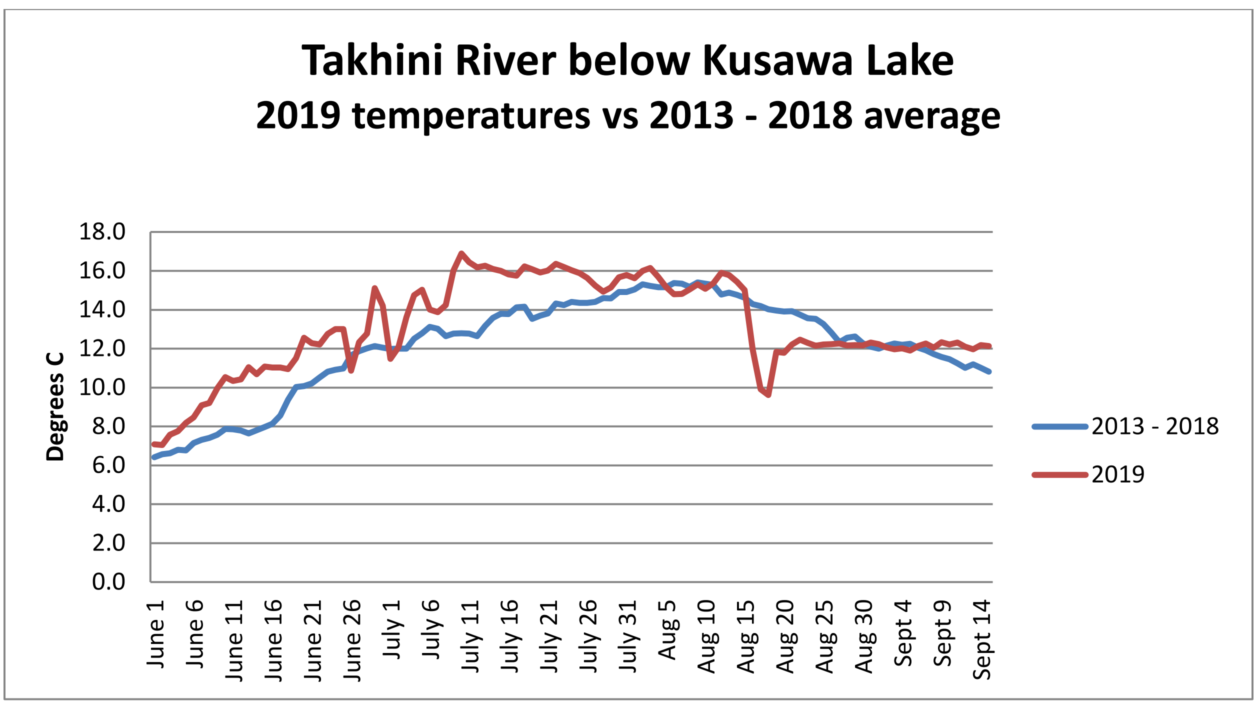
Water Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada
Annual Project Report
2019

Yukon River Restoration and Enhancement Fund
CRE-20-19

Al von Finster
AvF R&D
2019



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Abstract

The Temperature Monitoring of Yukon River Chinook Salmon Spawning and Migration Habitats in Canada Program (the Program) continued in 2018/19. Data was collected at 3 Seasonal- and 12 Annual Stations. Current coverage includes 7 of 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. Onset Tidbit v2 data loggers measure temperatures each hour, on the hour. Data from 2018/19 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. Alaskan Standards have been exceeded annually at almost all Stations in most years. Canadian Thresholds have been exceeded much less frequently and for shorter periods. In 2019 an early spring lifted water temperatures. Water levels remained low. Temperatures climbed but were constrained by a series of periods of cool, dry weather. This allowed respite to those salmon entering the spawning areas. Annual Accumulated Thermal Units (AATUs) and Accumulated Thermal Units by Brood Year Cohort (ATUBYC) were calculated for Annual Stations. Almost all Stations had 2018 AATUs and 2017 ATUBYCs less than any year since the program began. Regardless, both values varied widely across the CYRB, implying significant differences in potential biological productive capacity between different areas and types of watercourses. AATUs have supported preliminary classification of Chinook spawning rivers and streams as Cold, Cool and Warm. ATUBYCs have allowed insight into potential production of juvenile Chinook Salmon prior to the onset of overwintering of young-of-year fry. Data sets are in the process of distribution. All 2018/19 data is being uploaded to yukonwatertemperatures.info.

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: The Takhini River below Kusawa Lake was typical of almost all Stations. A warm spring raised water temperatures to above average values. The temperatures were then about average in mid-summer and then plunged sharply as cool dry north winds flowed across the Yukon

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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). The Program initially built on basin wide projects conducted by the Alaska Department of Fish and Game (ADF&G) in 2011 and 2012 (Leba, 2011 & 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. With the completion of the ADF&G projects the author continued- and expanded the Program.

