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

Progress Report

2014

Yukon River Restoration and Enhancement Fund
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Abstract

The second year of implementation of the Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program (the Program) was successfully conducted in 2014. The Program has two components. Three Seasonal Stations collect data during the Chinook Salmon upstream migration period. Twelve 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. Preliminary results indicate that Alaskan Standards are regularly exceeded. Canadian Thresholds for migration are exceeded much more rarely. Thermal conditions for Chinook Salmon upstream migration and spawning were excellent in 2014. 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. 209 data sets have been distributed and more is anticipated. All data collected in the Program is now publicly available at yukonwatertemperatures.info. Temperatures are being measured and recorded at 12 Annual Stations during the winter of 2014/15.

Acknowledgements

Funding from theYukon 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 contributed his time and expertise to design and administer the website yukonwatertemperatures.info

Cover: Nordenskiold River at “Nordenskiold River at Elk Sign” Annual Station

Table of contents

Appendices

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 and 2014. The Program built on annual projects conducted by the Alaska Department of Fish and Game (ADF&G) beginning in mid-summer 2011. The author implemented the Yukon component of the ADF&G projects. Due to administrative difficulties the author 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 2014 the objectives of the Project were as follows:

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 ewatch 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 2014 Project proceeded as planned. Monitoring and evaluation functions for field activities included close attention to the siting of Stations; designing and following 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 maintaining one layer of redundancy through 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 by the km.

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 3 full years of data for 2 of the Seasonal Stations and 4 years for the third. Upon replacement of the Annual Stations in autumn of 2015 there should be 1 full year data for 1 Station, 2 full years for 2 Stations, 3 full years for 2 Stations, 4 full years for 6 Stations, and 5 full years for one Station. 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; and 2014 which had a warm spring followed by a cool summer. Missing are warm water, low flow years.

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 and uploading data sets. Risk assessment of the likelihood of being able to retrieve loggers and to do so on schedule was conducted at each Station whenever loggers were 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 may be established if a suitable location is found. New Stations are added to the network to meet an opportunity or need.

No Stations were decommissioned in 2014. However, loggers at the Mcquesten River at WSC Station were displaced downstream during freshet and deposited on the shore. Data between April 28 and June 30 was lost. In 2013 the loggers at this Station were lost during spring freshet. Additionally, it is located 11 km from the Klondike Highway. The access trail is too wet to safely traverse until late June in most years. Measures are being taken to replace the Station with one which is more accessible. On July 5, 2014 a new Station, Mcquesten River below Klondike Highway, was established. Both Stations will be operated until at least autumn of 2015. Data collected at both Stations will be compared to determine the degree of concordance between the Stations.

Takhini River below Kusawa Lake was disturbed by persons unknown on June 18, 2014. The loggers will be moved to an adjacent and less visible area in spring 2015.

Ibex River at WSC Station was added to the Network. The Station had originally been established in support of an investigation into the distribution of introduced Rainbow Trout (von Finster, 2013). The Station is reasonably accessible and the Ibex River has been identified as a candidate for Chinook Salmon Stock Restoration (Zurachenko and Finnson, 1998). It was therefore considered justified to maintain the Station and add it to the Network.

All other Stations performed as expected.

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. The make, model and serial number of each logger is provided as metadata for each data set, allowing future data users 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 from the mouths of upstream tributaries sufficient enough 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^{o} C cooler than surface waters in midsummer and up to 7^{o}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 unacceptably 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 data loggers chosen are robust, accurate, and simple to operate and download. Two loggers are set at each Station at each deployment to maintain a level redundancy. Loggers and associated equipment left in the field are 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 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 save 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. Chinook spawning in the White River Watershed is limited to the Nisling and Klottasin Rivers and Tincup Creek. All are functionally accessible only by air. 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, -13 and -14
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, -13 & -14
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, -12, -13 & -14
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: No concerns.

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.
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 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
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 is located upstream but has not performed well due to excessive flows and difficulty in accessing the Station.
Performance: To be determined.

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 – present. 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 is likely in 2015.

