulting firm. The approach selected consists of re-establishing the right bank of the stream where the erosion has occurred approximately 25 metres upstream of the culvert. The design was done by an experienced firm (5R Environmental Consultant inc.) in 2023. The permits were delivered in fall 2023 and the works were done in November (Figure 10). Three root wads were placed in the scoured-out area of the bank to help form the new face of the bank. Additionally, woven brush mats were placed on the bottom of the scour hole and between the root wads to assist with the collection of sediment, bedload material, and debris migrating downstream. The collected material will form the new bank and reduce the flow energy that is currently scouring material from the bank and channel bottom.

Figure 10: Bank stabilization works on the Coxs Brook, November 9th, 2023 (Photograph D. LeBlanc)

Actions

- ➢ Ensure a follow-up of vegetation regrowth and bank stability in Spring and Fall 2024 (2024)

7. Objective 3: Securement, stewardship, education and awareness

As stated in the Policy, this objective is a cross-cutting one. On the Restigouche River watershed (NB), it is pursued through all the activities implying discussions and interactions with local actors, stakeholders and government representatives. In this way, many actions to be taken have already been identified in previous sections of this document (see for example section 5.6).

The main actors implied in the CWR management on the Restigouche River watershed (NB) are listed in Table 1 below.

Table 1: Main actors implied in the management of CWRs on the Restigouche River watershed (NB)

Organism	Role regarding CWR management and protection
RRWMC	- WaterShade Policy and Implementation plan - 10 Mile Pool project - Restoration/replanting projects management - Field work - Outreach, communication, education
GINU	- WaterShade Policy and Implementation plan - Applied research coordination and linkage with INRS and UNB research projects - CWR enhancement projects - Restoration/replanting projects management - Field work - Outreach, communication, education
OBVMR	- Sharing of experience and capacity building for education, awareness and protection (ex: booklets)
Licensees on Crown Lands	- Application of the FMM requirements (buffer zones) - Voluntary additional protection of CWRs
Private woodlots owners	- Voluntary protection of CWRs
Restigouche River Camp Owners Association	- Promotion of WaterShade project among members - Consultation of members for site specific restoration
Farmers	- Voluntary protection of CWRs
Municipalities	- Adopt and apply municipal regulation for CWR protection
First Nations	- Collaboration, share of traditional knowledge - Collaboration to submit new CWRs into Indigenous Protected and Conserved Area (IPCA) program

Actions

➢ Once the selected CWRs are identified and characterized, prepare information booklets on CWRs to be shared with local actors (counties, municipalities, land owners, population, First Nations, licensees), based on the booklet model elaborated by OBVMR in Avignon and Matapedia RCMs (2024-2025)

➢ Investigate the possibility of creating a “cold-water network” gathering actors and sectors representatives from the Restigouche River watershed (NB) (2026)

Such a network would allow sharing information, co-designing sector-specific support strategies, increasing local awareness and empowerment, and improve collaboration to deal with conflicting CWR uses.

8. Objective 4: Applied research

Several ongoing research projects are related to thermal heterogeneity and CWRs in the Restigouche River watershed (NB). The progress of these projects are presented each year during the Restigouche River Watershed Science Advisory Committee meeting.

8.1. Mapping of thermal refuges and their drivers (H. Green's MSc project - University of New Brunswick / GINU)

This study aims at better understanding the landscape drivers of confluence plumes on the Restigouche River Basin (other than groundwater). The objectives are to determine if there is a relationship between certain landscape attributes (ex: protected areas) to confluence temperature at the catchment level and determine if GIS is an accurate aid in identifying possible confluence plume locations.

