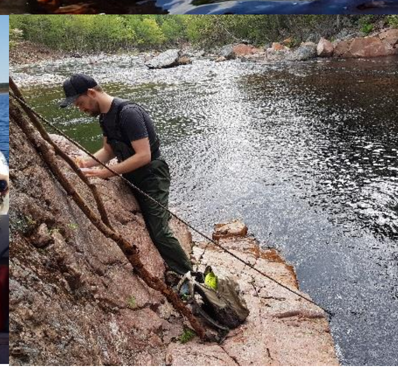
Managing Atlantic salmon and other cold-water species in a changing climate

Focus on water temperature of the Cheticamp River, key tributaries, and the Cheticamp reservoir

Summary report of 2019 investigation



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December 2019

Background:

The Cheticamp River Salmon Association (CRSA) and Parks Canada's Cape Breton Highlands National Park (CBHNP) have a common interest in protecting the Cheticamp River's population of Atlantic salmon and recognizing the value of working together, have increased collaboration in recent years on several conservation projects. And given that high water temperatures and low water/reduced flow conditions occur frequently in Atlantic salmon rivers in the Maritimes, recent and ongoing CRSA and CBHNP led projects have sought to address one or both of these limiting factors. This is particularly important as the combination of these changing environmental conditions – elevated water temperatures and low flows – pose the greatest risk for early-run salmon rivers like the Cheticamp.

Elevated water temperatures have already resulted in action being taken on the Cheticamp River. The CRSA and CBHNP's shared concerns over how elevated summer water temperatures combined with less rainfall were exacerbating problems with fish passage at several sites on the lower Cheticamp River led to the largest instream restoration project ever undertaken on the river. Completed in 2018, the 5-year project involved the installation of 72 instream structures designed to improve fish passage through a series of critically and unnaturally overwidened sites on the lower Cheticamp River.

While the restoration work has resulted in positive changes, including significantly narrower channels and deeper thalwegs at some of the project work sites, the CRSA and CBHNP agreed that a better understanding of the water temperature regime of the Cheticamp River would be a critical component in the planning of future conservation efforts, especially in light of projected warming associated with climate change. In 2017 the CRSA and CBHNP initiated an investigation of summer water temperatures on the Cheticamp River, including key tributaries and the Cheticamp River reservoir.

The 2017 study revealed several noteworthy findings, including:

1. the presence of a small but perhaps significant thermocline in the Cheticamp reservoir,
2. a correlation between the surface water temperatures of the reservoir and the temperature recorded by a logger installed below the dam, and
3. evidence that Faribault Brook's cooling influence on the main river appears to be negligible.

While the CRSA and CBHNP obtained a large amount of data in 2017, logistical and equipment issues left the investigators with many gaps in their first year of study.

The CRSA and CBHNP learned from their experiences in 2017 and continued with a second year of investigation in 2018. The second year of study sought to remedy the shortfalls from the previous year and involved the use of additional loggers installed over more of the critical summer period. The 2018 data allowed investigators to confirm that water temperature decreases somewhat as it makes its way down to the barrier falls, located about 10 kilometers (need to check this) below the dam. This is likely due to the influence of the cold water being introduced by two major upper tributaries located on the northeast (Park) side of the main river. Additional findings from 2018 included that Aucoin Brook – like Faribault- fails to result in cooling of the main river, however the data suggested a possible cool-water source somewhere between Faribault Brook and Petit Cap warranting further investigation. Unfortunately, several loggers - including the logger at the surface of the reservoir - were lost or failed to record data over the full study period.

The goals of the 2019 water temperature study included obtaining water temperature data for the full critical period of mid-June to mid-September and adding loggers to a number of new locations in order to strengthen some of the findings from the previous years and start to narrow down locations/sources of possible cooling or warming. The remainder of this summary report will provide an overview of what was accomplished in 2019, including results of preliminary data analysis.

This third year of the Cheticamp River water temperature study was made possible with funding from the Atlantic Salmon Conservation Foundation, the Nova Scotia Salmon Association's NSLC Adopt-a-Stream Program, and the Atlantic Canada Opportunities Agency (ACOA). In addition to the central partnership with Parks Canada's Cape Breton Highlands National Park, the following partners also provided generous in-kind contributions: Dr. Barrett Kurylyk's research group affiliated with Dalhousie University's Groundwater Lab (Centre for Water Resource Studies), Fisheries and Oceans Canada (DFO's Cheticamp conservation/enforcement office), and L'Institut national de la recherche scientifique (specifically INRS' RivTemp: A water temperature network for Atlantic salmon rivers in Eastern Canada).