Blind Creek below 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
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
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.
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 during open water period, but subject to disturbance from persons and/or animals. The loggers have been pulled out of the water, resulting in data gaps. 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.
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 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 – present.
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: No concerns.

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 - present.
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. In June 2014 he 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
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 last 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.

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 the 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.

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

Only 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 0.2^0 C. The instruments stability, or drift, is less than 0.1^0C 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.

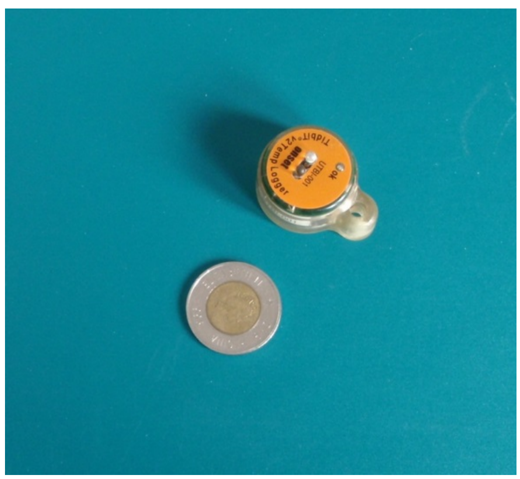


Image 1. Onset Tidbit v2. A Canadian two dollar coin provides scale. The hole used to secure the logger is visible on its right side.

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 and placed 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. Each logger is downloaded. The status of its battery and remaining memory is 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^{o} C. The -0.2^{o} value was chosen for three reasons:

- the data loggers are accurate within 0.2^{o}C;
- slush/frazil ice is usually slightly below 0^{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^{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 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. As such, the studies poorly represent the variable temperatures characteristic of natural environments and the ability of fish to leave areas of elevated temperatures.

The Canadian process reflects the legal and socio-economic characteristics of Canada. Water is, constitutionally, a provincial area of 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 ewatch 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 13^0 and 15^0 C during the specified periods were determined for the US process, and those with MeDT above 18, 19, 20 and 21 degrees 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 lengths 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)
Nordenskiold 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 were 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)
Nordenskiold 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)
Takhini River below Kusawa Lake: 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 is calculated over a specified period of time. The Annual Accumulated Thermal Units (AATU) for a river is the sum of all mean daily temperatures for a given calendar year. Where a Station records temperatures less than -0.2^{o}C a value of 0^{o}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. 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 temperature of 4.5^{o}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^{o}C a value of 0^{o}C is used in the calculation.

Results

Chinook Salmon Upstream Migration

Highest recorded Maximum Daily Temperatures (MaxDT) and the number of days that the Standard of 15^{0}C for Chinook upstream migration were exceeded by Station and year within the specified periods may be found in Appendix 1. Generally, MaxDTs were higher in 2014 than in 2012 but lower than in 2013. The exception was the Nordenskiold River at Elk Sign which had a MaxDT of 16.8^{0} in both 2012 and 2013, and a MaxDT of 16.1^{0} in 2014. The number of days with one or more hourly temperature records exceeding 15^{0}C exhibited a similar pattern. Most Stations had more days with MaxDTs above 15^{0} in 2014 than in 2012, and less than in 2013. Exceptions were the Nordenskiold River at Elk sign and the Teslin River at Hootalinqua. Each had one less day in 2014 than in 2012. The numbers of days with temperatures exceeding 15^{0} was greater in 2013 than in 2012 or 2014 at all Stations.

Appendix 1 also includes the highest calculated Mean Daily Temperatures (MeDT) and numbers of days that the Fraser River ewatch Thresholds for upstream migration were exceeded by Station and year within the specified periods. In 2012 none of the migration Stations exceeded the lowest Threshold temperature of 18^{0}C. In 2013 all Stations except the Mcquesten River at WSC exceeded this Threshold. MeDTs in the Pelly and Teslin Rivers exhibited short excursions beyond the second Threshold temperature of 19^{o}C. This could have resulted in early signs of physiological distress and slow migration in some of the adult Chinook. In 2014 none of the Stations exceeded the lowest Threshold of 18^{0} MeDT.