8.2. River-specific thermal regimes contribution to variation in thermal aggregation thresholds for juvenile Atlantic salmon (Salmo salar) (E. Collet, T. Linnansaari, A. O'Sullivan - University of New Brunswick)

It is well understood that Atlantic salmon (*Salmo salar*) will seek thermal refuge once certain temperature thresholds are exceeded, and these thresholds differ with age - this behaviour is termed 'thermoregulation'. However, the temperature that induces behavioural thermoregulation is not homogeneous across the range of Atlantic salmon. Recent research has shown that the temperature that triggers behavioural thermoregulation in juvenile Atlantic salmon differs for salmon in two relatively warm rivers. Here we investigate whether juvenile Atlantic salmon in one warm river, and one relatively cooler river, will exhibit a difference in aggregation onset temperatures. Further, using a hysteresis model that considers the time since the previous thermally stressful event (TsE) and the frequency of thermally stressful events (FoE), we test whether aggregation onset temperatures will vary throughout the summer. To accomplish this, we placed custom-made underwater cameras in two thermal refuges in the Miramichi River, NB, and in one thermal refuge in the Restigouche River, NB, to observe the onset of aggregations of juvenile Atlantic salmon. Water and air temperatures were also measured. The duration of this study was from June 1st to August 31st in 2022 and 2023. The results from this study further our understanding of the dynamic nature of salmonid behavioural thermoregulation and have implications for the future management of Atlantic salmon in an increasingly warming climate.

8.3. Effects of heat stress events and thermal refuge availability on Atlantic salmon growth and conditiotn (E. Chrétien - INRS-ETE)

This ongoing research project aims at assessing: 1) the frequency, duration and amplitude of heat stress events in East Canada rivers, including the Restigouche River, in recent years, and 2) relationships between temperature metrics and Atlantic salmon growth and condition. The next step will be to explore the effects of other environmental factors on fish growth and condition (i.e. fish density, thermal refuge characteristics, etc.).

8.4. Importance of the height of riparian vegetation for thermal regimes of Atlantic salmon rivers to strategically inform restoration decisions (E. Enders - INRS-ETE / GINU)

The project proposes to model the amount of solar radiation reaching the surface of salmon rivers as a function of basin topography, riparian vegetation characteristics, local stream reach orientation, and solar elevation. The project aims to integrate the amount of solar radiation received at any point of the river over different time periods (day, week, summer season) and identify reaches receiving high amounts of solar radiation. It will also test the hypothesis that these reaches correspond to areas of water warming identified on long temperature profiles obtained from thermal imagery. In a restoration approach, it will identify areas where selective reforestation of river banks would have a positive effect on stream temperature by reducing solar radiation and model the expected effect of selective reforestation on stream temperature.

8.5. Assess thermal refuge enhancement success for Atlantic Salmon (V. Simard - INRS-ETE / GINU)

The general objective of the project is to assess the importance of cold-water refuges for juvenile Atlantic salmon. To do this, various field studies will be conducted in refuges targeted by restoration efforts, before and after the restoration work, to quantify their physical characteristics and their importance for Atlantic salmon. The study of physical characteristics includes the surface area, depth, temperature, and temporal stability of the refuge. To assess the importance of cold-water refuges for Atlantic salmon, the frequency and duration of thermal refuge use, temperature experienced by fish, as well as in situ metabolic rates will be quantified, before and after restoration. Evaluating the effectiveness of restored thermal refugia and the bioenergetic benefits to juvenile Atlantic salmon using them is necessary to better target future conservation efforts.

8.6. Define best practices for CWR enhancement (GINU, RRWMC and collaborators)

Based on a literature review, case studies and experience sharing within the scientific community, this project aims at defining a concerted methodological approach for CWR enhancement, as presented in the Policy. A paper is in preparation and will be submitted for publication in 2024.

- ➢ Publish a paper on best practices for CWR enhancement (2024)

8.7. Other projects to be potentially developed

Assess the socio-economic impact of CWR protection at the watershed scale

A socio-economic valuation of CWRs may be used to justify their protection, as a counterpart of the potential economic loss caused by the protection of buffer zones and drainage basins from forest harvesting. A cost/benefit approach could be used to take into account the cost of land protection regarding tree harvesting.

