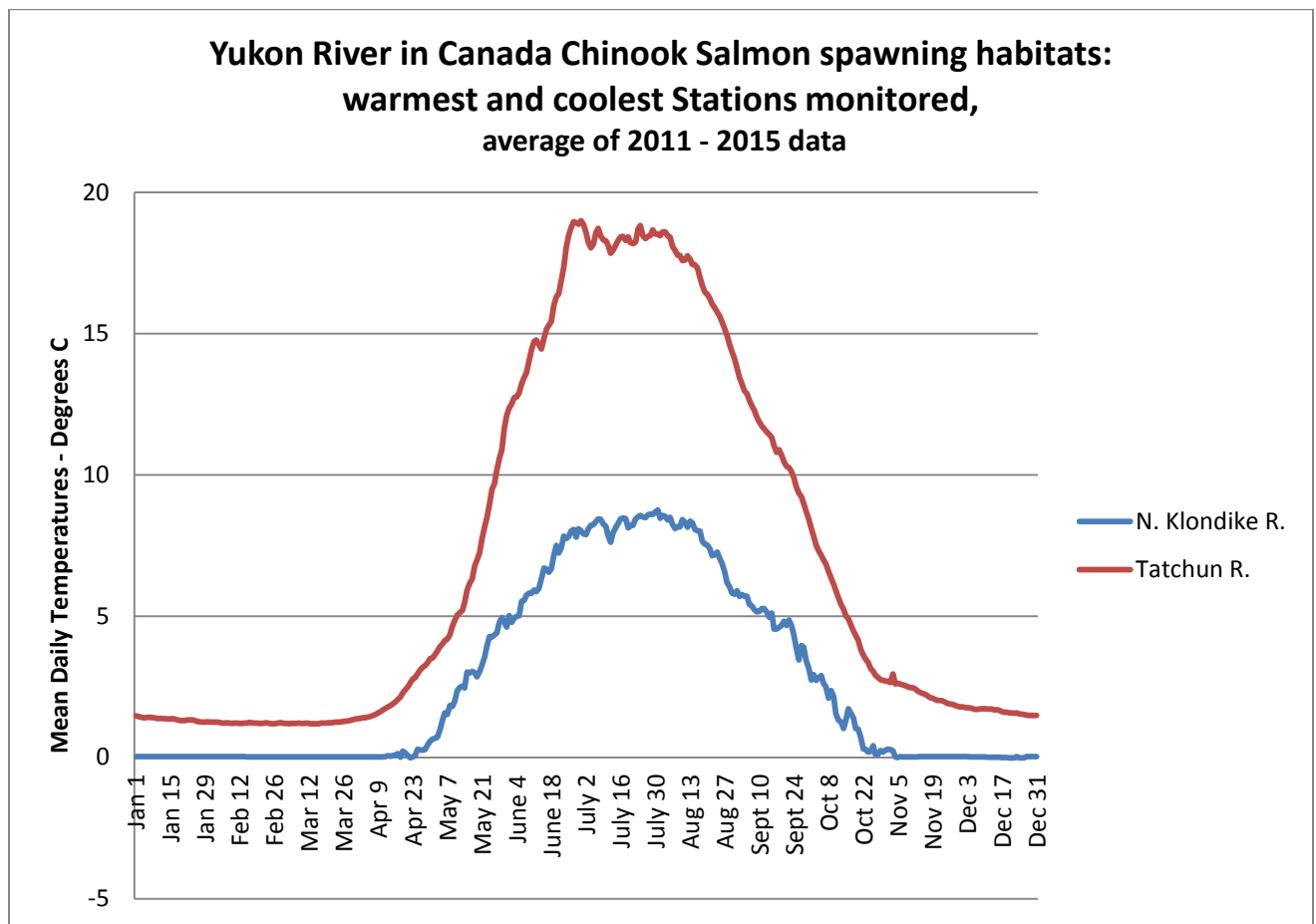


Water Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada

Progress Report

2015



Yukon River Restoration and Enhancement Fund
CRE-20-15

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Abstract

The Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program (the Program) was successfully conducted in 2015. The Program has two components. Three Seasonal Stations collect data during the Chinook Salmon upstream migration period. Eleven Annual Stations collect data throughout the year. Data is collected in 7 of the 8 watersheds in the Canadian Yukon River Basin (CYRB) and 9 of 11 DFO Conservation Units (CUs). All Stations are geo-located. A single make and model of data logger is used. Measurements are taken each hour, on the hour. Data is downloaded and saved as data sets. Each data set is checked to ensure integrity. Mean Daily Temperatures (MeDTs) are calculated and Maximum Daily Temperatures (MaxDTs) are determined. Data is analysed against established Standards and Thresholds. Annual Accumulated Thermal Units (AATUs) and Accumulated Thermal Units by Brood Year Cohort (ATUBYC) are calculated for Annual Stations. Alaskan Standards for migration and spawning are regularly exceeded. Canadian Thresholds for migration are exceeded much more rarely. Thermal conditions for Chinook Salmon upstream migration and spawning were excellent in 2015. AATUs and ATUBYCs vary widely across the CYRB, implying significant differences in potential productivity between different types of YR Chinook spawning and rearing watercourses. AATUs support preliminary classification of YR Chinook spawning waters into cold, cool and warm categories. ATUBYCs may allow insight into potential production of juvenile Chinook Salmon up to the onset of young-of-year overwintering. 174 data sets have been distributed and more is anticipated. All data collected in the Program will be publicly available at yukonwatertemperatures.info. Temperatures are being measured and recorded at 11 Annual Stations during the winter of 2015/16.

Acknowledgements

Funding from the Yukon River Panel made this project possible. Their support is greatly appreciated. The contribution of the members of the Joint Technical Committee in reviewing applications is acknowledged. Pacific Salmon Commission staff Angus Mackay and Victor Keong are thanked for their efficient administration of the Restoration and Enhancement Fund. Finally, Kieran O'Grady contributes his time and expertise to the administration the website yukonwatertemperatures.info

Cover: Graph shows the extraordinary temperature range of Upper (Canadian) Yukon River Chinook Salmon spawning habitat. The North Klondike River is the coolest river monitored, but may not be the coolest river utilized. The Tatchun River is the warmest monitored and likewise may not be the warmest river utilized.

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Introduction

The Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program (the Program) received funding from the Yukon River Panel's Restoration and Enhancement Fund (the Fund) in 2013, 2014 and 2015. The Program built on annual projects conducted by the Alaska Department of Fish and Game (ADF&G) beginning in mid-summer 2011 and ending in 2012. The author implemented the Yukon component of the ADF&G projects, supplied loggers to start the project and thereafter set companion loggers to ensure that data collected would be available to citizens of the Yukon.

The Program Goal is to develop a robust baseline range of water temperatures of selected Yukon River Chinook Salmon spawning and migration habitats in Canada. In 2015 the objectives of the Project were:

Objective

To operate, maintain and adaptively manage the existing Water Temperature Monitoring Network.

Deliverables:

- Narrative of the conduct of the project in the Annual Project Report;
- Deploying, retrieving and downloading data loggers from all Annual and Seasonal Stations;
- Preparation of data sets;
- Analysis of data against Alaska Department of Environmental Conservation Water Temperature Standards and Canadian Fraser River watch Thresholds, and reporting results.

Objective

To distribute the data to interested parties

Deliverables:

- A list detailing the recipients of the data sets distributed, and the numbers of data sets distributed.

Objective

To promote storage of the data in a publicly accessible data warehouse or equivalent facility.

Deliverables:

- Report the status of the initiative.

The implementation of the 2015 Project generally proceeded as planned. Monitoring and evaluation functions for field activities included close attention to the continued validity of Stations; design of and adherence to procedures to ensure that data from one Station could not and would not be confused with another; maintenance of a Master Data Logger Tracking Spreadsheet to track each logger and deployment; and deploying two loggers at each Station. Program related monitoring and evaluation included application of time, travel, and materials accounting and management principles to the project activities. Personnel time and watercraft use was tracked by the hour and vehicle use was by the kilometer.

There has been substantial progress toward meeting the Program's Goal of establishing a baseline of the range of water temperatures of Chinook Salmon migration and spawning habitats in the CYRB. There are now 4 full years of data for 2 of the Seasonal Stations and 3 for the third. There are 4 calendar years of data for 5 Stations; 3 calendar years for 2 Stations; 2 calendar years for 1 Station, 1 calendar year for 2 Station, and 2 Stations have yet to record a full calendar year. Data is also available for each Station for the period prior to the initial January 1 of its deployment and the period following the last Dec 31. The period of record includes 2012 which was a cold and wet year; 2013 which had a late spring but was much warmer in mid- and late summer. Both 2014 and 2015 had warm springs followed by cool summers. No warm water, low flow years have yet been monitored.

Detailed descriptions of the activities undertaken to address each of the three Objectives follow.

Operation, Maintenance and Adaptive Management of the Water Temperature Monitoring Program

This included deploying, retrieving, and downloading loggers; preparing data sets; conducting analyses; and distributing data sets. Risk assessment of the likelihood of being able to continue to safely retrieve loggers on schedule was conducted at each Station whenever loggers were deployed or replaced. The performance of each Station in collecting uninterrupted data series of sufficient quality was assessed during data set preparation. Stations are decommissioned if their physical viability may be compromised due to channel instability or if the data collected is compromised by repeated disturbance by people or animals. A new Station on the same river or stream may be established if a suitable location is found. New Stations are added to the network to meet an opportunity or need.

The Yukon River at Policemans Point Station was decommissioned in 2015 due to heavy sediment deposition in the inlet of Lake Laberge. This appeared to be caused by 5 years of high river flow and consequent upstream erosion of river banks on the Yukon and Takhini Rivers. Considerable volumes of sand/silt has been transported to the inlet of the lake, where it formed deep deposits on the river bed. In spring 2015 the loggers were found to be buried in sand.. The risk that the loggers would measure the temperature of ground water discharging to the river rather than the river water itself was considered too high to continue with this Station. The Mcquesten River at WSC Station was to be decommissioned in 2015 due to poor performance. The loggers were not retrieved in 2015 as a result of high water and poor bush trail conditions early in the season. When I was able to drive to the head of the walking trail, a black bear was present and showed too much interest in me. I was too busy to shoot it, so I left the area. The replacement Station, Mcquesten River below Klondike Highway, met expectations and collected quality data throughout the winter of 2014/15 and the summer of 2015.

The Yukon River above Hootalinqua Station was added to the Network. This section of the Yukon River has apparently excellent Chinook spawning habitat characteristics. Extensive areas of the river bottom are comprised of gravels and cobbles. The channel gradient is gently stepped, resulting in a wide variation of water velocities. Despite this, there are no known records of Chinook spawning. Carcasses are rarely observed. If there was a population prior to c. 1897, it may have been disrupted by paddle wheel steamer traffic. The steamers would have had a profound effect on any redds present in the river. Channel improvements, including

blasting boulders during the winter could also have affected incubating eggs. However, the steamers have been absent from this section of the river since the early 1950s, and the salmon population should have re-established itself by now.