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. The objectives of the Project are:

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;
- Monitoring the Stations by deploying, retrieving and downloading data loggers;
- 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:

- An account of the 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 2019 Project 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 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 continues to be made 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 period of record includes 2012, a cold and wet year; 2013, with a late spring but a much warmer 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. A delayed spring in 2018 resulted in relatively high flows in most rivers until mid-July. A period of warm weather followed and elevated water temperatures. A cooling phase in early August reduced temperatures across the CYRB to favorable levels for spawning Chinook. In 2019 spring was warm and water levels were low throughout the CYRB. Cool, dry weather in mid/late summer lowered the water temperatures across the entire region during much of Chinook spawning season.

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 reporting results. Risk assessment of the likelihood of being able to continue to safely retrieve loggers on schedule was conducted at each Station when loggers were deployed or replaced. Stations were decommissioned if their physical viability was 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.

The Station at Yukon River above Hootalinqua was decommissioned in 2019. This Station had not performed well since implementation on June 29, 2015. In spring of 2019 the loggers were missing and were not replaced. The Station at Yukon River above Klondike Highway was on private property and will be moved in 2020. The Station at Blind Creek above abandoned Bridge was moved downstream and is now Blind Creek below abandoned Bridge. The Station at Mcquesten River below Klondike Highway Bridge was moved slightly downstream due to low water conditions. These conditions also affected the Stations at North Klondike River below North Fork Bridge, Pelly River belwo Pelly Crossing, and Stewart River at Stewart Crossing which had to be located in deeper water at the same location.

Program design and description

The Network is based on 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. The serial number of each logger is provided in metadata for each data set. 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 below 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 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 allow collection of repeatable data. Stations are geo-located by GPS and photographs. 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. Seasonal Stations are generally located on major tributaries used by large numbers of migrating adult Chinook Salmon. 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. They are generally located on Chinook spawning streams and rivers. Loggers at Annual Stations are replaced in spring- and before freeze up.

The design of the Project was 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;
- Implementation over a variety of types of Chinook Salmon spawning habitats, and on primary tributaries used as major Chinook upstream migration routes;
- Locating Stations where they can be safely accessed to comply with current Yukon Occupation Health and Safety regulations;
- Maintaining close attention to economy to allow Stations to be efficiently and economically serviced;
- Maintaining data security. The Tidbit V2 loggers are robust, accurate, and simple to operate and download.

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, towns; long-standing structures such as bridges, signs, 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. Main-stem segments include the Yukon River North Main-stem, 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 is – or was - a small spawning population in the Kluane River between the outlet of Kluane Lake and the mouth of the Duke River. It is considered to be poorly representative of the more heavily utilized habitats in the White River watershed. 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 Big Salmon main-stem; North Big Salmon River and its tributary, Northern Creek; the South Big Salmon; and Scurvy Creek. Most spawning in the Big Salmon River 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: Loggers were dewatered due to low river levels in 2017. Station was modified and performed well in 2018. Loggers had to be adjusted in 2019 due to low water.

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: Loggers were dewatered due to low river levels in 2018, and were moved by about 20 meters downstream in spring of 2019. Despite this the loggers had to be placed in deeper water due to very low river flows.

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: August 2016 - 2019
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: The Station worked well, but was on private land. It will be moved in 2020.

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- or ice 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.
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 flows vary from year-to–year. In 2019 the loggers had to be moved to deeper water due to low river levels.

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 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. Loggers failed from June to September, 2018. In 2019 water levels dropped so far that the ground water seep became visible and was affecting temperatures. The Station was moved about 30 meters downstream.

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.
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: Channel shifting has resulted in increasing icing of the loggers. In 2019 a significant freshet event occurred, limiting safe access to the abandoned bridge. A new Station was installed at Blind Creek below abandoned bridge.

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 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.
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: Loggers are at some risk due to beaver activity.

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: 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: 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.. 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.

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.

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 at some risk of disturbance from persons unknown or animals.

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.

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.
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.
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 identified.

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.

Yukon River above Hootalinqua – Annual Station. The Station was vulnerable to disruption from ice and human disturbance. The logger were not present in spring of 2019 and the Station was decommissioned.

Methods

Temperature Measurement

Onset Tidbit v2 Water Temperature Data Loggers are used. An example is shown in Image 1. They are waterproof to 305 meters and accurate within 0.2^0 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 epoxy case is vulnerable to abrasion or impact and must be protected.

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 section 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.

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**.**

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 hole in the epoxy case facing toward the nearest end. The logger is 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 opposing 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 any 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.