- ➢ Investigate the state of knowledge (literature review) and possible collaborations (2024)

Modeling the thermal regime of the Restigouche River and its tributaries

The application of water temperature model on the Restigouche River watershed would enable to assess the effects of changes in land use (for example intensive forest harvesting vs. protected natural areas) on the thermal regime and heterogeneity in sensitive river reaches, or to forecast water temperature and the needs for CWRs in a future warmer climate.

- ➢ Evaluate modeling options and needs (2024)
- ➢ If relevant, acquire temperature data, implement a model, define land use scenarios and assess their impact on thermal heterogeneity (2025-...)

9. Summary of actions

Table 2: Summary of actions

Number	Category	Actions	2023	2024	2025	2026+
1	Management	Have a developed first version the Policy for Thermal Refuge Management and a first version of WaterShade Implementation Plan	X			
2	Management	Create a WaterShade Committee for good management practices, funding securement and fostering relations. Holding a yearly meeting	X	X	X	X
3	Management	Collaborate with DNRED to agree on the WaterShade Policy objectives and guidelines		X		
4	Management	Update the Policy and the Implementation Plan according to new data		X	X	X
5	Management	Discuss with DNRED to find an agreement to upgrade their database according to coherent CWR protection standards		X		
6	Management	Investigate the way to include cold-water refuges data of the Restigouche River Watershed in the GeoNode platform		X		
7	Characterization	Gather existing data and information regarding CWR inventory, protection and enhancement projects on the Restigouche River watershed	X			
8	Characterization	Specify the location of CWRs identified by thermal imagery in 2013		X		
9	Characterization	Characterize the river mainstem temperature pattern, target warm water reaches and create a map		X		
10	Characterization	Identify and map potential surface flow based on LIDAR data to localize intermittent streams		X		
11	Characterization	Create the CWR prioritization score method for site selection based on the Policy criteria		X		
12	Characterization	Select the 30 drainage basin for CWR protection and create a map		X		
13	Characterization	Use LIDAR to detect riparian zones protection status among selected sub-watershed and create maps		X		
14	Characterization	Characterize and map the catchment of selected CWRs		X		
15	Characterization	Drone flight for in-river CWR characterization of selected sub-watersheds		X	X	X
16	Characterization	Field validation of selected sites (location, spatial configuration, riparian zone, drainage areas and fish presence)		X	X	

Number	Category	Actions	2023	2024	2025	2026+
17	Characterization	Temperature monitoring: installation and retrieval of in-river loggers		X	X	X
18	Characterization	Do the final selection of 5 priority CWRs and areas to be protected/restored			X	X
19	Management	Prepare site-specific action plans for selected areas		X	X	X
20	Management	Assess the impact of the action plans on forest harvesting for each selected CWR			X	X
21	Restoration	Create vegetated riparian buffers on unvegetated zones along main rivers of the watershed - any private lands and/or specific known sites		X	X	X
22	Restoration	Create vegetated riparian buffers on unvegetated zones along tributaries related to selected sub-watershed to be protected- Crown Land			X	X
23	Restoration	Create new vegetal covers with permanent protection on selected areas in selected CWRs catchment			X	X
24	Outreach	Ensure education and awareness of licensees, forestry workers, farmers and general population regarding buffer zone protection	X	X	X	X
25	Management	Advocate and perpetuate the practice of full 30 m buffer zone along all permanent watercourses on license 9		X		
26	Management	Discuss with DNRED and find an agreement to have the chance to comment on the new Forestry Goals & Objectives Manuals to harmonize with Restigouche CWR protection objectives		X	X	X
27	Management	Discuss with DNRED on opportunities regarding land protection within the Restigouche River Watershed (i.e., enhanced intermittent streams protection or equivalent cut areas application)		X	X	X
28	Management	Advocate for the increase of NB Protected Areas beyond the 10%		X		
29	Management	Propose areas (related to CWRs protection) to be included within the next round of PNAs of the Natural Legacy Initiative			X	
30	Management	Propose areas (related to CWRs protection) to be protected through the Indigenous Protected and Conserved Area (IPCA) program			X	
31	Management	Prepare site-specific conservation agreements adapted to land use and ownership (woodlots, farmed lands, urban areas)		X	X	X