All other Stations performed as expected, with the exception of Teslin River at Hootalinqua. The loggers were deployed but could not be located in the autumn.

Program design and description

The following principles provided the framework for the Network:

- All data collected must be comparable. Comparison may be between different years at one or more Stations, or between different Stations in a single year. Tidbit V2 data loggers are used exclusively and the serial number of each logger is provided as metadata for each data set. Future data users will therefore be able to determine the capabilities of the equipment used. All loggers record temperatures each hour, on the hour.
- All Stations must be representative. The data collected represents the temperature of the water course being monitored and the purpose for which the monitoring is being conducted. Specifically:
 - Stations are located at a distance far enough from the mouths of upstream tributaries that the potential risk of measuring the temperature of the tributary rather than the subject watercourse is minimized;
 - With the exception of Stations purposefully located downstream of lake outlets to represent this type of Chinook Salmon spawning habitat, Stations located downstream of lakes are located far enough downstream that the potential effects of lakes on water temperatures are minimized;
 - Stations are located where there are no obvious ground water discharges at the Station or a reasonable distance upstream. Discharging ground water may be in excess of 15°C cooler than surface waters in midsummer and up to 7°C warmer in the winter. The resulting temperature induced difference in water density may result in the surface and ground waters not readily mixing. Avoiding ground water discharges reduces the potential risk of measuring the ground water temperatures rather than those of the subject watercourse.
- All data collections must be repeatable. Stations are geo-located by GPS. Should data collection cease for whatever reason, future investigators will be able to return to the Site and resume data collection.

The Program includes Seasonal and Annual Stations. Seasonal Stations are located in rivers which experience mechanical ice breakups. The risk of losing the loggers during breakup is unacceptable in these systems. Seasonal Stations are generally located on major tributaries in locations where large numbers of Chinook Salmon pass on their spawning migration. Loggers are deployed prior to the beginning of the upstream migration of Chinook Salmon and retrieved after the migration is considered to be over. Annual Stations record temperatures throughout the year and are generally located on Chinook spawning streams. Loggers at Annual Stations are replaced after spring high water and again prior to freeze up.

A set of principles guided the detailed design of the Network, and continue to guide its adaptive management. These include:

- Implementation over a wide geographical area to ensure a reasonable degree of coverage of the portion of the CYRB utilized by Chinook Salmon. This principle addresses the wide distribution of Yukon River Chinook Salmon migration and spawning habitats in the CYRB. Chinook spawning has been reported in more than 100 watercourses (von Finster, 2006). These watercourses, and the rivers they contribute to, span 7 terrestrial ecoregions (Smith et al, 2004) and, more importantly, 4 climatic zones (Wahl, 2004);
- Implementation over a variety of types of Chinook Salmon spawning habitats, and on primary tributaries (ie Teslin, Stewart and Pelly) used as major Chinook upstream migration routes;
- Compliance with current Yukon Occupation Health and Safety regulations in the operation of the Network by locating Stations where they can be safely accessed and maintained;
- Maintenance of close attention to economy to allow Stations to be efficiently and economically accessible;
- Maintenance of data security. The Tidbit V2 loggers are robust, accurate, and simple to operate and download. Two loggers are set at each Station at each deployment to maintain one level of redundancy. Loggers and associated equipment left in the field is concealed to reduce potential disturbance by humans. Loggers are replaced at each deployment to allow them to be cleaned and the status of their remaining battery life and storage capacity to be determined. Stations are located on reasonably stable channels to reduce the potential for loss due to channel shift and bank erosion.

Monitoring Network – Station Descriptions

The Stations which comprise the Network are described below. The following terms and identifiers are used.

Stations are named in relation to geographical features such as lakes or towns or long-standing structures such as bridges, signs, or landings, or reflect historical events. Of necessity, many of the names are local and will not be familiar to some readers. The coordinates provided allow stations to be located with Google Earth or another mapping tool.

Watersheds are the principal tributaries to, or main-stem segments of, the Yukon River in Canada. Tributary Watersheds include the Stewart, White, Pelly and Teslin Rivers. Mainstem segments include the Yukon River North Mainstem, from the Yukon-Alaska border to immediately upstream of the mouth of the Selwyn River, and including the Yukon River and all tributaries except for the White and Stewart Rivers; the Yukon River Mid Mainstem, from immediately upstream of the mouth of the Selwyn River to the mouth of the Teslin River, and including the Yukon River and all tributaries except for the Pelly River; and the Yukon River Upper Lakes, from the mouth of the Teslin River and including the remainder of the watershed. The Network includes Stations in all Watersheds except that of the White River.

Conservation Units are management units developed by Fisheries and Oceans Canada to implement Canada's Wild Salmon Policy. Yukon River Chinook Conservation Units include:

- CK-68 – Yukon River-Teslin headwaters – Teslin River and all tributaries;
- CK-69 – Upper Yukon River – Yukon River and all tributaries above the mouth of the Teslin;
- CK-70 – Big Salmon – Big Salmon River and all tributaries;
- CK-71 – Nordenskiold – Nordenskiold River and all tributaries;
- CK-72 – Pelly – Pelly River and all tributaries;
- CK-73 – Middle Yukon River & tributaries – Mainstem Yukon River and all tributaries between the mouth of the Teslin River and the White River except the Big Salmon, the Nordenskiold and the Pelly;
- CK-74 – Stewart – Stewart River and all tributaries;
- CK-75 – White – White River and all tributaries; and
- CK-76 – N Yukon River & tributaries – Mainstem Yukon River (migration only) below the White River and all tributaries except for the Stewart and White Rivers.

The Network includes all Conservation Units except for the CK-75 - White (River) and CK-70 - Big Salmon (River). These are excluded due to geographical isolation and the related expense of operating and maintaining Stations. Major Chinook spawning in the White River Watershed is limited to the Nisling River, Klottasin River and Tincup Creek. All are functionally accessible only by air. There is a small population in the Kluane River between the outlet of Kluane Lake and the mouth of the Duke River, but it is poorly representative of the more heavily utilized habitats. Chinook spawning in the Big Salmon River Watershed occurs in the North Big Salmon and its tributary, Northern Creek; the South Big Salmon; Scurvy Creek; and the mainstem river. Most spawning in the Big Salmon Watershed occurs well above the mouth of the river. Efficient boat access is not possible in the mid-Big Salmon River under low water conditions. A representative Station would have to be operated and maintained by air.

Sides of streams or rivers. “Right” or “left” is determined by looking downstream.

Use by Chinook – although only migration, spawning and incubation are explicitly noted, all rivers and streams are also utilized by rearing Chinook Salmon. Overwintering of young-of-year Chinook is believed to occur in most of the spawning rivers.

Seasonal Stations

Mid Stewart River at Stewart Crossing.

Type of Station: Seasonal

Watershed: YR Stewart River

Conservation Unit: CK-74 Stewart

Coordinates: NAD 83 63 22.947/136 41.036

Use by Chinook: upstream migration

Existing data: 2012 – present

Rationale for inclusion: The Stewart River is a principal tributary of the Yukon River and a major adult Chinook Salmon migration route. The Station is downstream of 8 documented spawning rivers in the mid- and upper Stewart River Watershed. The upper Stewart River Watershed is poorly explored. It is likely that there are more Chinook Salmon spawning rivers than are currently documented. Low river flows in 2002 were suggested as a reason that Chinook Salmon appeared to be experiencing difficulties in migrating over Fraser Falls (Osbourne et. al., 2003). Low summer flows generally result in high(er) water temperatures. The Station is in an excellent location, on the right side of river, against a bedrock bluff. Access is by vehicle via the Klondike Highway.

Performance: No concerns.

Pelly River downstream of Pelly Crossing.

Type of Station: Seasonal

Watershed: YR Pelly River

Conservation Unit: CK-72 Pelly

Coordinates: NAD 83 62 50.467/136 40.988

Use by Chinook: upstream migration

Existing data: 2012 - present

Rationale for inclusion: The Pelly River is a principal tributary of the Yukon River and a major adult Chinook Salmon migration route. The Station is downstream of all 22 documented spawning rivers in the Pelly River Watershed. It is in an excellent location, on the right side of river, against a bedrock bluff. Access is by vehicle via the Pelly Farm Road

Performance: No concerns.

Teslin River at Hootalinqua.

Type of Station: Seasonal

Watershed: YR Teslin River

Conservation Unit: CK-68 Teslin River Headwaters

Co-ordinates: NAD 83 61 35.118/134 53.897

Use by Chinook: upstream migration past the Station and spawning within 30 km upstream

Existing data: 2011 – 14; no data for 2015

Rationale for inclusion: The Teslin River is a principal tributary of the Yukon River and a major adult Chinook Salmon migration route. The Station is downstream of all 21 documented spawning rivers in the Teslin River Watershed. The lowest portion of the Teslin River is laterally unstable. There are no suitable sites for establishing and servicing a Station. Sites exist upstream but are difficult to access with a propeller driven boat at low water levels. The current Station is at the confluence of the Yukon and Teslin Rivers and upstream of where the mixing zone between the two rivers reaches across the river. Access is by boat from the Deep Creek Launch on Lake Laberge.

Performance: Hootalinqua is a heavily used locality, and the loggers are vulnerable to disturbance. The loggers were likely stolen in 2015, and the Station will be relocated in 2016.

Annual Stations

North Klondike River at North Fork Bridge

Type of Station: Annual

Watershed: YR North Mainstem

Conservation Unit: CK-76 North Yukon River

Coordinates: NAD 83 - 64 00.102/138 35.761

Use by Chinook: spawning and incubation.

Existing data: August 5, 2011 – present, continuous.

Access: by vehicle via the Dempster Highway and North Fork Road.

Rationale for inclusion: The North Klondike River is a mid-sized mountain river. It is considered typical of Chinook spawning rivers flowing south from the Ogilvie Mountains. These include Coal Creek, Fifteen Mile River and Twelve Mile (Chandindu) River, and possible spawning tributaries in the little explored upper South Klondike River. The Station is located at or near the apex of the alluvial fan the North Klondike River has formed in the Klondike Valley.

Performance: No concerns during open water period. The loggers record freezing temperatures in some winters, as the location of the winter channel varies from year-to-year.

Mcquesten River below Klondike Highway

Type of Station: Annual

Watershed: YR Stewart River

Conservation Unit: CK-74 Stewart

Coordinates: NAD 83 - 63 33.318/137 24.912

Use by Chinook: spawning and incubation. Upstream migration to the confluence of the North- and South Mcquesten Rivers and then to spawning locations further upstream on each fork.

Existing data: July 5, 2014 – present, continuous.

Access: by vehicle via the North Klondike Highway

Rationale for inclusion: The Mcquesten River is the primary Chinook Spawning river in the Stewart River Watershed. The original Station for the Mcquesten River was located upstream. It has not performed well due to excessive flows displacing the loggers. The Station has proven difficult to access at times.

Performance: No concerns.

