Assessing the Limits to Production of Juvenile Canadian-Origin Yukon River Chinook Over-Wintering Habitat

Interim Report

CRE-99-16

Prepared for The Yukon River Panel

Prepared by Fisheries and Oceans Canada
Pacific Region
Yukon / Transboundary River Area
Yukon River Treaties and Fisheries
100-419 Range Road
Whitehorse, YT, Y1A 3V1

February 2017

Table of Contents

List of Tables

List of Figures

Context

This document summarizes the project activities conducted to date for the Restoration and Enhancement funded Juvenile Chinook salmon (JCS) overwintering project, CRE-99-16. A summary of background, methods, results to date, discussion of results, and planned activities for the remainder of project is outlined. Project data collection and analysis are ongoing and this report provides an update of activities to date.

Background

Juvenile rearing is an important life stage of Yukon River Chinook, a species currently at historically low productivity (JTC, 2016). Understanding limits to production is one of the near term priorities identified by the Yukon River Panel (YRP, 2015). Due to the technical and logistical challenges of fieldwork, there is very limited information on overwintering juvenile habitat use and distribution.

This project addresses a current knowledge gap in habitat use of Yukon River Chinook salmon during a critical life stage: freshwater over-wintering. One of the principal literature summaries of life history and habitat use of Chinook salmon provides limited reference of freshwater overwintering (Healey 1991), and studies examining juvenile Chinook overwintering usually focus on southerly populations, and coastal river systems unaffected by ice cover (Morgan and Hinojosa).

After late summer spawning and incubation, Chinook salmon typically emerge from the substrate in May and June (Healey et al. 1991. This has been collaborated by work on the Yukon River (DFO Stream Files) and a recent juvenile outmigration project at Big Salmon River (project CRE-26). Movements downstream immediately after emergence are known in other systems (Bradford and Taylor, 1997), and there is evidence for movement of freshly emerged young with high river flows in Big Salmon River. Downstream redistributions of juveniles have been observed in June (Bradford et al. 2008), but whether these fish had been in a natal or non-natal area previous to this is unknown. They are thought to be moving to downstream rearing areas, as Canadian-origin JCS have been observed rearing in tributaries to the Yukon River hundreds of kilometers downstream of their natal spawning bed (Daum and Flannery, 2011). All Yukon River Chinook are considered stream-type, that is they over winter as free swimming fish before out-migrating as age 1+ juveniles in the spring (Bradford et al. 2001). Therefore, Chinook spend two winters in a harsh environment, through incubation and rearing stages.

This project focuses on the rearing aspect of winter habitat. The primary study on overwintering juveniles in the upper Yukon River drainage occurred in a non-natal stream, where the presence of aufeis (overflow from continued freezing of groundwater (Kane, 1981)) had a negative impact on survival, and excluded juveniles from sections of the stream. Most of the fish in the study spent the winter in a localized area downstream of groundwater sources (Bradford et al. 2001). This study focused on one stream type, in one location, and life history strategies have the potential to vary depending on factors such as available habitat. Gathering more information about overwintering, comparing overwintering success between different areas, and understanding more about JCS life history is important to increase our understanding and restoration of stocks.

The main objective of this project's first year is to describe and characterize habitats used by Yukon juvenile Chinook salmon during the winter and how it differs from habitat used in the summer months. Our aim is to describe limits to production in freshwater, to inform both stock and habitat restoration activities. This involves the assessment of overwintering habitat of juvenile Canadian-origin Chinook salmon in the Yukon River through the delineation of over-wintering populations of Chinook salmon and through the characterization of this habitat. Results can help guide the quantification of overwintering habitat across a larger geographic scale and evaluate the role of overwintering habit in limiting productivity. The identification of key overwintering habitat characteristics will inform the design and implementation of stock and habitat restoration projects, to ensure they consider all aspects of juvenile salmon needs in the Yukon basin.

Methods

Information Gathering and Site Selection

An initial review was conducted on previous winter work in the area, and previous juvenile sampling. A variety of sites within the Upper Yukon sub drainage were selected for initial summer sampling from among potential sites near known Chinook salmon habitats that were accessible from the Whitehorse office within a work day, and aimed to encompass a variety of macro habitats.

Site Visits

Water quality measurements and habitat data were collected at initial site visits. A habitat assessment based on a modified CABIN/placer assessment protocol was conducted. This included data on substrate type, percent cover, coarse woody debris, temperature, pH and dissolved oxygen, along with watercourse width and depth. Benthic collections were not included. Capture of JCS at each sites used a minimum of 10 Gee traps baited with roe and set, and then checked 24 hours later. During fall and winter visits data was collected on water measurements (repeated), ice cover, and water velocity at each trap location.

