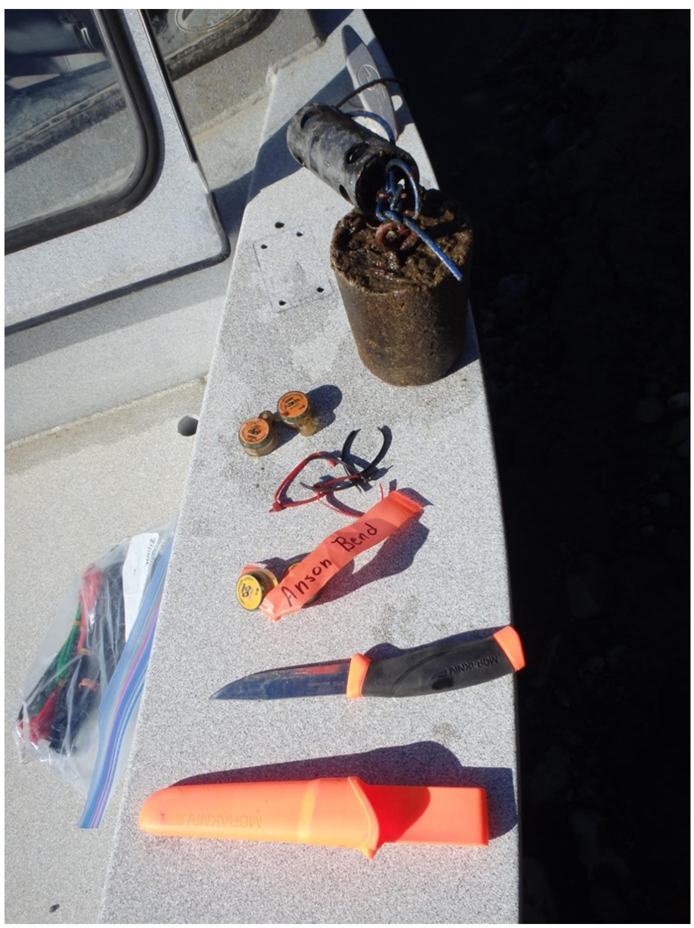
Water Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada
Annual Project Report
2017

Yukon River Restoration and Enhancement Fund
CRE-20-17

Al von Finster
AvF R&D
2017



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Abstract

The Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program (the Program) continued in 2016/17. Data was collected at 3 Seasonal- and 12 Annual Stations. Current coverage includes 7 of the 8 watersheds in the Canadian Yukon River Basin (CYRB) and 9 of 11 (Draft) DFO Conservation Units (CUs). Temperatures are being recorded at all Annual Stations during the winter of 2017/18. A single make and model of data logger has been used and log temperatures each hour, on the hour. 2016/17 data was downloaded, checked and saved. Mean Daily Temperatures (MeDTs) were calculated and Maximum Daily Temperatures (MaxDTs) determined. Data was analysed against Alaskan Standards and Canadian Thresholds. Annual Accumulated Thermal Units (AATUs) and Accumulated Thermal Units by Brood Year Cohort (ATUBYC) were calculated for Annual Stations. Alaskan Standards for migration and spawning have been exceeded at almost all Stations in all years and Canadian Thresholds for migration have been rarely exceeded. In 2017 temperatures were generally cool in all rivers monitored, although warm mid-summer weather in the Central Yukon resulted in elevated temperatures in the Tatchun River. AATUs and ATUBYCs have varied widely across the CYRB, implying significant differences in potential biological productive capacity between different types of watercourses. AATUs have supported preliminary classification of Chinook spawning rivers and streams as cold, cool and warm. ATUBYCs allow insight into potential production of juvenile Chinook Salmon prior to the onset of young-of-year overwintering. 182 data sets have been, or are in the process of distribution. All 2016/17 data collected in the Program has been uploaded to yukonwatertemperatures.info and is publicly available.

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: Spring replacement of data loggers at Station "Yukon River at Anson Bend". Anchor and logger housing are at top of photo; removed loggers in centre; and replacement loggers tied with survey tape below.

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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 through 2017. 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 2017 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 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 2017 Project generally proceeded as planned. Monitoring and evaluation functions for field activities included assessment of the validity of each Station; adherence to established procedures to ensure that data from one Station would not and could not be confused with another; maintenance of a Master Data Logger Tracking Spreadsheet to track each logger and deployment; and deployment of two loggers at each Station to provide one level of redundancy in case of instrument failure. Program related monitoring and evaluation included application of time, travel, and materials accounting and management principles to all project activities. Personnel time and watercraft use was tracked by the hour and vehicle use was by the kilometer.

Substantial progress has been achieved 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. Active Stations are listed in the "Monitoring Network – Station Descriptions". The years of record are provided for each 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, 2015 and 16 which had warm springs followed by cooler summers. There was a geographical split in 2017, with cool and generally moist weather south of the Pelly/Stewart River watershed boundary and warm and dry weather to the north of it. 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. Stations are decommissioned if their physical viability is likely to be compromised due to channel instability, repeated disturbance by people or animals or any other threat to data quality. A new Station on the same river or stream may be established if a suitable location is found. .

The performance of each Station in collecting an uninterrupted data series of sufficient quality was assessed during data set preparation.

New Stations may be added to the network to meet an opportunity or need. In 2016/17 an Annual Station was added at Tatchun River above the Klondike Highway. This Station will monitor water temperatures at the downstream end of substantive Chinook spawning in the river.

There were no other major modifications to the Program in 2016/17. Minor modifications were effected to address icing conditions or local erosion/deposition processes.