Chinook Salmon Spawning

Highest recorded Maximum Daily Temperatures (MaxDT) and the number of days that the US Standard of 13^{0}C MaxDT for Chinook spawning were exceeded by Station and year within the specified periods may be found in Appendix 2. The North Klondike River at North Fork Bridge and the Ibex River at WSC Station have never exceeded the Standard. All other Stations exceeded 13^{0}C every year. Numbers of days in excess of the Standard were greatest in 2013 at all Stations. There was no clear trend in numbers of days exceeding 13^{0} between 2012 and 2014: Mcquesten River, Tatchun River, Teslin River had greater numbers of days exceeding 13^{0} C in 2014; Nordenskiold River and McIntyre Creek had less; and Yukon River at Anson Bend and Blind Creek had equal numbers.

The Fraser River ewatch was used as a proxy for assessing the effects of elevated temperatures on spawning Chinook Salmon. Appendix 2 also includes the highest calculated Mean Daily Temperatures (MeDT) and numbers of days that Thresholds of 18^{0}, 19^{0}, 20^{0} and 21^{0}C were exceeded by Station and Year within the specified periods. In 2012 none of the rivers exceeded the lowest Threshold of 18^{0}C. In 2013 Tatchun River below Tatchun Lake exceeded 18^{0} on 18 days; 19^{0} on 15 days; 20^{0} on 8 days and 21^{0} on 1 day. Other Stations exceeding Thresholds in 2013 included the Little Salmon River at Canoe Landing, with 3 days in excess of 18^{0}; Yukon River at Anson Bend, with 2 days in excess of 18^{0}; and Teslin River at Hootalinqua with 7 days in excess of 18^{0} and 3 days in excess of 19^{0}. In 2014 the Threshold of 18^{0} was exceeded only at the Tatchun River below Tatchun Lake, and then only for 2 days.

Annual Accumulated Thermal Units

Appendix 3 provides the calculated AATUs by Station and calendar year, the range of AATUs for the period of record and the mean AATU for each Station. Sufficient data was available to calculate AATUs for 2012 and 2013. AATUs in 2013 were greater than in 2012 with the exception of the North Klondike at North Fork Bridge, which was slightly lower. The North

Klondike at North Fork Bridge had the lowest AATU with an average (2012 & 2013) of 983 AATU. Tatchun River below Tatchun Lake had the greatest number of AATUs with a mean of 2502 AATU. The North Klondike also had the smallest range between years, at 18.8 ATU, while the greatest range was Yukon River at Policemans Point at 208.8 ATU.

Accumulated Thermal Units by Brood Year Cohort

Appendix 4 provides the calculated ATUBYC by Station and calendar year, the range of ATUBYCs for the period of record and the mean ATUBYC for each Station. Sufficient data was available to calculate ATUBYCs for Brood Years 2011 and 2012. ATUBYCs for 2012 were greater than the 2011 cohort with the exception of the North Klondike at North Fork Bridge, where the ATUBYC was slightly lower. The North Klondike at North Fork Bridge had the lowest ATUBYC with a mean of 1226 ATUBYC. Tatchun River below Tatchun Lake had the greatest ATUBYC a mean of 3196 ATUBYC. The North Klondike also had the smallest range between brood years 2011 and 2012, at 30 ATU, while the greatest range was at Tatchun River below Tatchun Lake with 282 ATU.

Discussion

Water temperature monitoring at Annual Stations is a continuous process. This report is based on data collected between autumn of 2013 and autumn of 2014. 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 is also extended to precipitation and air temperatures of a general or specific area.

Water temperatures may be influenced by air temperatures and precipitation of past years. In the CYRB a series of wet years preceded 2014. Considerable water was stored in lakes, ponds and wetlands and in underground aquifers. Flows in streams and rivers were 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 were fully charged.

The winter of 2013/14 was warmer than normal in the CYRB. The south central Yukon experienced heavy snowfalls early in the winter followed by a mid-winter melt. By May 8 the snow-water equivalent was between 110 – 130 % of normal south of Pelly Crossing and 90 – 110 % north of Pelly Crossing (Yukon Government, 2014). Spring was early and warm. The weather cooled in late June. Depending on the area, one or more major precipitation events occurred in July and early August. The remainder of August was dry but cool.