Sites where juvenile Chinook were caught on the initial site visit and that had reasonable winter access were retained for continued sampling. These sites were re-visited in the fall (October and November) to set traps and examine ice conditions. Repeat winter visits are ongoing as winter conditions allow, in consideration of both safety of field staff and risk to and stress of capture and handling fish.

Fish Capture and Sampling

Gee traps were baited with a perforated bag of preserved roe. The traps were left overnight, aiming for a "soak" time for approximately 24 hours. From the number of traps set, the total soak time, and the overall catch, a Catch per Unit Effort (CPUE) was calculated for each site. The catch was confined to juvenile Chinook salmon (other species captured are not included) and the unit of effort is 1 "trap-day" (24 hours).

The numbers of all species caught in Gee traps were recorded and species other than Chinook were released after identification. Juvenile Chinook were retained for length, weight, and genetic tissue sampling prior to release back into the stream. Emphasis was placed to reduce stress to fish, including releasing weak-looking fish, using anaesthetic to decrease the stress of sampling, monitoring holding water conditions, monitoring recovery of fish from anaesthetic, and releasing fish in areas where they would not be vulnerable to predation or high water velocity. All mortalities were retained for potential further examination.

Up to a maximum of 30 fish were sampled per location at each seasonal site visit. The fish to be sampled were chosen randomly and considered to be representative of all Chinook captured.

Video Testing (GoPro)

As part of this project, a GoPro camera was purchased for trial use. The use of action cameras such as Go Pros is becoming more prevalent in the literature (Struthers et al. 2015), with the advantage of observing fish without handling them. Applications range from determining the relative abundance of imperilled fish species (Ellender et al. 2012) to specific use under stream ice (Davis et al., 2013). Advantages include passive observation of fish, fish behaviour, and better access in difficult conditions. Although improved technology is making high quality video more accessible and practical, winter constraints exist in terms of battery life in cold water, and visibility during shortened days.

Results

Site Summary

A total of 11 sites were sampled over the summer (Figure 1 and Table 1). Based on captures and access, this was narrowed down to five sites for continued sampling over the winter (Figure 1 and Table 1).