To the extent possible data logger strings are set in a shaded area with turbulent flow in the open water period. 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.

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

At each Annual 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 this piece of flagging. The replacement loggers are cable tied to the housing, which is deployed back in the stream or river. The data logger strings for Seasonal Stations are left concealed on the river bank in the winter and used in the summer to come.

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. The logger 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 discharge 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 loggers may occasionally be pulled out of the water by wildlife, people or as a result of high flows. They may also be dewatered during extreme low flow conditions. This results in the daily range of temperatures being much wider than expected. 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 Maximum Temperatures.

As noted, loggers are placed in locations with turbulent flow where water is mixed from bed to surface. Water levels rise and fall seasonally and as a result of precipitation (or lack thereof). Depth is 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 Temperatures (MaxDT) are determined. Only full daily data sets are used. The functional “day” is from 0100 to 2400 hrs.

The American process results from significant efforts by government agencies and others on the US West Coast to determine effects of water temperatures on Chinook salmon and other 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.

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 in the CYRB 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) 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 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 are:

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 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)
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)

Please note that the following analysis only describes the periods of migration and/or spawning.

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) 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^oC a value of 0^oC is used in the calculation. AATUs are an indicator of a stream or river's potential habitat 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 also 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 young-of-year remaining in 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 for all Stations. The end date for each Station was the day during the following year on which a MeDT of 4.5^oC 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^oC a value of 0^oC is used in the calculation.

Results

Chinook Salmon Upstream Migration

Data on Chinook Salmon upstream migration rivers is presented in Appendix 1.

Temperatures at all Stations identified as migration routes exceeded the 15^0 C AEDC Maximum Daily Temperature (MaxDT standard during the specified migration period in 2019. Record MaxDTs were measured at Stewart River at Stewart Crossing (20.2^0), Mcquesten River below Klondike Highway (18.5^0) and Pelly River below Pelly Crossing (21.7^0). The number of days during the assumed upstream migration period when 15^0 was exceeded was within the range of previous years except at the Yukon River above Klondike Highway and the Teslin River above Hootalinqua. These stations recorded less days above 15^0 MaxDT than at any period since the Program began.

Mean Daily Temperatures (MeDT) met or exceeded the lowest Fraser River eWatch Threshold of 18^0 at Stewart River at Stewart Crossing, Pelly River below Pelly Crossing, and the Yukon River above Klondike Highway. The Threshold MeDT temperature of 19^0 was exceeded at Stewart River at Stewart Crossing and Pelly River below Pelly Crossing. The Threshold of 20^0 was exceeded at Pelly River below Pelly Crossing. Yukon River above Klondike Highway exceeded 18^0 on 4 days, and the Teslin River above Hootalinqua exceeded 18^0 on 5 days.

Record high MeDT were recorded at Mcquesten River below Klondike Highway (17.0^0), Stewart River at Stewart Crossing (19.8^0) and Pelly River below Pelly Crossing (20.2^0).

Chinook Salmon Spawning

Data on Chinook Salmon spawning streams is presented in Appendix 2.

Maximum Daily Temperatures measured at all Stations exceeded the 13^0C AEDC spawning standard during the specified spawning period in 2019. Record MaxDTs were measured at North Fork of Klondike River at North Fork Bridge (13.7^0), Blind Creek at abandoned bridge (16.8^0), Mcquesten River below Klondike Highway (18.5^0) and Ibex River at WSC Station (17.3^0).

MeDT exceeded the Fraser River ewatch thresholds at the Tatchun River below Tatchun Lake, with exceedances of 18^0 for 9 days and 19^0 for 2 days, and at Tatchun River above the Klondike Highway, exceedances of 18^0 for 2 days. Yukon River above Klondike Highway exceeded 18^0 on 4 days, and the Teslin River above Hootalinqua exceeded 18^0 on 5 days

MeDT at all other Stations remained below 18^0.

Annual Accumulated Thermal Units

The AATUs by Station and calendar year, the range of AATUs for the period of record and the mean AATU (MeAATU) of each Station may be found in Appendix 3. The Mean AATUs, the

AATUs for calendar year 2018 and the variance from the Mean AATU are presented in Table 1. The 2018 values were not used in the calculation of the MeAATUs.