Mcquesten River below WSC Station

Type of Station: Annual

Watershed: YR Stewart River

Conservation Unit: CK-74 Stewart

Coordinates: NAD 83 - 63 36.489/137 16.634

Use by Chinook: spawning and incubation. Upstream migration to the confluence of North- and South Mcquesten Rivers and then to spawning locations upstream on each fork.

Existing data: July 1, 2011 – ???. There have been significant data gaps due to data logger loss or displacement.

Access: by four wheel drive vehicle via the Vancouver Creek Trail.

Rationale for inclusion: The Mcquesten River is the primary Chinook spawning river in the Stewart River Watershed. The Station is located at the approximate mid-point of the main spawning area and is at- or near the apex of the alluvial fan the Mcquesten River has formed in the Stewart River valley.

Performance: Overall, inadequate. Loggers were lost during the 2013 freshet and displaced and deposited on the river bank during the 2014 freshet. Significant data gaps resulted. The loggers record freezing temperatures in some winters, as the location of the winter channel varies from year-to-year. Decommissioning will occur in 2016.

Blind Creek above abandoned bridge

Type of Station: Annual

Watershed: YR Pelly River

Conservation Unit: CK-72 Pelly

Coordinates: NAD 83 62 11.624/133 10.799

Use by Chinook: Spawning and incubation.

Existing data: July 20, 2011 – present, continuous.

Access: by vehicle via the Blind Creek Road and the original Faro Mine Access Road.

Rationale for inclusion: Blind Creek is a small stream with a number of minor headwater lakes. It is typical of a number of spawning streams tributary to the Pelly and upper Stewart River. The enumeration fence located near the mouth of the creek has recorded the longest wild Chinook escapement data set in the CYRB (Wilson, 2011). Summer flows have been measured by Government of Yukon Water Resources and its predecessor agency (DIAND) since 1992 (Yukon Government 2005). The Station is located at or near the apex of the alluvial fan Blind Creek has formed in the Pelly Valley.

Performance: No concerns.

Tatchun River downstream of Tatchun Lake outlet

Type of Station: Annual

Watershed: YR Mid-Mainstem

Conservation Unit: CK-73 Yukon River Mid-Mainstem

Coordinates: NAD 83 62 17.216/136 14.316

Use by Chinook: spawning and incubation.

Existing data: July 20, 2011 – present, continuous.

Access: by vehicle via the Tatchun Lake Road

Rationale for inclusion: The Tatchun River is relatively small and has significant lake storage. It is typical of a number of highly productive Chinook Salmon spawning streams distributed across all Watersheds of the CYRB except

for the YR North Mainstem Watershed. These include, among others, Tincup Creek in the White River Watershed; Janet Creek in the Stewart River Watershed; Glenlyon River in the Pelly River Watershed, the Swift River (North) in the Teslin River Watershed and Michie Creek in the Yukon River Upper Lakes Watershed. These streams often support very high densities of spawning Chinook and have extensive spawning dune complexes. They are also vulnerable to direct effects of periods of low flow/high water temperatures, and to indirect effects such as beaver damming of spawning streams.

Performance: No concerns.

Nordenskiold River at Elk Sign

Type of Station: Annual

Watershed: YR Mid-Mainstem

Conservation Unit: CK-71 Nordenskiold

Coordinates: NAD 83 61 51.438/136 06.539

Use by Chinook: spawning and incubation. Upstream migration during high water years to Hutshi Lake outlet and Kirkland Creek.

Existing data: July 24, 2010 – present, continuous from September 28, 2011 - present.

Access: by vehicle via the Mayo Road/North Klondike Highway.

Rationale for inclusion: The Nordenskiold River is a mid-sized river during wet weather years. Much of its drainage basin is in the rain shadow of the Coastal Ranges. There is only limited high elevation terrain to provide seasonal water storage. During drought periods flows in the river are greatly reduced. The river is vulnerable to the direct and indirect effects of climate change. A Chinook Salmon stock on one tributary, Klusha Creek, has been extirpated due to extended droughts and associated effects of low stream flows.

Performance: generally good, but somewhat vulnerable to disturbance. The loggers record freezing temperatures in some winters, as the location of the winter channel varies from year-to-year.

Little Salmon River at canoe landing

Type of Station: Annual

Watershed: YR Mid-Mainstem

Conservation Unit: CK-73 Yukon River Mid-Mainstem

Coordinates: NAD 83 62 05.610/135 18.381

Use by Chinook: spawning and incubation. Upstream migration to Bearfeed Creek and Drury Creek.

Existing data: September 28, 2012 – present, continuous.

Access: by vehicle via the Campbell Highway

Rationale for inclusion: The Little Salmon River is a mid-sized river with significant mid- and upper elevation lake storage. It is typical of a number of mid-sized rivers with lake storage and Chinook Salmon spawning extending for some distance downstream from the lake outlet. These include, among others, the Woodside River below the Pelly Lakes; the Morley River below Morley Lake; and the Big Salmon River below Big Salmon Lake. These streams often have

pockets of very high densities of spawning Chinook. Many of the lakes are located in glacial troughs and are deep and cold, with adjacent high altitude areas. The outlet streams tend to be less subject to low flows during drought periods than are smaller streams. Assuming a continuing warming trend, this type of spawning stream may be of increased relative importance to the overall YR Chinook Salmon stock due to extirpation of stocks in warmer streams.

Performance: No concerns.

Yukon River above Hootalinqua

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 61 33.31/134 56.17

Use by Chinook: upstream migration.

Existing data: June 29, 2015 – present.

Access by boat from Lake Laberge.

Rationale for inclusion: This section of the Yukon River has apparently excellent Chinook spawning habitat. The channel gradient is gently stepped, resulting in a wide variation of water velocities and extensive areas of sorted gravel and cobble. Despite this, there are no known records of Chinook spawning. Carcasses are rarely observed. If there was a population prior to c. 1890, it may have been disrupted by paddle wheel steamer traffic. The steamers would have had a profound effect on any redds present in the river. Channel improvements, including blasting boulders during the winter, could also have affected incubating eggs. However, the steamers have been absent from this section of the river since the early 1950s, and the salmon population should have re-established itself.

Performance: No concerns.

Yukon River at Policeman's Point

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 60 56.808/135 5.647

Use by Chinook: upstream migration.

Existing data: May 5, 2011 – June 2, 2015, continuous.

Access by boat from Lake Laberge or Whitehorse.

Rationale for inclusion: The Yukon River at this location is a large river. All documented spawning in the Yukon River Upper Lakes Watershed (spawning downstream of Lake Laberge is suspected but not yet documented) occurs upstream of the Station. The river ice rots out in the spring rather than breaking up. This reduces the risk of loss to an acceptable level and allows an annual Station to be maintained.

Performance: Considered no longer reliable due to heavy deposits of sand in the backwatered area of the Yukon River above Lake Laberge. Decommissioned on June 2, 2015.

Takhini River downstream of Kusawa Lake

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 60 38.593/136 07.410

Use by Chinook: spawning and incubation.

Existing data: October 1, 2012 – June 16, 2014, and from September 12, 2014 to present, continuous.

Access: by vehicle via the Kusawa Lake Road

Rationale for inclusion: The Takhini River is a mid-sized river. It is the only unregulated Chinook spawning river to receive significant input from actively melting glaciers. Augmentation of flows from glacier melt has been increasing in the South West Yukon, particularly late summer flows. Glacier mass has been decreasing. A tipping point where the glacial augmentation begins to decline is anticipated. When this occurs late summer flows in rivers directly draining the glaciers will be reduced (Moore et. al., 2009). Flows in rivers located downstream and mediated by lakes will also be reduced, including the Takhini River below Kusawa Lake.

Performance: generally good during open water period, but subject to disturbance from persons unknown or animals. In June 2014 the loggers were pulled out of the water and the summer's data was compromised.

McIntyre Creek downstream of Mountainview Drive

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 60 45.578/135 06.045

Use by Chinook: spawning and incubation.

Existing data: May 4, 2011 – present, continuous.

Access: by vehicle via Range Road.

Rationale for inclusion: McIntyre Creek is a small spawning stream with regulated flows. It supports the only Yukon River Chinook Salmon stock that is known to have developed during the 20th century. The capture of watershed area by a hydro-electrical development in the early 1950s increased the effective size of the creek's watershed. This action, and the release of a constant volume of water in the winter for electrical generation, created habitat for adult Chinook to enter the creek and then successfully spawn and incubate. The Yukon Government is actively looking for hydro-electrical sites. These may include projects with similar characteristics to McIntyre Creek. The effects of hydro development could be similar, with the conversion of Chinook Salmon rearing streams to spawning streams. The creek provides an opportunity to investigate the effects of water regulation on a small stream in a northern environment.

Performance: No concerns.

Yukon River at Anson Bend

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 60 56.808/135 5.647

Use by Chinook: possible spawning and incubation. Upstream migration to M'clintock River, Michie Creek and Byng Creek.

Existing data: June 19, 2013 – present, continuous.

Access: by boat from the Schwatka Lake East Boat Launch

Rationale for inclusion: The Yukon River in this area is large. The Station is in the first Chinook Salmon spawning area in the Yukon to be documented (Dawson, 1887). The stock appears to have been negatively affected and possibly extirpated by dams at the outlet of Marsh Lake and at the Whitehorse Rapids. Whitehorse Rapids Hatchery fry have been released near the Station since 2004 (JTC, 2013). The current stock status is unknown. Data from this Station may complement temperature data collected at the Whitehorse Rapids Fishway, as the Yukon River generally sounds in Schwatka Lake and flows through the lake rather than mixing with it. Flows in the Fishway are from the top layers of water, and may be warmer than the river water.

Performance: No concerns.

Ibex River at WSC Station

Type of Station: Annual

Watershed: YR Upper Lakes

Conservation Unit: CK-69 Upper Yukon River

Coordinates: NAD 83 60 43.539/135 29.175

Use by Chinook: Chinook Salmon spawn downstream, and there is local/traditional knowledge of salmon spawning upstream of the Station.

Existing data: July 4, 2013 – present, continuous.

Access: by 4X4 or ATV via the Ibex River Road

Notes: The Ibex River has a small population of Chinook Salmon at present. Local/traditional knowledge implies that the area of river used was significantly larger in the past and the stock size was considerably greater. Bio-physical assessments funded under the Yukon River Interim Salmon Agreement determined that the river was a candidate for habitat- and possibly stock restoration (Zurachenko and Finnson, 1998). It is likely that there will be future interest in the watershed.

Performance: No concerns.

Methods

Temperature Measurement

Onset Tidbit v2 Water Temperature Data Loggers are used. An example is shown in Image 1. They are waterproof to 305 meters and accurate within 0.2°C . The instruments stability, or drift, is less than 0.1°C per year of use. The memory capacity is approximately 42,000 temperature measurements, or about 5 years of collecting hourly data. Each logger is in a sealed epoxy case. The case has a tab with a hole to allow the logger to be secured. There are two epoxy pins through which the logger is programmed and downloaded. The case is vulnerable to abrasion or impact and must be protected.