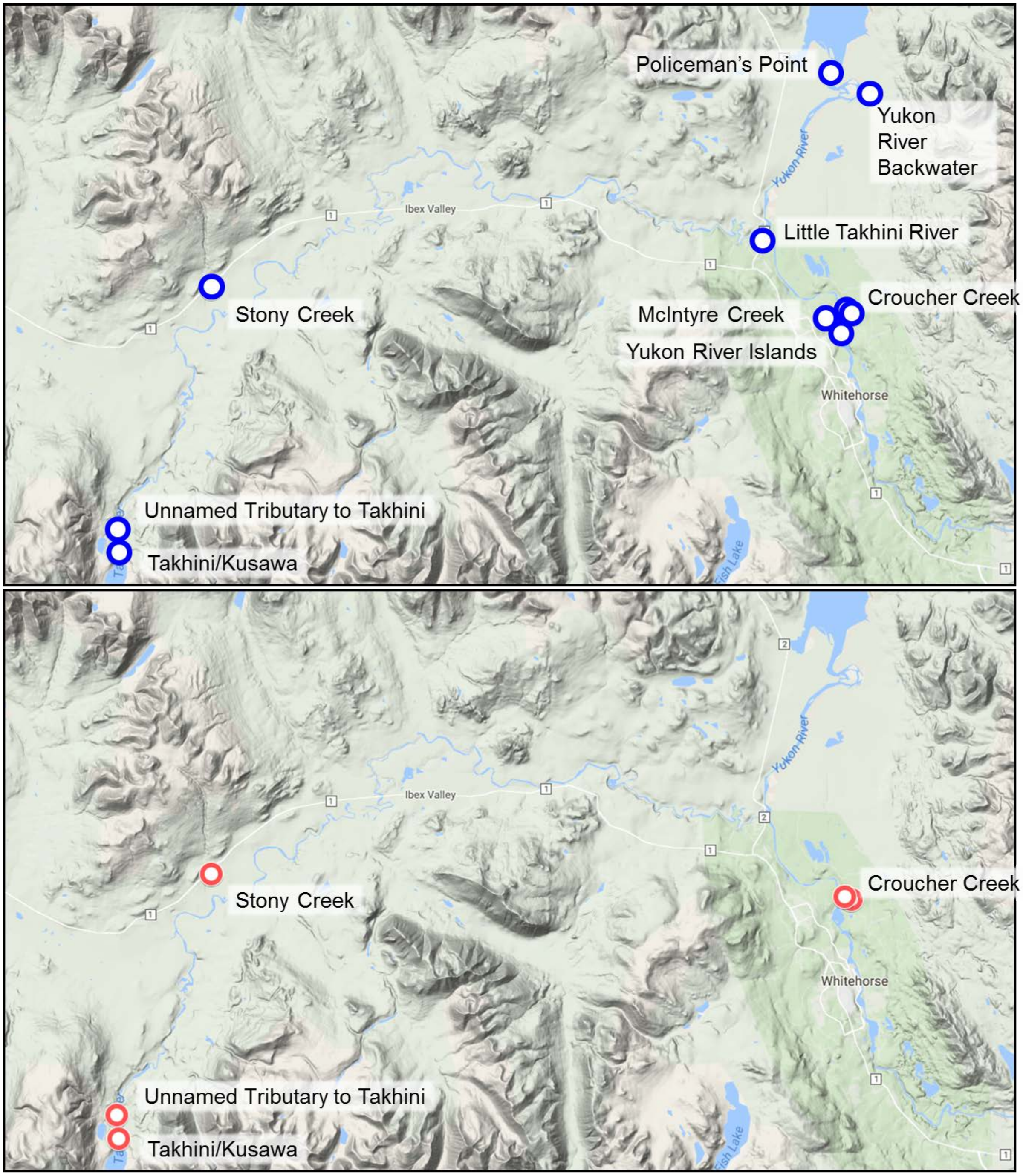

Figure 1: Map of sampling locations. Summer sampling locations on top, and those selected for continued fall and winter sampling on bottom.

In addition to a summer, fall, and winter fish capture efforts, visits were also made to all winter sites in December to assess ice formation conditions, collect abiotic data (water temperate, pH, conductivity, dissolved oxygen), and to deploy temperature loggers at Croucher Creek and Stony Creek. Habitat and water quality data of each site are summarised in Table 2 and 3.

Table 1: List of sampling locations and date(s) sampled.

Location	Summer Visit	Fall Visit	Winter Visit
Policeman's Point	June 29-30, 2016	X	X
Little Takhini River	June 29-30, 2016	X	X
McIntyre Creek	June 29-30, 2016	X	X
Croucher Upper	July 11-12, 2016	24-25 October, 2016	January 16-17, 2017
Croucher Middle	July 11-12, 2016	24-25 October, 2016	January 17-18, 2017
Takhini/Kusawa	July 27-28, 2016	26-27 October, 2016	January 3-4, 2017
Unamed Trib to Takhini	July 27-29, 2016	26-27 October, 2016	January 4, 2017
Stony Creek	July 28-29, 2016	27-28 October, 2016	January 4-5, 2017
McIntyre Islands	August 4-5, 2016	X	X
Croucher Mouth	August 4-5, 2016	X	X
Yukon River Backwater	August 4-5, 2016	X	X

Table 2: Basic site habitat characteristics

Location	General Description	Gradient	Mean width	Max depth	Primary Substrate	Canopy Cover	Woody Debris
Policeman's Point	Large River	<1%	30 m	> 2 m	Sand + Silt	0%	Sparse
Little Takhini River	Medium Creek	<1%	30 m	1-2 m	Sand + Silt	0%	Sparse
McIntyre Creek	Medium Creek	<1%	15 m	1.4 m	Sand + Silt	10%	Variable
Croucher Upper	Medium Creek	~1.5%	3 m	0.8 m	Sand + Gravel	50-75%	Complex
Croucher Middle	Medium Creek	<1%	3 m	0.6 m	Sand + Pebble	25%	Complex
Takhini/Kusawa	Lake -> River	<1%	n/a	n/a	Cobble	0-100%	Sparse
Unamed Trib to Takhini	Small Creek	>2%	<1m	0.9 m	Silt + Sand	50-75%	Complex
Stony Creek	Medium Creek	1-2%	5-6 m	1 m	Pebble + Cobble	50%	Complex
McIntyre Islands	Yukon River	<1%	25 m	2 m	Pebble + Sand	0%	Spare
Croucher Mouth	Medium Creek Mouth	<1%	2 m	55 cm	Pebble + Sand	0-10%	Sparse
Yukon River Backwater	Large River Backwater	<1%	30 m	2 m	Silt + Sand	50%	Variable