Table 1. Variance of 2018 AATS from MeAATUs

Station	Years data	MeAATU	2018 AATU	Minus	Plus
North Klondike R. at North Fork Bridge	7	997.6	892.6	105	
Ibex R. at WSC Station	5	1175.4	1046.6	128.8	
Blind Cr. at abandoned bridge	7	1271.1	1135.1	136	
Mcquesten R. below Klondike Hwy	3	1638			
Nordenskiold R. at Elk Sign	7	1685.3	1565.3	119.8	
Takhini R. below Kusawa L.	5	1997.9	1840.2	157.7	
McIntyre Cr. below Mountainview Dr	7	1846.3	1702.2	144.1	
Little Salmon R. at Canoe Landing	6	1732.1	1595.3	136.8	
Yukon R. at Anson Bend	5	2248.9	2083.5	165.4	
Tatchun R. below Tatchun L.	7	2643.5	2679.6		36.1

Calendar year 2018 AATUs exceeded the MeAATUs only at the Tatchun River below Tatchun Lake. All other Stations recorded temperatures below the MeAATUs.

In 2018 record low AAYUs were recorded at the North Klondike River at North Fork Bridge, Little Salmon River at Canoe Landing, Blind Creek at abandoned bridge, Mcquesten River below Klondike Highway, Nordenskiold River at at Elk Sign, McIntyre Creek below Mountainview, Tahkini River below Kusawa Lake and Ibex River at WSC.

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 ATUBYCs for Brood Year 2017 and the variance from the MeATUBYCs are shown in Table 2. The 2017 ATUBYCs values were not used in the calculation of the MeATUBYCs. Brood Year 2017 ATUBYCs met or exceeded the MeATUBYCs only at the Tatchun River below Tatchun Lake. Additionally, record low MeATUBYCs were recorded at all other Stations for the 2017 Brood Year.

Discussion

This report is based on data collected between the summer of 2017 and autumn of 2019. The 2017 and summer of 2018 data was required for the calculation of ATUBYCs; the calendar year data was required for the AATUs; and the summer of 2019 data was required to assess risk to to migrating and spawning adult salmon.

Table 2. Variance of 2017 ATUBYC from MeATUBYC

Station	Years data	Mean ATUBYC	2017 ATUBYC	Minus	Plus
North Klondike R. at N. Fork Bridge	7	1238.0	1166.0	72	
Ibex R. at WSC Station	5	1468.2	1263.7	204.5	
Blind Cr. at abandoned bridge	7	1580.5	1459.0	121.5	
Mcquesten R. below Klondike Hwy	2	1779.1			
Nordenskiold R. at Elk Sign	6	2109.6	1937.2	82.4	
McIntyre Cr. below Mountainview Dr	7	2281.0	2098.4	182.6	
Little Salmon R. at Canoe Landing	5	2354.8	2225.1	129	
Yukon R. at Anson Bend	5	3052.1	2886.2	165.9	
Tatchun R. below Tatchun L.	7	3363.7	3414.5		50.8

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 generally wet years in the CYRB preceded 2015. Water was 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 had been dry during the 1990s and 2000s, implying that some or most aquifers had become fully charged. During the summer of 2015 some areas started to dry, indicating that ground water levels had fallen. This continued through to 2018 although at a reduced rate.

The winter of 2018/19 was generally dry across the CYRB. Spring came suddenly. Melt water in some locations flowed over the top of frozen ground. This limited recharge of aquifers. . Water temperatures were above normal in early summer. However, water temperatures cooled in the southern portion of the CVRB in mid summer. The cooling trend moved north, despite continued low flows. Adult salmon that had escaped in-river fisheries and the effects of high water temperatures in Alaska and the central Yukon had close to ideal conditions on the spawning grounds. The exception to this was those adults spawning in small streams. The very low flows in small spawning streams could have limited the area in which spawning could take place. Predation by bears and other mammals probably increased as the adult salmon would have had less areas such as deep pools to escape to. Finally, small, highly productive streams are vulnerable to beaver damming at low flows. The dams may obstruct upstream migration and increase the efficiency of predators. Additionally, the ponds upstream of the beaver dams back water spawning areas and render them unsuitable for spawning.

The low water conditions continued into the autumn. Flows in streams and rivers are low to very low. This may negatively affect incubating Chinook Salmon eggs, particularly if spawning areas freeze. .

Application of Standards and Thresholds – Migration and Spawning

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 even in cold(er) years. However, Standards such as those used by the ADEC are prepared in other jurisdictions for other purposes. They are based, in part, on other species or stocks/populations. Such Standards must *always* be cautiously applied.

The ADEC Standards were transferred from the US Pacific North West. In the CYRB they are considered to be too conservative to assess risk for the upstream migration and spawning of Chinook Salmon. If the 7DADM process were to be applied there would be fewer days where the Standards were exceeded. However, temperatures at most Stations would still have exceeded the Migration and Spawning Standards during some or most of the sensitive periods in 2019 and preceding years.

Additionally, 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 large excursions. They are therefore limited in their ability to assess risk to Chinook in the aquatic environments 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 Appendices 1 and 2 will not be discussed further.