Number	Category	Actions	2023	2024	2025	2026+
32	Management	Discuss with municipality representatives about the possibilities for a legal protection of CWRs		X	X	X
33	Management	Coordinate the development of tools and strategies for CWR protection and enhancement and share experiences with the OBVMR	X	X	X	X
34	Enhancement	Update the selection of potential sites for CWR enhancement		X	X	X
35	Enhancement	Develop an enhancement plan specific to each site		X	X	X
36	Enhancement	Select enhancement methods, design, permitting and field works		X	X	X
37	Enhancement	Monitor and evaluate the effect of the enhancement projects on water temperature and salmonid		X	X	X
38	Enhancement	Communicate about the enhancement projects		X	X	X
39	Enhancement	10 Mile Pool site: Continue temperature monitoring and field observations to better assess the effect of groundwater pumping on thermal heterogeneity and fish behaviour during warm temperature events (2024-2025)		X	X	
40	Enhancement	10 Mile pool site: if this site is included in the 30 selected ones, ensure a long-term protection of the drainage basin of the CWR from intensive harvest (for instance by adding it in to the surrounding PNA)			X	
41	Enhancement	Coxs Brook site: ensure a follow-up of vegetation regrowth and bank stability in Spring and Fall 2024 (2024)		X		
42	Outreach	Prepare information booklets on CWRs to be shared with local actors		X	X	X
43	Outreach	Investigate the possibility of creating a “cold-water network” gathering actors and sectors representatives from the Restigouche River watershed (NB) (2025)				X
44	Research	Mapping of thermal refuges and their drivers (UNB / GINU)	X	X	X	X
45	Research	River-specific thermal regimes contribution to variation in thermal aggregation thresholds for juvenile Atlantic salmon (UNB)	X	X	X	X
46	Research	Effects of heat stress events and thermal refuge availability on Atlantic salmon growth and condition (INRS-ETE)	X	X	X	X

Number	Category	Actions	2023	2024	2025	2026+
47	Research	Importance of the height of riparian vegetation for thermal regimes of Atlantic salmon rivers to strategically inform restoration decisions (INRS-ETE / GINU)	X	X	X	X
48	Research	Assess thermal refuge enhancement success for Atlantic Salmon (INRS-ETE / GINU)	X	X	X	X
49	Research	Publish a paper on best practices for CWR enhancement		X	X	X
50	Research	Investigate the state of knowledge (literature review) and possible collaborations for the assessment of the socio-economic impact of CWR protection at the watershed scale			X	X
51	Research	Evaluate modeling options and needs		X		
52	Research	If relevant, acquire temperature data, implement a model, define land use scenarios and assess their impact on thermal heterogeneity			X	X

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Appendix A: Water temperature trends in the Restigouche River watershed

DFO operates 13 active water temperature stations in the Restigouche River (Figure A.1). The station located in the Matapedia River at Village Bridge, which was operated between 2003 and 2016, is also considered in the present analysis. Other stations have been used punctually in the past by DFO, MFFP, GINU or RRWMC in specific rivers and brooks.