Table 3: Water measurements summary

Location	Season	Temp. (°C)	Conductivity (µS)	pH	DO (mg/L)	Visibility (Secchi)
Policeman's Point	Summer	15.5	-	8.3	-	-
Little Takhini River	Summer	16.5	-	8.4	-	-
McIntyre Creek	Summer	16.7	-	8.7	-	-
Croucher Upper	Summer	17.1	243	8.6	-	> 0.6 m
	Fall	0.1	270	8.7	12.54	> 0.6 m
	December	0.2	363	8.2	14.25	> 0.6 m
	Winter	0.1	373	9.1	14.02	> 0.6 m
Croucher Middle	Summer	16.1	265	8.7	-	> 0.8 m
	Fall	0.2	302	8.3	12.7	> 0.6 m
	December	0.2	363	8.2	14.25	> 0.6 m
	Winter	0.0	383	8.5	13.96	> 0.6 m
Takhini/Kusawa	Summer	14.3	44	8.4	-	> 1.0 m
	Fall	3.0	40	8.3	11	> 0.6 m
Unamed Trib to Takhini	Summer	11.9	125	7.9	9.03	0.85 m
	Fall	0.8	146	8.3	12.7	> 0.6 m
	Winter	0.0	76	7.8	9.2	-
Stony Creek	Summer	8.4	123	8.4	9.73	> 0.6 m
	Fall	0.5	180	7.8	12.91	> 0.6 m
	December	0.5	149	8.2	13.86	> 0.6 m
	Winter	0.1	157	8.4	14.56	> 0.6 m
McIntyre Islands	Summer	18.0	100	8.2	9.27	> 1.8 m
Croucher Mouth	Summer	14.0	288	8.5	8.5	> 1 m
Yukon River Backwater	Summer	17.7	108	8.7	9.41	0.7 m

Catch Summary

Catch of JCS ranged from 0 to 90 fish. The largest catch occurred at the Unnamed tributary during summer sampling (Tables 4 and 5). CPUE is calculated as the catch of juvenile Chinook per each sites effect (the number of trap hours). Summaries of juvenile Chinook length, weight and Fulton's condition factor (K) are presented in Figure 2.

Table 4: Site catch summaries. (JCS = juvenile Chinook salmon).

	Summer		Fall		Winter	
Location	**JCS**	**Other Spp.**	**JCS**	**Other Spp.**	**JCS**	**Other Spp.**
Policeman's Point	None	None	-	-	-	-
Little Takhini River	None	None	-	-	-	-
McIntyre Creek	None	5 Sculpin 4 Suckers	-	-	-	-
Croucher Upper	20	3 Sculpin 1 Rainbow Trout	10	4 Sculpin	5	1 Sculpin
Croucher Middle	8	1 Sculpin	5	1 Sculpin	1	None
Takhini/Kusawa	2	1 Sculpin	None	2 Sculpin	None	1 Sculpin
Unamed Trib to Takhini	90	11 Sculpin	2	None	Frozen Over	Frozen Over
Stony Creek	30	None	4	None	None	1 Sculpin
McIntyre Islands	None	1 Juv. Pike	-	-	-	-
Croucher Mouth	1	8 Sucker	-	-	-	-
Yukon River Backwater	None	None	-	-	-	-

Table 5: Catch per unit effort (CPUE) for selected sites. Reported as the number of JCS caught per trap day (24 hrs).

	Summer	Fall	Winter
Croucher Upper	2.00	1.08	0.65
Croucher Middle	0.70	0.54	0.08
Takhini/Kusawa	0.20	0.00	0.00
Unamed Trib to Takhini	8.85	0.22	-
Stony Creek	4.72	0.40	0.00
Croucher Mouth	0.11	-	-

