Water Temperature Analysis
Cheticamp River and Cheticamp Reservoir
Summer 2017

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Parks Canada Parcs Canada

The Atlantic Salmon Conservation Foundation

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Introduction:

Low stream flows and high water temperatures are two factors limiting the migration and survival of Atlantic salmon in Nova Scotia's Cheticamp River. With climate change contributing to a trend of increasing water temperatures and decreased flows, significant concerns have been raised regarding the potential impacts to the long-term health of Atlantic salmon and other native fish populations in the Cheticamp River. To address these concerns, the Cheticamp River Salmon Association (CRSA), working in collaboration with Cape Breton Highlands National Park (CBHNP), initiated a temperature study in 2017 focused on the Cheticamp River, its tributaries, and the Cheticamp reservoir. The following report covers the first phase of the study, with the objective of creating a daily temperature profile for both the Cheticamp River and the Cheticamp reservoir. This report also includes analysis of additional related data, including flow rates from the Roberts Brook Environment Canada hydrometric gauge station and summer rainfall amounts for Cheticamp..

Baseline temperature data for the Cheticamp River system will allow the project proponents to share data and work with other entities and agencies such as Nova Scotia Power and Environment Nova Scotia to develop a plan for the long-term survival of Atlantic salmon in the Cheticamp River.

The Background

The Cheticamp River Salmon Association (CRSA), working with its partners at Cape Breton Highlands National Park (CBHNP) has initiated a study focused on the summer water temperatures of the Cheticamp River, its tributaries, and the Cheticamp reservoir. Located almost entirely within Cape Breton Highlands National Park, Nova Scotia, the Cheticamp River is an important Atlantic salmon watercourse as it has one of only two remaining spring (late May- early July) runs of Atlantic salmon in Nova Scotia. The Cheticamp River has also been a Live Release river for Atlantic salmon since the late 1980's.

Atlantic salmon have significant ecological and cultural value in Nova Scotia and along with brook trout are socially, recreationally and economically important to the province's

Cheticamp River, Cape Breton Highlands National Park. One of two remaining spring (June migration) Atlantic salmon rivers in Nova Scotia.

fisheries (DFO, 2010 and DFO, 2015). Over much of its range in Eastern Canada, there have been significant decreases in Atlantic salmon numbers in the past decades. Overharvesting in the ocean, climate change, habitat damage and water quality problems, as well as poor land use practices, are among some of the anthropogenic problems (Macmillan et al., 2005). However, despite these challenges, the Cheticamp River has, over the last 20-30 years, maintained a relatively stable salmon population. Anecdotal information suggests that it is in more recent years that certain factors such as climate change seem to be having a more significant impact on the river. With the increasing impacts of climate change, other key factors such as controlled water flow from the Cheticamp reservoir and the presence of shallow over-widened areas in the lower river may now be having greater impacts on vulnerable species such as the Atlantic salmon. Anecdotal sources also report that for the first time in memory, low water levels in the Cheticamp River prevented much of the

2012 Atlantic salmon migration (Goff-Beaton and MacInnis, 2015). Unfavourable conditions, such as occurred in 2012 (i.e., very low water levels during the June salmon run), now seem to be occurring more often (June precipitation below 75mm occurred twice between 2004 – 2010, but four times between 2010 – 2017, (Table 2. Total Precipitation (mm) in Cheticamp, Environment Canada, Historical Weather) and are influencing the migration of Atlantic salmon.

Water temperature is a crucial parameter in stream ecology. It can determine the overall health of aquatic ecosystems, affect the availability of dissolved oxygen, and can influence metabolic fish rates as well as their distribution within rivers (Macmillan et al., 2005). Brook trout and Atlantic salmon are part of the salmonid family, and are particularity sensitive to water temperature. In water temperatures above 19°C, Brook trout will move into cold-water areas (Cherry et al., 1977). This often results in many fish migrating to small areas, and can result in increased competition, predation and disease (Macmillan 2008, Kanno and Macmillan 2004). Temperatures ranging from 22°C to 28°C cause thermal stress for Atlantic salmon parr, with even slightly lower temperature values negatively affecting their alevins (J. M. Elliott and J. A. Elliott, Journal of Fish Biology 2010). The incipient lethal temperature for adult Atlantic salmon is likely near 25°C (Canadian Science Advisory Secretariat Science Advisory Report 2012). Note that water temperature of 25°C was recorded by Parks Canada and CRSA staff in the lower Cheticamp River in the summer of 2012.

In the 1970's, Nova Scotia Power built a dam at the headwaters of the Cheticamp River. The Cheticamp reservoir, now the source of the Cheticamp River, is

"Wreck Cove is the largest hydroelectric plant in Nova Scotia with a generating capacity of 200 MW. Constructed from 1975-1978 south of the Cape Breton Highlands National Park, Wreck Cove collects drainage water from 216 square kilometers of the Cape Breton Highlands plateau to generate electricity." (*https://www.nspower.ca/en/home/about-us/how-we-make-electricity/renewable-electricity/default.aspx*)

part of Nova Scotia Power's Wreck Cove Hydroelectric project. This structure changed the flow regime, increasing the flushing time from about 15 days in the original Cheticamp Lake up to 305 days in the Cheticamp reservoir (Klasses and Locke, 2010). Such changes may have resulted in the following:

a) Allowing time for the water in the reservoir to heat up before being released to the river, and

b) Changing the flow pattern in the crucial salmon migration period.

The Cheticamp dam and reservoir have had an impact on the river flow and possibly the river temperature; however, the emergence and growing influence of climate change has added another important dimension to the ecosystem. The result is raised concerns regarding the future of the Atlantic salmon in the Cheticamp River.

With these concerns in mind, in 2017, the Cheticamp River Salmon Association initiated a water temperature analysis with the objective of determining the following:

What are the present temperature regimes in the Cheticamp River and in the Cheticamp reservoir particularly during the period from June to September?