Loggers and deployment:

The water temperature loggers used in the 2019 study were a combination of HOBO Water Temperature Pro v2 Data Loggers and HOBO 8k Pendant Data Loggers. The Cheticamp River Salmon Association contributed 13 loggers to the study, seven were provided by Cape Breton Highlands National Park, and an additional two loggers were loaned to the CRSA by INRS' RivTemp project. As was the case in the previous years of the study, the water temperature loggers were programmed to record water temperature at one-hour intervals (on the hour, i.e., 1:00pm, 2:00pm, etc.) over the sampling period. The loggers were again installed in homemade protective housings made from PVC pipe with holes drilled to allow for water flow, and either secured to the streambed by anchors or weighted down with rocks and secured to fixtures such as trees or boulders using a combination of clothesline and rope. Deployment sheets were filled out when each logger was installed and later retrieved and included information such as depth of deployment and type of habitat (e.g., pool, riffle).

Figure 1: ***The housing for CRSA's water temperature loggers used in the 2019 study period.***

One of the shortfalls of the previous years' water temperature studies was the inability to successfully deploy the loggers early enough to capture the full target period of June 15th to September 15th (~half the 2017 loggers were not installed until early July and the majority of the 2017 loggers were only installed at the start of August). The investigators were able to improve on this in 2019, deploying all of the loggers in the Cheticamp River by June 15th and the loggers at the Cheticamp reservoir by June 25th, resulting in data from the previously missing key time period of late June and early July. The majority of the loggers in the Cheticamp River were removed early (September 6th) ahead of post-tropical cyclone Dorian to avoid possible losses due to the forecasted major storm event.

Table 1. ***Locations and dates of deployment of water temperature loggers that the investigators were able to successfully obtain data from as part of the 2019 Cheticamp River water temperature study.***

Location	Date deployed	GPS coordinates
Cheticamp Reservoir - bottom	June 25, 2019	46.65198, -60.66170
Cheticamp Reservoir – 2m from bottom	June 25, 2019	46.65198, -60.66170
Cheticamp Reservoir - Surface	June 25, 2019	46.65198, -60.66170
Below dam	June 20, 2019	46.65167, -60.67353
3rd Pool	June 15, 2019	46.63672, -60.87692
2nd Pool	June 15, 2019	46.63612, -60.88666
1st Pool	June 15, 2019	46.63295, -60.90633
Faribault Pool	June 13, 2019	46.63056, -60.92505
Midway Faribault – Fence	June 13, 2019	46.63428, -60.93076
Fence Pool	June 13, 2019	46.63661, -60.93854
Midway Fence – Petit Cap	June 13, 2019	46.63828, -60.94436
Cabot Trail bridge	June 14, 2019	46.64711, -60.95384
Below CT – channel divide	June 14, 2019	46.65022, -60.95780
South channel – above Aucoin	June 14, 2019	46.65204, -60.96192
Cheticamp River below Aucoin	June 14, 2019	46.65178, -60.96441

With access to slightly more temperature loggers (20 loggers in 2019 compared to 16 in 2018 and 14 in 2017), the CRSA and CBHNP were able to include additional locations in the 2019 study. This was important as the 2018 temperature data included several interesting findings warranting further investigation. In particular, the investigators were interested in deploying additional loggers between the Faribault Brook tributary and Petit Cap to confirm and narrow down the location of a possible cool-water input, as well as installing additional loggers between the Warden's Station and Aucoin Brook to better understand the warming observed between these locations. In addition, the investigators had yet to obtain full summer (late June – September) temperature data from both the surface and bottom of the Cheticamp reservoir – data that is needed to determine if there is an identifiable and significant thermocline in the reservoir.

While the 2019 study involved an increase in the number of temperature loggers deployed, as in previous years, a variety of issues prevented the study group from successfully obtaining data from all the units. The investigators were able to successfully retrieve data from 15 of the 20 loggers deployed at the start of the study period (3 loggers were lost over the summer and the remaining two unusable due to a combination of corrupt and missing data). This is a similar success rate to the first two years of the study (e.g., data was obtained from 13 of the 16 loggers in 2018).