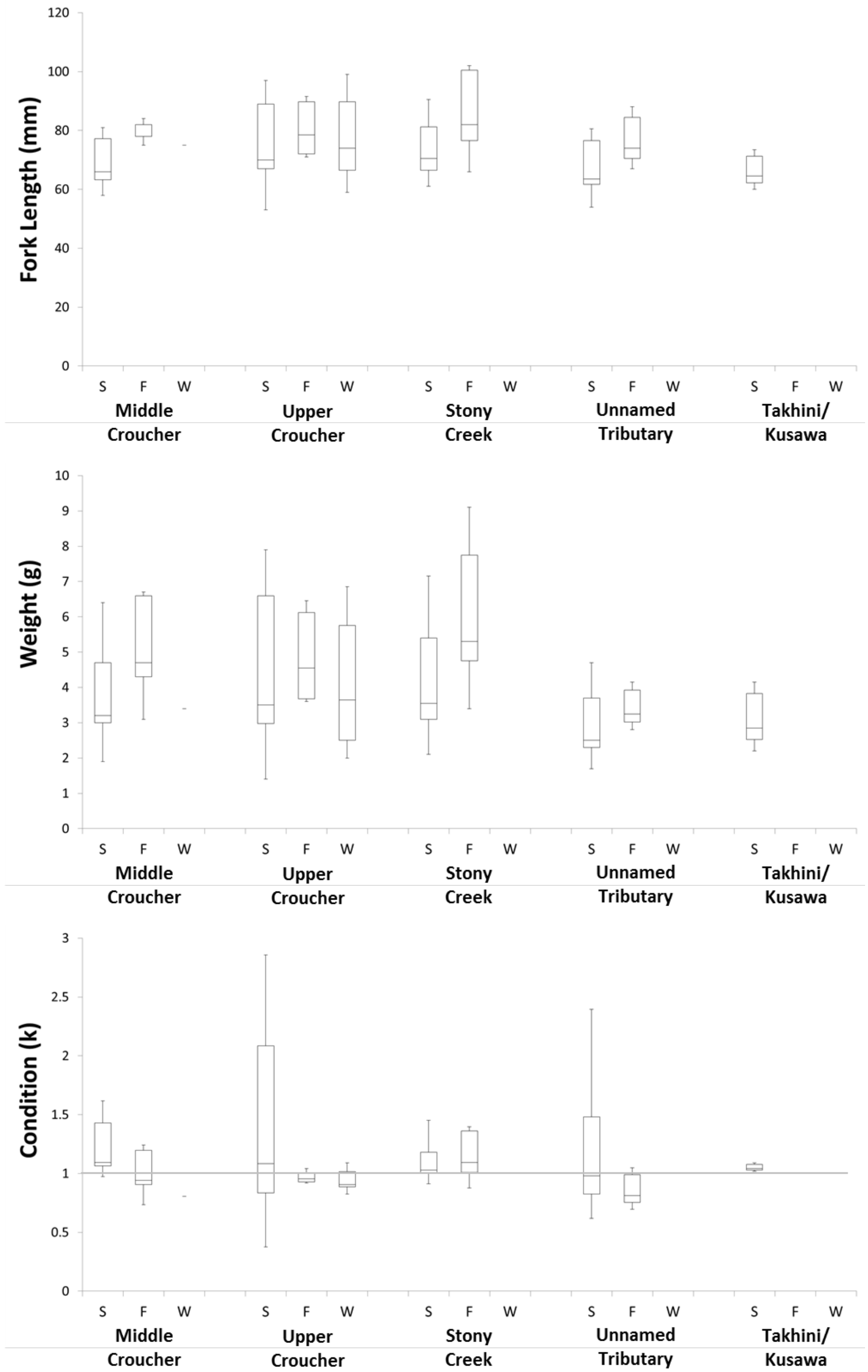

Figure 2: Juvenile Chinook sampling results from five sites selected for year-round sampling.

Discussion

Sites and relationship with CPUE

Over the summer, juvenile Chinook salmon were caught in locations with lower water temperatures, higher dissolved oxygen, larger substrate and variable in-stream woody debris and cover. Initial indications are that cover may be especially important as Chinook salmon were not captured in locations such as McIntyre Islands, which had varied substrate, but low levels of cover and coarse woody debris.

Fewer juveniles were caught during the fall trapping visits. Traps where Chinook salmon were caught were often traps placed in the same location as the summer, where similar proportions of the total catch for the site occurred. Habitat characteristics that correlated with higher catches included pools with abundant coarse woody debris, and cobble sized substrate.

Two sites which had noticeable changes in catch between summer and fall were the Kusawa/ Takhini site and the small unnamed tributary to the Takhini River. In the summer, two juvenile Chinook were caught at the Takhini/Kusawa site (see Table 4). These fish were caught in locations with cobble substrate with estimated 1/4 embeddedness, and with dense overhanging alders and willows. During fall sampling, the water level had dropped significantly and while the substrate was still similar, cover had significantly decreased. In addition to the drop in cover, the lack of JCS catch corresponds with the area having water velocity at the lake/river transition, and a previous lack of evidence of juvenile Chinook using lakes for rearing in Yukon (von Finster 1991).

Summer juvenile Chinook densities were the highest of any site in the small Unnamed Tributary to the Takhini. With an average wetted width less than a meter, a channel highly affected by fallen and uprooted trees, as well as larger boulders and significant deadfall, it was difficult to find locations deep enough for 10 traps. The gradient increased rapidly from the river up to the road; however juveniles were caught above barriers up to 35 cm in height. This stream obviously provides good summer habitat, given the high numbers of Chinook salmon caught. However, only 2 JCS were caught in the fall. Water depth had dropped by half, and it was more difficult to find adequate locations to set traps. These results likely indicate a large movement out of the stream in the fall. Gee traps could not be deployed during the January visit as frozen overflow was filling the creek channel down to the river, with overflow widths approximately 1-2m and only a few cm of water accessible under over 30 cm of ice.