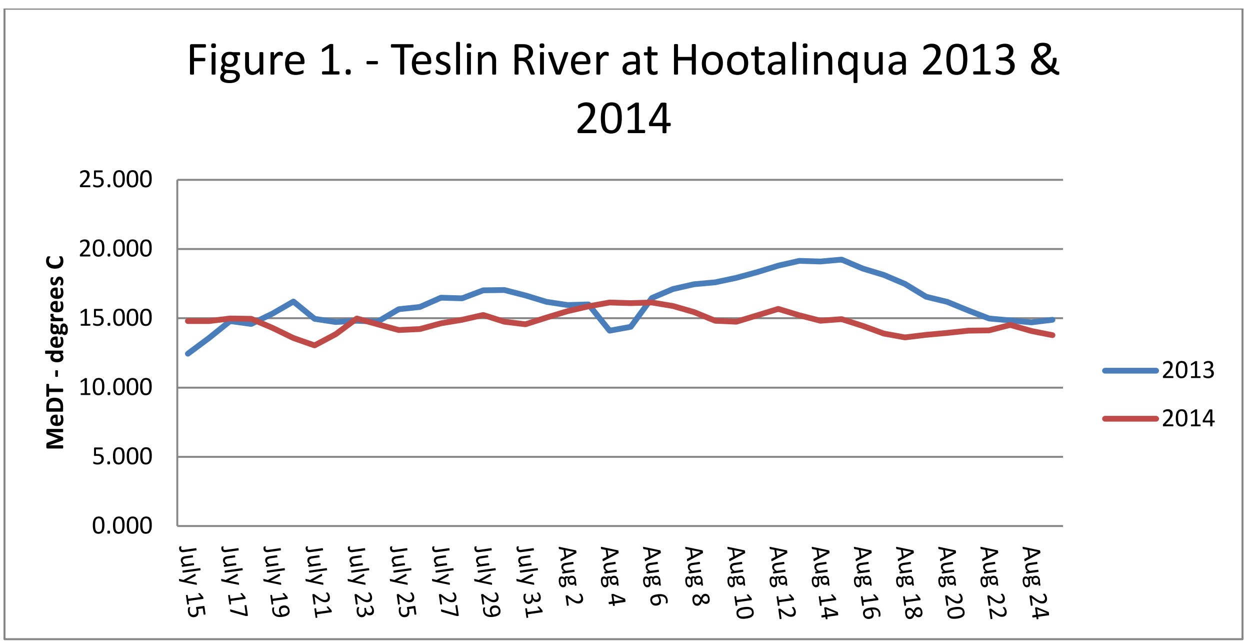
Water levels in the Teslin and Upper Yukon Rivers remained high throughout the summer and autumn. Levels in the Pelly and Stewart Rivers were somewhat higher than normal. High flows in the Klondike followed a precipitation event in late July/early August. There was a small area that seemed to have escaped significant precipitation and included the Nordenskiold and Tatchun River basins. Flows in both rivers were lower than in recent years.

Application of Standards and Thresholds – Migration and Spawning

Application of the ADEC Upstream Migration and Spawning Standards implies that many CYRB Chinook salmon stocks are at risk during these life processes even in cold years. However, Standards such as those of the ADEC that are prepared in other jurisdictions for other purposes and based other species or stocks must always be cautiously applied. The ADEC Standards were transferred from the US Pacific North West and are 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 have temperatures that exceeded the Standards some or most of the time.

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 for upstream migrating salmon 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. Pending development of Yukon River Chinook specific thresholds, the Fraser River Thresholds are considered the best tool to provide guidance for risk assessments of water temperatures.