Figure 2: ***Map of Cheticamp River showing the locations of the 15 water temperature loggers successfully deployed as part of the 2019 water temperature study.***

As well, as seen in Figure 2, no loggers were placed in the mid area of the river, from 3rd Pool to the barrier falls, a distance of about 12 kilometers. Limited resources and difficulty of access have been the main impediments to properly monitoring this area. The CRSA and Parks Canada, with access to additional staff and equipment, hope to install several loggers at key locations in this mid section of the river in 2020.

Results:

Water temperatures >20°C

Atlantic salmon – like other salmonids – are sensitive to water temperature, and exposure to elevated temperatures can cause a range of harmful effects, including decreased oxygen supply, disrupted metabolism, increased vulnerability to toxins and disease, and reduced ability for juveniles to avoid predation. Given that Atlantic salmon can begin experiencing stress and other negative effects when water temperatures exceed 20 degrees Celsius, the investigators used the data from the water loggers to determine the numbers of hours and locations where water temperatures exceeded 20°C. Note: the investigators used the period of June 25 – September 6 (period of 73 days) for comparison, as this was the maximum number of days where all loggers were installed between the critical period of June 15th to September 15th.

Table 2. ***Number of hours and degree hours where water temperatures exceeded 20 degrees Celsius at logger locations where sufficient data exists to allow for comparison for period between June 25th and September 6th, 2019.***

Logger	n (hrs)	n (days)	hrs T > 20	deg-hrs T > 20
Cheticamp reservoir - bottom	1752	73	22	16
Cheticamp reservoir – 2m from bottom	1752	73	189	60
Cheticamp reservoir - surface	1752	73	473	454
Below dam	1752	73	268	339
3rd Pool	1752	73	77	65
2nd Pool	1752	73	81	74
Ist Pool	1752	73	102	98
Faribault Pool	1752	73	135	151
Midway Faribault - Fence	1752	73	38	31
Fence Pool	1752	73	221	403
Midway Fence – Petit Cap	1752	73	208	320
Cabot Trail bridge	1752	73	161	241
Below CT – channel divide	1752	73	215	388
South channel – above Aucoin	1752	73	236	444
Cheticamp River below Aucoin	1752	73	221	399

As shown in Table 2, the water temperature exceeded 20°C at all logger locations in 2019. Temperatures above the 20°C threshold were similarly spread across the logger locations in 2018, when only the logger at Robert's Brook did not exceed 20°C (note: the logger installed at Robert's Brook in 2019 went missing so no data is available for 2019 at that location). Not surprisingly, the logger at the bottom of the reservoir recorded the fewest hours above 20°C (22), followed by the upper pools, which showed slight increases in temperature moving down river: 3rd Pool (77), 2nd Pool (81), and 1st Pool (102). As was the case in 2018, the loggers generally recorded higher temperatures, and more time with temperatures >20°C, the further downstream they were located. An exception, however, was the logger located at Fence Pool. This logger recorded the second highest temperatures (high of 25.7°C with 403 degree hours >20°C), with only the logger below the Cabot Trail bridge on the south channel of the split recording higher temperatures (high of 26°C and 444 degree hours >20°C).

The investigators were surprised by the data recorded on the logger installed at a midway point between Faribault Brook and Fence Pool. The water temperatures were significantly cooler at this location, with only 38 hours recorded where the temperature exceeded 20°C. This was despite the logger being installed at a shallower depth and at a location with no cover. As can be seen in Figure 3, the logger midway between Faribault Pool and Fence Pool was consistently cooler than the loggers at Faribault Pool and Fence Pool. The logger at Faribault Pool was up to 2.28°C warmer than the logger midway to Fence Pool, while the Fence Pool logger recorded a difference of up to 4.57°C warmer.