At the time of winter sampling, site conditions had changed significantly, specifically in terms of ice cover and the effects on flow. Ice cover had increased drastically and had variable thickness depending on localized conditions. Reductions in water level combined with changes to flow patterns meant that sites that were previously suitable for gee-traps were now too shallow and/or the water velocity was too high for trap deployment. Ten traps were set at each of the Takhini River/Kusawa Lake interface and Stony Creek locations. No traps were set at the Unnamed Tributary location due to poor conditions. No fish were captured at the Takhini River/Kusawa lake interface. This was expected, as no fish had been captured at this location in the fall. Water levels at Stony Creek were suitable but no JCS were caught.

Given that overwintering has been confirmed in Croucher Creek (Bradford et al. 2001) we increased the numbers of traps used to 12 at each Croucher site. The method of baiting was also changed from roe inside perforated plastic bags to similar sized chunks of roe loose in the traps. Roe remained in one piece as they were cut from skeins. The rationale behind this change in baiting method was to increase the amount of oil release. Oil (scent) release from the perforated plastic bags was limited due to cold water conditions and "gumming" of the roe. This, combined with low JCS movements in colder water, may have reduced chances of catching fish.

To date, all juvenile Chinook captured in the winter sampling were caught in Croucher, but how much of this is due to change in bait cannot be determined. Another winter visit to Stony Creek is anticipated where revised baiting methods will be used.

Fish Size and Condition

Fish length and weight had increased at sites where fish were caught in both the summer and fall. All summer fork lengths suggest significant growth since emergence, as fry generally emerge at 30-40 mm (Healey 1991, Bradford et al. 2008). Previous work in Croucher Creek reported average lengths at the end of October to be 71 mm (Moodie 2000, Bradford et al., 2001) and weight to range from 3.1 grams (Bradford et al. 2001) to 3.4 grams (Moodie 2000). This year's average October length was 78 mm (n=13) and average weight of 4.5 grams. However this sample size is too small to draw strong conclusions.

Middle Croucher shows an increase from summer to fall in fork length and weight, and a decrease in condition (Figure 2). The single fish caught in the winter was smaller, lighter and had a reduced condition factor than the average fish caught in the fall. At the Upper Croucher site, there was a wide range of fish lengths and weights, with the average weight and length increasing from the summer to fall, and decreasing in the winter. The majority of fish had condition factors less than 1 (considered an approximate threshold for healthy fish) in the fall and winter. In Stony Creek there was a defined increase in all measurements between summer and fall and having data from winter periods would help assess whether this pattern persists. The two fish captured in the fall from Unnamed Tributary had a higher average length and weight than the summer, although condition factor was low. As only two JCS were captured in the Takhini/Kusawa site in the summer (no winter captures), comparisons between seasons are not possible. However both fish did have condition factors above one.

GoPro

The GoPro operated for longer periods than expected given cold temperatures. Taking one photo every 60 seconds resulted in over 6 hours of photos, and taking continual video resulted in 1 hour and 20 minutes of recording time, both at water temperatures near 0.0°C. Optimal usage of the GoPro is still being assessed. Limitations are more a factor of battery life and light availability than storage space. As of the time of writing this report, the GoPro has not recorded an identifiable juvenile Chinook salmon, but has been used to examine under ice conditions that otherwise might not be evident (Figure 3), and has recorded other species (sculpin).

Figure 3: GoPro photo samples. Overhanging ice with lowered levels of light (Stony Creek, left) and an underwater still from Croucher Creek (right).

Known considerations when working with cameras include changes to behaviour, such as attraction to the camera, or attraction/avoidance based on spectral response to artificial light. The operational lights of a camera (recording light, screen illumination) or additional light used to supplement low levels of natural light, could affect behaviour (Muller et al. 2006).

During summer field tests on the Big Salmon River, the camera recorded a large group of feeding juvenile Chinook salmon for fifteen minutes, with both a flashing red right and a flashing blue light. The feeding juveniles did not appear to exhibit avoidance or attraction to the camera. White light from a small dive light used in Croucher Creek did not appear to attract fish (Figure 3, right).

Other fish species which might be attracted to the camera are also a consideration, as their presence could influence target species behaviour. Species known to predate on Chinook juveniles (northern pike, burbot, inconnu) are unlikely to reside in streams the size of Croucher and Stony Creek, but would be a consideration in larger watercourses.