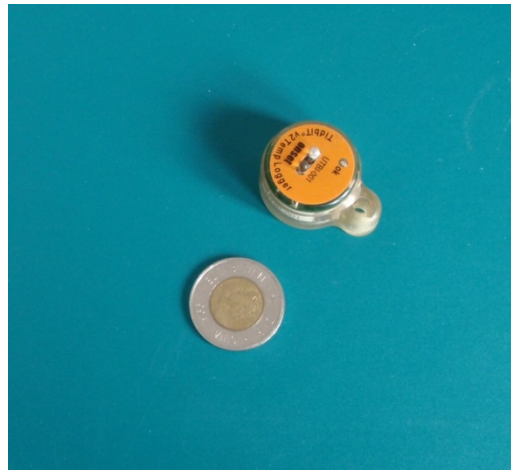


Image 1. Onset Tidbit v2. A Canadian two dollar coin provides scale. The hole used to secure the logger is visible on its right side.

All loggers are placed in flow-through housings. The housings are manufactured from 40 mm inner diameter black PVC pipe. Black pipe is used as it is much less visible than white pipe and less likely to be disturbed by curious or destructive mammals. Concerns that the housings may heat under conditions of bright sunlight are mitigated by the following measures:

- the logger measures the water temperature directly rather than the air temperature within a water proof case;
- no part of the logger touches the housing. Heat from solar warming of the housing cannot be transferred directly to the logger;
- housings and loggers are deployed in moving water, allowing a constantly renewed supply of water for measurement to flow over the logger;
- housings are deployed where they will be shaded for most or all of the day.

Each housing is ~120 mm long. Eight 18 mm diameter holes are drilled in the housing, with 4 at each end. The holes are at roughly right angles and 10 – 15 mm from the end of the housing. Each logger is placed in the housing with the tab facing toward the nearest end and then secured with 2 sets of cable ties. Two loggers are secured in each housing. Commercial plastic coated metal clothesline is used to secure the housing to a weight and to a feature on shore. The

clothesline is passed through the end of the housing and then through one of the 18 mm holes. It is then passed through an 18 mm hole near the other end of the housing and through the end itself. This maximizes the strength of the clothesline if the logger is displaced by ice or debris. The end of the clothesline which has been passed through the housing is tied to a weight. This is usually a 1 kg or larger piece of scrap metal. The housing is cable tied to the clothesline at the desired distance from the weight. The distance varies depending on the observed characteristics of the stream or river: if there is a risk of the logger being buried in bed load it is secured so it will be above the stream or river bed. Cable ties are applied to all knots. The housing, weight and clothesline securing them are termed a “data logger string”. Image 2 provides an example of a data logger string being prepared for deployment.



Image 2. Data logger string, showing the clothesline, housing and weight.

To the extent possible data logger strings are set in a shaded area with turbulent flow. The weight is lowered or placed on river bed with the housing at the desired distance above it. The clothesline is tied a reasonably stable feature such as the base of a tree. The clothesline is concealed under debris or in a cut made in the soil of the river bank. Moss or forest floor material is used to conceal the portion of clothesline around the tree. A photograph is taken.

Loggers are launched (commence measuring temperatures) prior to leaving for the field. When possible, one new- and one older logger are chosen for each Station. The serial number of each logger and the Station it will be deployed at are entered into a Master Data Logger Tracking

spreadsheet. The loggers for each Station to be replaced (Annual) or deployed (Seasonal) are tied with a length of flagging on which the Station name has been written in indelible ink. At the Station the flagging is untied from the replacement loggers. The data loggers that have been recording are then retrieved from the river, removed from the housing and tied together with the same piece of flagging. The replacement loggers are cable tied to the housing, which is then deployed back in the stream or river.

Upon return from the field, each logger is cleaned. The serial number checked against the Master Data Logger Tracking Spreadsheet. The date of retrieval is recorded in the spreadsheet. Each logger is downloaded and the status of its battery and remaining memory checked. It is then placed in storage or discarded. The downloaded data from each Station is exported and saved to an Excel Workbook. When both loggers at any given Station have recorded data, the data is graphed from each and visually compared. If the graphs are concordant the data from the newest logger (highest serial number) is accepted as the data set of record, as newer loggers are likely to have experienced less drift.

Quality Control of the data is conducted by scanning each graph to determine periods where the data may be questionable. This includes periods during the winter when the logger may have been frozen in ice or dewatered. The latter is relatively easy to determine, as the recorded temperatures are below -0.2°C . The -0.2° value was chosen for three reasons:

- the data loggers are accurate within 0.2°C ;
- slush/frazil ice is usually slightly below 0°C and often accumulates under ice cover during freeze-up and again during the spring; and
- winter flows in rivers of the Yukon River Basin depend on ground water discharges in most locations. Most ground water has elevated levels of total dissolved solids (Brabets et. al., 2000). This is likely to result in a minor freezing point depression, as 0°C is the freezing point for pure (ie distilled) water.

During the open water periods the loggers are occasionally pulled out of the water by wildlife, people or as a result of high flows. This results in the daily range of temperatures being much wider than expected for water temperatures. Air temperatures warm earlier in the day and fall more quickly in the evening. The dates of when disturbance have occurred is generally simple to determine.

Questionable data is identified as such in the data sets and excluded from the calculations of Daily Mean Temperature and determination of Daily Minimum- and Maximum Temperatures.

Descriptive metadata for each data set includes the following fields:

Stream/River:
Tributary to:
Watershed:
Name of station
Co-ordinates:
Date deployed:
Date retrieved:

Person/agency deploying/retrieving:
Make/model/serial number:
Purpose:
Notes on location:
Body or agency contributing funding:
Program:
WSP Conservation Unit:

As noted, loggers are placed in locations with turbulent flow where water is mixing from bed to surface. Water levels rise and fall seasonally and as a result of precipitation (or lack thereof). Depth is not recorded as it not a meaningful metric in measuring river temperatures in the CYRB.

Data Analysis

Comparison with Standards and Thresholds

Analysis of potential risk from elevated water temperatures is conducted for each Station against Standards in an American process and Thresholds in a Canadian process. Mean Daily Temperatures (MeDT) are calculated and Maximum and Minimum Daily Temperatures (MaxDT) are determined. Only full daily data sets are used. The functional “day” is from 0100 to 2400 hrs.

The American process is based on the significant effort expended by government agencies and others on the US West Coast to determine effects of water temperatures on Chinook salmon and other salmonid species. Reviews were prepared (McCullough 1999, Carter 2005) and made operational through guidance documents (US EPA 2003). A primary driver was the United States Clean Water Act (US CWA) which compelled States and Tribes to set Water Quality Standards. Water temperatures are a specified standard (von Finster 2010). Alaska has complied with the US CWA and has prepared temperature standards (Alaska DEC 2012). The standards are based on *Maximum Instantaneous Temperature* (generally equivalent to MaxDT) and are:

- For migration, not to exceed 15 degrees C;
- For spawning, not to exceed 13 degrees C;
- For egg and fry incubation, not to exceed 13 degrees C;
- For rearing, not to exceed 15 degrees C.

If a stream has “natural” temperatures in excess of the Standards, a variance may be applied for. The US EPA (2003) recommends that the application of the Standards be based on a 7 day average of the daily maxima (7DADM). The 7DADM is a rolling mean: that is, each maximum daily temperature contributes to multiple 7DADM values. Even so, the Standards are highly restrictive, in part as they were largely based on the effects of constant temperatures on fish in laboratory experiments. These studies poorly represent the variable temperatures characteristic of natural environments and the ability of fish to enter, and leave, areas of elevated temperatures.

The Canadian process reflects the legal and socio-economic characteristics of Canada. Water is, constitutionally, an area of provincial responsibility. Fisheries and fish habitat is a federal responsibility. Water temperature is not recognised as a statutory quality of water by either level of government except for a limited number of specified purposes. British Columbia prepared a set of guidelines (BC MOE 2001) that addressed aquatic environments. However, the Guidelines are dated, technically questionable and their application is unclear.

The southern portion of BC experienced a drought in the late 1990s and early 2000s. Associated high water temperatures were believed to have contributed to pre-spawn mortalities of sockeye salmon in the Fraser River Basin (Mathes et. al, 2010). Results of scientific investigations were combined with local knowledge to set water temperature risk Thresholds for the Fraser River e-watch <http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.htm> The Thresholds are based on *Mean Daily Temperature* (MeDT) and are:

- 18°C - Decreased swimming performance;
- 19°C - Early signs of physiological stress and slow migration;
- 20°C - Associated with high pre-spawn mortality and disease;
- 21°C - Chronic exposure can lead to severe stress and early mortality.

Application of the Standards and Thresholds required choosing assumed migration and spawning periods for each Station. The number of days with MaxDT above 13⁰ (spawning/incubation) and 15⁰ C (upstream migration and rearing) during the specified periods were determined for the US process, and those with MeDT above 18, 19, 20 and 21 degrees (all life processes) for the Canadian process.

Migration Standards and Thresholds were applied to all Seasonal Stations and those Annual Stations which migrating salmon pass to spawn in upstream tributaries. The length of the migration periods are conservative to address a potentially wide range of annual- or inter-annual migration timing. Stations assessed, and assumed upstream migration periods for each follow:

Stewart River at Stewart Crossing - July 5 – August 31 (58 days)
Mcquesten River below WSC Station - July 5 – August 31 (58 days)
Pelly River downstream of Pelly Crossing - July 5 – August 31 (58 days)
Nordenskiöld River at Elk Sign - July 21 – September 3 (48 days)
Teslin River at Hootalinqua - July 15 – September 10 (58 days)
Yukon River at Policeman's Point - July 21 – September 3 (46 days)
Yukon River at Anson Bend - July 25 – September 3 (42 days)

Spawning Standards and Thresholds are generally applied only to Annual Stations. The Yukon River at Policemans Point was not included as it does not represent any of the spawning tributaries upstream of it. The lengths of the spawning periods are conservative to address a potentially wide range of annual or inter-annual spawning timing. Stations assessed and the assumed spawning periods follow:

North Klondike River at North Fork Bridge: July 15 – August 20 (37 days)
Mcquesten River below WSC Station: July 15 – August 31 (48 days)
Blind Creek at abandoned bridge: July 20 – August 20 (32 days)

Tatchun River below Tatchun Lake: August 5 to September 5 (32 days)
Nordenskiöld River at Elk Sign: August 1 – 31 (31 days)
Little Salmon River at canoe landing: August 1 – 31 (31 days)
Teslin River at Hootalinqua: July 20 – September 10 (52 days)
Yukon River above Hootalinqua – July 25 – August 25
Takhini River below Kusawa Lake: August 1 – 31 (31 days)
Ibex River at WSC Station: August 1 – 31 (31 days)
McIntyre Creek below Mountainview Drive: August 1 – 31 (31 days)
Yukon River at Anson Bend: August 1 – 31 (31 days)

Annual Accumulated Thermal Units

Accumulated Thermal Units (ATU) are the equivalent of degree days. The sum of the mean daily temperatures (MeDT) is calculated over a specified period of time. The Annual Accumulated Thermal Units (AATU) for a river is the sum of all MeDTs for a given *calendar* year. Where a Station records temperatures less than -0.2°C a value of 0°C is used in the calculation. AATUs are an indicator of a stream or river's potential productivity. As a rule, a warm(er) stream in a north temperate environment such as that of the South- and Central Yukon will have a more diverse and numerous invertebrate community than a cool(er) stream (Castella et. al., 2001). AATUs provide a means of comparing and classifying streams.