Though this initial study focused on 2017 summer water temperatures, with comparison to temperatures from previous years where CBHNP data was available, many important and related questions were raised regarding changes to the river which may have occurred in recent decades and may still be occurring today. While this water temperature analysis is an important first step in better understanding summer water temperature levels on the Cheticamp River, and explores potential sources of elevated water temperature, other lines of investigation should also be pursued in the future. For example, further study could attempt to answer the following questions:

- Has the Cheticamp River experienced a measurable change in rainfall, river water levels and mean air temperature?
- Has there been a statistically significant increase in water temperature in the Cheticamp River and Cheticamp Lake/reservoir?
- Is there an identifiable and significant thermocline in the Cheticamp reservoir?
- Has there been a change in the flow regime in recent decades? Since the construction of the Cheticamp reservoir?
- Are there steps that can be taken to mitigate higher water temperatures in the Cheticamp River?
- Are there steps that can be taken to mitigate high water temperatures in the river?
- Are there steps that can be taken to increase water flow in the Cheticamp River during the Atlantic salmon migration?

Materials and Methods

During the summer of 2017, the Cheticamp River Salmon Association (in partnership with Parks Canada's Cape Breton Highlands National Park and with funding from the Fisheries and Oceans Canada's Recreational Fisheries Conservation Partnership Program (RFCPP), the Atlantic Salmon Conservation Foundation (ASCF), the Nova Scotia Salmon Association's NSLC Adopt-A-Stream Program) and the Canada Student Program collected water temperature data from the Cheticamp River, several tributaries, and the Cheticamp reservoir. Historical data for the Cheticamp River and other lakes in the Cape Breton Highlands was provided by CBHNP.

Loggers in the Cheticamp reservoir

On August 3rd, a group composed of CRSA employees and volunteers as well as DFO staff travelled to the Cheticamp reservoir. The maximum depth recorded during the 2017 August 3rd sampling date was seven meters. Note that the maximum depth at the Cheticamp reservoir (probably achieved in late fall and after the spring thaw) is nine meters.

a. A thermophile line was left in the reservoir reaching a depth of ***6.4 meters*** located approximately 180 meters from the dam outlet at N 46.65198, W -060.66170. The line was weighted and had loggers attached using zip ties at 1 meter, 3 meters, and 6 meters from the bottom of the line. An anchor of approximately 40lbs was secured to one end of the line and a polystyrene foam buoy attached to the other end. The loggers were programmed to record temperatures at one-hour intervals. The line was retrieved on September 25th.

b. Temperature at 12 locations was also measured on August 3rd using a handheld HOBO 8k Pendant Temp/Alarm (Waterproof) Data Logger tied to a weighted rope. The locations were roughly along two cross sections along the outlet end of the reservoir (see Figure 16). Proximity to the reservoir outlet and depth were the two critiria used for cross sections selection. At each location, the logger was lowered to the bottom of the lake where it remained for one minute before being raised by one meter at a time, at one-minute intervals, until it reached the surface.

c. Temperature and dissolved oxygen data were also collected from the 12 locations in Cheticamp reservoir using a YSI multi-parameter water-sampling probe. The data was collected up to a 4-meter depth (the probe was attached to the unit by a 4-meter cable, thus preventing sampling at greater depths).

Temperature loggers in the Cheticamp River

This study involved analysis of the following three sources of data from the Cheticamp river:Nine HOBO Water Temperature Pro v2 Data Loggers and two HOBO 8k Pendant Temp/Alarm (Waterproof) Data Loggers were installed at ten locations along the Cheticamp River in July 2017 . (Fig. 1-7 and Table 1). Loggers were installed in different types of locations: holding pools,

Data Logger Location	Lat/Long	UTM
Salmon Trap	46.65796N, -060.96186W	5169173.1, 655935
Gauge Station	46.64154N, -060.94600W	5167380.1, 657196
Faribault (Pool)	46.63056N, -060.92505W	5166202.1, 658831.4
Faribault (Confluence)	46.63031N, -060.92478W	5166174.8, 658852.8
Faribault (Brook)	46.63015N, -060.92495W	5166156.7, 658840.2
Faribault (Above)	46.63024N, -060.92428W	5166168.1, 658891.3
2nd Pool	46.63612N, -060.88663W	5166898, 661755.7
3rd Pool	46.63672N, -060.87692W	5166984.7, 662497.1
Cheticamp Lake outflow	46.65167N, -060.67353W	5169086, 678014
Warden's station	46.64613N, -060.95310W	5167876, 656639

shallow areas, confluences, and tributaries along the river. The loggers were programmed to record temperature at one-hour intervals over the course of the sampling period. Homemade housings, made from PVC pipes with drilled holes to allow for water flow, were used to protect the loggers (Fig. 8). Loggers were secured in the housing with zip ties, and the housings were filled with rocks to prevent floating. The housings were secured in the river with clothesline that was fastened to a long rope and tied to nearby trees. Large rocks were also used to anchor the housings. Data was collected periodically in the field using an HOBO Waterproof Shuttle and HOBOware Pro-Mac/Win software.