Initial tests indicate that a camera may provide useful data regarding Chinook salmon habitat use, and that further testing to determine the best methods of use merits continued consideration.

Winter Sampling Challenges and Methods

The main challenges of winter sampling have been cold air temperatures and changes to watercourses as a result of freezing. Air temperatures below -20°C have postponed winter sampling. At these temperatures there is elevated risk to fish and staff, and field work becomes more complex and time consuming.

As watercourses have frozen, water levels have dropped and the freezing of ice has created changing conditions. Ice dams may cause newly formed pools which often do not last long. Ice formation can change previously optimal Gee trap locations to unsuitable winter sites. A sufficient water depth and low water velocity are the two primary challenges to capturing fish.

Sampling occurred successfully in both October site visits, and winter site visits to date, at air temperatures not below -10°C. Extra precautions were taken including the use of insulated holding buckets to ensure water temperature did not drop below that of the water the fish inhabited. Data collection (measurements of fork length and weight) occurred on a continually wetted surface. At colder temperatures, mass data could be collected using a scale that measures up to 200 grams, so fish can remain fully immersed in water. Technicians used towels to keep hands dry, hand warmers in mitts to keep hands warm, and long rubber gloves, neoprene waders, and dry suits when necessary for trap setting and checking.

Instrumentation also becomes more difficult to use in colder temperatures. Digital instruments are slow to respond, and moving parts quickly freeze once they are wet. These challenges were successfully addressed by keeping instruments (ProODO, Oakton pH and conductivity meter) warm en route to sites by carrying them either under a jacket, or in an insulated container with a source of heat (hot pockets). Similar measures were taken to prevent the Price AA style current meter from freezing.

Pending Work

The current focus is returning to Stony Creek and increasing effort in an attempt to capture JCS under winter conditions. Other results from this year's work include the final analysis and documentation of winter sampling protocols (both discussed below). In addition, we will conduct a review of previous winter fish sampling throughout the Yukon River drainage and provide a summary of locations and catches.

GoPro

Best practices for GoPro deployment will be refined in consideration of the relative utility of time lapse photos and videos, how baits or lights should be used, the merits of attempting to attract fish versus passive observation. The camera is also useful for examining underwater ice conditions, and can be used to photograph an entire section of channel to observe how conditions change with ice formation and changing water levels (Davis et al., 2012, 2015).

Analysis

Data collected over the season will be analyzed to describe CPUE, length and weight, habitat characteristics. The differences between catch, fish measurements, and habitat availability will be compared between sites and seasons. Comparisons with existing literature will also be discussed to place this work in the larger context and to contextualize our findings.

Measures of Success

Measures of success and how to meet them were identified in the project proposal (Table 5, Columns 1 and 2 complete lists). Below we provide how they have achieved in the context of the work completed to date (Table 5, Columns 2 and 3). All measures of success will be fully met by project completion.

Table 6: Proposal Measures of Success.

Measure of Success	How to meet success	Current Status	● completed ◐ ongoing ○ pending
Improved understanding of the habitat use by juvenile Chinook salmon over the winter	Habitat assessment is done according to protocols. Site selection considers all relevant inputs. Fish sampling uses appropriate methods. Data management and quality control measures are in place.	◐ Habitat Assessment ● Site inputs recorded ◐ Fishing sampling under DFO protocols ◐ Data entry done under management and QA/QC procedures	
Field work is carried out safely and efficiently	There are no safety occurrences. Staff are comfortable and have what they need. Equipment is maintained according to standards and duties are clearly established.	◐ No safety occurrences ● Winter and cold water gear supplied ◐ Equipment maintained Duties and protocols established	
Those who would like to participate in the project know about it and are provided opportunities to participate	Reach out to First Nation government with specific invitation to participate	◐ Site visits with Ta'an Kwäch'än Council Lands and Resources Staff, continued communication regarding future field visits ◐ Communication regarding future field visits with Kwanlin Dün First Nation Lands and Resources Staff	
A report on the project is available and the data are securely stored and accessible to those who need them.	Complete report by target date and share with Pacific Salmon Commission. Review and finalize data and store in an organized and secure manner.	● Interim report completed ◐ Data collected to date reviewed and securely stored ○ Final Report pending	

Winter Sampling Protocol

A winter sampling protocol is in development based on this project. This document is intended to provide considerations and guidance for future work. It focuses on adaptions and considerations to standard Gee-trapping and fish handling that facilitate winter work, ensure safety for field staff, and minimize stress to fish. The adopted winter protocol will be based on content from other projects, input from experienced DFO staff, as well as methods developed in the current year. This protocol will provide an important resource for future winter sampling work.