Accumulated Thermal Units by Brood Year Cohort

The Accumulated Thermal Units by Brood Year Cohort (ATUBYC) provides an indication of the amount of thermal energy available to Chinook Salmon from egg deposition until the onset of overwintering by the resulting young-of-year that did not leave the natal stream. For the purposes of analysis, August 15 was assumed to be the mid-point of spawning and the starting date for calculation of the ATUBYC. The end date for each Station was the day during the following year on which a DMeT of 4.5°C or greater was last recorded. This value was chosen as it is considered to be the lower limit of positive growth for juvenile Chinook Salmon (McCullough et.al., 2001). The ATUBYC is the sum of all Mean Daily Temperatures between the two dates. Where a Station records temperatures less than -0.2°C a value of 0°C is used in the calculation.

Results

Chinook Salmon Upstream Migration

Chinook Salmon upstream migration data is presented in Appendix 1.

Maximum Daily Temperatures (MaxDT) were low in 2015 at all Stations during the assumed upstream migration period. The number of days that the 15⁰ ADEC Migration Standard was exceeded at each Station was also low. The Nordenskiöld River at Elk Sign and the Yukon River at Anson Bend recorded the lowest number of days above the Standard since monitoring began.

Mean Daily Temperatures (MeDT) did not exceed the lowest Fraser River eWatch Threshold of 18⁰ in 2015 at any Station.

Chinook Salmon Spawning

Chinook Salmon upstream migration data is presented in Appendix 2.

MaxDT were low in 2015 at all Stations during the assumed spawning period. Stations at Mcquesten River below Klondike Highway, Blind Creek above abandoned bridge, Tatchun Creek below Tatchun Lake, Nordenskiold at Elk Sign, Little Salmon River at Canoe Landing, and Takhini River below Kusawa Lake recorded the lowest number of days above the 13⁰ Standard since monitoring began.

Mean Daily Temperatures (MeDT) exceeded the 18⁰ Threshold at Tatchun River below Tatchun Lake on 6 days, and the 19⁰ Threshold on 1 day during the assumed spawning period. MeDT at other Stations did not exceed the 18⁰ Threshold.

Annual Accumulated Thermal Units

The calculated AATUs by Station and calendar year, the range of AATUs for the period of record and the mean AATU for each Station may be found in Appendix 3. AATUs in 2014 were generally lower than 2013 and greater than 2012. Exceptions were the North Klondike River at North Fork Bridge, which established a new low of 952.5 AATU. McIntyre Creek below Mountainview Drive also had the lowest AATU since monitoring began there. AATUs in the Little Salmon River at Canoe Landing were higher in 2014 than 2013.

Accumulated Thermal Units by Brood Year Cohort (ATUBYC)

The calculated ATUBYC by Station and calendar year, the range of ATUBYCs for the period of record and the mean ATUBYC for each Station may be found in Appendix 4. ATUBYCs for the 2013 Brood Year Cohort tended to fall between those of 2011 and 2012. Exceptions were Blind Creek at Abandoned Bridge, which was higher than either preceding year, and Nordenskiold River at Elk Sign, which was lower.

Sufficient data is now available for most Stations to calculate Mean ATUBYC (MeATUBYC). This provides a baseline from which annual thermal energy available to those members of the cohort that remain in the natal river or creek, those that enter it, or those using streams or river with similar characteristics can be compared over time. For the 2013 brood year, the North Klondike River at North Fork Bridge, the Nordenskiold River at Elk Sign and McIntyre Creek below Mountainview Drive had slightly less ATUBYC than their respective MeATUBYCs and Blind Creek at abandoned bridge, Yukon River at Policemans Point and Tatchun River below Tatchun Lake had more.

Discussion

Water temperature monitoring at Annual Stations is continuous. This report is based on data collected between autumn of 2014 and autumn of 2015.

Water temperatures are primarily influenced by weather and climate. For the purpose of this report weather is short(er) term air temperatures and precipitation, and climate is long(er) term. The definition of climate also extends to the typical precipitation and air temperatures of a general or specific area.

Water temperatures may be influenced by air temperatures and precipitation of past years. A series of wet years preceded 2015 in the CYRB. Considerable volumes of water were stored in lakes, ponds and wetlands and in underground aquifers. Flows in streams and rivers were generally greater than in years preceding 2011. Ground water discharged into areas that were dry throughout the 1990s and 2000s, implying that some or most aquifers became fully charged. During the summer of 2015 some areas started to dry, indicating that ground water levels had fallen.

The winter of 2014/15 was warmer than normal in the CYRB. Precipitation varied across the sub-basin. By May 1 the snow-water equivalent was lowest in the south-west Yukon, at between 51 – 71% of average. Most of the south-east of the sub-basin had relatively normal snow-water equivalent, at 91 – 110% of average. There was a rapid gradient in snow-water equivalent in the central Yukon, with the Pelly Crossing area having 51-71% and Dawson City 131 – 150% of average (Environment Yukon, 2015). The spring of 2015 was early and very warm. Water temperatures in streams and rivers rose quickly. In July and August a series of local and frontal precipitation events occurred in July and August, and water temperatures initially stabilized and then fell. A major frontal event occurred in late August in most areas, and water temperatures at monitored Stations fell more swiftly than in the preceding years, and thereafter remained lower than normal.

Water levels in the Teslin and Upper Yukon River remained high throughout the summer and autumn. Levels in the Pelly and Stewart Rivers were somewhat higher than normal. High flows in the Klondike followed a precipitation event in late July/early August. Flows in the McQuesten remained high well into the autumn.

Application of Standards and Thresholds – Migration and Spawning

Application of the ADEC Upstream Migration and Spawning Standards indicates that many CYRB Chinook salmon stocks are at some risk of high temperatures during these life processes even in cold years. However, Standards such as those of the ADEC are prepared in other jurisdictions for other purposes and are based other species or stocks and must always be cautiously applied. The ADEC Standards were transferred from the US Pacific North West and are considered to be too conservative to assess risk for the upstream migration of Chinook Salmon in the CYRB. If the 7DADM process were to be applied there would be less days where the Standards were exceeded. However, most Stations would still have temperatures that exceeded the Standards some or most of the time.

The Standards are binary in nature: values are either below or above the stated temperatures. Slight but lengthy excursions above the Standard lead to the same level of concern as significant excursions of the same length of time. The converse is also true in respect of significant but short excursions above the Standard.

The Standards do, however, provide a framework to communicate the results of water temperature monitoring to scientific/technical/regulatory agency staff, and particularly those from Alaskan and US Federal Agencies.

The Fraser River ewatch Thresholds provide a graduated approach and are believed to be more applicable to Yukon River Chinook Salmon. An important consideration is that they were based on in-river and laboratory investigations, and on local knowledge. The Thresholds have significantly higher temperatures than the ADEC standards and are based on the more conservative MeDT. Pending development of Yukon River Chinook-specific Thresholds, Guidelines or other documents, the Fraser River Thresholds are considered the best tool to provide guidance for risk assessments.

Application of the ewatch Thresholds to the MeDTs of Stations in the CYRB implies that water temperatures did not negatively affect upstream migration in 2015 at any Station monitored for this purpose.

The Fraser River ewatch Thresholds were used as a proxy for thermal tolerance of spawning Chinook for the specified spawning periods. No thresholds were exceeded in 2012. In 2013 MeDT at 4 of 11 Stations exceeded 18⁰C, two exceeded 19⁰, and one, Tatchun River below Tatchun Lake, exceeded both 20⁰ and 21⁰. In 2014 and 2015 only Tatchun River below Tatchun Lake exceeded 18⁰: in 2014, MeDT of 18⁰ was exceeded for 2 days; and in 2015 18⁰ was exceeded for 6 days and 19⁰ was exceeded for a single day. All exceedances took place at the start of the assumed spawning period. Chinook salmon were delayed by beaver dams in Tatchun River and did not reach the spawning area at and above the Station until late in August.

Water temperatures in 2015 were considered to be favourable at all of the Stations monitored for upstream migration and spawning. It is likely that conditions were favourable for the remainder of the Canadian Yukon River Basin.

Annual Accumulated Thermal Units

The AATUs are a measure of temperature related productivity of streams. Productivity is defined as either the “Capacity or ability of an environmental unit to produce organic material” or the “Rate of formation of new tissue or energy use by one or more organisms” (Armantrout, 1998). Higher water temperature in northern streams is related to greater productivity at multiple trophic levels (Hannesdóttir et.al, 2013). Increases in stream temperatures related directly- or indirectly to climate change are anticipated to result in increased productivity (Prowse et.al., 2006). The calculated AATUs have consistently indicated that the Tatchun River is the most biologically productive river monitored and the North Klondike is the least.

Sufficient data is now available for most Stations to calculate Mean AATUs (MeAATU) for use as a basis of classifying and comparing Stations. Table 1 presents the MeAATUs of all stations in ascending order, the range of MeAATUs and the number of years of data used in the calculations. The North Klondike at North Fork Bridge has the lowest MeAATU at 972.8 ATU. The Tatchun River below Tatchun Lake has the highest at 2502.7 ATU, or about 2.6 times that of the North Klondike. Importantly, these Stations represent types of rivers. Salmon spawning in low elevation rivers with significant lake storage upstream of the actual spawning areas may have a much greater thermal subsidy than those spawning in rivers with little or no lake storage and significant high altitude lands in their watershed.

There is no universally accepted method of classifying streams on the basis of temperatures. Most classification systems and processes reflect the purpose for which the classification was made, the role or function of the person or agency that developed it, and the geographical area which it originated in (Coker et al., 2001; Chu et al., 2009; Nelitz et al, 2007). There is also an understandable bias toward mid-temperate regions, as the majority of the population and research institutions are located there. In addition, the lands and waters that contribute to fish habitat have been under greater development stress than those located at higher latitudes.

For the purposes of this program, streams and rivers will be provisionally classified as:

- Cold – MeAATU - 1300 or less;
- Cool – MeAATU - more than 1301, less than 2200;
- Warm – MeAATU – more than 2201.