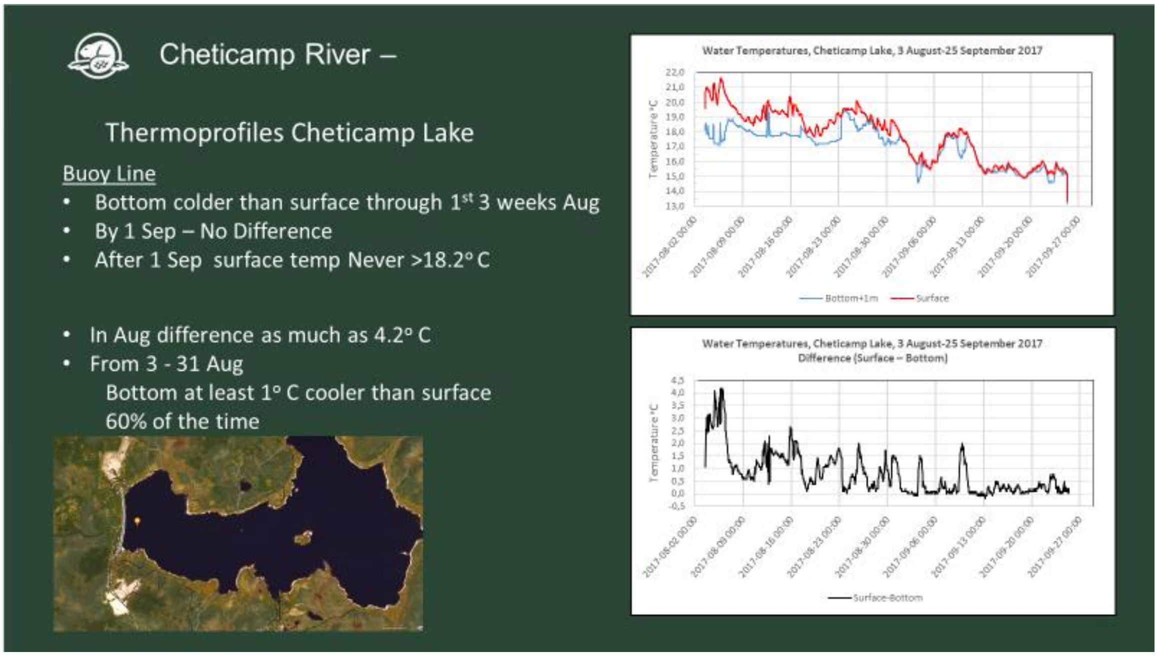
1) Data was also obtained from loggers installed by Parks Canada (notably below the Cheticamp reservoir).
2) Additional data was gathered from kayakers using handheld thermometers to measure water temperature at 10 locations on July 2nd and 3rd over approximately 20 kilometers along the Cheticamp River (Figure 10a).

   The loggers in both the Cheticamp river and reservoir were retrieved between late September and early October. The extracted data was analyzed and compared with data collected from various locations on the Cheticamp River and CBHNP over the previous ten years.

Temperature Data Results

Cheticamp Reservoir:

<u>Data from the thermophile line:</u> The thermophile line is considered the more accurate of the methods of data collection from the reservoir as it covered a period of almost two months (August 3rd to September 25th) and had no human intervention during that time



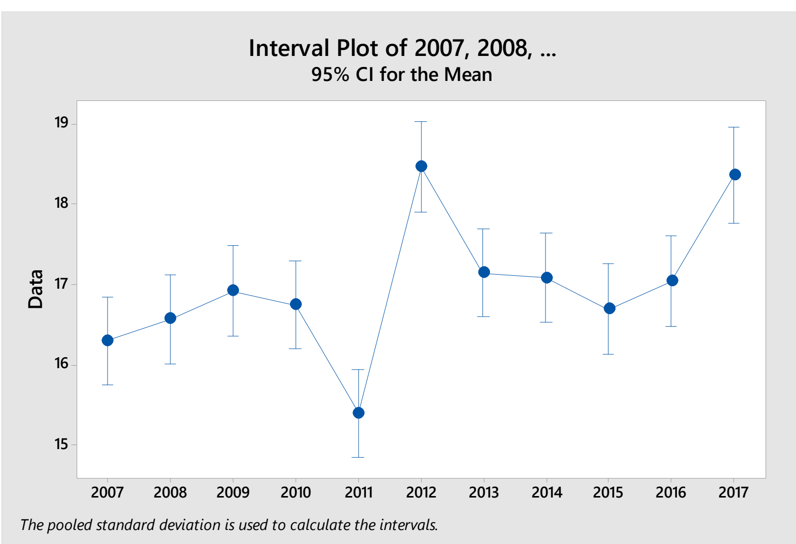
frame. Figure 18 above (Courtesy of James Bridgland, CBHNP) shows the spatial distribution of temperatures. The results indicate that the lowest logger (1 meter from bottom at 5.4 meters) is cooler than the surface for the first three weeks of August by as much as 4.2°C. By September 1st, the surface and bottom temperatures are virtually the same. The highest bottom temperature in the time series was 19.4°C recorded at 3PM on the 24th of August. *The depth of mixing depends in part on the exposure of the lake to wind (its <u>fetch</u>), but is most closely related to the lake's size. Smaller to moderately*-sized *lakes (50 to 1000 acres) reasonably may be expected to stratify and be well mixed to a depth of 3–7 meters in north temperate climates. Larger lakes may be well mixed to a depth of 10–15 meters in summer (e.g., Western Lake Superior near Duluth, MN).*

http://www.lakeaccess.org/ecology/lakeecologyprim4.html

Though more data will be required for a complete analysis, the general trend observed (Figure 11b, Parks Canada logger located below the dam) is that ***there is a small thermocline from surface to bottom in the Cheticamp reservoir.***

<u>Data using handheld loggers at various depths in the reservoir</u>: The point sampling conducted onAugust 3rd at the Cheticamp reservoir provides only snapshots of the temperature profile through the water column at various locations in the reservoir. Data collected (Figure 16 and Table 4) shows the distribution of the 12 profile stations at the outlet end of the Cheticamp Lake along with the water depth at each station. Water depth varied from 3.4 to 7.0 meters (mean = 5.1 ± 1.0). Table 4 shows the temperatures recorded at each depth in the water column at each station. Table 4 also shows that the greatest difference in temperature between the warmest and coolest parts of the individual water columns measured was 3.2°C. A difference of 3.2°C was recorded at two of the twelve stations measured. Station 12 had the warmest surface temperature at 22.9°C, while the bottom temperature at 4.5 meters was 19.8. Station 9 had the lowest recorded surface temperature at 20.5°C and 19.4 °C at a depth of 5.4 meters. The lowest temperature was recorded at station 8, (19.3°C) at a depth of seven meters.

No clear trend was evident from the August 3rd sampling.