Conclusions

To date the project has successfully located areas suitable for winter sampling. Preliminary results indicate continued use of tributary streams into the late fall, and reductions in occupancy by juvenile Chinook salmon from these tributaries as water levels drop and ice levels increase. The final report will focus on winter results of JCS catch, and size compared between sites and season. Additional assessment of changes in usable habitat area between seasons, and how it differs based on the microhabitat will provide additional context for potential limiting factors.

References Cited

Bradford, M.J., J.A. Grout, and S. Moodie. 2001. Ecology of juvenile Chinook salmon in a small non -natal stream of the Yukon River drainage and the role of ice conditions on their distribution and survival. Can. J. Zool 79: 2043-2054.

Bradford, M.J., Duncan, J. and Jang, J.W., 2008. Downstream migrations of juvenile salmon and other fishes in the upper Yukon River. Arctic, pp.255-264.

Davis, L., Cockburn, J. and Villard, P.V., 2016. Deploying action cameras to observe fish in shallow, ice-covered streams. Journal of Freshwater Ecology, pp.1-6.

Davis, J.C., G.A. Davis, L.R. Jensen, H.N. Ramage and E. Rothwell. 2013. Winter Habitat Associations of Juvenile Salmon in the Susitna and Talkeetna Rivers. National Marine Fisheries Service. Available online at: http://www.arrialaska.org/reports/Winter%20Habitat%20Glacial%20Rivers%20Final%20 Report.pdf

Davis, J.C., G.A. Davis, L.R. Jensen, and E. Rothwell. 2015. Juvenile Salmon Winter Habitat Characteristics in Large Glacial Rivers. National Marine Fisheries Service. Available online at: http://www.arrialaska.org/reports/2013-2014%20NMFS%20Winter%20Fish%20Report%20Final.pdf

Daum, D. and B.G. Flannery. 2011. Canadian-Origin Chinook Salmon Rearing in Nonnatal U.S. Tributary Streams of the Yukon River, Alaska, Transactions of the American Fisheries Society, 140:2, 207-220, DOI: 10.1080/00028487.2011.545004

Ellender, B.R., Becker, A., Weyl, O.L. and Swartz, E.R. 2012. Underwater video analysis as a non-destructive alternative to electrofishing for sampling imperilled headwater stream fishes. Aquatic Conservation: Marine and Freshwater Ecosystems, 22(1), pp.58-65.

Healey, M.C. 1991. Life history of Chinook salmon (Oncorhynchus tshawytscha), pages 311-394 *In* Groot, C. and Margolis, L. 1991. Pacific salmon life histories. University of British Columbia Press, UBC, Vancouver, B.C.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2016. Yukon River salmon 2015 season summary and 2016 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A16-01, Anchorage.

Kane, D.L. 1981. Physical mechanics of aufeis growth. Can. J. Civ. Eng. 8: 186–195.

Moodie, S., Grout, J.A., and von Finster, A. 2000. Juvenile chinook salmon utilization of Croucher Creek, a small non-natal tributary of the upper Yukon River. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 256

Morgan, A. and F. Hinojosa. No date. Winter habitat utilization by juvenile salmonids; a literature review. Northwest Indian Fisheries Committee. Available online at: http://access.nwifc.org/tfw/documents/winhab.pdf

Mueller, R.P., Brown, R.S., Hop, H. and Moulton, L., 2006. Video and acoustic camera techniques for studying fish under ice: a review and comparison. Reviews in Fish Biology and Fisheries, 16(2), pp.213-226.

Rublee, W.O., Goldberg, I.L. and Gamble, D.B., WINTER HABITAT USE AND RELATED CONSTRAINTS TO PRODUCTION OF INTERIOR BC SALMONIDS.1995 Available online at: http://cripe.civil.ualberta.ca/Downloads/08th_Workshop/Rublee_et_al_1995.pdf

Struthers, D.P., Danylchuk, A.J., Wilson, A.D. and Cooke, S.J., 2015. Action cameras: bringing aquatic and fisheries research into view. Fisheries, 40(10), pp.502-512.

von Finster, A. October 14, 1991. Overwinter of Juvenile Chinook Salmon in the Yukon River Drainage Basin. Memo to file. Habitat Enhancement Branch, Yukon and Transboundary Rivers Division, Dept. Fisheries and Oceans. 2 p.

Yukon River Panel (YRP) Restoration and Enhancement Find. 2015 Neat Term Priorities. Available online at: http://yukonriverpanel.com/salmon/wp-content/uploads/2009/03/2_2015-near-term-priorities.pdf