Table 1. Classification of Stations on the basis of MeAATUs			
<u>Station</u> <u>Cold</u>	<u>Years of Data</u>	<u>Range AATU</u>	<u>MeAATU</u>
N. Klondike R. at North Fork Bridge	3	952.5 - 991.4	972.8
Ibex R. at WSC Station	1	n/a	1085.9
Blind Cr. at abandoned bridge	3	1174.8 - 1258.2	1230.1
<u>Cool</u>			
Nordenskiold R. at Elk Sign	3	1580.5 - 1707.8	1657
Little Salmon R. at Canoe Landing	2	1610.8 - 1737.8	1674.3
McIntyre Cr. below Mountainview	3	1744.8 – 1866.9	1778.5
Takhini R. below Kusawa L.	1	n/a	1899.1
Yukon R. at Policemans Point	3	1842.3 - 2050.9	1970.7
Yukon R. at Anson Bend	1	n/a	2076.7
<u>Warm</u>			
Tatchun R. below Tatchun L.	3	2398.4 - 2604.9	2502.7

Table 1 demonstrates the great range of thermal diversity in Yukon River tributaries in Canada that are used by spawning Chinook Salmon. It raises questions as to the degree of genetic adaptation of Chinook Salmon populations to the different thermal regimes. This is of particular concern due to recent initiatives to restore Chinook Salmon stocks through transplants from other populations: should the thermal regime of candidate donor stocks be a consideration?

The very low temperatures at the North Klondike River at North Fork Bridge is troubling, as it implies that the incubation/alevin stage would exceed a year in that system, and the 0+ rearing stage correspondingly reduced. Adult enumeration is not carried out in the North Klondike River, so the status of the adult population is unknown. Juvenile monitoring in the North Klondike has been conducted by the Dawson District Renewable Resources Council for a number of years. Captures have been low in most years (Taylor 2010, 2011, 2012, 2013, 2014, 2015). Water temperature monitoring of the North Klondike has only been conducted since 2011, and it is not known whether the river had higher AATUs in the past.

Tatchun River below Tatchun Lake has consistently had the highest AATUs. Summer temperatures may be high, with recorded MaxDT exceeding 22°. This is not considered a matter of concern, as adult Chinook Salmon do not enter the river until temperatures fall in August. Juveniles may leave the river or move to locally cooler areas downstream or in off channel areas if temperatures become excessive. Loggers and housings are covered with benthic organisms when loggers are replaced, indicating the high productivity of the Tatchun River and the similar rivers it represents. Fry are thought to emerge earlier than in colder rivers: in 2015 there were schools of free swimming Chinook at the Station on May 12..

Accumulated Thermal Units by Brood Year Cohort.

The ATUBYC were designed to be a measure of describing the available thermal energy for cohorts, or brood year classes, of juvenile Chinook Salmon. The ATUBYCs are best considered an index for the CYRB rather than a direct measure of production of juvenile Chinook Salmon in the specific river or stream being monitored. Production reflects a number of factors, including variation in the supply of juveniles produced by given brood year. The production of juveniles will reflect in part the overall stock strength or the fitness of individual fish in the brood year. Additionally, an unknown (and probably variable) percentage of juvenile Chinook Salmon either leave or are carried away from natal streams each year. Many or most ascend non-natal streams to rear and overwinter (Bradford et.al., 2009). Streams entered by juvenile Chinook Salmon may be at considerable distance downstream from natal streams (Daum and Flannery, 2012). They may also enter streams or rivers that support other Chinook spawning populations: as an example, MacKenzie-Grieve (2014) found 34% of juvenile Chinook sampled in the Klondike River below Hunker Creek were not of Klondike River origin. Finally, temperature is only one of a number of environmental (ie suspended sediment and bed load transport regimes) and ecosystematic (ie competition and predation) variables determining the production of juvenile Chinook Salmon.

The date that MeDT crossed 4.5° threshold for the final time at each Station ranged from 5 to 18 days, with Tatchun River having the most narrow range and McIntyre Creek the widest.

The Mean ATUBYC (MeATUBYC) was based on a maximum of 3 years of data which included the 2013 ATUBYC. This results in serious limitations in drawing any but the most general inferences from the results of the analysis shown in Table 2. However, it appears that 2013 ATUBYC was greater than the MeATUBYC at half the Stations with 2 or more years of data. The Stations with positive MeATUBYCs had a cumulatively higher value than those with negative MeATUBYC. The differences tended to be relatively low except at the Yukon River at Policemans Point, at 154 ATUs over the MeATUBYC for the Station. Overall, temperatures in 2013 appear to have been equally- or more favourable for juvenile Chinook Salmon than either of the preceding years.

Table 2. Variance of 2013 ATUBYC from MeATUBYC

<u>Station</u>	<u>Years data</u>	<u>MeATUBYC</u>	<u>2013 ATUBYC</u>	<u>2013 +/-</u>
North Klondike R. at Viceroy Bridge	3	1224.4	1221	-3.4
Ibex R. at WSC Station	1	n/a	1408.1	n/a
Blind Cr. at abandoned bridge	3	1545	1611.5	66.5
Nordenskiold R. at Elk Sign	2	2115	2110.2	-4.8
McIntyre Cr. below Mountainview Dr	3	2215.3	2197.3	-18
Little Salmon R. at Canoe Landing	1	n/a	2274.6	n/a
Yukon R. at Policemans Point	3	2677.7	2831.7	154
Yukon R. at Anson Bend	1	2928.6	n/a	n/a
Tatchun R. below Tatchun L.	3	3229.2	3295.9	66.7

Distribution of Data to Interested Parties

Methods

A spreadsheet was developed in 2013 listing all agencies and interested parties to whom data sets were sent. In 2015 the relevant data sets were sent to the same persons and those who had asked for data following the submission of the 2014 report.

Results

To date in 2015, a total of 174 data sets have been distributed. Recipients have been government agencies including DFO, YG Fisheries, ADF&G, NOAA, TKC, SFN, CAFN, TH, TTC and NND and one local consulting firms.

Ensuring Public Accessibility of Data collected

Methods

A complete set of all data files was provided to the ADF&G for inclusion in the web-based, publicly available data base referred to by Leba (2011, 2012). A web site has been developed to allow the public to access the data collected. Copy and paste yukonwatertemperatures.info into your browser to access it. The contributions of the Yukon River Panel are acknowledged.

Results

[Yukonwatertemperatures.info](http://yukonwatertemperatures.info) has been tested and found to be publicly accessible. All data sets developed to date have been uploaded and are currently available as “Open Data”. [Yukonwatertemperatures.info](http://yukonwatertemperatures.info) will be updated early in 2016. Yukon Government will be approached to have the Stations comprising the network included in the Yukon Water Catalogue <http://yukonwater.ca/>

Conclusion

The third year of implementation of the “Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program” was successfully completed. The Temperature Monitoring Network was operated, maintained and adaptively managed as proposed. One Annual Station was added at Yukon River above Hootalinqua and one Station was decommissioned at Yukon River at Policemans Point.

Considerable interest was shown in the data collected. Data sets were widely distributed and the distribution continues.

Data collected to date will be available at yukonwatertemperatures.info early in 2016.

As this document is being completed, 24 data loggers are measuring temperatures at 12 Annual Stations. They are developing the base line with which future salmon managers will compare the environments that, hopefully, they and the salmon will be contending with.

References

- Alaska Dept. Environmental Conservation. 2012. Water Quality Standards. Amended as of April 8, 2012. 18 AAC 70. 56 p.
- BC MOE. 2001. Water Quality Guidelines for Temperature. Prepared pursuant to S2(e) of the Environmental Management Act. Environmental protection Division. 10 p.
- Brabets, T.P., B. Wang, and R.H. Meade. 2000. Environmental and Hydrologic Overview of the Yukon River Basin, Alaska and Yukon. U.S. Geological Survey Water Resources Investigations Report 99-4204. 106 p.
- Bradford, M.J., A. von Finster, and P.A. Milligan. 2009. Freshwater Life History, Habitat, and the Production of Chinook Salmon from the Upper Yukon Basin. Pages 19 – 39 in Pacific Salmon: Ecology and Management of Western Alaska's Populations. C.C. Krueger and C.E. Zimmerman, editors. American Fisheries Symposium 70, Bethesda, Maryland.
- Castella, E., H. Adelstiensson, J.E. Brittan, G.M. Gislason, A. Lehmann, V. Lencion, B. Lods-Crozet, B. Maiolini, A.M. Milner, J.S. Olafsson, S.J. Saltveit, and D.L. Snook. 2001. Macroinvertebrate richness and consumption along a latitudinal gradient of European glacier-fed streams. *Freshwater Biology* 46, 1811 - 1831
- Coker, G.A., C.B. Portt, and C.K. Minns. 2001. Morphological and Ecological Characteristics of Canadian Freshwater Fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2554. 89 p.
- Chu, C., N.E. Jones, A.R. Piggott, J.A. Buttle. 2009. Evaluation of a Simple Method to Classify the Thermal Characteristics of Streams Using a Nomogram of Daily Maximum Air and Water Temperatures. *North American Journal of Fisheries Management* 29:1605–1619.
- Coker, G.A., C.B. Portt, and C.K. Minns. 2001. Morphological and Ecological Characteristics of Canadian Freshwater Fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2554. 89 p.
- Daum, D.W. and B.G. Flannery. 2012. Distribution and Genetic Origin of Chinook Salmon Rearing in Non-Natal U.S. Tributary Streams of the Yukon River, Alaska. U.S. Fish and Wildlife Service. Alaska Fisheries Data Series No. 2012-10. 37 p.
- Dawson, G.M. 1887. Report on an Exploration in the Yukon District, N.W.T. and adjacent northern portion of British Columbia. Geological and Natural History of Canada, Annual Report Volume III Part I, 1887-88. Montreal: William Foster Brown & Co. 1889.
- Environment Yukon. May 1, 2015. Yukon Snow Survey Bulletin and Water Supply Forecast. Yukon Government Water Resources Branch. 28 p.

Fleming, S.W. and G.K.C. Clarke. 2003. Glacial Control of Water Resource and Related Environmental Responses to Climatic Warming: Empirical Analysis Using Historical Streamflow Data from Northwestern Canada. *Canadian Water Resources Journal*. Vol. 28, No. 1, 2003 69 – 86.

Gu, R., S. Montgomery, and T.A. Austin. 1998. Quantifying the effects of stream discharge on summer river temperatures. *Hydrological Sciences – Journal – des Sciences Hydrologiques*. 43(6) 885 – 904.

Hannesdóttir, E.R., G.M. Gíslason, J.S. Ólafsson, Ó.P. Ólafsson*, E.J. O’Gorman. 2013. Increasing Stream Productivity with Warming Supports Higher Trophic Levels. *Advances in Ecological Research*, Volume 48: 285 - 341

JTC (Joint Technical Committee of the Yukon River US/Canada Panel). 2013. Yukon River Salmon 2012 Season Summary and 2013 Season Outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A13-02 Anchorage. 195 p.

Leba, H. 2011. Temperature Monitoring on Select Yukon River Tributaries. Alaska Department of Fish and Game. Yukon River Panel URE 25N-10. 18 p.