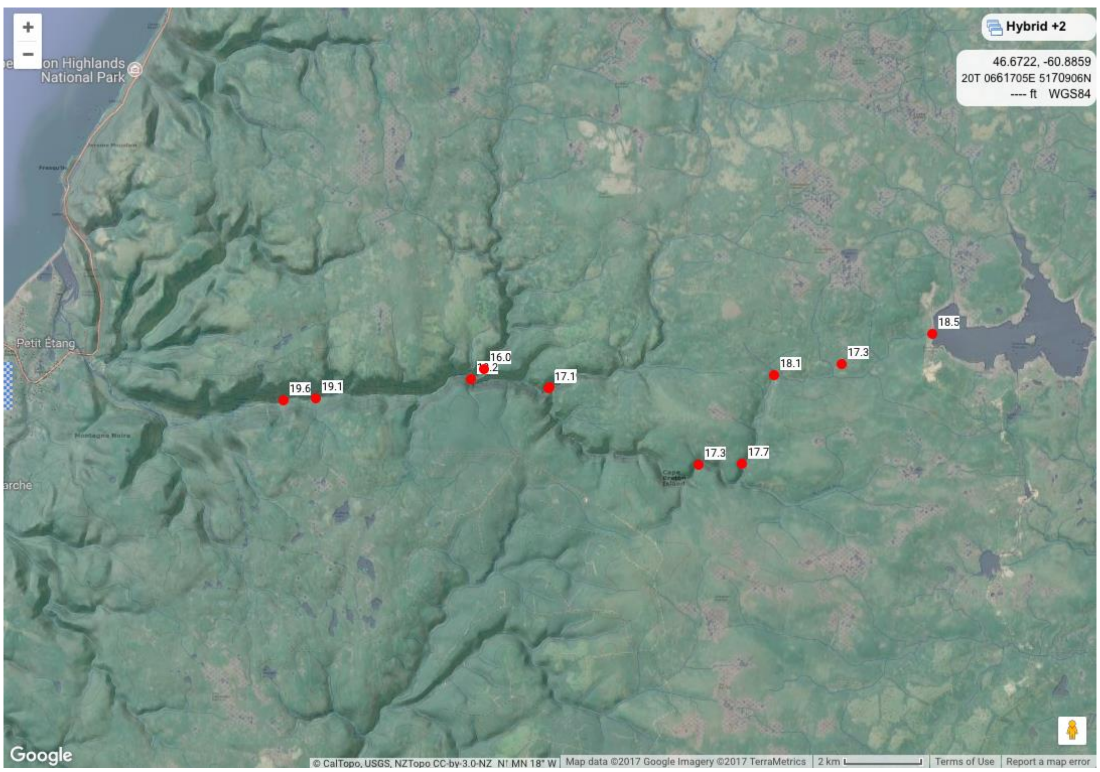
<u>Data from logger located below the dam:</u>

Water temperature data for the sampling location below the dam on the Cheticamp River (available for 2007 to 2017 from CBHNP) was compared and among the findings is what appears to be a trend of gradually increasing average water temperatures. Daily average water temperatures measured below the Nova Scotia Power dam between June 1st and August 31st from 2007 to 2017 were graphically compared. Figure 11a below shows data across all 11 years, but for clarity Figure 11b focuses on four years from the 11-year timeline. A statistical one-way ANOVA test was performed using the averages to determine the P-value, and thus the significance of these results. The interval plot for this test, with a 95% confidence interval (CI), is shown in Figure 11c (left). Since the P-value (0.00) is less than 0.05, the means are significantly different. With a 95% CI, temperatures measured in 2017 were significantly higher than all other years, except 2012, by a difference ranging from 0.072 (2017 to 2013) to 1.824 (2017 to 2011) degrees Celsius.

b) the water released from the reservoir corresponds generally with the reservoir's surface temperature.

<u>Data from water temperature measurements by kayakers:</u>

The water temperature data recorded by kayakers using handheld thermometers provides the only water temperature data in this study from the mid-section of the Cheticamp River, and, although limited, it does provides some indication of water temperature changes from the outlet of the dam to 3rd pool, including the possible cooling effects of the upper tributaries. Two kayakers navigated over 20 kilometers of the Cheticamp River on July 2nd and 3rd. The kayakers launched from just below the



Cheticamp dam, and periodically took water temperature readings using a handheld thermometer. The resulting temperature data and locations were recorded on a mapping system (**https://caltopo.com/m/84H3**). Figure 10a above shows the locations and water temperature distributions, measured over two days along the Cheticamp River.

Water temperature of 18.5°C was measured by the kayakers near the river's outflow at the dam, and temperature readings showed some cooling immediately below the three main upriver tributaries (Artemise Brook and two unnamed tributaries flowing from the Northeast). A low reading for the main channel of the Cheticamp River of 17.1°C was measured below Artemise Brook with the highest temperature (19.6°C) recorded at Third Pool (no readings were done below this point by the kayakers). The greatest temperature difference between sampling points was 2.5°C. Note that a lowest measurement (16°C) was recorded in the 2nd Northeast tributary.

There are no major tributaries from the 2nd Northeast tributary where the temperature was recorded at 17.2°C to Faribault Brook, approximately 10 to 12 km downstream. Note that the kayakers were not part of the project team and as such, accuracy of sampling methods and data is uncertain. Though not necessarily an accurate picture of water temperatures along the length of the river, the readings give a sense of temperature changes in the upper part of the watershed and support the idea of the cooling influence of the upper tributaries.

<u>Data from loggers, reservoir to Terre Rouged:</u> Water temperature data from different loggers along the river, starting from the reservoir (Thermophile line 1 meter

Temperatures recorded at five locations: Reservoir to Terre Rouge (Tidal) over three days in August 2017

Date	Time	Reservoir*	Outlet*	3rd Pool	Faribault*	Terre Rouge
August 4	4PM	17.6 °C	20.2°C	20.2°C	22.3°C	25.5°C
August 14	4PM	17.8°C	19.9°C	19.3°C	20.5°C	22.3°C
August 24	4PM	17.8°C	18.9°C	18.2°C	18.8°C	20.7°C

*Reservoir: Thermophile logger 1 meter from bottom

* Faribault Pool (below confluence)