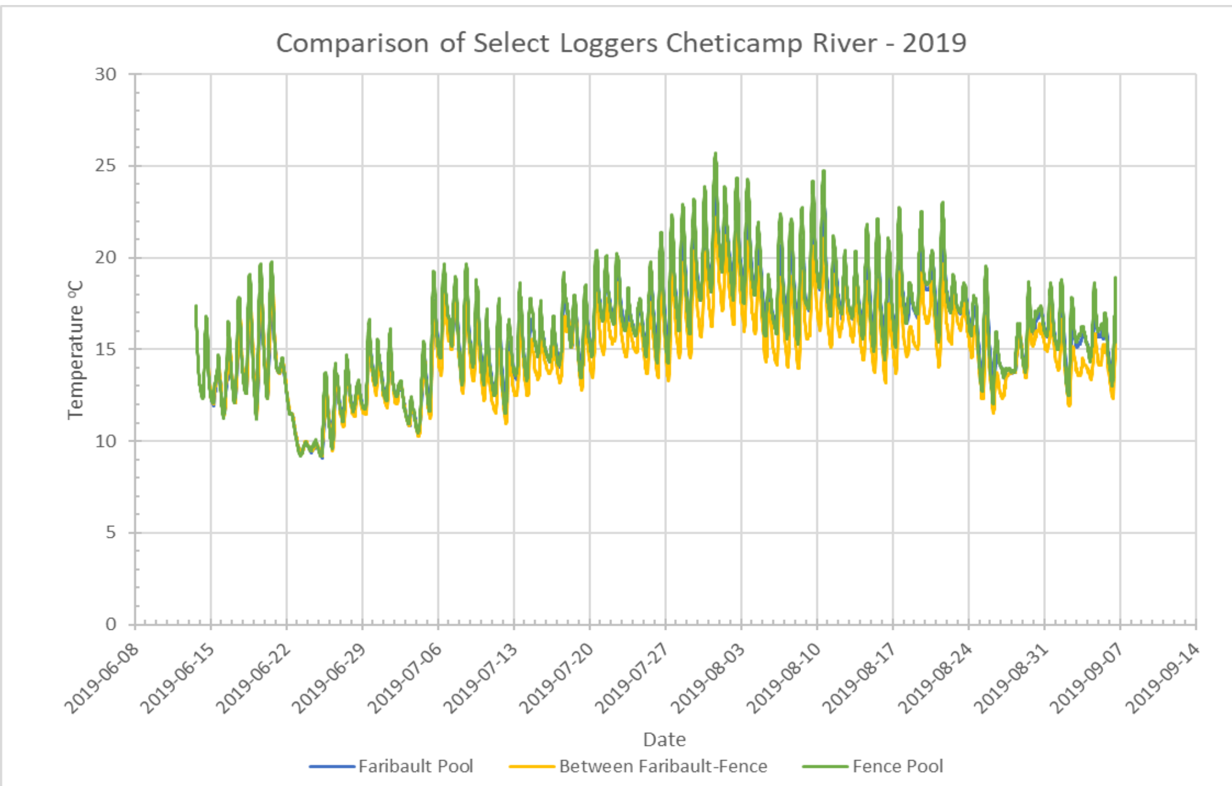

Figure 3. ***Graph showing a comparison of the water temperatures recorded by the loggers at Faribault Brook Pool, location midway between Faribault Brook and Fence Pool, and Fence Pool.***

The data from the logger installed at Petit Cap in 2019 was inaccessible. This location had cooler temperatures than the loggers both up and downstream of it in 2018 (e.g., 349 degree hours >20°C at Petit Cap compared to 937 at the logger above Faribault Brook and 599 at the logger installed behind the Warden's Station). Given that the loggers at Fence Pool and midway between Fence Pool and Petit Cap did not show any cooling, it is possible that there is still a source of cooling downstream of the logger midway between Fence Pool and Petit Cap. This will be explored with further monitoring in 2020.

Overall, water temperatures were lower in 2018 than in 2019, both in terms of the total hours where temperatures exceeded 20°C and the degree hours >20°C. For example, the logger at 1st Pool in 2018 recorded 449 hours where temperatures >20°C and 500 degree hours >20°C, compared to the logger at the same location in 2019 which recorded 102 hours >20°C and 98 degree hours >20°C. Higher maximum water temperatures were also recorded in 2018 than in 2019. Again, using 1st Pool as an example as there is data from this location for both 2018 and 2019, the water reached a maximum temperature of 24.46°C in 2018 at this location compared to a maximum of 23°C in 2018. Given that air temperature is the major factor affecting the water temperature in rivers, cooler air temperatures between June-September 2019 are presumed to be responsible for the slightly cooler summer water temperatures recorded in 2019 (investigators have yet to quantify the differences in summer air temperatures in Cheticamp).

Cheticamp reservoir

As was the case in 2018, the logger installed nearest to the headwaters, below Nova Scotia Power's D1 dam, recorded the second highest number of hours with temperatures above 20°C (268). The only location with higher temperatures and more time with temperatures >20°C was the logger installed at the surface of the Cheticamp reservoir. The investigators suspected in 2018 that the temperature of the water at the logger located below the dam was closer to the temperature at the surface of the reservoir than the bottom. As can be seen in Figure 4, data obtained in 2019 supports this hypothesis.