The Fraser River ewatch Thresholds provide a graduated approach. An important consideration is that the Thresholds were based on in-river investigations, laboratory experiments and local knowledge. They are considered to be more applicable to Yukon River Chinook Salmon. The Thresholds are set at higher temperatures than ADEC standards and are based on the intrinsically more conservative Mean Daily Temperatures. 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 Chinook Salmon. The results will be discussed below.

Upstream migration

Water temperatures at the mouth of the Yukon River were alarmingly high during part of the Chinook Salmon upstream migration. It is likely that water temperatures were measured at some location above the mouth in the Yukon River in Alaska. However, this data – if it was collected – was not available as this report was composed.

The lowest Fraser River ewatch Threshold for upstream migration is 18^0 MEeDT. This Threshold was not exceeded at any migration Station in 2012, 2014 or 2015 during the upstream migration period(s). Thresholds were exceeded in 2013, 2016, 2017 and 2018. In 2019 they were exceeded at the Stewart River at Stewart Crossing, Pelly River below Pelly Crossing; the Yukon River above Klondike Highway, and Teslin River above Hootalinqua

The Stewart River at Stewart Crossing had MeDTs exceeding 18^0 from July 5th (first day of monitoring) to 9th and from July 16th to 27th. The next Threshold was 19^0 and was exceeded from July 18th to 25th except for on the 20th.

The Pelly River below Pelly Crossing had MeDTs exceeding 18^0 from July 5th (first day of monitoring) to 12th and from July 15th to 29th. The 19^0 Threshold was exceeded from July 5th to the 10th and again from July 15th to the 25th. The 20^0 Threshold was exceeded on July 22nd to 23rd.

The Yukon River above Klondike Highway had MeDTs exceeding18^0 from July 22nd to 23rd and from August 4th to 5th.

The Teslin River above Hootalinqua 18^0 had MeDTs exceeding from July 21st to 22nd and from August 2nd to 5th.

Elevated water temperatures *in Canada* posed a meaningful risk to adult salmon migrating up the Stewart and Pelly Rivers. Water temperatures in the main-stem Yukon in Canada may also have posed a risk. Short term exceedances in the Yukon River near Carmacks and the lower Teslin River are not thought to have posed a risk.

As an aside, record high MeDTs for migration Stations were recorded at Mcquesten River below Klondike Highway (17.0^0), Stewart River at Stewart Crossing (19.8^0), and Pelly River below Pelly Crossing (20.2^0).

Spawning

The same Fraser River Thresholds are used to assess the risk to spawning Chinook Salmon.

Tatchun River below Tatchun Lake continues to be the warmest stream measured. In 2019 the maximum MeDT of 19.4^0 was calculated on August 5th, the first day of the specified spawning period. MeDT descended below 19^0 on August 6 and below 18^0 on August 12th.

Tatchun River above the Klondike Highway was considerably cooler than the Station below the lake. This is attributed to in-stream cooling and to a complex interplay of hyporheic- and surface waters between the Stations. MeDT exceeded 18^0 on August 5th and 6th. Tatchun River below Tatchun Lake is at the upstream end of Chinook spawning and Tatchun River above the Klondike Highway is at the downstream end. Salmon enter Tatchun River from the Yukon River. It is likely that the downstream areas of the river may be spawned in while areas further above the mouth continue to be too warm to do so.

As noted in the Migration section, the Yukon River above Klondike Highway had MeDTs exceeding 18^0 on July 22nd and 23rd and on August 4th and 5th, and the Teslin River above Hootalinqua 18^0 had MeDTs exceeding from July 21st to 22nd and from August 2nd to 5th.

No other spawning Stations exceeded 18^0 MeDT during the specified periods.

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In the CYRB some water temperatures were elevated early in the period of specified upstream migration but fell rapidly as the season advanced. By early August all Stations were near or below the 18^0 Threshold. Continued declines in water temperatures occurred in mid-August, resulting in temperatures well below any Threshold of effect. Water levels remained low, however, and some or many returning Chinook Salmon may have found their spawning areas significantly diminished or blocked by beaver dams.

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 at high latitudes are anticipated to result in increased productivity (Prowse et.al., 2006).

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 stresses in mid-latitudes than those located at higher latitudes.

Mean AATUs (MeAATU) can be used to classify streams, although the process may be arguable. Table 3 presents the MeAATUs of all annual Stations in ascending order, the range of each Station's MeAATUs and the number of calendar years of data used in the calculations. In 2018 North Klondike at North Fork Bridge continued to have the lowest MeAATU, now at 982.6 ATU. The Tatchun River below Tatchun Lake continued to have the highest which in 2018 was at 2648.7 MeAATU, or about 2.5 times that of the North Klondike. Importantly, these Stations represent *types* of spawning rivers. The North Klondike is a moderate sized, moderate gradient river draining high ground and with little lake storage. The Tatchun River is a small river with a more moderate gradient draining low ground and with a large lake immediately above the Chinook spawning area. The remaining Stations are located in watersheds with intermediate characteristics.