Program design and description

The framework for the Network is based on the following 3 principles:

- 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 far enough from the mouths of upstream tributaries that the potential risk of measuring the temperature of the tributary rather than that of the subject watercourse is minimized;
    - Stations located downstream of lakes are located far enough downstream that the potential effects of lakes on water temperatures are minimized unless the Station is purposely located to represent lake outlet Chinook Salmon spawning habitat;
    - Stations are located far enough from obvious ground water discharges that the potential risk of measuring the temperature of the discharging ground water is minimized.
- All Stations must be adequately described so that data collection will 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 considered unacceptable in these systems. Seasonal Stations are generally located on major tributaries where large numbers of Chinook Salmon pass on their spawning migration. Loggers are deployed prior to the beginning of the upstream migration of adult Chinook and retrieved after the migration is considered to be substantively complete. Annual Stations record temperatures throughout the year and are generally located on Chinook spawning streams and rivers. Loggers at Annual Stations are replaced in spring- and again prior to freeze up.

The detailed design and adaptive management of the Project is based on the following guidelines:

- Implementation over a wide geographical area to ensure a reasonable degree of coverage of the portion of the CYRB utilized by Chinook Salmon. This addresses the wide distribution of Yukon River Chinook Salmon migration and spawning rivers in the CYRB. To date Chinook spawning has been reported in 98 watercourses (Brown et.al, 2017). 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 serviced;
- 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. Small(er) streams are assessed for risk of beaver dams that could result in loss of the loggers or compromised data.

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 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. Draft 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 Chinook Conservation Units except for the CK-75 - White (River) and CK-70 - Big Salmon (River). This is due to the geographical isolation of these watersheds and the related expense of operating and maintaining Stations in them. Known 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 was a small population in the Kluane River between the outlet of Kluane Lake and the mouth of the Duke River, but it was considered to be poorly representative of the more heavily utilized habitats. Additionally, it is vulnerable to the reduction of flow from the lake consequent to the capture of the Slims River by the Kaskawulsh River (Schugar et.al., 2017). The status of this population is currently unknown. Chinook spawning in the Big Salmon River Watershed occurs in the North Big Salmon River and its tributaries, Northern Creek; the South Big Salmon; and Scurvy Creek. 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 natal to those waters, Additionally, juveniles from upstream spawning populations also enter and use spawning rivers and streams (MacKenzie-Grieve, 2014). Overwintering of young-of-year Chinook is believed to occur in most or all spawning rivers.

Seasonal Stations

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 spawning rivers than currently documented. Low river flows in 2002 were suggested as a reason that Chinook Salmon appeared to be experiencing difficulties in ascending Fraser Falls (Osbourne et. al., 2003). 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: Generally good, but low water levels in 2017 resulted in the loggers being dewatered through most of August.

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 identified.

Yukon River above the Klondike Highway

Type of Station: Seasonal
Watershed: YR Mid-Mainstem
Conservation Unit: Middle Yukon River & tributaries; CK-70 – Big Salmon; CK-68 Teslin River Headwaters; and CK-69 – Upper Yukon River
Co-ordinates: NAD 83 62 05.684/136 16.275
Use by Chinook: CN spawning downstream; migration to upstream Watersheds.
Existing data: 2016 & 2017
Rationale for inclusion: Chinook spawning in the Yukon River within the YR Mid-Mainstem is poorly defined. Most occurs downstream of the Station. All salmon spawning in the Big and Little Salmon Rivers, Walsh Creek and the Teslin and Upper Yukon River Watersheds migrate past the Station. The Station is located on the left side of the Yukon River and is accessible by foot from an old coal mine road.
Performance: No concerns identified.

Annual Stations

Please note that most Annual Stations experience temperatures below -0.2^0 C in some winters due to ice formation processes. If the temperatures measured during the following spring are consistent with a submerged logger recording water temperatures the data is considered “continuous”. If the temperatures measured are consistent with loggers recording air temperatures the data is not considered to be continuous.

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 further upstream and was abandoned due to access difficulty and displacement of loggers during high flows.
Performance: A minor groundwater influence has been observed during winter flows.

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, 2015). 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 identified.

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 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 identified.

Tatchun River above Klondike Highway

Type of Station: Annual
Watershed: YR Mid-Mainstem
Conservation Unit: CK-73 Yukon River Mid-Mainstem
Coordinates: NAD 83 62 16.925/136 18.632
Use by Chinook: spawning and incubation.
Existing data: August 29 2016 – present, continuous.
Access: by vehicle from Klondike Highway
Rationale for inclusion: The Tatchun River is described above in the Station description for Tatchun River downstream of Tatchun Lake. The lake outlet Station is located at the effective upstream limit of Chinook spawning. This Station is located at the effective downstream limit of Chinook spawning. Data collected at the two Stations will be compared to start to develop an understanding of the thermal regimes within a single spawning stream.
Performance: No concerns identified.

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 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.. 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 identified.

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 appears to have excellent Chinook spawning habitat. The profile of 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: In the spring of 2016, the loggers were out of the water for an extended period. A longer line was attached to the logger, allowing it to be located further from shore. The problem persisted in 2017, and a new logger location will be sought in 2018.

Teslin River above Hootalinqua

Type of Station: Annual

Watershed: YR Teslin River

Conservation Unit: CK-68 Teslin River Headwaters

Co-ordinates: NAD 83 61 34.047/134 53.949

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

Existing data: June 27, 2016 - present.

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 Station was formerly at the confluence of the Yukon and Teslin Rivers and upstream of where the mixing zone between the two rivers reaches across the river. It was difficult to service at high water levels and dewatered under low water conditions. Access is by boat from the Deep Creek Launch on Lake Laberge.

Performance: No concerns identified.

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 in late summer. 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.

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 spawning upstream of the Station.
Existing data: July 4, 2013 – present, continuous.
Access: by 4X4 or ATV via the Ibex River Road
Notes: The lower 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. A complicating effect will be that flows from a significant area of the watershed are usually diverted to Porter and thence McIntyre Creek for the purposes of electrical power generation.
Performance: No concerns identified.

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 creek provides an opportunity to investigate the effects of water regulation on a small stream in a northern environment.
Performance: No concerns identified.

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 identifed.

Decommissioned Stations

Decommissioned Stations include:

Takhini River above Mendenhall – Annual Station - July 29, 2011 to October 1, 2012. Annual Station. Loggers were dewatered in spring. Station relocated to Takhini River below Kusawa Lake.