The investigators were also interested in whether the loggers at the Cheticamp reservoir would reveal the existence of a thermocline. While a malfunction with the surface logger prevented a comparison of surface and bottom temperatures in 2018, data collected in 2017 in August and September revealed that the temperatures were up to 4.2°C warmer at the surface than the bottom during the first three weeks of August. By September in 2017, the surface and bottom water temperatures approached the same. Figure 4 shows that the greatest difference in temperatures in 2019 occurred between the end of July and the first week of August, with the maximum temperature difference again recorded as 4.2°C.

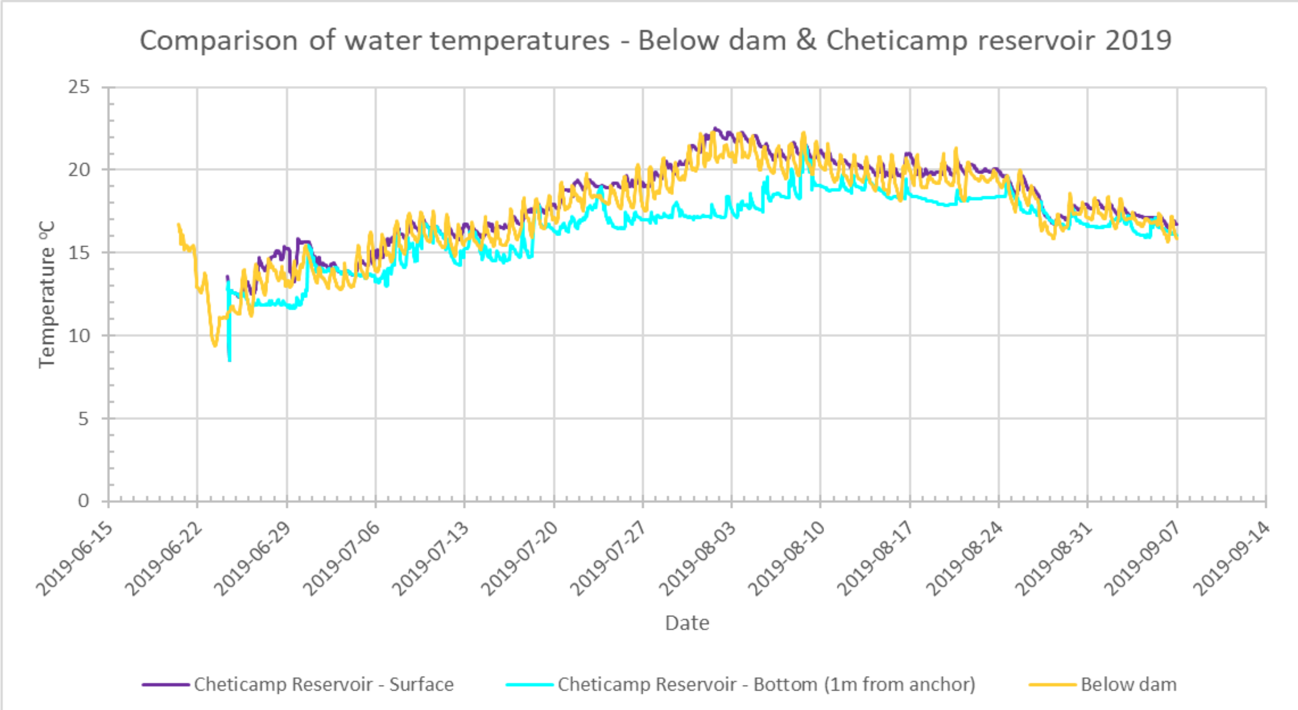

Figure 4. ***Graph showing a comparison of the water temperatures recorded by the loggers located at the surface and bottom of the Cheticamp reservoir and below the D1 dam.***

DTS and thermal imaging

Being able to identify cool-water inputs (groundwater and surface water) requires spatially extensive temperature monitoring – monitoring that is difficult to do solely with conventional temperature loggers. It follows that a reliance on traditional temperature loggers has been one of the limitations of the CRSA and CBHNP's water temperature study over the past three years. Fortunately, a new partnership with Dr. Barret Kurylyk with Dalhousie University's Groundwater Lab (part of the university's Centre for Water Resource Studies) has resulted in opportunities for greatly increasing the spatial and temporal resolutions of the water temperature data being collected on the Cheticamp River.