Reservoir Surface temperature

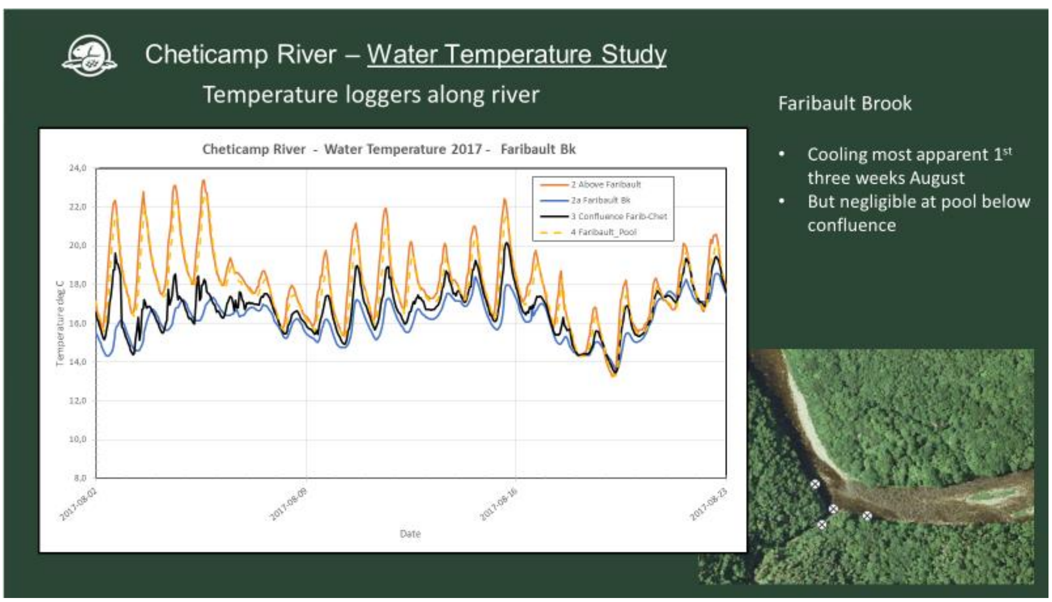
- August 4, 68.4 (20.1),
- August 14, 66.9 (19.4)
- August 24, 67.1 (19.5)

above bottom) are shown for three days in August shown in the table above. The other logger locations included the Park logger at

the outlet of the dam, at Third Pool, at Faribault Brook pool and at Terre Rouge (tidal pool). The time of recorded temperature was 4PM. Note: August 4th was the first possible day for comparison between these locations as the thermophile line was only installed at the reservoir on August 3rd, and the other dates were chosen as ten days apart in order to look for potential changes over time. On August 4th, the data shows a difference of +2.6°C between the temperatures recorded by the logger one meter from the bottom of the reservoir and the logger located on the Cheticamp River about a half kilometer below the dam. Below this, the data suggests that the temperature remains steady to the Third Pool, a distance of about 17 kilometers. By the time it reaches Faribault Brook (a distance of approximately six kilometers), the water temperature increased by 2.1°C on August 4th . The peak temperature from the August 4th dataset is reached at the tidal pool (Terre Rouge), with water temperature recorded at 25.5°C at **4PM. At this location, the river is subject to the influence of tides and Aucoin** Brook. Note: no logger was placed in Aucoin Brook, the river's lowest tributary; but, given that the brook runs through an unshaded marsh for approximately 1 kilometer before entering the Cheticamp River, it suggests that Aucoin Brook has the potential to elevate the water temperature of the main river at Terre Rouge.

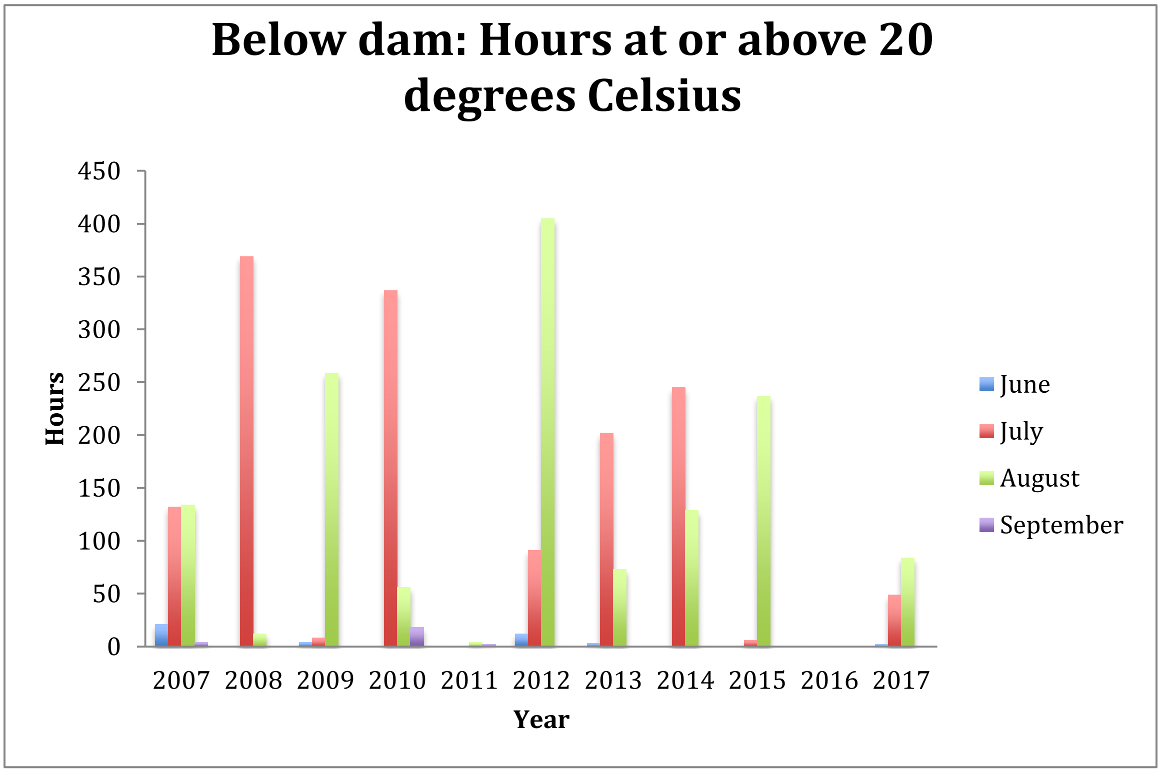
By August 14th, the temperature change is far less pronounced and almost negligible by August 24th.