Yukon River at Policeman's Point – Annual Station - May 8, 2011 to June 2, 2015. Loggers were continually being buried under sand deposited in channel bottom. No suitable replacement sites identified.

Pelly River above Faro Bridge – Seasonal Station, 2011 & 2012. River channel was laterally unstable and the risk of losing loggers was considered unacceptable.

Stewart River at Viewpoint – Seasonal Station - 2011. Risk of loggers dewatering was considered to be too high. Station was relocated to Stewart River at Stewart Crossing.

Mcquesten River at WSC Station – Annual Station – July 2, 2011 – September 14, 2016. Loggers were lost on two occasions due to very high flows. Station relocated to Mcquesten River below Klondike Highway.

Teslin River at Hootalinqua – Seasonal Station – 2011 to 2015. Station vulnerable to disturbance and dewatering. Replaced by Teslin River above Hootalinqua.

Methods

<u>Temperature Measurement</u>

Onset Tidbit v2 Water Temperature Data Loggers are used exclusively. 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.

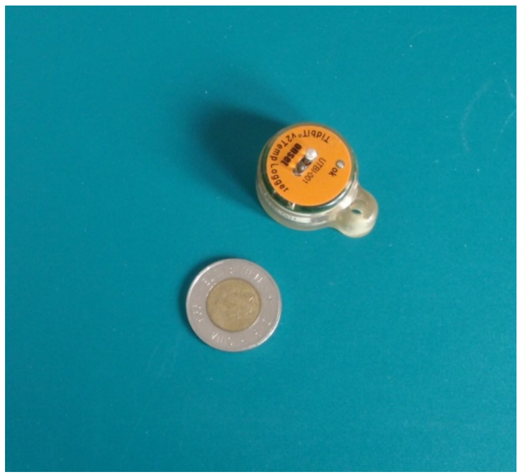

Image 1. Onset Tidbit v2. A Canadian two dollar coin provides scale. The hole used to secure the logger is visible on its right side**.**

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 measuring 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 through the wall of 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 such as a tree. The clothesline is passed through the end of the housing and 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 the weight. This is usually a 1 kg or larger piece of scrap metal or concrete. 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 to reduce the possibility that they will slip. 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.

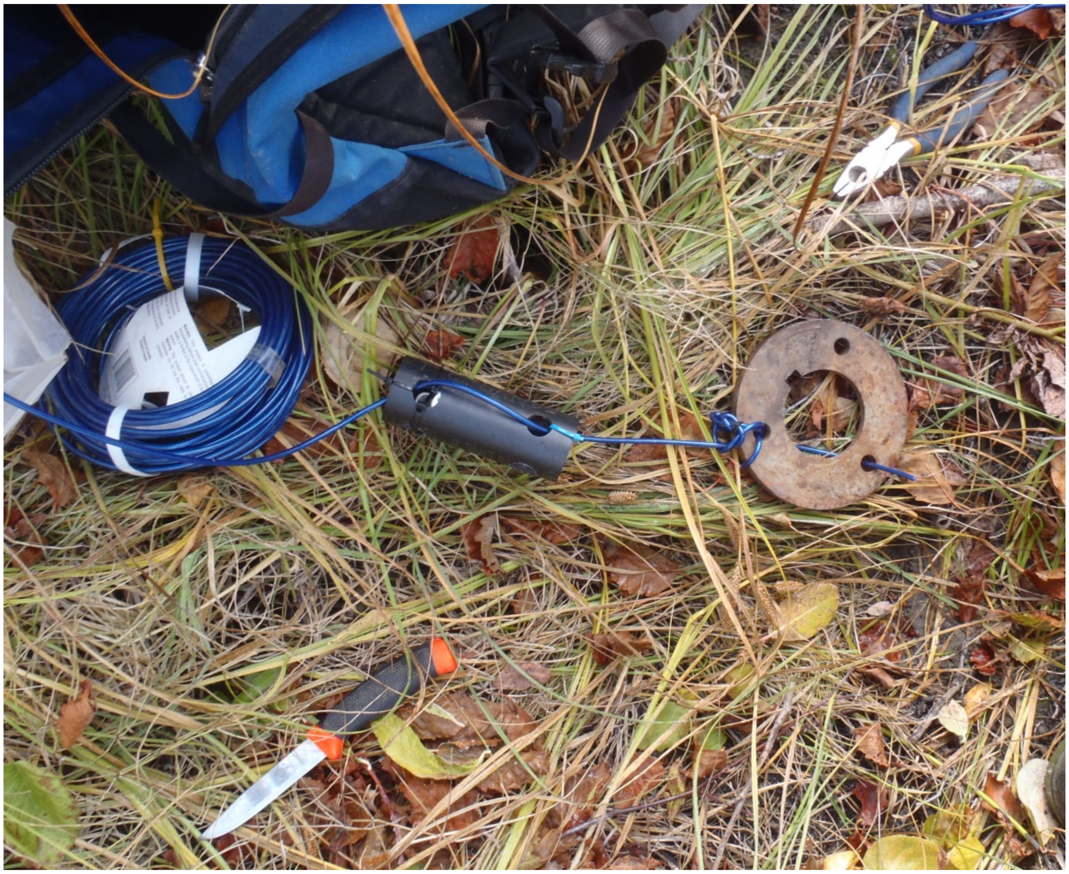

Image 2. Data logger string, showing the clothesline, housing and weight.

To the extent possible data logger strings are set in a shaded area with turbulent flow. The weight is lowered or placed on the river bed with the housing at the desired distance above it. 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 prior to leaving for the field. When possible, one new- and one older logger is deployed at 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 clothes line is checked for damage and replaced if necessary. The flagging is untied from the replacement loggers. The loggers that have been recording are retrieved from the river, removed from the housing and immediately tied together with the piece of flagging. The replacement loggers are cable tied to the housing, which is deployed back in the stream or river.

Upon return from the field, each logger is cleaned. The serial number is checked against the Master Data Logger Tracking Spreadsheet and the date of retrieval recorded. Each logger is downloaded. The battery status and memory are 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 will be 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.