Application of the ewatch Thresholds to the MeDTs of Stations in the CYRB indicate that water temperatures did not negatively affect upstream migration in 2012 at any Station. Thresholds were exceeded for short periods in the Teslin- and Pelly Rivers in 2013, but effects would probably have been minor. In 2014 no thresholds were exceeded during the assumed upstream migration period. This is believed due to the cooling of air temperatures in late June and early

July. Water temperatures either fell or remained stable. Warm, sunny weather in August 2013 resulted in a rise in water temperatures. Thresholds of 18^{0}C and 19^{0}C were exceeded on 7 and 3 days, respectively. In comparison, the cool August of 2014 resulted in the greatest MeDT of 16.1^{0}C. An example is illustrated in Figure 1, which shows the differences between the warm August of 2012 and the much cooler August of 2013.

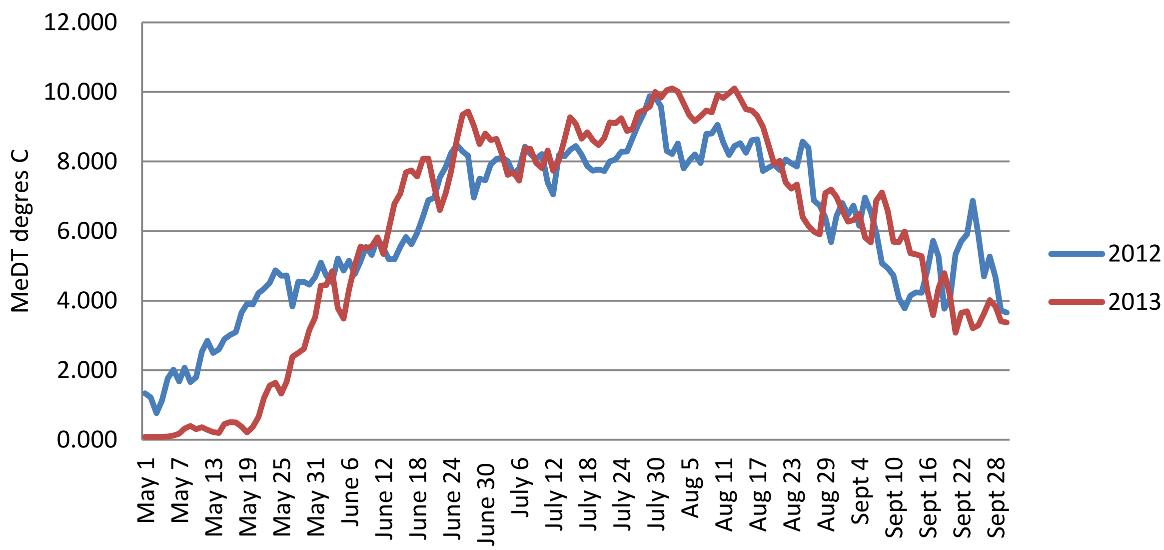
The Fraser River ewatch Thresholds were used as a proxy for thermal tolerance of spawning Chinook for the specified periods. No thresholds were exceeded in 2012. Four of 11 Stations exceeded 18^{0}C in 2013, two exceeded 19^0, and one, Tatchun River below Tatchun Lake, exceeded both 20^0 and 21^0. In 2014 only Tatchun River below Tatchun Lake exceeded 18^0, and then only did so for 2 days.

Water temperatures at all of the Stations monitored for upstream migration and spawning had favourable thermal conditions for these life stages in 2014. It is likely that conditions were as favourable for the remainder of the Canadian Yukon River Basin.

Annual Accumulated Thermal Units

Most Annual Stations had sufficient data for AATUs to be calculated for 2012 and 2013. The North Klondike River at North Fork Bridge was the only Station with lower AATUs in 2013 than in 2012. Figure 2. illustrates the 2012 and 2013 MeDTs at the Station from May 1 to September 28. In 2012 temperatures increased earlier than in 2013 and remained higher for the entire month of May: 95.8 ATUs were calculated for May 2012 and 27.5 for May 2013. Although the temperatures during the remainder of the open water period in 2013 were generally warmer than in 2012, the AATUs at years end of 2013 remained 30.4 ATUs less than for 2012.