Leba, H. 2012. Temperature Monitoring of Canadian and Alaskan Yukon River Tributaries (URE-25-11). Alaska Department of Fish and Game. Yukon River Panel URE 25-11. 20 p.
Maheu, A., N.L. Poff, and A. St. Hilaire. 2015. A Classification of Stream Water Temperature Regimes in the Conterminous USA. *River Res. Applic.* Wiley Online Library DOI: 10.1002/rra.2906

Mathes, M.T., S.G. Hinch, S.J. Cooke, G.T. Crossin, D.A. Patterson, A.G. Lotto, and A.P. Farrell. 2010. Effect of water temperature, timing, physiological condition, and lake thermal refugia on migrating adult Weaver Creek sockeye salmon. *Can. J. Fish. Aquat. Sci.* 67: 70-84.

Mackenzie-Grieve, J. July 30, 2014. Klondike River JCS DNA sampling. Memo to file. DFO FCSAP. 4 p.

McCullough, D., S. Spalding, D. Sturdevant and M. Hicks. 2001 Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmon. Prepared as Part of EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. US EPA-910-D-01-005. 114 p.

Mercer, B. 2005. Distribution and Abundance of Radio Tagged Chinook Salmon in the Canadian portion of the Yukon River Watershed as determined by 2004 Aerial Telemetry Surveys. Yukon River Restoration and Enhancement Fund Project 77-04. 38 p.

Mercer, B. 2011. 2010 Klondike River DIDSON Sonar CRE-16-10 Prepared for the Yukon River Panel Restoration and Enhancement Fund. 24 p.

- Mercer, B. 2011. 2011 Klondike River DIDSON Sonar CRE-16-11 Prepared for the Yukon River Panel Restoration and Enhancement Fund. 26 p.
- Milligan, P.A., W.O. Rublee, D.D. Cornett and R.A.C Johnston. 1985. The Distribution and Abundance of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Upper Yukon River Basin as determined by a Radio-Tagging and Spaghetti Tagging Program: 1982 – 1983. Canadian Technical Report of Fisheries and Aquatic Sciences No.1352. 159 p.
- Moore, R.D., S.W. Fleming, B. Menounos, R. Wheate, A. Fountain, K. Stahl, K. Holm, and M. Jacob. 2008. Glacier change in western North America: influences on hydrology, geomorphic hazards and water quality. *Hydrological Processes* 23, 42-61 (2009)
- Nelitz, M.A., E.A MacIsaac, R.M. Peterman. 2007. A Science-Based Approach for Identifying Temperature Sensitive Streams for Rainbow Trout. *North American Journal of Fisheries Management* 27:405-424.
- Osbourne, C.T., B.J. Mercer and J.H. Eiler. 2003. Radio telemetry tracking of Chinook salmon in the Canadian portion of the Yukon River Watershed – 2002. Project RE-78-02. Prepared for the Yukon River Panel. 59 p.
- Otto, D.K. 1998a. Tatchun Creek Chinook Spawner Enumeration 1997. Prepared for Yukon River Panel Restoration and Enhancement Fund and Fisheries and Oceans Canada. 15 p.
- Otto, D.K. 1998b. Tatchun Creek Chinook Spawner Enumeration 1998. Prepared for Yukon River Panel Restoration and Enhancement Fund and Fisheries and Oceans Canada. 13 p. & Appendices
- Otto, D.K. 1999. Tatchun Creek Chinook Spawner Enumeration 1999. Prepared for Yukon River Panel Restoration and Enhancement Fund and Fisheries and Oceans Canada. 5 p.
- Prowse, T.D., F.J. Wrona, J.D. Reist, J.J. Gibson, J.E. Hobbie. L.M.J. Levesque and W.F. Vincent. 2006. Climate Change Effects on Hydroecology of Arctic Freshwater Ecosystems. *Ambio* Vol. 35, No. 7, November 2006: 347 – 358.
- Snow, B. 2010. 2010 Mcquesten River Sonar Pilot Program. Prepared by EDI Environmental Dynamics Inc. for First Nation of the the Na-Cho Nyak Dun. YRR&EF Project CRE-142N-10. 20 p. & Appendices
- Smith, C.A.S., J. Meikle and C.F. Roots (editors). 2004. Ecoregions of the Yukon Territory: Biophysical properties of Yukon Landscapes. Agriculture and Agri-food Canada. PARC Technical Bulletin No. 04-01, Summerland, British Columbia. 313 p.
- Taylor, L. 2010. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Project CRE09-06. 29 p.

Taylor, L. 2011. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Project CRE11-06. 38 p.

Taylor, L. 2012. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Fund. CRE12-06 39 p.

Taylor, L. 2013. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Fund. CRE13-06 45 p.

Taylor, L. 2014. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Fund. CRE14-06 45 p.

Taylor, L. 2015. Yukon River North Mainstem Stewardship. DDRRC. Yukon River R&E Fund. CRE15-06 49 p.

U.S. Environmental Protection Agency (EPA). (2014) Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams. Global Change Research Program, National Center for Environmental Assessment, Washington, DC; EPA/600/R-13/170F. Available from the National Technical Information Service, Springfield, VA, and online at <http://www.epa.gov/ncea>.

von Finster, A. 2001. Possible Effects of Climate Change on the Physical Characteristics of Fish Habitats in the Yukon River Basin in Canada. Habitat and Enhancement Branch, Dept of Fisheries and Oceans Canada. 17 p. <http://www.taiga.net/reports/dfo1.html>

von Finster, A. 2006. Utilisation of Habitats by Chinook, Chum and Coho salmon in the Yukon River Basin in Canada DFO OHEB. 3 p.

von Finster, A. 2010. Monitoring Fresh Water Thermal Regimes: A Technical Context. Prepared for Ta'an Kwäch'än Council. 20 p.

von Finster, A. 2013. The distribution of introduced Rainbow Trout (*Oncorhynchus mykiss*) in the Upper Yukon River Basin. Prepared for the Yukon Fish and Game Association. 21 p.

Wahl, H. 2004. Climate. In: Ecoregions of the Yukon Territory: Biophysical properties of Yukon Landscapes. Agriculture and Agri-food Canada. PARC Technical Bulletin No. 04-01, Summerland, British Columbia. 313 p.

Yukon Government. 2005. Yukon Water Resources Hydrometric Program Historical Summary 1975-2004. Water Resources, Environment Programs Branch.

Wilson, J. 2011. Blind Creek Chinook Salmon Enumeration Weir, 2010. Yukon River Restoration and Enhancement Fund Project CRE-37-10. 22 p.

Zurachenko, P., and P. Finnson. 1998. Small Stream Investigations regarding Restoration and Enhancement of Chinook Salmon Habitat on select Tributaries of the Takhini River. Prepared for the Yukon River Restoration and Enhancement Fund by Blue River Consulting. 55 p. and Appendices.

Appendix 1 – Application of Standards & Thresholds for Upstream Migration

Standards are those of the Alaska Department of Environmental Conservation (DEC). Thresholds are those of the Fraser River ewatch.

Stewart River at Stewart Crossing.

Type of Station: Seasonal

Assumed migration period: July 5 – August 31 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2012	17 ⁰	14
2013	18.7 ⁰	43
2014	17.8 ⁰	31
2015	16.2 ⁰	22

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	16.5 ⁰	0	0	0	0
2013	18.1 ⁰	2	0	0	0
2014	17.2 ⁰	0	0	0	0
2015	15.7 ⁰	0	0	0	0

Mcquesten River below WSC Station

Type of Station: Annual

Assumed migration period: July 5 – August 31 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2012	14.2 ⁰	0
2013	16.7 ⁰	26
2014	15 ⁰	1
2015	Station could not be accessed – no data	

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	13 ⁰	0	0	0	0
2013	15.3 ⁰	0	0	0	0
2014	13.3 ⁰	0	0	0	0
2015	Station could not be accessed – no data				

Mcquesten River below Klondike Highway

Type of Station: Annual

Assumed migration period: July 5 – August 31 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		$\frac{15^0}{0}$
2015	14.6	0

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:
		$\frac{18^0}{0} \quad \frac{19^0}{0} \quad \frac{20^0}{0} \quad \frac{21^0}{0}$
2015	15.7 ⁰	0 0 0 0

Lower Pelly River downstream of Pelly Crossing.

Type of Station: Seasonal

Assumed migration period: July 5 – August 31 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		$\frac{15^0}{0}$
2012	17.3 ⁰	20
2013	20.8 ⁰	49
2014	19.3 ⁰	47
2015	18.5 ⁰	23

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:
		$\frac{18^0}{0} \quad \frac{19^0}{0} \quad \frac{20^0}{0} \quad \frac{21^0}{0}$
2012	16.8 ⁰	0 0 0 0
2013	19.1 ⁰	15 2 0 0
2014	17.9 ⁰	0 0 0 0
2015	17.0 ⁰	0 0 0 0

Nordenskiöld River at Elk Sign

Type of Station: Annual

Assumed migration period: July 21 – September 3 (45 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		$\frac{15^0}{0}$
2012	16.8 ⁰	10
2013	16.8 ⁰	22
2014	16.1 ⁰	9
2015	15.8 ⁰	6

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:
		$\frac{18^0}{0} \quad \frac{19^0}{0} \quad \frac{20^0}{0} \quad \frac{21^0}{0}$
2012	16.1 ⁰	0 0 0 0
2013	18.4 ⁰	3 0 0 0
2014	15.2 ⁰	0 0 0 0
2015	15.1 ⁰	0 0 0 0

Teslin River at HootalinquaType of Station: SeasonalAssumed migration period: July 15 – September 10 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2012	16.5 ⁰	28
2013	19.8 ⁰	46
2014	16.7 ⁰	27
Loggers lost, no data collected		

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	15.8 ⁰	0	0	0	0
2013	19.2 ⁰	7	3	0	0
2014	16.2 ⁰	0	0	0	0
Loggers lost, no data collected					

Yukon River above HootalinquaType of Station: AnnualAssumed migration period: July 20 - Aug 25 (35 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2015	16.1	30

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2015	15.7	0	0	0	0

Yukon River at Policeman's PointType of Station: AnnualAssumed migration period: July 21 – September 3 (46 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2012	16 ⁰	20
2013	18.2 ⁰	31
2014	16.6 ⁰	22
Station decommissioned in June, 2015		

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	15.6 ⁰	0	0	0	0
2013	18.2 ⁰	3	0	0	0
2014	16.2 ⁰	0	0	0	0

Station decommissioned in June, 2015

Yukon River at Anson Bend

Type of Station: Annual

Assumed migration period: July 25 – September 3 (42 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:	
		<u>15⁰</u>	
2013	18.2 ⁰	34	
2014	17.4 ⁰	18	
2015	16.9	27	

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2013	18.1 ⁰	2	0	0	0
2014	16.1 ⁰	0	0	0	0
2015	15.9	0	0	0	0

Appendix 2 – Application of Standards & Thresholds for Chinook Spawning

Standards are those of the Alaska Department of Environmental Conservation (DEC). Thresholds are adopted from the Fraser River ewatch upstream migration thresholds.