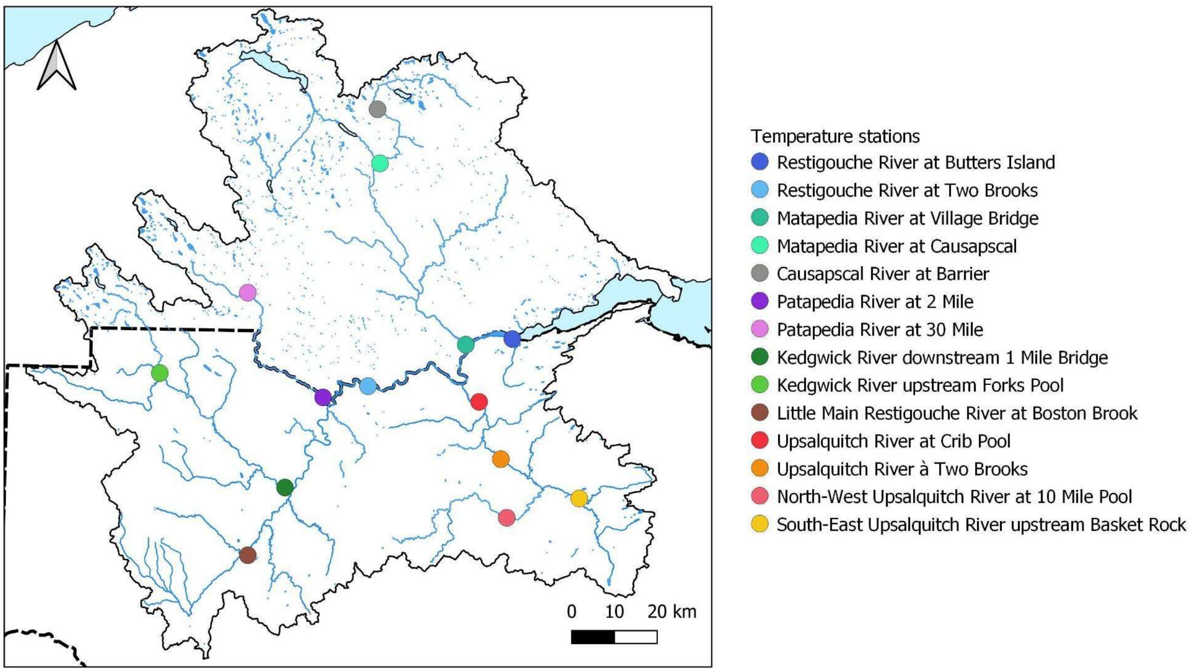


Figure A.1: Localisation of water temperature stations in the Restigouche River watershed (source: RivTemp, 2023)

Median and maximum summer water temperatures over the period 2003-2022 are indicated for each station on table A.1. Temperature is higher in the Restigouche River and the Upsalquitch River than in the other tributaries. In the Upsalquitch River at Two Brooks, mean summer temperature (17.8°C) is close to the one recorded in the Restigouche River at Two Brooks (17.9°C). In New Brunswick, temperature is cooler at stations located upstream in the watershed (Kedgwick River upstream Forks Pool, Little Main Restigouche River and Patapedia River).

Table A.1: Water temperature in summer (July-August) in the main tributaries of the Restigouche River watershed between 2003 and 2022