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 (MaxDT) and Minimum Daily (MinDT) Temperatures 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. Additionally, the experiments do not account for daily variations in temperature.

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 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 (spawning/incubation) and 15^0 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 migration periods are conservative to address a potentially wide range of annual- or inter-annual migration timing. Assumed upstream migration periods for each Station past which significant upstream migration will occur follow:

Stewart River at Stewart Crossing - July 5 – August 31 (58 days)
Mcquesten River below Klondike Highway - July 5 – August 31 (58 days)
Pelly River below Pelly Crossing - July 5 – August 31 (58 days)
Yukon River above the Klondike Highway – July 15 to September 5 (57 days)
Nordenskiold River at Elk Sign - July 21 – September 3 (48 days)
Teslin River at Hootalinqua - July 15 – September 10 (58 days)
Yukon River above the Klondike Highway - July 10 – September 10 (63 days)
Yukon River at Anson Bend - July 25 – September 3 (42 days)

Spawning Standards and Thresholds are generally applied only to Annual Stations. The lengths of the spawning periods are generally 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 Klondike Highway: 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)
Tatchun River above Klondike Highway: August 5 to September 5 (32 days)
Yukon River above the Klondike Highway: July 15 to September 5 (57 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)
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

Thermal Units (TU) are the equivalent of degree days. Accumulated Thermal Units (ATU) are 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^{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 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^{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^{o}C a value of 0^{o}C is used in the calculation.

Results

Chinook Salmon Upstream Migration

Chinook Salmon upstream migration data is presented in Appendix 1.

Temperatures measured at all Stations identified as migration routes exceeded the AEDC standard for upstream migration of 15^{0} C Maximum Daily Temperatures (MaxDT) in 2017. The annual maximum MaxDT and the number of days during the assumed upstream migration period when 15^{0} was exceeded fell within the range of MaxDT recorded for past years.

Mean Daily Temperatures (MeDT) met the lowest Fraser River eWatch Threshold of 18^{0} C at a single Station, and on a single day. This was at the Teslin River above Hootalinqua.

Chinook Salmon Spawning

Chinook Salmon spawning data is presented in Appendix 2.

MaxDT at all Stations on spawning waters exceeded the AEDC standard of 13^{0} C MaxDT in 2017 except for the North Klondike River below North Fork Bridge. The annual highest MaxDT and the numbers of days during the assumed upstream migration period when 13^0 was exceeded in 2016 fell within the range of MaxDT calculated for past years.

MeDT met or exceeded the Fraser River ewatch thresholds at the Tatchun River below Tatchun Lake, with exceedances of 18^0 for 18 days, 19^0 for 15 days, 20^0 for 8 days and 21^0 for 1 day. MeDT at Tatchun River above the Klondike Highway had exceedances of 18^0 for 9 days and 19^0 for 6 days, while the Teslin River above Hootalinqua exceeded 18^0 on a single day. MeDT at all other Stations were below 18^0.

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 of each Station may be found in Appendix 3. The Mean AATUs, the calculated AATUs for calendar year 2016 and the variance from the Mean AATU are presented in Table 1. Data from 2016 was included in the calculation of the MeAATUs due to the limited number of years of data.

Calendar year 2016 AATUs exceeded the MeAATUs at all Stations. Exceedances varied from the North Klondike River at North Fork Bridge with +34.9 ATUs to the Tatchun River below Tatchun Lake with +207.1 ATUs. The relative variance, expressed as the percentage of the MeAATUs, generally increased from the Stations with the lowest MeAATUs to those with the highest MeAATUs: the Takhini River below Kusawa Lake was lowest at 3.4% relative variance and the Mcquesten River below Klondike Highway was highest at 10.6% relative variance.

Table 1. 2016 AATUs and variance from MEAATUs.

Station	Years data	MeAATU	2016 AATU	2016 +	2016%
North Klondike R. at North Fork Bridge	5	983	1017.9	34.9	3.6%
Ibex R. at WSC Station	3	1182.5	1297.6	115.1	9.7%
Blind Cr. at abandoned bridge	5	1276.5	1407	130.5	10.2%
Mcquesten R. below Klondike Hwy	2	1638	1811.7	173.7	10.6%
Nordenskiold R. at Elk Sign	5	1699.3	1811.7	101.4	6.0%
Takhini R. below Kusawa L.	3	2033.9	2102.9	69	3.4%
McIntyre Cr. below Mountainview Dr	5	1852.4	2008.9	156.5	8.9%
Little Salmon R. at Canoe Landing	4	1725.3	1826.8	101.5	5.9%
Yukon R. at Anson Bend	3	2279.7	2440.6	160.9	7.1%
Tatchun R. below Tatchun L.	5	2620.8	2827.9	207.1	7.9%

Accumulated Thermal Units by Brood Year Cohort (ATUBYC)

The calculated ATUBYC by Station and brood year, the range of ATUBYCs for the period of record and the mean ATUBYC for each Station may be found in Appendix 4. The Mean ATUBYCs, the calculated ATUBYCs for Brood Year 2015 and the variance from the MeATUBYCs are shown in Table 2. Data from Brood Year 2015 was included in the calculation of the MeATUBYCs due to the limited number of years of data.

Brood Year 2015 ATUBYCs exceeded the MeATUBYCs at every Station, with McIntyre Creek below Mountainview having the greatest exceedance at 150.1 ATUs and Little Salmon at Canoe Landing the least at 18 ATUs. Relative exceedances ranged from Blind Creek at abandoned bridge at 8.3% to Little Salmon at Canoe Landing with 0.8%.