For the purposes of this Program, streams and rivers are provisionally classified as:

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

The significant range of thermal environments used by Yukon River Chinook salmon for spawning implies either some degree of genetic adaptation by Chinook Salmon populations or a high degree of resiliency within the greater (ie Yukon River in Canada) population. Resolution of this matter deserves attention, particularly in the present climate of Stock (population) restoration.

Table 3. 2018 - Classification of Stations using MeAATUs

Station	Years of Data	Range AATU	MeAATU
Cold (<1300)			
N. Klondike R. at North Fork Bridge	7	892 - 1017.9	982.6
Ibex R. at WSC Station	5	1046.6 – 1297.6	1149.5
Blind Cr. at abandoned bridge	7	1135.1 - 1407.9	1251.7
Cool (1301 - 2200)			
Mcquesten below Klondike Hwy	3	1464.3 - 1811.7	1607.0
Nordenskiold R. at Elk Sign	7	1565.5 - 1811.7	1668.7
Little Salmon R. at Canoe Landing	6	1595.3 - 1837.4	1709.3
McIntyre Cr. below Mountainview	7	1702.2 – 2008.9	1825.7
Teslin R. above Hootalinqua	2	1781.3 - 1971.2	1876.3
Takhini R. below Kusawa L.	5	1840.2 - 2102.9	1966.3
Warm (>2200)			
Yukon R. at Anson Bend	5	2076.7 - 2440.6	2215.8
Tatchun River above Klondike Hwy	2	2309.0 -2398.9	2354.0
Tatchun R. below Tatchun L.	7	2416.8 - 2827.9	2648.7

The low MeAATUS 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 and the status of the adult population is unknown.

Tatchun River below Tatchun Lake has always had the highest AATU. The river supports a large Chinook 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 crawl with mobile organisms in both spring and fall.

With the exception of Tatchun River below Tatchun Lake and the Yukon River at Anson Bend. all Annual Streams had record low MeAATUs in 2018 . This is attributed to the late spring in 2018 and the early onset of cold weather in late September and early October during that year. This cold weather could have affected the incubating eggs of the Chinook Salmon: we are trained to only consider high temperatures as potentially negative, but low(er) temperatures may also have an effect.

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 or those similar to them. 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 tool 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 and nurture juvenile 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 population size and the fitness of individual spawners in the brood year. 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 variables with potential to affect juvenile production. These include, but are not limited to, volume of flow, suspended sediment and bed load transport regimes, available nutrients and ability of the stream to convert them to food for juvenile salmon. Eco-systematic components, primarily competition with other juvenile Chinook and other fish species and predation by fish, mammals and birds also affect production of juvenile Chinook Salmon.

With the exception Tatchun River below Tatchun Lake and Little Salmon River at Canoe Landing each Station had ATUBYCs lower than any recorded to date. This basin-wide reduction of thermal energy could well have negatively affected the growth of Chinook Salmon during the first year growth period. The growth could have included the fat reserves the juveniles rely on to successfully over winter. There may be implications for the CYRB Chinook Salmon populations overall.

Distribution of Data to Interested Parties

Methods

In 2013 a spreadsheet was developed that listed 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

Twenty five data sets were developed in 2019. Ninety nine data sets have been distributed to date, and an additional 80 are expected to be sent out in the new year.

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

Results

Data set to autumn 2019 will be uploaded to Yukonwatertemperatures.info early in the new year.

Conclusions

The eighth 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 by DFO, consultants and institutions.

As this document is being completed, 22 data loggers are measuring temperatures at 11 Annual Stations.

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Appendix 1 – Application of Standards & Thresholds for Upstream Adult 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]	X	X
2018	19.1^{0}	26
2019	20.2	36

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]	X	X	X	X	X
2018	18.6^{0}	3	0	0	0
2019	19.8^{o}	19	7	0	0

[1] logger was dewatered on and subsequent to August 5 2017 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
2018	Data not collected – equipment failure	
2019	18.5^{0}	21

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
2018	Data not collected – equipment failure				
2019	17.0^0	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
2018[1]	X	X
2019	21.7^0	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
2018[1]	X	X	X	X	X
2019	20.3^0	22	14	2	0

[1] logger was dewatered from July 30 2018 to August 8 2018 inclusive due to very low flows in the Stewart river

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
2018	18.2^0	17
2019	16.9^0	10

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
2018	17.5^0	0	0	0	0
2019	16.3^0	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
2018	19.5^0	30
2019	18.9^0	26