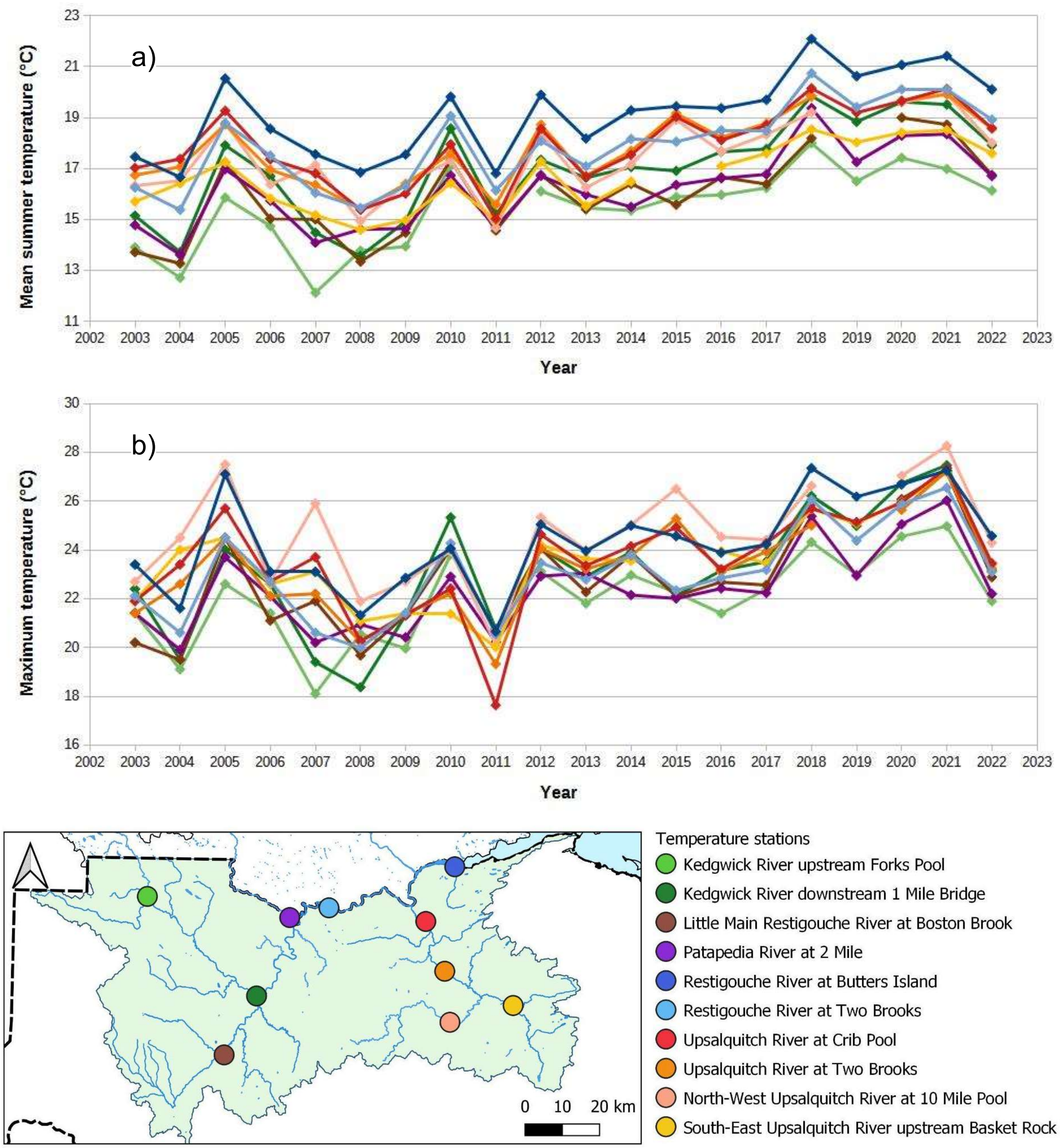
River	Mean daily temperature (°C)	Maximum daily temperature median value over the period (°C)	Maximum daily temperature maximum value over the period (°C)
Restigouche River at Butters Island	19.1	24.1	27.4
Restigouche River at Two Brooks	17.9	23.0	26.6
Patapedia River at 2 Mile	16.2	22.2	26.0
New Brunswick			
Upsalquitch River at Crib Pool	17.9	23.6	27.4
Upsalquitch River at Two Brooks	17.8	23.2	27.2
Southeast Upsalquitch River upstream Basket Rock	16.6	23.6	27.2
Northwest Upsalquitch River at 10 Mile pool	17.5	24.5	28.3
Kedgwick River downstream 1 Mile Bridge	17.0	23.1	27.5
Kedgwick River upstream Forks Pool	15.5	22.3	25.0
Little Main Restigouche River at Boston Brook	16.0	22.6	27.2
Quebec			
Matapedia River at Village Bridge (2003-2016)	17.3	23.2	25.9
Matapedia River at Causapscal	17.7	23.4	26.2
Causapscal River at Barrier	16.8	24.3	27.3
Patapedia River at 30 Mile	16.7	24.1	27.4

Data source: RivTemp (2023), DFO (2023)

The historical evolution of the mean water temperature in summer for all the stations located in New Brunswick is depicted on Figure A.2 (a). Temperature has increased between 2003 and 2022 in a relatively homogenous way among the different rivers. At the same time, the evolution of annual maximum water temperature is more heterogeneous (Figure A.2, b). It is often higher in the Upsalquitch Nord-Ouest (10 Mile pool) than in the other rivers (even at the outlet of the Restigouche River), especially in 2007 (25.9°C), 2015 (26.5°C) and 2021 (28.3°C).