Influence of Faribault Brook on the Cheticamp River: Four loggers were installed on July 23rd in the Faribault Brook area: above the brook, in the brook, at the confluence, and in the pool below the confluence. Temperature data from these loggers reveals that there is a significant difference in afternoon temperatures between the brook and the river, but that the influence of Faribault Brook on water temperature in the Cheticamp River is minimal. For example, on July 31st at 4PM, the temperature logger above Faribault Brook shows a temperature of 22°C, while the Faribault Brook logger shows a temperature of 15.6°C. Temperatures measured in the pool below Faribault Brook were not significantly different (21.2°C) than those measured above the brook. The assumption is that by the time the main river reaches Faribault Brook, its flow has been enlarged by several major tributaries in the upper part of the watershed such that Faribault Brook has a limited cooling effect on the Cheticamp. The slide below (Courtesy of James Bridgland, CBHNP) shows this trend for a three-week period in August 2017.



Temperatures above 20 degrees Celsius: The number of hours and locations where the water temperature measured 20 degrees Celsius or higher were also tabulated and plotted. Since some locations did not have sufficient data, only three of the locations are shown (Figures 15a, b, d). These include the logger located below the dam, the logger located above Faribault Brook, and the logger behind the Warden's Station near the CBHNP Cheticamp Campground.

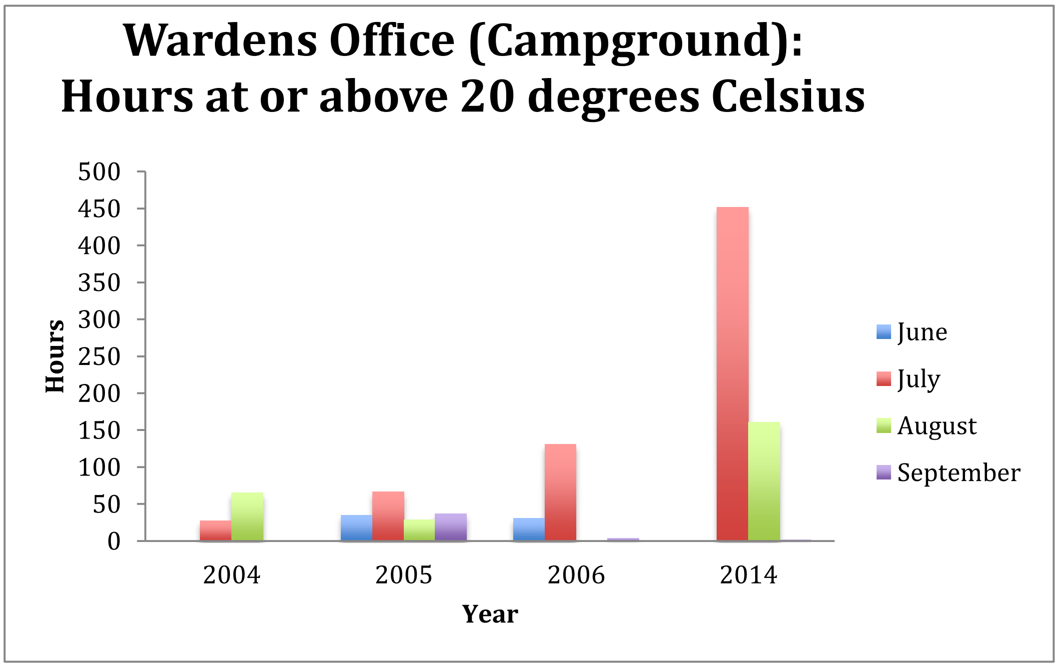
In Figure 15a (Below the dam), most of the hours that temperatures met the



threshold value (20°C) occurred in August. 2012 had the most hours measured that met the threshold, with 508 hours at or above 20°Cfrom June to September. This is followed by 2010 (411 hours) and 2008 (381 hours). There were no hours recorded at or above 20°Cin 2016, leading investigators to questions if there may have been a problem with the logger in 2016. It should be noted that some years also had incomplete data, making comparisons problematic.

In Figure 15b (Above Faribault Brook), most of the hours that met the threshold value were measured in July and August. 2017 had the most hours measured at or above 20°C (401), despite there being an additional month of data for 2004, 2005, and 2006 (temperature was measured from June to September for these years, while data was only available from July to September for 2017. 2004, 2005 and 2006 had similar hours at or above the threshold value (between 218 and 246 hours).