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
2018	18.8^0	6	0	0	0
2019	18.5^0	5	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
		15^0
2016	18.4^0	48
2017	18.0^0	31
2018	19.6^0	26
2019	18.7^0	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
2016	18.0^0	1	0	0	0
2017	17.6^0	0	0	0	0
2018	18.6^0	7	0	0	0
2019	18.2^0	4	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
2018	18.4^0	27
2019	17.7^0	24

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
2018	18.0^0	2	0	0	0
2019	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
2018	12.7^0	0
2019	13.7^0	2

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
2018	10.5^0	0	0	0	0
2019	11.1^0	0	0	0	0

Mcquesten River below Klondike Highway

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
2014	15.1^0	19
2015	14.4^0	18
2016	15.9^0	15
2017	16.4^0	31
2018	Data not collected – equipment failure	
2019	18.5^0	27

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
2018	Data not collected – equipment failure				
2019	17.0^0	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
2018	16.0^0	16
2019	16.4^0	15

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
2018	14.7^0	0	0	0	0
2019	14.2^0	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

2018	20.5^0	All
2019	19.7^0	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
2018	20.3^0	6	3	1	0
2019	19.4^0	9	2	0	0

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
2018	19.9^0	All
2019	19.5^0	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
2018	18.8^0	2	0	0	0
2019	18.3^0	2	0	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
2018	19.6^0	51
2019	18.7^0	38

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
2018	18.8^0	7	0	0	0
2019	18.2^0	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
2015	15.4^0	12
2016	16.5^0	18
2017	16.0^0	16
2018	17.8^0	14
2019	16.7^0	16

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
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
2018	17.2^0	0	0	0	0
2019	16.1^0	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
2018	19.1^0	22
2019	17.4^0	16

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2013	18.3^0	3	0	0	0
2014	15.9^0	0	0	0	0
2015	16.4^0	0	0	0	0
2016	17.1^0	0	0	0	0
2017	17.7^0	0	0	0	0
2018	18.8^0	3	0	0	0
2019	16.3^0	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:
		13^o
2012	16.5^0	45
2013	19.8^0	All
2014	16.7^0	51
2015	17.2^0	39
2016	18.5^0	37
2017	18.6^0	52
2018	19.5^0	42
2019	18.9^0	28

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	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
2015	16^0	0	0	0	0
2016	17.9^0	0	0	0	0
2017	18.0^0	1	0	0	0
2018	18.9^0	7	0	0	0
2019	18.5^0	5	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
2018	18.6^0	All
2019	16.8^0	17

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
2018	17.3^0	0	0	0	0
2019	16.1^0	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
2018	13.6^0	2
2019	13.7^0	2

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
2018	12.1^0	0	0	0	0
2019	12.0^0	0	0	0	0

McIntyre Creek below Mountainview Drive.

Type of Station: Annual

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

ADEC assessment process (maximum daily temperatures)

	Maximum hourly	Number of days with maximum temperatures exceeding:
		13^0
2012	15.2^0	18
2013	18.1^0	19
2014	17.0^0	17
2015	16.7^0	18
2016	17.4^0	20
2017	17.3^0	13
2018	17.6^0	6
2019	17.7^0	15

Adopted Fraser River thresholds (mean daily temperatures)

	Maximum MeDT	Number of days with mean daily temperatures exceeding:			
		18^0	19^0	20^0	21^0
2012	13.7^0	0	0	0	0
2013	15.8^0	0	0	0	0
2014	14.4^0	0	0	0	0
2015	14.9^0	0	0	0	0
2016	15.8^0	0	0	0	0
2017	15.4^0	0	0	0	0
2018	15.8^0	0	0	0	0
2019	15.8^0	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
2015	16.1^0	28
2016	17.5^0	30
2017	17.8^0	All
2018	18.4^0	All
2019	16.8^0	17

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	18.0^0	2	0	0	0
2014	16.4^0	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
2018	18.0^0	2	0	0	0
2019	17.5^0	0	0	0	0

Appendix 3. Annual Accumulated Thermal Units

North Klondike River at North Fork Bridge

Commissioned August 8, 2011		
Calendar year 2012		991.3
Calendar year 2013		973.6
Calendar year 2014		953
Calendar year 2015		983
Calendar year 2016		1017.9
Calendar year 2017		1066.7
Calendar year 2018		892.8
	Mean	**982.6**
	Range	**173.9**

Mcquesten River below Klondike Highway

Commissioned July 5, 2014		
Calendar year 2015		1464.3
Calendar year 2016		1811.7
Calendar year 2017		1545.1
Calendar year 2018 – data missing		
	Mean	**1607.0**
	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
Calendar year 2017		1244.2
Calendar year 2018		1135.9
	Mean	**1251.7**
	Range	**272.0**