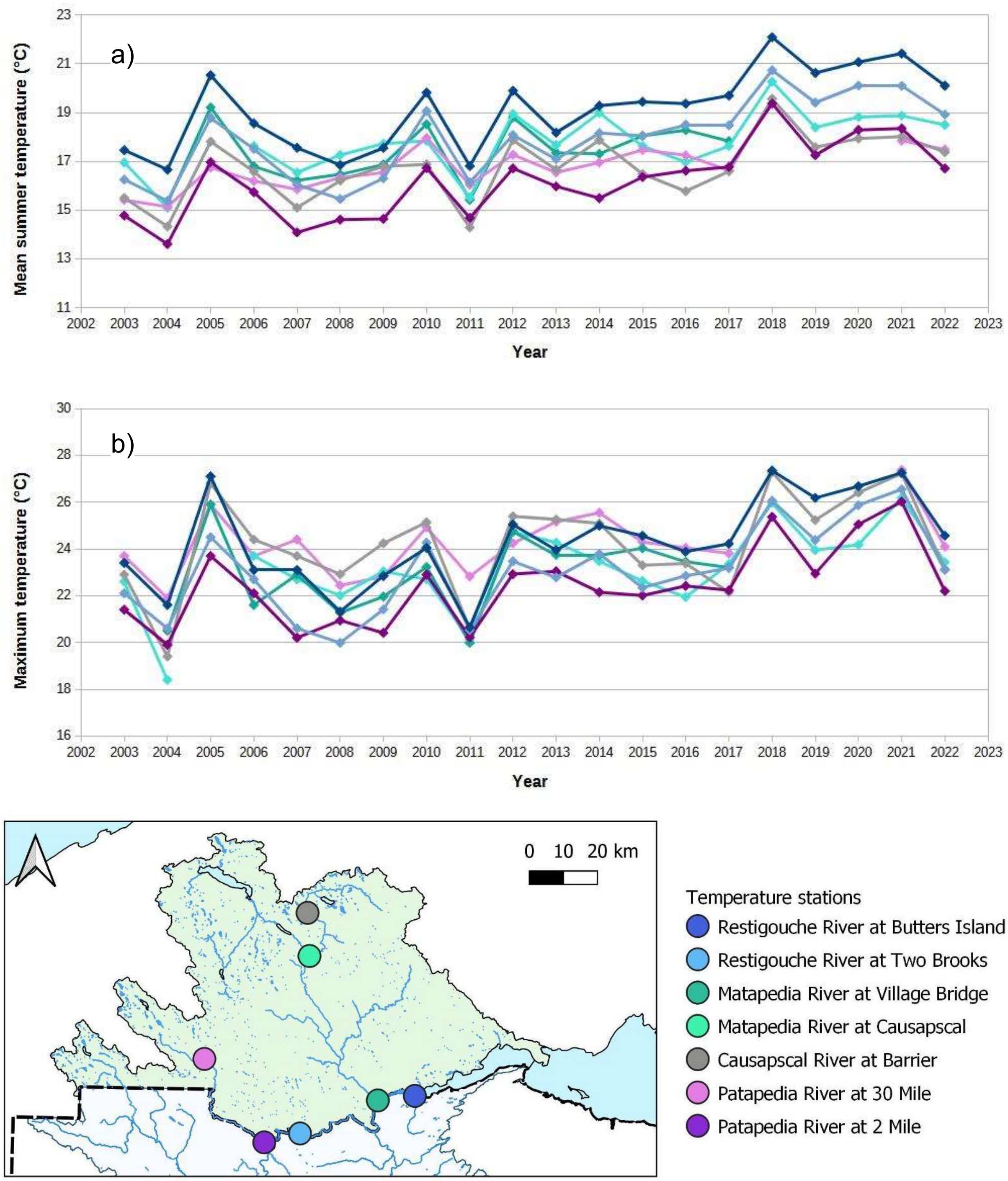
For comparison, the historical data for stations located in Quebec is depicted on Figure A.3. These stations show a similar thermal evolution to the New Brunswick However, the increase of water temperature since 2014 is more obvious in New Brunswick stations than in Quebec ones. For example, at the station located on the Matapedia River at Causapscal, mean temperature was close to the one measured in the Restigouche River between 2003 and 2014, but remained relatively steady between 2015 and 2022 while it increased in the Restigouche River and in all New Brunswick tributaries. In 2021, the mean temperature was 18.9°C at this station as compared to 21.4°C in the Restigouche River (at Butters Islands).