Figure 2. North Klondike River at North Fork Bridge 2012 & 2013



All other Stations had greater AATUs in 2013 than in 2012. Spring of 2013 was delayed throughout the CYRB. Most monitored rivers had higher than normal flows throughout the open water period. This is believed to have resulted in correspondingly lower than normal water temperatures. Had spring been earlier, or flows lower, the AATUs would have been greater in 2013 than they were.

The Stations monitored for Chinook spawning exhibited a significant range of AATUs. Average AATUs from 2012 and 2013 resulted in a range of 983 to 2501.7 AATU between the coldest and warmest Stations. The former, North Klondike River at North Fork Bridge represents a mountain river draining an erosional landscape. The latter, Tatchun River below Tatchun Lake, represents smaller rivers draining a lake in a depositional landscape. Assuming that Chinook Salmon have adapted to the thermal environment of the streams in which they spawn, the thermal environment of donor and recipient streams should be considered in Stock Restoration planning.

Data collected to date support preliminary classification of Chinook spawning streams by AATU into "cold", "cool" and "warm" categories as illustrated in Table 7. AATUs calculated in future years will allow the table to be refined. It is likely that the Mcquesten and Ibex Rivers will be in the "Cold" category and the Yukon River at Anson Bend will be in the "Cool" category.

Table 1. Classification of Stations using AATUs

	AATU	
Station	2012	2013
Cold		
North Klondike River at North Fork Bridge	991.4	974.6
Blind Creek at abandoned bridge	1174.8	1258.2
Cool		
Little Salmon River at Canoe Landing		1610.8
Nordenskiold River at Elk Sign	1580.5	1707.8
McIntyre Creek below Mountainview Dr	1744.8	1866.9
Takhini River below Kusawa Lake		1899.1
Yukon River at Policemans Point	1842.3	2050.9
Warm		
Tatchun River below Tatchun Lake	2398.4	2604.9

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, would indicate that the Tatchun River is the most productive and the North Klondike the least productive of the monitored streams.

Accumulated Thermal Units by Brood Year Cohort.

The ATUBYC were designed to be a measure of describing the available thermal energy for cohorts, or age classes, of juvenile Chinook Salmon. Of importance, 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. This 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). 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 Network includes only about 10% of the more than 100 known Chinook spawning rivers in the CUYRB. These rivers have not been classified on the basis of physical characteristics. There is recognition that Chinook spawn in main-stem rivers, small streams, downstream of lakes and waters that are intermediate to these (von Finster, 2006). Classification of all CUYRB spawning rivers on the basis of physical characteristics is beyond the scope of this project. A provisional classification process will be developed and implemented prior to the implementation of the 2015 project, should it be funded.

Data loggers are replaced at Annual Stations in the autumn prior to Mean Daily Water Temperatures falling below 4.5^{0C} and again in the spring. In 2014 data was not analysed until after the loggers were replaced in the autumn. Analysing data shortly after the loggers are replaced in the spring will provide researchers insight regarding the environmental conditions under which the 1+ outmigrants developed. In 2015 this analysis will be conducted and the data distributed.

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 2014 the relevant data sets were sent to the same persons and those who had asked for data following the submission of the 2013 report.

Results

To date in 2014, a total of 209 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 two local consulting firms.

Discussion

This will be the final year that data sets will be distributed. Should the 2015 project be funded the data sets will be uploaded to yukonwatertemperatures.info in the autumn of 2015. All interested parties will be informed by email after the upload is complete.

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 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".

Discussion

Yukonwatertemperatures.info will be announced early in 2015. Yukon Government will be approached to have the Stations comprising the network included in the Yukon Water Catalogue http://yukonwater.ca/

Conclusion

The second 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 on the Mcquesten River in preparation for decommissioning the original Station. An Annual Station was added on the Ibex River in anticipation of potential Stock Restoration.

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

Data collected to date is now available on the web at yukonwatertemperatures.info

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. Brittian, G.M. Gislason, A. Lehmann, V. Lencion, B. Lods-Crozet, B. Maiolini, A.M. Milner, J.S. Olaffson, S.J. Saltveit, and D.L. Snook. 2001. Macrobenthic invertebrate richness and consumption along a latitudinal gradient of European glacier-fed streams. Freshwater Biology 46, 1811 - 1831

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, 2013. 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 Hihger 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.