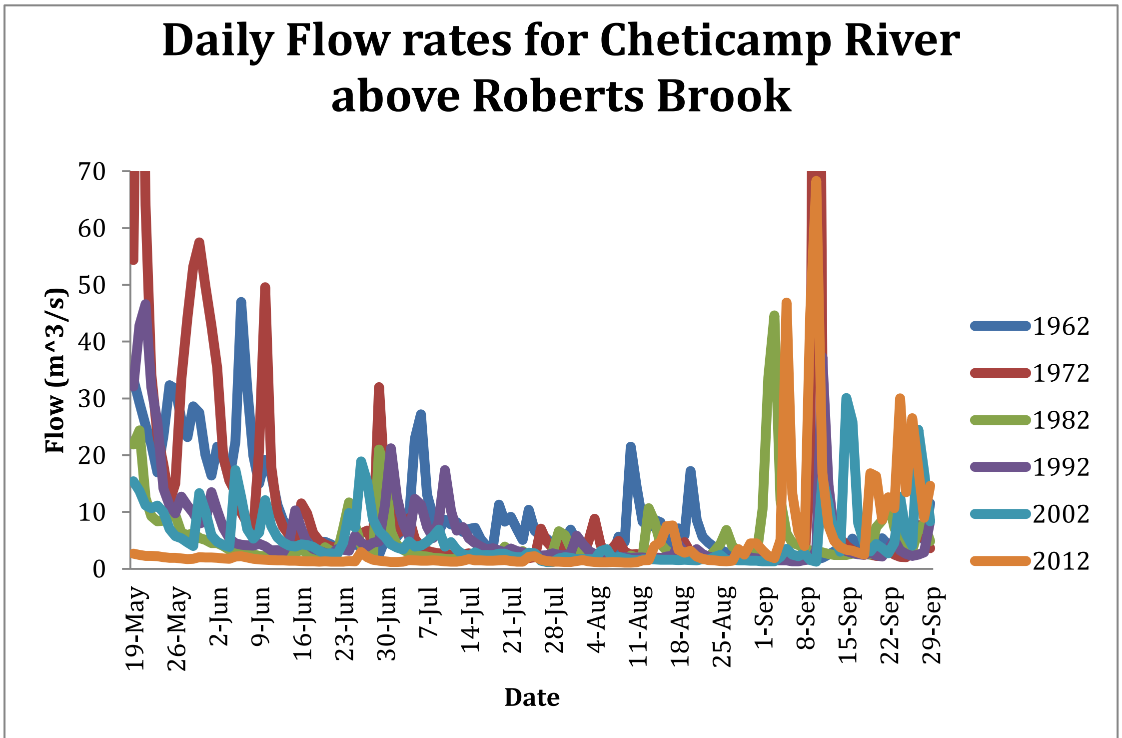
Figure 15d (Warden's Office, CBHNP) shows that 2014 had the highest July temperatures, with 450 hours measured at or above 20°C. 2004 had the lowest with 92.5 hours. Compared to the Faribault Brook location, the 2005 and 2006 Warden's Office location had between 50 and 60 fewer hours counted at or above 20°C over the four months. Focusing on data from 2014, there were 241 more hours at the Warden's Office location than the location below the dam where water temperature was recorded at or above 20°C.



<u>Flow rate at Roberts Brook hydrometric gauge station</u>

Though not directly part of the temperature analysis, the hydrometric gauge station information gives an indication of the seasonality of flows and, particularly for 2012, the extremely low water levels during the Atlantic salmon migration period. Figure 9 shows daily flow rates for the Cheticamp River measured above Roberts Brook (https://wateroffice.ec.gc.ca/index_e.html) between mid-May and the end of September for one year each decade, between 1962 to 2012. (Note: 2012 was chosen as the base year in each decade as it was a year of known critically low flows,

In 1962, flow rates in the spring run season were 47m^3/s at the beginning of June and dropped to 27m^3/s at the end of the same month. In 1972, there was a similar



pattern with a flow rate of 49.6m^3/s at the beginning of the June, dropping to 32m^3/s at the end of the month. In the decades following the construction of the dam, the pattern seems to have changed. Since the construction of the dam in (1978), the highest flow rate in the series at the beginning of June was measured in 2002 with a flow rate was of 17.4m^3/s, followed by a slightly higher rate later in the month of 18.9m^3/s. The highest flow rate during the spring Atlantic salmon run season in the decades following the construction of the dam was measured in 1992 with a value of 21.2m^3/s in late June. Monthly flow rates at the gauge seem to show a change after the construction of the dam, i.e., low flow starting in early June after 1978 as opposed to starting in late June prior to 1978. More research is necessary to

- Confirm the change in flow pattern, and
- Identify other variables such as environmental change (less rainfall) that may be influencing the flow (Note: this might be possible by looking at nearby rivers such as the Northeast Margaree River, which is not influenced by the Cheticamp reservoir)

Though adequate river water levels are important year-round, they are particularly important during the month of June when the Atlantic salmon migration occurs.

Rainfall and air temperature: While not directly part of the 2017 water temperature analysis, monthly precipitation and air temperature are two key variables affecting both lake and river water temperatures. Rainfall information was collected for Cheticamp, Nova Scotia between June and August for the years 2006 to 2017 (see Table 2 below) in an attempt to identify any potential trends. Although some of the data is incomplete, the available information reveals a trend of decreasing rainfall in June and July. It should be stressed that while a trend of less rainfall through the summer months is

Table 2. Total Precipitation (mm) in Cheticamp, Nova Scotia, *note that some data is incomplete.

	2006	2008	2010	2012	2014	2016	2017
June	92.8	104.3	174	23.1	55.6	63.1	33.6
July	142.1	94.2	79.9	40.7	58.1	72.8	26.4
August	126.6	146	72.3	63.7	105.5	65.3	122.2
Total	361.5	344.5	326.2	127.5	219.2	201.2	182.2

http://climate.weather.gc.ca/climate_data/daily_data_e.html?StationID=27600 *Historical Data apparent, there are still ups and downs from year to year. For example, 2015 received the most precipitation with 383.7mm of rainfall over the 3 months. This is three times the amount of rain in 2012, which had the least amount of precipitation with 127.5mm.

Monthly average air temperature data for Cheticamp was also collected for the period between June and August from 2004 to 2017 (listed in Table 3). Available data indicates that 2006 had the warmest average temperature over the three months (18.7°C), and 2015 had the overall lowest average (16.4°C). In looking at the temperature data for the series, no apparent trend was readily decernable.

Issues and suggestion for follow-up research and analysis

The water temperature project undertaken in 2017, involving both the Cheticamp River and the Cheticamp reservoir, will require additional information to make a more complete and definitive analysis. The project proponents are hoping to add an important second year of data in 2018. With limited data from 2017 only preliminary conclusions should be considered.

Below are some of the study's shortfalls, including equipment and logistical issues, along with other suggestions that the investigators plan to address as part of a follow-up study in 2018.

