Assessing the Fate of Returning Upper Yukon River Chinook Salmon

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Table of Contents

Abstract

A 50-receiver acoustic telemetry array was deployed throughout the Upper Yukon River and supporting tributaries to identify spawning locations of Chinook Salmon (*Oncorhynchus tshawytscha*) upstream of Lake Laberge, YT. Fish of both wild and hatchery origin were gastrically implanted with acoustic transmitters at the Whitehorse Rapids Fishladder viewing chamber or downstream via gill net capture to evaluate passage success and subsequent spawning locations. Fish were captured and acoustically tagged in the Takhini River (a barrier-free river) as a control group for the potential consequences of gill net capture on migration. A total of 55 tagged fish passed upstream of the Whitehorse Hydro Plant with 80% terminating in the Michie Creek - M'Clintock River system, 9% in Wolf Creek, 9% traveling back through the WHP spillway, and one wild male fish terminating in an unknown location. All ten gill netted fish tagged in the Takhini River reached the Alaska Highway crossing (~50 km upstream), indicating long-term recovery from gill net capture and handling. In the Yukon River, nine gill-netted fish approached the Whitehorse Hydro Plant, six of which successfully passed the facility. The three fish remaining downstream of the WHP migrated downstream and spent at least two days on the Robert Service Way spawning grounds, and one gill-netted individual migrated directly to this location without visiting the WHP. Findings from 2018 suggest gill netting can be an effective means of capturing fish for fish passage research.

Introduction

Upper Yukon River Chinook Salmon (*Oncorhynchus tshawytscha*) populations (defined for the purpose of this study as fish that terminate in the mainstem Yukon River or its tributaries upstream of the Teslin River) have experienced similar declines to other Yukon River populations in the past half century. Greater declines probably occurred much earlier in the past century throughout the river, possibly due to overfishing associated with human population increases in the region in the wake of the Klondike Gold Rush (Gilbert and O'Malley 1921; von Finster pers. comm.). Traditional ecological knowledge and historical accounts indicate that many Chinook Salmon were harvested annually in the Michie Creek - M'Clintock River system (Cox 1997, Herkes, 2015). Brown et al. (1976) convey reports of several families each harvesting 500 fish. Indigenous families would dry and smoke salmon along the banks of the M'Clintock River, and some caches of dried salmon were large enough to last through winter (Herkes, 2015). In 1957, the Chief Biologist for the Pacific Area wrote to the Deputy Minister of Fisheries that "as many as 10,000 spring salmon were taken in the M'Clintock River some years ago" (Cox 1997). Similarly, a fishery officer recorded that as many as 25 families once harvested 300-400 fish each there, based on an interview with Johnny Joe (Cox 1997). However, by the mid-1950s, annual harvests appear to have declined to a few hundred fish or less per year, and there was much debate about whether previous versions of the Lewes Dam had contributed to this decline by acting as a barrier to migration (Cox 1997). Commercial fishing in the lower reaches of the Yukon River early in the 20^{th} century also contributed to declines (Gilbert and O'Malley 1921).

The current spawning and rearing capacity of the primary spawning grounds upstream of Whitehorse, the Michie Creek – M'Clintock River system, is unknown. Returns counted at the Whitehorse Rapids Fishladder (ladder) have averaged ~1200 since the ladder was constructed in 1959. Initial returns were ~1100 for the first four years, then declined until the late 1980's when returning hatchery-reared fish began to supplement wild returns (W. R. Ricks Consulting and DNA Enterprises 1996). The fate of many Chinook Salmon after they pass the ladder is largely unrecorded. Previous radio telemetry studies (Cleugh and Russel 1980; Matthews 1999a) showed that 77% to 88% of these Chinook Salmon traveled to the Michie Creek - M'Clintock River system, though sample sizes were small. Contemporarily, the majority of Chinook Salmon migrating upstream of the WHP are believed to spawn in Michie Creek, between Michie Lake and Byng Creek (de Graff 2015); although, M'Clintock River upstream of Michie Creek has been identified as a historically important spawning location as well (Cox 1997; Herkes 2015). In 1998, a beaver dam prevented access to the upper reaches of Michie Creek, and spawning occurred >12.5 km downstream of Michie Lake (Matthews 1999b). Confirming where Chinook Salmon spawn in the Michie Creek - M'Clintock River system will inform further efforts to recover the stock. The fate of Chinook Salmon that pass the ladder but do not terminate in the Michie Creek - M'Clintock River system is partially known. Fish spawn in Wolf Creek and may spawn in other unknown locations between the Whitehorse Hydro Plant (WHP) and Southern Lakes system, or they may expire before reaching any spawning ground. Determining the terminal location of all Chinook Salmon migrating upstream of the WHP will help identify management actions for restoring the habitat and vitality of this stock.