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.

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.

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 hydrolology, geomorphic hazards and water quality. Hydrological Processes 23, 42-61 (2009)

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.

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 (Oncorhyncus 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.

Environment Yukon. May 8, 2014. Yukon Snow Survey Bulletin and Water Supply Forecast. Yukon Government Water Resources Branch. 28 p.

Wilson, J. 2011. Blind Creek Chinook Salmon Enumeration Weir, 2010. Yukon River Restoration and Enhancement Fund Porject 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:
		15^0
2012	17^0	14
2013	18.7^0	43
2014	17.8^0	31

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	16.5^0	0	0	0	0
2013	18.1^0	2	0	0	0
2014	17.2^0	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:
		15^0
2012	14.2^0	0
2013	16.7^0	26
2014	15^0	1

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	13^0	0	0	0	0
2013	15.3^0	0	0	0	0
2014	13.3^0	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: 15^0
2012	17.3^0	20
2013	20.8^0	49
2014	19.3^0	47

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	16.8^0	0	0	0	0
2013	19.1^0	15	2	0	0
2014	17.9^0	0	0	0	0

Nordenskiold 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: 15^0
2012	16.8^0	10
2013	16.8^0	22
2014	16.1^0	9

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	16.1^0	0	0	0	0
2013	18.4^0	3	0	0	0
2014	15.2^0	0	0	0	0

Teslin River at Hootalinqua

Type of Station: Seasonal
Assumed migration period: July 15 – September 10 (58 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding: 15^0
2012	16.5^0	28
2013	19.8^0	46
2014	16.7^0	27

Teslin River at Hootalinqua (continued)

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	15.8^0	0	0	0	0
2013	19.2^0	7	3	0	0
2014	16.2^0	0	0	0	0

Yukon River at Policeman's Point

Type of Station: Annual

Assumed migration period: July 21 – September 3 (46 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		15^0
2012	16^0	20
2013	18.2^0	31
2014	16.6^0	22

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	15.6^0	0	0	0	0
2013	18.2^0	3	0	0	0
2014	16.2^0	0	0	0	0

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:
		15^0
2013	18.2^0	34
2014	17.4^0	18

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2013	18.1^0	2	0	0	0
2014	16.1^0	0	0	0	0

Appendix 2 – Application of Standards & Thresholds for 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: 15^0
2012	12.2^0	0
2013	12.6^0	0
2014	10.6^0	0

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding: 18^0	19^0	20^0	21^{00}
2012	9.9^0	0	0	0	0
2013	10.1^0	0	0	0	0
2014	8.5^0	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: 13^0
2012	14.1^0	5
2013	16.7^0	35
2014	15^0	14

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding: 18^0	19^0	20^0	21^0
2012	13^0	0	0	0	0
2013	15.3^0	0	0	0	0
2014	13.3^0	0	0	0	0

Blind Creek at abandoned bridge

Type of Station: Annual

Assumed spawning period: July 20 - August 20 (32 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding: 13^0
2012	13.9^0	8
2013	15.7^0	19
2014	14.4^0	8

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding: 18^0	19^0	20^0	21^0
2012	12.9^0	0	0	0	0
2013	13.7^0	0	0	0	0
2014	12.8^0	0	0	0	0

Tatchun River below Tatchun Lake

Type of Station: Annual

Assumed spawning period: August 5 – September 5 (32 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding: 13^0
2012	17.9^0	31
2013	22.1^0	All
2014	19.5^0	All

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	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

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^o
2012	14.6^0	19
2013	16.7^0	20
2014	15.4^0	12

Nordenskiold River at Elk Sign (continued)

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	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

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^o
2013	19.2^0	24
2014	16.5^0	18

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	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

Teslin River at Hootalinqua

Type of Station: Seasonal

Assumed spawning period: July 20 – September 10 (52 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		13^o
2012	16.5^0	45
2013	19.8^0	All
2014	16.7^0	51

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding:			
		18^o	19^o	20^o	21^o
2012	15.7^0	0	0	0	0
2013	19.2^0	7	3	0	0
2014	16.1^0	0	0	0	0

Takhini River below Kusawa Lake.