- Several temperature loggers were lost or had no data due to equipment malfunctions;
- Due to logistical problems, loggers in the Cheticamp reservoir were not installed until August 3rd, thus missing key data for June and July;

- In 2018, loggers in the Cheticamp River should also be installed at an earlier date (June 1st or 15th);
- 2017 temperature data for the Cheticamp River did not include the upper river, with the exception of the logger below the dam, thus additional loggers should be installed in 2018 in the area of the upper tributaries;
- Additional loggers could also be installed in Roberts Brook and Aucoin's Brook (above their confluences with the Cheticamp) and above Terre Rouge;
- More research should be done on historical temperature data for both the Cheticamp River and the reservoir;
- A more complete picture of the Cheticamp River water temperatures could include more in-depth information on rainfall, water levels as measured at various gauges on the river;
- Late spring and summer water release from the Cheticamp dam should be researched for possible effects on water temperature and water levels during the period of Atlantic salmon migration;
- More research is necessary to confirm the change in flow pattern after the 1978 opening of the reservoir;
- More research should be included on declining flows, e.g., are the declining flow rates due to one of the following?
    - Declining release from the dam and /or
    - Environmental changes such as less rainfall available to other sources of water for the Cheticamp (tributaries);

- An evaluation/steering committee should be established and should include representatives from CRSA, Parks Canada, NS Power, Province of Nova Scotia, and the Atlantic Salmon Federation.

Preliminary Conclusions

1) **-Indication of a thermocline in the Cheticamp reservoir:** The Cheticamp reservoir appears to have some degree of temperature variation between the surface and bottom layers (see figure below). This is based on the data from the thermophile line installed at the reservoir on August 3rd to September 25th approximately 180 meters from the dam For example, as shown below, the results indicate that temperature recorded by the bottom logger (1 meter from bottom of the reservoir), is cooler than the surface logger for the first three weeks of August by as much as 4.2°C. (CBHNP PowerPoint slide #4)
2) **Maximum depth and thermocline – Cheticamp Reservoir**: The maximum depth recorded in the Cheticamp reservoir during the 2017 August 3rd and September 25th sampling dates was seven meters. The maximum depth is estimated to be 10 meters. This is significant, as sufficient depths are one requirement for a thermocline to be present in a waterbody. As comparison, the thermocline in Freshwater Lake, Ingonish (see Figure19) develops at a depth of between six and nine meters, below which the temperature is as much as 10-15°C lower than at the surface. It is likely that the reservoirs' greater size and exposure to wind (fetch) limites the amount of mixing thus effecting the thermocline.
3) **Water release from the reservoir correlates to the reservoir's surface (warmest) water temperature**

Though more data will be required for a complete analysis, data collected as part of this study in 2017 indicates that the water released from the Cheticamp reservoir corresponds generally with the reservoir's surface temperature and not from the reservoir's bottom temperatures (see figure below).

Water Temperatures – Cheticamp Reservoir -
Surface – 1 meter from bottom – Park logger below Dam

2017 Date	Cheticamp Reservoir Surface temperature	Park Logger below dam	Reservoir (1 meter from Bottom)
August 4 -	68.4 (20.2)*	20.2	17.6 ºC
August 14 -	66.9 (19.4)	19.9	17.8ºC
August 24 -	67.1 (19.5)	18.9	17.8ºC

* Reservoir surface temperature taken at surface from stationary thermophile line.

4) Trends of increasing water temperatures

Daily average water temperatures measured below the Nova Scotia Power dam between June 1 and August 31 from 2007 to 2017 were graphically compared and revealed a trend of increasing temperatures over the series. The warming trend appears stronger in the last decade as only two years (2011 and 2015) had lower daily average temperatures.

5) Declining flow rates for June, starting in 1978, are recorded by the Roberts Brook Hydrometric Gauge

As an important and related component to the temperature analysis, an examination was undertaken of flow information from the Roberts Brook hydrometric gauge station (available for the years starting in 1958) . Flow rates provide an indication of the seasonality of water levels, and

a) Shows, in the time series, the extremely low water levels which sometimes occurs during the Atlantic salmon migration period. In 1962, flow rates were 47m^3/s at the beginning of June and dropped to 27m^3/s at the end of the same month. In 1972, there was a similar pattern with a flow rate of 49.6m^3/s at the beginning of the June, dropping to 32m^3/s at the end of the month.

b) June flow rates show a significant change after the construction of the dam, with low flow starting in early June after 1978 as opposed to starting in late June prior to 1978. Since the construction of the dam, the highest flow rate measured at the beginning of June was in 2002 (flow rate of 17.4m^3/s).

6) Trend towards lower rainfall in June and July

Rainfall information was also collected for Cheticamp, Nova Scotia between June and August for the period from 2006 to 2017. Analysis of the data revealed a trend of

Table 2. Total Precipitation (mm) in Cheticamp, Nova Scotia,
*note that some data is incomplete.

	2006	2008	2010	2012	2014	2016	2017
June	92.8	104.3	174	23.1	55.6	63.1	33.6
July	142.1	94.2	79.9	40.7	58.1	72.8	26.4
August	126.6	146	72.3	63.7	105.5	65.3	122.2
Total	361.5	344.5	326.2	127.5	219.2	201.2	182.2

http://climate.weather.gc.ca/climate_data/daily_data_e.html?StationID=27600 *Historical Data

decreasing monthly precipitation amounts over the study period. This trend of lower rainfall is particularly evident for the months of June and July (Table 2 below).

Closing thoughts:

As the results from this preliminary study highlight several concerns to the long-term survival of the Atlantic salmon and the overall health of the Cheticamp River ecosystem, further studies are needed to better understand the situation and to determine possible strategies for addressing the issues of warming water temperatures and declining flows particularly during the June salmon migration.

Expanding this study and contining with data collection is important in order to reach a better understanding of water temperatures in the Cheticamp River and reservoir and their impact on Atlantic salmon. Data collection should continue in 2018 and ideally continue for several more years as well. Collection of data should also start in June (as discussed earlier in this report). Further, potential factors influencing water temperature, e.g., tributaries, shading from streamside vegetation, river width and depth, ambient temperature, precipitation, flow rates, should be investigated to determine their impact on fish populations.

Once more data is available and conclusions can be strengthened, the Cheticamp River Salmon Association hopes to work with its partners, including partners at Cape Breton Highlands National Park, to explore options for improving the future for Atlantic salmon on the Cheticamp River.

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