The highest temperature between 2003 and 2022 was measured in August 2022 in the Northwest Upsalquitch River at 10 Mile Pool (28.3°C).



Data source: RivTemp (2023), DFO (2023)

Figure A.2: Historical evolution of daily mean (a) and maximum (b) water temperature in summer in the Restigouche River watershed (New Brunswick)

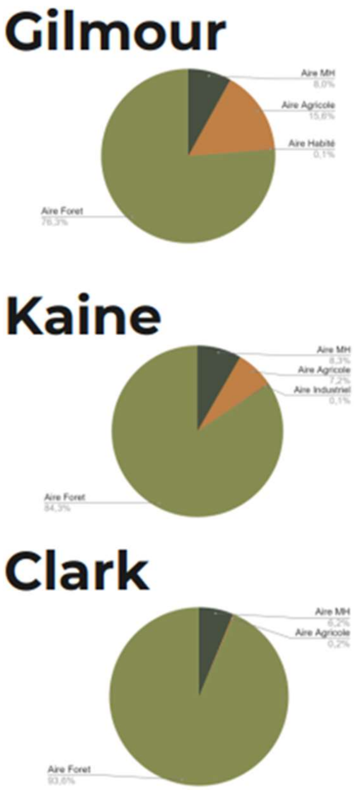


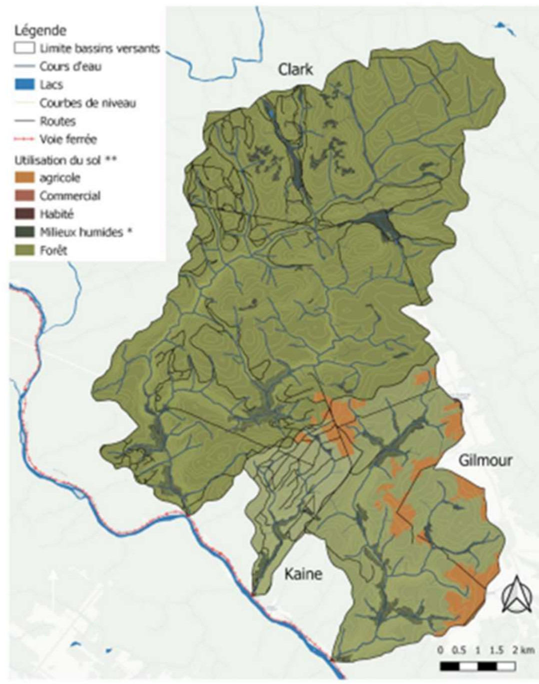
Data source: RivTemp (2023), DFO (2023)

Figure A.2: Historical evolution of daily mean (a) and maximum (b) water temperature in summer in the Restigouche River watershed (Quebec)

Appendix B: Example of a selected CWR drainage catchment characterization

This is an example of GIS characterization of a CWR drainage basin (Gillis *et al.*, 2020).





* Les milieux humides proviennent des données de carte écoforestière du 4e décennal et de l'analyse des photographies Satellite ESRI
** L'utilisation du sol provient de l'analyse des photographies Satellite ESRI
Les autres couches proviennent des bases de données géomatique de l'OBVMR