Table 2. 2015 Cohort ATUBYCs and variance from MeATUBYCs

Station	Years data	Mean	2015	2015 +	2015%
North Klondike R. at North Fork Bridge	5	1224.5	1274.4	49.9	4.1%
Ibex R. at WSC Station	3	1464.8	1542.9	78.1	5.3%
Blind Cr. at abandoned bridge	5	1590.8	1723.2	132.4	8.3%
Mcquesten R. below Klondike Hwy	2	1779.1	1903.1	124.1	7.0%
Nordenskiold R. at Elk Sign	4	2139.5	2210.4	70.9	3.3%
Takhini R. below Kusawa L.	1	2824.2	2824.2	n/a	n/a
McIntyre Cr. below Mountainview Dr	5	2287.8	2437.9	150.1	6.6%
Little Salmon R. at Canoe Landing	3	2354.8	2372.8	18	0.8%
Yukon R. at Anson Bend	3	3067.5	3162.2	94.7	3.1%
Tatchun R. below Tatchun L.	5	3334.7	3479.0	144.3	4.3%

Discussion

This report is based on data collected between the summer of 2015 (for the calculation of ATUBYCs) and autumn of 2017.

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 past precipitation. A series of wet years in the CYRB preceded 2015. 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. This continued through 2017, although at a reduced rate.

The winter of 2016/17 was warmer than normal in the CYRB. Precipitation varied across the sub-basin. Snowpack is shown in Table 3. It was generally slightly lower than normal by April 1. Late season snowfall resulted in increases in the snowpack in the Yukon River Upper Lakes and the Yukon River Mid-Mainstem.

Table 3. 1017 Yukon Government Snow Survey and Water Supply Bulletin		
Watershed	Percent of normal	
	April 1	May 1
Yukon River Upper Lakes	92	111
Pelly River	93	84
Stewart River	81	77
Yukon River Mid-Mainstem	98	164
Yukon River North Main-stem	91	100

Precipitation during the summer was low in the Yukon River North Mainstem and the Stewart River Watersheds but was normal to above normal in the remainder of the Canadian Sub-Basin. Flows in the Stewart River Watershed and the Yukon River North Mainstem Watershed were generally low to very low. However, flows in the Pelly River were high until late in the open water period, and floods occurred in the upper watershed. Precipitation was so high in the Blind Creek drainage that the long standing Chinook Salmon enumeration fence was washed out and the project abandoned. The upper White River tributaries experienced high flows. The Yukon River at Carmacks was high until late August, implying corresponding high flows in the Teslin and/or the Big Salmon Rivers. The Nordenskiold River experienced one or more overbank floods in the mid-summer.
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<u>Application of Standards and Thresholds – Migration and Spawning</u>

Application of the ADEC Upstream Migration and Spawning Standards implies that most CYRB Chinook salmon stocks are at significant risk of high temperatures during migration and spawning processes even in cold years. However, Standards such as those of the ADEC are prepared in other jurisdictions for other purposes and are based, in part, on other species or stocks. Such Standards must *always* be cautiously applied.

The ADEC Standards were transferred from the US Pacific North West. They 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, temperatures at most Stations would still have exceeded the Standards some or most of the time in 2017 and preceding years.

The ADEC Standards are binary in nature: values are either below (pass) or above (fail) the Standard. Slight but lengthy excursions above the Standard lead to the same level of concern as significant excursions of the same length of time. They are therefore of little use in the assessment of risk to Chinook in the natural aquatic environment enjoyed by most of the Canadian Yukon River Sub-Basin.

The Standards do, however, provide a framework to communicate the results of water temperature monitoring to Alaskan and US Federal Agency staff. The results are provided in the relevant Appendices, but will not be further discussed here.

The Fraser River ewatch Thresholds provide a graduated approach and are considered to be more applicable to Yukon River Chinook Salmon. An important consideration is that the Thresholds were based on in-river investigations, and laboratory experiments and local knowledge. The Thresholds are set at higher temperatures than the ADEC standards and are based on the intrinsically more conservative MeDT. Pending development of Yukon River Chinook-specific Thresholds, Guidelines or other instruments, the Fraser River Thresholds are considered the best tool to provide guidance for risk assessments for both migration and spawning. The results will be discussed below

Upstream migration

The lowest Fraser River ewatch Threshold for upstream migration is 18^0. It was not exceeded at any Station in 2012, 2014 or 2015 during the upstream migration period. Thresholds were exceeded in 2013 and 2016. In 2017 the 18^0 threshold was met at Teslin River above Hootalinqua for a single day.

It is likely that elevated temperatures did not pose a risk to upstream migrating Chinook Salmon in the Canadian Sub-Basin in 2017.

Spawning

MeDTs in Tatchun River below Tatchun Lake have exceeded one or more Fraser River ewatch thresholds in each year except for 2012, and met or exceeded the uppermost threshold of 21^0 in 2013 and 2017. In 2017 MeDTs were above 20^0 between August 6 to 11^{th} inclusive and peaked at 21^0 on August 9. Of interest, no adult salmon were observed the mid-reaches of the river on August 5, 2017.

Tatchun River above Klondike Highway was established in late August, 2016 at the downstream end of substantive spawning to investigate relationships of intra-stream water temperature regimes. In 2017 MeDTs were generally lower than at the upstream Station during the assumed spawning period with 18^0 exceeded on 9 days and 19^0 on 6. The reason for this Station being cooler than the upstream Station may be related to discharging ground water or hyporheic interchange in the channel between them.

Teslin River above Hootalinqua had a MeDT of 18^0 for a single day.

It is likely that elevated temperatures did not pose a risk to spawning Chinook Salmon in the CTYB in 2017, with the exception of early-run fish in the Tatchun River. These fish can be expected to have been delayed in cooler water either in the lower Tatchun River or in the Yukon River off the mouth of the Tatchun River.

Annual Accumulated Thermal Units

The AATUs are a measure of temperature related productivity of streams. Productivity may be defined as 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 has been 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 inferred that the Tatchun River is, potentially, the most biologically productive river monitored in the Program and the North Klondike is the least.

Sufficient data is available for most Stations to calculate Mean AATUs (MeAATU) for use as a basis of classifying and comparing Stations. Table 4 presents the MeAATUs of all stations in ascending order, the range of each Station's MeAATUs and the number of years of data used in the calculations. The North Klondike at North Fork Bridge has the lowest MeAATU at 983.8 ATU. The Tatchun River below Tatchun Lake has the highest at 2620.8 MeAATU, or about 2.5 times that of the North Klondike. Importantly, these Stations represent *types* of spawning rivers, with the North Klondike being a moderate sized, moderate gradient river with little lakes storage and the Tatchun River being a small river with a large degree of lake storage.