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	17.4^0	All
2014	Data gaps	-

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	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	-	-	-	-	-	-

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

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	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

Yukon River at Anson Bend.

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	18.2^0	27
2014	16.4^0	All

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum mean daily	Number of days with mean daily temperatures exceeding: 18^0	19^0	20^0	21^0
2013	18^0	2	0	0	0
2014	16.4^0	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
	Mean	**983**
	Range	**16.8**
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
	Mean	**1216.5**
	Range	**83.4**
Tatchun River below Tatchun Lake		
Commissioned July 20, 2011		
Calendar year 2012		2398.4
Calendar year 2013		2604.9
	Mean	**2501.7**
	Range	**206.6**
Nordenskiold River at Elk Sign		
Commissioned July 20, 2011		
Calendar year 2012		1580.5
Calendar year 2013		1707.8
	Mean	**1644.2**
	Range	**127.3**
Little Salmon River at canoe landing		
Commissioned September 28, 2012		
Calendar year 2013		1610.8
Yukon River at Policeman's Point		
Commissioned May 7, 2011		
Calendar year 2012		1842.3
Calendar year 2013		2050.9
	Mean	**1946.6**
	Range	**208.8**
Takhini River below Kusawa Lake.		
Commissioned October 1, 2012		
Calendar year 2013		1899.1

McIntyre Creek below Mountainview Drive.

Commissioned May 12, 2011		
Calendar year 2012		1744.8
Calendar year 2013		1899.1
	Mean	**1805.9**
	Range	**159.3**

Stations with insufficient data to calculate AATUs

Yukon River at Anson Bend.
Commissioned June 19, 2013

Ibex River at WSC Station
Commissioned July 4, 2013

Appendix 4. Accumulated Thermal Units by Brood year Cohort

North Klondike River at North Fork Bridge

Commissioned August 8, 2011		
2011 Brood year cohort: temperature was below 4.5^0 on September 24, 2012		1241
2012 Brood year cohort: temperature was below 4.5^0 on September 20, 2013		1211
	Mean	**1226**
	Range	**30**

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: temperature was below 4.5^0 on September 30, 2012		1471
2012 Brood year cohort: temperature was below 4.5^0 on September 27, 2013		1553
	Mean	**1512**
	Range	**81**

Tatchun River below Tatchun Lake

Commissioned July 20, 2011		
2011 Brood year cohort: temperature was below 4.5^0 on October 18, 2012		3055
2012 Brood year cohort: temperature was below 4.5^0 on October 22, 2013		3337
	Mean	**3196**
	Range	**282**

Nordenskiold River at Elk Sign

Commissioned July 20, 2011	
2011 Brood year cohort: temperature was below 4.5^0 on October 10, 2012	Incomplete data
2012 Brood year cohort: temperature was below 4.5^0 on October 4, 2013	2120

Yukon River at Policeman's Point

Commissioned May 7, 2011		
2011 Brood year cohort: temperature was below 4.5^0 on October 19, 2012		2487
2012 Brood year cohort: temperature was below 4.5^0 on October 31, 2013		2715
	Mean	**2601**
	Range	**228**

McIntyre Creek below Mountainview Drive.

Commissioned May 12, 2011		
2011 Brood year cohort: temperature was below 4.5^0 on October 11, 2012		2146
2012 Brood year cohort: temperature was below 4.5^0 on October 7, 2013		2303
	Mean	**2224**
	Range	**157**

Stations with insufficient data to calculate ATUBYCs

Yukon River at Anson Bend.
Commissioned June 19, 2013

Ibex River at WSC Station
Commissioned July 4, 2013

Mcquesten River below Klondike Highway
Commissioned July 5, 2014
Takhini River below Kusawa Lake.
Commissioned October 1, 2012
Little Salmon River at canoe landing
Commissioned September 28, 2012