North Klondike River at North Fork Bridge

Type of Station: Annual

Assumed spawning period: July 15 – August 20 (37 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>15⁰</u>
2012	12.2 ⁰	0
2013	12.6 ⁰	0
2014	10.6 ⁰	0
2015	11.3 ⁰	0

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰⁰</u>
2012	9.9 ⁰	0	0	0	0
2013	10.1 ⁰	0	0	0	0
2014	8.5 ⁰	0	0	0	0
2015	9.2 ⁰	0	0	0	0

Mcquesten River below WSC Station

Type of Station: Annual

Assumed spawning period: July 15 – August 31 (48 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13⁰</u>
2012	14.1 ⁰	5
2013	16.7 ⁰	35
2014	15 ⁰	14
2015	Station could not be accessed – no data	

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	13 ⁰	0	0	0	0
2013	15.3 ⁰	0	0	0	0
2014	13.3 ⁰	0	0	0	0
2015	Station could not be accessed – no data				

Mcquesten River below Klondike HighwayType of Station: AnnualAssumed migration period: July 15 – August 31 (48 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13⁰</u>
2014	15.1	19
2015	14.4 ⁰	18

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2014	13.8 ⁰	0	0	0	0
2015	13 ⁰	0	0	0	0

Blind Creek at abandoned bridgeType of Station: AnnualAssumed spawning period: July 20 - August 20 (32 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13⁰</u>
2012	13.9 ⁰	8
2013	15.7 ⁰	19
2014	14.4 ⁰	8
2015	14.4 ⁰	5

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2012	12.9 ⁰	0	0	0	0
2013	13.7 ⁰	0	0	0	0
2014	12.8 ⁰	0	0	0	0
2015	13 ⁰	0	0	0	0

Tatchun River below Tatchun LakeType of Station: AnnualAssumed spawning period: August 5 – September 5 (32 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13⁰</u>
2012	17.9 ⁰	31
2013	22.1 ⁰	All
2014	19.5 ⁰	All
2015	20.2 ⁰	26

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2012	17.4 ⁰	0	0	0	0
2013	21.1 ⁰	18	15	8	1
2014	18.7 ⁰	2	0	0	0
2015	19.3 ⁰	6	1		

Nordenskiold River at Elk Sign

Type of Station: Annual

Assumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:	
		13 ⁰	
2012	14.6 ⁰	19	
2013	16.7 ⁰	20	
2014	15.4 ⁰	12	
2015	15.4 ⁰	12	

Nordenskiold River at Elk Sign

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2012	13.8 ⁰	0	0	0	0
2013	16.1 ⁰	0	0	0	0
2014	15.2 ⁰	0	0	0	0
2015	14.9 ⁰	0	0	0	0

Little Salmon River at canoe landing

Type of Station: Annual

Assumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:	
		13 ⁰	
2013	19.2 ⁰	24	
2014	16.5 ⁰	18	
2015	17.5 ⁰	16	

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2013	18.3 ⁰	3	0	0	0
2014	15.9 ⁰	0	0	0	0
2015	16.4 ⁰	0	0	0	0

Teslin River at HootalinquaType of Station: SeasonalAssumed spawning period: July 20 – September 10 (52 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13^o</u>
2012	16.5 ^o	45
2013	19.8 ^o	All
2014	16.7 ^o	51
2015	Loggers lost, no data collected	

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18^o</u>	<u>19^o</u>	<u>20^o</u>	<u>21^o</u>
2012	15.7 ^o	0	0	0	0
2013	19.2 ^o	7	3	0	0
2014	16.1 ^o	0	0	0	0
2015	Loggers lost, no data collected				

Yukon River above HootalinquaType of Station: AnnualAssumed spawning period: July 25 - Aug 25 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13^o</u>
2015	16.1 ^o	All

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18^o</u>	<u>19^o</u>	<u>20^o</u>	<u>21^o</u>
2015	15.7 ^o	0	0	0	0

Takhini River below Kusawa Lake.Type of Station: AnnualAssumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13^o</u>
2013	17.4 ^o	All
2014	Data gaps	-
2015	15.2 ^o	26

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2013	17.2 ⁰	0	0	0	0
2014	Data gaps	-	-	-	-
2015	14.9 ⁰	0	0	0	0

Ibex River at WSC Station.

Type of Station: Annual

Assumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:			
		13 ⁰			
2013	12.2 ⁰	0			
2014	11.2 ⁰	0			
2015	10.9 ⁰	0			

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2013	10.8 ⁰	0	0	0	0
2014	9.6 ⁰	0	0	0	0
2015	10.1 ⁰	0	0	0	0

McIntyre Creek below Mountainview Drive.

Type of Station: Annual

Assumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:			
		13 ⁰			
2012	15.2 ⁰	18			
2013	18.1 ⁰	19			
2014	17 ⁰	17			
2015	16.7	18			

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18 ⁰	19 ⁰	20 ⁰	21 ⁰
2012	13.7 ⁰	0	0	0	0
2013	15.8 ⁰	0	0	0	0
2014	14.4 ⁰	0	0	0	0
2015	14.9 ⁰	0	0	0	0

Yukon River at Anson Bend.Type of Station: AnnualAssumed spawning period: August 1 – 31 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		<u>13⁰</u>
2013	18.2 ⁰	27
2014	16.4 ⁰	All
2015	16.1 ⁰	28

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		<u>18⁰</u>	<u>19⁰</u>	<u>20⁰</u>	<u>21⁰</u>
2013	18 ⁰	2	0	0	0
2014	16.4 ⁰	0	0	0	0
2015	15.9 ⁰	0	0	0	0

Appendix 3. Annual Accumulated Thermal Units

North Klondike River at North Fork Bridge

Commissioned August 8, 2011	
Calendar year 2012	991.4
Calendar year 2013	974.6
Calendar year 2014	952.4
Mean	972.8
Range	39.0

Mcquesten River below WSC Station

Commissioned July 1, 2011	
Calendar year 2012	Incomplete data
Calendar year 2013	Incomplete data

Blind Creek at abandoned bridge

Commissioned July 18, 2011	
Calendar year 2012	1174.8
Calendar year 2013	1258.2
Calendar year 2014	1257.4
Mean	1230.1
Range	83.4

Tatchun River below Tatchun Lake

Commissioned July 20, 2011	
Calendar year 2012	2398.4
Calendar year 2013	2604.9
Calendar year 2014	2504.9
Mean	2502.7
Range	206.6

Nordenskiold River at Elk Sign

Commissioned July 20, 2011	
Calendar year 2012	1580.5
Calendar year 2013	1707.8
Calendar year 2014	1665.5
Mean	1657
Range	127.3

Little Salmon River at canoe landing

Commissioned September 28, 2012	
Calendar year 2013	1610.8
Calendar year 2014	1737.8
Mean	1674.3
Range	127.0

Yukon River at Policeman's Point

Commissioned May 7, 2011	
Calendar year 2012	1842.3
Calendar year 2013	2050.9
Calendar year 2014	2018.9

	Mean	1970.7
	Range	208.8
Takhini River below Kusawa Lake.		
Commissioned October 1, 2012		
Calendar year 2013		1899.1
Calendar year 2014		Loggers disturbed
Ibex River at WSC Station		
Commissioned July 4, 2013		
Calendar year 2014		1085.9
McIntyre Creek below Mountainview Drive.		
Commissioned May 12, 2011		
Calendar year 2012		1744.8
Calendar year 2013		1899.1
Calendar year 2014		1723.7
	Mean	1778.5
	Range	175.4
Yukon River at Anson Bend.		
Commissioned June 19, 2013		
Calendar year 2014		2076.7
Stations with insufficient data to calculate AATUs		
Mcquesten River below Klondike Highway		
Commissioned July 5, 2014		
Yukon River above Hootalinqua		
Commissioned June 29, 2015		

Appendix 4. Accumulated Thermal Units by Brood year Cohort

North Klondike River at North Fork Bridge

Commissioned August 8, 2011	
2011 Brood year cohort: DMeT was below 4.5 ⁰ on September 24, 2012	1241.3
2012 Brood year cohort: DMeT was below 4.5 ⁰ on September 20, 2013	1210.9
2013 Brood year cohort: DMeT was below 4.5 ⁰ on September 22, 2014	1221.0
Mean	1224.4
Range	30.4

Mcquesten River below WSC Station

Commissioned July 1, 2011	
Calendar year 2012	Incomplete data
Calendar year 2013	Incomplete data

Blind Creek at abandoned bridge

Commissioned July 18, 2011	
2011 Brood year cohort: DMeT was below 4.5 ⁰ on September 30, 2012	1470.5
2012 Brood year cohort: DMeT was below 4.5 ⁰ on September 27, 2013	1552.9
2013 Brood year cohort: DMeT was below 4.5 ⁰ on September 23, 2014	1611.5
Mean	1545.0
Range	147.0

Tatchun River below Tatchun Lake

Commissioned July 20, 2011	
2011 Brood year cohort: DMeT was below 4.5 ⁰ on October 18, 2012	3054.5
2012 Brood year cohort: DMeT was below 4.5 ⁰ on October 22, 2013	3337.0
2013 Brood year cohort: DMeT was below 4.5 ⁰ on October 20, 2014	3295.9
Mean	3229.2
Range	282.5

Nordenskiold River at Elk Sign

Commissioned July 20, 2011	
2011 Brood year cohort: DMeT was below 4.5 ⁰ on October 10, 2012	Incomplete data
2012 Brood year cohort: DMeT was below 4.5 ⁰ on October 4, 2013	2119.9
2013 Brood year cohort: DMeT was below 4.5 ⁰ on October 2, 2014	2110.2
Mean	2115.0
Range	9.7

Little Salmon River at canoe landing

Commissioned September 28, 2012	
2013 Brood year cohort: DMeT was below 4.5 ⁰ on October 13, 2014	2274.7

Yukon River at Policeman's Point

Commissioned May 7, 2011	
2011 Brood year cohort: DMeT was below 4.5 ⁰ on October 19, 2012	2486.7
2012 Brood year cohort: DMeT was below 4.5 ⁰ on October 31, 2013	2714.6
2013 Brood year cohort: DMeT was below 4.5 ⁰ on October 26, 2014	2831.7
Mean	2677.7
Range	345.0

Ibex River at WSC Station

Commissioned July 4, 2013	
2013 Brood year cohort: DMeT was below 4.5 ⁰ on September 29, 2014	1408.1

McIntyre Creek below Mountainview Drive.

Commissioned May 12, 2011

2011 Brood year cohort: DMeT was below 4.5⁰ on October 11, 2012 2146.02012 Brood year cohort: DMeT was below 4.5⁰ on October 7, 2013 2302.52013 Brood year cohort: DMeT was below 4.5⁰ on September 30, 2014 2197.3**Mean 2215.3****Range 156.5****Yukon River at Anson Bend.**

Commissioned June 19, 2013

2013 Brood year cohort: DMeT was below 4.5⁰ on October 28, 2014 2928.6**Stations with insufficient data to calculate ATUBYCs****Mcquesten River below Klondike Highway**

Commissioned July 5, 2014

Takhini River below Kusawa Lake.

Commissioned October 1, 2012

Yukon River above Hootalinqua

Commissioned June 29, 2015