There is no universally accepted method of classifying streams on the basis of thermal regimes. Most classification systems and processes have reflected the purpose for which the classification was made, the role or function of the person or agency that developed it, and the geographical area in which it originated (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 North American 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 4. 2017 - Classification of Stations using MeAATUs

Station	Years of Data	Range AATU	MeAATU
Cold (<1300)			
N. Klondike R. at North Fork Bridge	5	953 - 1017.9	983.8
Ibex R. at WSC Station	3	1085.9 – 1297.6	1182.5
Blind Cr. at abandoned bridge	5	1164.8 - 1407.9	1276.5
Cool (1301 - 2200)			
Mcquesten R. below Klondike Hwy	2	1464.3 - 1811.7	1638.0
Nordenskiold R. at Elk Sign	5	1575.3 - 1811.7	1699.3
Little Salmon R. at Canoe Landing	4	1610.8 - 1837.4	1725.3
McIntyre Cr. below Mountainview Dr.	5	1723.8 – 2008.9	1852.4
Takhini R. below Kusawa L.	3	1899.1 - 2102.9	2033.9
Warm (>2200)			
Yukon R. at Anson Bend	3	2076.7 - 2440.6	2279.7
Tatchun R. below Tatchun L.	5	2416.8 - 2827.9	2620.8

Table 4 shows the current listing of the monitoring Stations for which sufficient data has been collected in ascending order of MeAATUS. In 2017 the order was unchanged from 2016. Yukon River at Anson Bend was reclassified from Cool to Warm, as its MeAATU climbed from 2199 to 2279.7.

The significant range of thermal diversity in Yukon River tributaries in Canada used by spawning Chinook Salmon implies some degree of genetic adaptation by Chinook Salmon populations. This is of particular concern due to recent initiatives to restore Chinook Salmon stocks through transplants from other populations. Matching of donor- to release populations on the basis of like-to-like thermal regimes should be a consideration in planning and perhaps funding and permitting.

The consistently very low AATUS at the North Klondike River at North Fork Bridge imply that the Chinook incubation/alevin stage could exceed a year if general bio-standards are applied. The rearing period for 0+ juveniles following emergence would be correspondingly limited. 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 and the ground water fed Viceroy Channel 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, 2016 & 2017). 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, and the river supports a large spawning population. Habitat productivity has not been determined, but appears to be considerable: the housing protecting the data loggers is generally encrusted with attached benthic organisms and crawls with mobile organisms. A new Station, Tatchun River above the Klondike Highway was established in August 2016 to investigate differences between upper- and lower river temperatures. It has yet to measure temperatures for a complete calendar year, but data collection to date indicates that the Station will have lower AATUs that that at the Lake outlet.

Accumulated Thermal Units by Brood Year Cohort.

The ATUBYC was designed to be a measure of describing the available thermal energy for brood year classes (cohorts), of juvenile Chinook Salmon remaining in the rivers monitored. Assuming that the thermal environment exerts a significant influence on the capacity of CYRB aquatic environments to produce juvenile Chinook Salmon, the ATUBYCs may be considered an index to monitor inter-annual variation in fry growth and productivity. The ATUBYC also provide an index of the ability of different *types* of habitats to produce Chinook.

However, juvenile Chinook production reflects a number of factors beyond the total available thermal energy. This includes variation in the supply of juveniles resulting from any given brood year. The supply will reflect, in part, the overall stock strength and the fitness of individual fish in the brood year. Additionally, an unknown (and probably variable) percentage of post-emergent juvenile Chinook Salmon either leave or are carried away from natal streams each year.

Many or most will subsequently 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 (MacKenzie-Grieve, 2016). Finally, temperature is only one of a number of environmental (ie volume of flow, suspended sediment and bed load transport regimes, and available nutrients) and eco-systematic (ie competition and predation) variables determining the production of juvenile Chinook Salmon.

Yukon River Chinook Salmon spawn in small streams, large rivers and watercourses of intermediate sizes. Spawning may occur at the outlet of lakes or further downstream and in watercourses with no upstream lakes. Sufficient data has now been collected to show the influence of proximate upstream lakes on the ATUBYCs. Stations on watercourses without upstream lakes or where upstream lakes were distant have consistently lower MeATUBYCs than those with lakes located a short distance upstream.

As a general statement, production of juvenile Chinook Salmon that remained in their natal streams would have been greater than average (based on data collected to date) in watercourses all water courses for the 2015 brood year. Non-natal streams would have exhibited similar characteristics to those of the natal streams. Those with proximate lakes would have produced more food for the juveniles than those without, and provided better conditions for summer growth and - probably - overwintering success.

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. The spreadsheet is updated as data sets are distributed and serves as both a planning and tracking tool.

Results

One hundred and eighty two data sets have been distributed or are in the process of distribution. Recipients have been staff of Canadian and American federal, territorial and state agencies, First Nations, and consultants.

Ensuring Public Accessibility of Data collected

Methods

A web site has been privately developed to allow the public to access the data collected. This is yukonwatertemperatures.info The contributions of the Yukon River Panel are acknowledged in the web site.

Results

Data to autumn 2017 has been uploaded to Yukonwatertemperatures.info is now publicly accessible.

Conclusion

The fourth 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.

Developing a baseline is an accretionary process: each year of data strengthens the baseline and makes it more useful for future users.

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

As this document is being completed, 24 data loggers are measuring temperatures at 12 Annual Stations.

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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
2015	16.2^0	22
2016	17.9^0	17
2017[1]	18.1^0	N/A

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	15.7^0	0	0	0	0
2016	17.5^0	0	0	0	0
2017[1]	17.6^0	0	0	0	0

[1] logger was dewatered on and subsequent to August 5 due to very low flows in the Stewart river.