Figure 5. ***DTS equipment setup on the Cheticamp River, October 2019.***

In 2019, Dr. Kurylyk and members of his research group, including researchers at McGill University, performed a test run of a more sophisticated method of water temperature monitoring using distributed temperature sensing (DTS) equipment and a drone with infrared thermal imaging capabilities. The combination of this high-tech equipment has the potential to vastly increase the quantity and quality of data that can be collected, allowing for the creation of a thermal map of the watercourse, clearly identifying cool-water inputs and any existing thermal barriers.

Instead of conventional temperature loggers recording temperature at individual points, the distributed temperature sensing equipment uses a fibreoptic cable as a sensor, providing a continuous temperature profile along the cable. During a trial run this fall, the DTS operated by Dr. Kurylyk's research group measured water temperature along a 900 m long cable at 0.01*C resolution. The DTS equipment was programmed to measure temperature each minute at 0.5 m spatial resolution. The cable used in the trial was installed in the thalweg, weighted down at regular intervals with rocks, in a ~700m stretch of channel from above Terre Rouge (tidal pool) to about 300 meters below the Cabot Trail bridge.

Figure 6. ***Installation of fibreoptic DTS cable as part of trial involving Dr. Kurylyk's research group, October 2019.***

Dr. Kurylyk's research group also used a drone with a thermal infrared camera capable of obtaining measurements of radiant temperature at the water's surface. The images captured by the camera allow for the possible quantification of spatial patterns of water temperature in the watercourse, including the identification of cool-water inputs and thermal pollution/barriers. Dr. Kurylyk's research group collected water temperature data simultaneously with the drone and the DTS equipment, increasing the amount of data available and allowing the investigators to validate their findings.

Given that the trial run occurred during the first week of October, the water temperatures on the Cheticamp River had already cooled to a point that made identifying cool-water inputs and thermal barriers unlikely. The objective of this initial fieldwork involving Dr. Kurylyk's research group, however, was primarily to familiarize the team with site conditions, test the equipment, and work out other logistics. The October trial was considered a success and Dr. Barret Kurylyk and members of his research team will be involved in further planning over the winter and spring, with the goal of returning in summer 2020 for more intensive fieldwork.

Next steps:

The CRSA and CBHNP are committed to additional investigation into summer water temperatures in the Cheticamp River watershed in 2020. The investigators plan to increase their capacity for collecting water temperature data in 2020 and at least begin to develop conservation recommendations that include a focus on thermal management options. This should be a priority as the study has provided evidence that the Cheticamp River regularly experiences high water temperatures during the summer that exceed critical thresholds for salmonids (25°C) and negative impacts related to elevated water temperatures are expected to worsen over time given projections for continued warming.

An important expansion of the water study will be possible through a partnership with Dr. Barret Kurylyk with Dalhousie University's Groundwater Lab (part of Dal's Centre for Water Resource Studies). By involving Dr. Kurylyk and members of his research team in the 2020 study, the CRSA and CBHNP will be bringing research expertise and equipment from both Dalhousie University and the University of McGill to this project. By using a combination of distributed temperature sensing (DTS) equipment and a drone with an infrared thermal camera to greatly increase the temperature monitoring capabilities in 2020, the investigators are looking to work with its partners on the development of a thermal map of the lower Cheticamp River which will include the identification of potential thermal barriers as well as cool-water inputs (including tributaries and groundwater seeps and springs). Given that reliance on cool-water refugia by salmonids is expected to increase with a warming climate, the investigators plan to also use the thermal mapping work to help generate management options for preserving, enhancing, and in some cases potentially creating cool-water refugia in the Cheticamp River.

In addition to research expertise from Dalhousie and McGill, the CRSA and CBHNP plan to consult with other partners, including Dr. Eddie Halfyard – biologist with the Nova Scotia Salmon Association who has experience related to cool-water refugia on the West River-Sheet Harbour – to identify specific thermal management options for the Cheticamp River (an important piece that is currently missing from the conservation plan).

The investigators are also hoping to place loggers and possibly use drone temperature sensing in the mid section of the river (between 3rd Pool and the barrier falls) where several major tributaries are located. Given the difficulty of access to this area, the logistics of this undertaking will be discussed over winter.