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
Calendar year 2017		2757.0
Calendar year 2018		2676.9
	Mean	**2648.3**
	Range	**411.1**

Tatchun River above Klondike Highway

Commissioned August 29, 2016

Calendar year 2017		2398.9
Calendar year 2018		2309.0
	Mean	**2353.9**
	Range	**89.9**

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
Calendar year 2017		1615.7
Calendar year 2018		1565.5
	Mean	**1668.2**
	Range	**246.2**

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
Calendar year 2017		1759.2
Calendar year 2018		1595.3
	Mean	**1709.3**
	Range	**242.1**

Teslin River above Hootalinqua

Commissioned June 27 2016		
Calendar year 2017		1971.2
Calendar year 2018		1781.3
	Mean	**1876.3**
	Range	**189.9**

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
Calendar year 2017		1889.9
Calendar year 2018		1840.2
	Mean	**1966.5**
	Range	**262.7**

Ibex River at WSC Station

Commissioned July 4, 2013		
Calendar year 2014		1085.9

Calendar year 2015		1164.2
Calendar year 2016		1297.6
Calendar year 2017		1170.3
Calendar year 2018		1046.6
	Mean	**1152.9**
	Range	**251.0**

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
Calendar year 2017		1815.8
Calendar year 2018		1702.0
	Mean	**1825.7**
	Range	**306.9**

Yukon River at Anson Bend.

Commissioned June 19, 2013		
Calendar year 2014		2076.7
Calendar year 2015		2321.7
Calendar year 2016		2440.6
Calendar year 2017		2156.3
Calendar year 2018		2083.5
	Mean	**2215.8**
	Range	**363.9**

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
2016 Brood year cohort: DMeT was below 4.5^0 on September 29, 2017	1305.3
2017 Brood year cohort: DMeT was below 4.5^0 on September 13, 2018	1166.0
Mean	**1227.7**
Range	**139.3**

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
2016 Brood year cohort: DMeT was below 4.5^0 on September 29, 2017	1894.0
2017 Brood year – insufficient information	
Mean	**1817.4**
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
2016 Brood year cohort: DMeT was below 4.5^0 on September 28, 2017	1528.9
2017 Brood year cohort: DMeT was below 4.5^0 on September 10, 2018	1459.0
Mean	**1563.0**
Range	**273.2**

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
2016 Brood year cohort: DMeT was below 4.5^0 on October 9, 2017	3508.8
2017 Brood year cohort: DMeT was below 4.5^0 on October 10, 2018	3414.5
Mean	**3371.1**
Range	**454.3**

Tatchun River above Klondike Highway

Commissioned August 26, 2016	
2017 Brood year cohort: DMeT was below 4.5^0 on October 8, 2018	2989.8

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
2016 Brood year cohort: DMeT was below 4.5^0 on September 29, 2017	1989.7
2017 Brood year cohort: DMeT was below 4.5^0 on September 15, 2018	1937.2
Mean	**2080.8**
Range	**273.0**

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
2016 Brood year cohort: DMeT was below 4.5^0 on October 12, 2017	2370.6
2017 Brood year cohort: DMeT was below 4.5^0 on October 23 , 2018	2225.1
Mean	**2328.8**
Range	**191.7**

Teslin River above Hootalinqua

Commissioned June 26, 2016	
2016 Brood year cohort: DMeT was below 4.5^0 on October 15, 2017	2640.3
2017 Brood year cohort: DMeT was below 4.5^0 on October 25, 2018	2494.1
Mean	**2567.2**
Range	**146.2**

Takhini River below Kusawa Lake

Commissioned October 1 2012	
2015 Brood year cohort: DMeT was below 4.5^0 on October 27, 2016	2824.2
2016 Brood year cohort: DMeT was below 4.5^0 on November 3, 2017	2692.2
2017 Brood year cohort: DMeT was below 4.5^0 on November 2, 2018	2606.9
Mean	**2707.8**
Range	**217.3**

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
2016 Brood year cohort: DMeT was below 4.5^0 on September 28, 2017	1478.4
2017 Brood year cohort: DMeT was below 4.5^0 on September 12, 2018	1263.7
Mean	**1427.3**
Range	**279.2**

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
2016 Brood year cohort: DMeT was below 4.5^0 on October 8, 2017	2247.4
2017 Brood year cohort: DMeT was below 4.5^0 on September 29, 2018	2098.4
Mean	**2255.0**
Range	**339.1**

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
2016 Brood year cohort: DMeT was below 4.5^0 on October 31, 2017	3005.8
2017 Brood year cohort: DMeT was below 4.5^0 on October 30, 2018	2886.2
Mean	**3018.9**
Range	**276.0**