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: 15^0
2015	14.6^0	0
2016	15.9^0	4
2017	17.0^0	23

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2015	15.7^0	0	0	0	0
2016	14.8^0	0	0	0	0
2017	15.1^0	0	0	0	0

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
2015	18.5^0	23
2016	20.5^0	38
2017	18.5^0	43

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	17.0^0	0	0	0	0
2016	19.3^0	11	3	0	0
2017	17.6^0	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
2015	15.8^0	6
2016	16.5^0	11
2017	16.3^0	15

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	15.1^0	0	0	0	0
2016	15.8^0	0	0	0	0
2017	15.8^0	0	0	0	0

Teslin River above Hootalinqua (formerly 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
2015	17.1^0	29
2016	18.5^0	36
2017	18.6^0	33

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	16.4^0	0	0	0	0
2016	17.9^0	0	0	0	0
2017	18.0^0	1	0	0	0

Yukon River above Klondike Highway

Type of station: Seasonal

Assumed Migration Period: July 15 – September 5 (57 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding
2016	18.4^0	48
2017	18.0^0	31

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2016	18.0^0	1	0	0	0
2017	17.6^0	0	0	0	0

Yukon River above Hootalinqua

Type of Station: Annual

Assumed migration period: July 20 - Aug 25 (35 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		15^0
2015	16.1^0	30
2016	17.6^0	All
2017	17.2^0	20

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2015	15.7^0	0	0	0	0
2016	17.1^0	0	0	0	0
2017	17.0^0	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
2015	16.9^0	27
2016	17.8^0	All
2017	17.8^0	27

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	15.9^0	0	0	0	0
2016	17.5^0	0	0	0	0
2017	17.5^0	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: 13^0
2012	12.2^0	0
2013	12.6^0	0
2014	10.6^0	0
2015	11.3^0	0
2016	11.6^0	0
2017	12.3^0	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^{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
2015	9.2^0	0	0	0	0
2016	9.4^0	0	0	0	0
2017	10.1^0	0	0	0	0

Mcquesten River below WSC Station (Decommissioned)

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
Station decommissioned		

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	13^0	0	0	0	0
2013	15.3^0	0	0	0	0
2014	13.3^0	0	0	0	0
Station decommissioned					

Mcquesten River below Klondike Highway

Type of Station: Annual

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

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding: 13^0
2014	15.1^0	19
2015	14.4^0	18
2016	15.9^0	15
2017	16.4^0	31

Adopted Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2014	13.8^0	0	0	0	0
2015	13^0	0	0	0	0
2016	14.8^0	0	0	0	0
2017	14.8^0	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
2015	14.4^0	5
2016	14.1^0	9
2017	13.4^0	7

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	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
2016	13.2^0	0	0	0	0
2017	12.5^0	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
2015	20.2^0	26
2016	20.0^0	All
2017	21.7^0	All

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	0	0
2016	19.6^0	10	5	0	0
2017	21.0^0	13	10	6	1

Tatchun River above Klondike Highway

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
2017	20.9^0	All

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
2017	19.7^0	9	6	0	0

Yukon River above Klondike Highway

Type of station: Seasonal

Assumed Spawning Period: July 15 – September 5 (57 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding: 13^0
2016	18.4^0	47
2017	18.0^0	55

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2016	18.0^0	1	0	0	0
2017	17.6^0	0	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
2015	15.4^0	12
2016	16.5^0	18
2017	16.0^0	16

Nordenskiold River at Elk Sign (continued)

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
2016	15.8^0	0	0	0	0
2017	15.5^0	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
2015	17.5^0	16
2016	17.9^0	29
2017	18.2^0	29

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
2016	17.1^0	0	0	0	0
2017	17.7^0	0	0	0	0

Teslin River at/above 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:
		13º
2012	16.5⁰	45
2013	19.8⁰	All
2014	16.7⁰	51
2015	17.2⁰	39
2016	18.5⁰	37
2017	18.6⁰	52

Teslin River at/above Hootalinqua (continued)

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18º	19º	20º	21º
2012	15.7⁰	0	0	0	0
2013	19.2⁰	7	3	0	0
2014	16.1⁰	0	0	0	0
2015	16⁰	0	0	0	0
2016	17.9⁰	0	0	0	0
2017	18.0⁰	1	0	0	0

Yukon River above Hootalinqua

Type of Station: Annual

Assumed spawning period: July 25 - Aug 25 (31 days)

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		13⁰
2015	16.1⁰	All
2016	17.5⁰	All
2017	17.2⁰	All

Fraser River ewatch thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18⁰	19⁰	20⁰	21⁰
2015	15.7⁰	0	0	0	0
2016	17.1⁰	0	0	0	0
2017	17.0⁰	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	-
2015	15.2^0	26
2016	16.3^0	28
2017	17.4^0	29

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
2016	15.8^0	0	0	0	0
2017	16.5^0	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
2016	12.9^0	0
2017	11.7^0	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
2016	11.0^0	0	0	0	0
2017	10.3^0	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: 13⁰
2012	15.2⁰	18
2013	18.1⁰	19
2014	17.0⁰	17
2015	16.7⁰	18
2016	17.4⁰	20
2017	17.3⁰	13

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding: 18⁰	19⁰	20⁰	21⁰
2012	13.7⁰	0	0	0	0
2013	15.8⁰	0	0	0	0
2014	14.4⁰	0	0	0	0
2015	14.9⁰	0	0	0	0
2016	15.8⁰	0	0	0	0
2017	15.4⁰	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: 13⁰
2013	18.2⁰	27
2014	16.4⁰	All
2015	16.1⁰	28
2016	17.5⁰	30
2017	17.8⁰	All

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding: 18⁰	19⁰	20⁰	21⁰
2013	18⁰	2	0	0	0
2014	16.4⁰	0	0	0	0
2015	15.9⁰	0	0	0	0
2016	17.5⁰	0	0	0	0
2017	17.5⁰	0	0	0	0

Appendix 3. Annual Accumulated Thermal Units

North Klondike River at North Fork Bridge		
Commissioned August 8, 2011		
Calendar year 2012		991.3
Calendar year 2013		973.6
Calendar year 2014		953
Calendar year 2015		983
Calendar year 2016		1017.9
	Mean	**983.8**
	Range	**64.9**
Mcquesten River below Klondike Highway		
Commissioned July 5, 2014		
Calendar year 2015		1464.3
Calendar year 2016		1811.7
	Mean	**1638**
	Range	**347.4**
Blind Creek at abandoned bridge		
Commissioned July 18, 2011		
Calendar year 2012		1164.8
Calendar year 2013		1258.1
Calendar year 2014		1257.3
Calendar year 2015		1294.3
Calendar year 2016		1407.9
	Mean	**1276.5**
	Range	**243.1**
Tatchun River below Tatchun Lake		
Commissioned July 20, 2011		
Calendar year 2012		2416.8
Calendar year 2013		2604.9
Calendar year 2014		2504.9
Calendar year 2015		2749.6
Calendar year 2016		2827.9
	Mean	**2620.8**
	Range	**411.1**
Nordenskiold River at Elk Sign		
Commissioned July 20, 2011		
Calendar year 2012		1575.3
Calendar year 2013		1707.8
Calendar year 2014		1667.4
Calendar year 2015		1734.0
Calendar year 2016		1811.7
	Mean	**1699.3**
	Range	**236.4**

Little Salmon River at canoe landing

Commissioned September 28, 2012		
Calendar year 2013		1610.8
Calendar year 2014		1626.3
Calendar year 2015		1837.4
Calendar year 2016		1826.3
	Mean	**1725.3**
	Range	**226.6**

Takhini River below Kusawa Lake.

Commissioned October 1, 2012		
Calendar year 2013		1899.1
Calendar year 2014		Loggers disturbed
Calendar year 2015		2099.6
Calendar year 2016		2102.9
	Mean	**2033.9**
	Range	**203.8**

Ibex River at WSC Station

Commissioned July 4, 2013		
Calendar year 2014		1085.9
Calendar year 2015		1164.2
Calendar year 2016		1297.6
	Mean	**1182.6**
	Range	**211.7**

McIntyre Creek below Mountainview Drive.

Commissioned May 12, 2011		
Calendar year 2012		1738.2
Calendar year 2013		1866.5
Calendar year 2014		1723.7
Calendar year 2015		1924.4
Calendar year 2016		2008.9
	Mean	**1852.4**
	Range	**285.2**

Yukon River at Anson Bend.

Commissioned June 19, 2013		
Calendar year 2014		2076.7
Calendar year 2015		2321.7
Calendar year 2016		2440.6
	Mean	**2279.7**
	Range	**363.9**

Annual Stations with insufficient data to calculate AATUs

Yukon River above Hootalinqua

Commissioned June 29, 2015, but data set is discontinuous.

Teslin River above Hootalinqua

Commissioned June 27, 2016.

Tatchun River above Klondike Highway

Commissioned August 29, 2016.

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
2014 Brood year cohort: DMeT was below 4.5^{0} on September 18, 2015	1175.1
2015 Brood year cohort: DMeT was below 4.5^{0} on September 24, 2016	1274.4
Mean	**1212.1**
Range	**66.2**

Mcquesten River below Klondike Highway

Commissioned July 5, 2014	
2014 Brood year cohort: DMeT was below 4.5^{0} on September 19, 2015	1655.1
2015 Brood year cohort: DMeT was below 4.5^{0} on September 18, 2016	1903.1
Mean	**1779.1**
Range	**248.0**

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
2014 Brood year cohort: DMeT was below 4.5^{0} on September 30, 2015	1595.8
2015 Brood year cohort: DMeT was below 4.5^{0} on September 24, 2016	1732.2
Mean	**1590.8**
Range	**261.7**

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
2014 Brood year cohort: DMeT was below 4.5^{0} on October 20, 2015	3507.2
2015 Brood year cohort: DMeT was below 4.5^{0} on October 13, 2016	3479.0
Mean	**3334.7**
Range	**452.7**

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
2014 Brood year cohort: DMeT was below 4.5^{0} on September 24, 2015	2117.7
2015 Brood year cohort: DMeT was below 4.5^{0} on September 27, 2016	2210.4
Mean	**2115.0**
Range	**100.2**

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
2014 Brood year cohort: DMeT was below 4.5^0	on October 23, 2015	2416.8
2015 Brood year cohort: DMeT was below 4.5^0	on October 8, 2016	2372.8
	Mean	**2354.8**
	Range	**142.1**

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
2014 Brood year cohort: DMeT was below 4.5^0	on September 30, 2015	1443.3
2015 Brood year cohort: DMeT was below 4.5^0	on September 25, 2016	1542.9
	Mean	**1464.8**
	Range	**134.8**

McIntyre Creek below Mountainview Drive.

Commissioned May 12, 2011

2011 Brood year cohort: DMeT was below 4.5^0	on October 11, 2012	2146.0
2012 Brood year cohort: DMeT was below 4.5^0	on October 7, 2013	2302.5
2013 Brood year cohort: DMeT was below 4.5^0	on September 30, 2014	2197.3
2014 Brood year cohort: DMeT was below 4.5^0	on October 10, 2015	2355.1
2015 Brood year cohort: DMeT was below 4.5^0	on September 30, 2016	2437.9
	Mean	**2287.8**
	Range	**291.9**

Yukon River at Anson Bend.

Commissioned June 19, 2013

2013 Brood year cohort: DMeT was below 4.5^0	on October 28, 2014	2928.6
2014 Brood year cohort: DMeT was below 4.5^0	on October 10, 2015	3111.6
2015 Brood year cohort: DMeT was below 4.5^0	on October 24, 2016	3162.2
	Mean	**3020.1**
	Range	**233.6**

Stations with insufficient data to calculate ATUBYCs

Yukon River above Hootalinqua

Commissioned June 29, 2015, but data set is discontinuous.

Teslin River above Hootalinqua

Commissioned June 26, 2016

Tatchun River above Klondike Highway

Commissioned August 26, 2016