The role of the WHP as a barrier to Chinook Salmon migration is largely unknown. No reports of passage numbers exist prior to the construction of the WHP in 1958, making it difficult to assess how the population was affected by its construction. The population has been in part maintained by the Whitehorse Hatchery, built in 1984 in an effort to mitigate increased Chinook Salmon fry loss as a result of a fourth turbine being constructed at the WHP (Yukon Energy Corporation 2011). In contrast with the exact records of Chinook Salmon migrating through the WHP, the portion that spawn or expire downstream of the WHP is less well studied. An average of 26 reds was observed near Robert Service Way from 1998-2002 (ACG and YES 2002). The Whitehorse Rapids Fishladder is a vertical slot ladder. Other studies on vertical slot ladders have shown high passage efficiency but low attraction efficiency (Roscoe et al. 2010; Pon et al. 2006). Little is currently known about the attraction efficiency of the Whitehorse Rapids Fishladder. Cleugh and Russel (1980) assessed passage success and delays at the WHP using radio telemetry. Of the 12 fish captured or released downstream of the WHP, 7 passed after delays ranging from 10 hours to 10 days (average 3 days).

Similarly, little is known about delays, stress, or energetic costs of fish passage at the WHP. More than five decades of successful passage and subsequent spawning in the Michie Creek - M'Clintock River system provide clear evidence of individual passage success. However, sub-lethal and population-level consequences of passage are unclear. No substantial studies on this specific site have been conducted but the broader literature on this topic is extensive. Dams can lead to passage delays, increased disease incidence, and higher pre-spawning mortality (Hinch et al. 2012) as well as acute energetic stress (Roscoe et al. 2010) resulting in suppression of reproductive hormones (Kubokawa et al. 2001) and mortality (Burnett et al. 2017). These studies show that salmon recover relatively quickly from acute energetic stress associated with approaching and ascending fish ladders (Roscoe et al. 2010), yet post-passage mortality has still been observed (Burnett et al. 2017), indicating potential long-term effects of ladder passage.

In 2017, we implemented a research program that would begin to evaluate the effectiveness of the Whitehorse Rapids Fishladder, and identify terminal locations of spawning fish. Fish were tagged at the ladder viewing chamber to evaluate passage efficiency of the upper ladder and post-passage migration behaviour. We also conducted two pilot studies to evaluate potential methods of addressing ladder attraction efficiency; one involved transporting fish from the WHP viewing chamber downstream, and the other involved capturing fish by gill net downstream of the WHP. The gill net pilot study appeared the most appropriate for assessing movement of fish downstream of the WHP (Sebes and Lapointe 2017), though questions arose regarding the potential sublethal impacts that gill net capture had on Chinook salmon movement and passage ability. To address this concern, we undertook a second pilot study in 2018.

This project has two primary goals. The first is to identify depleted stocks that are candidates for restoration, along with potential spawning restoration sites. Specific objectives associated with this goal are to assess:

1) Where salmon spawn in the Michie Creek - M'Clintock River system;
2) What other terminal locations exist upstream of Lake Laberge aside from the Takhini River, McIntyre Creek, the Yukon River downstream of the WHP, Wolf Creek, and the M'Clintock River.

3) Whether some fish that pass the WHP fail to reach Marsh Lake (and to subsequently assess whether these fish spawn successfully in the mainstem Yukon River or experience pre-spawning mortality).
4) What proportion of fish spawns in each terminal location.

The second goal is to assess whether challenges associated with passage at the WHP are limiting production of Upper Yukon River Chinook Salmon stocks. Specific objectives associated with this goal in 2018 are listed below. Objective 5 involved a pilot study that will inform future ladder efficiency research.

5) Whether fish resume normal behavior after capture by gill netting and tagging.
6) What proportion of fish return downstream after passing the WHP.

Methods

Study Site and Receiver Locations

The 2018 study site consisted of the Yukon River and its tributaries upstream of Lake Laberge, near Whitehorse, YT. Thirty Vemco VR2W receivers were deployed between the confluence of the Yukon and Takhini Rivers and the spawning grounds in the Michie Creek - M'Clintock River system and the Takhini River (Figure 1 and 2; Table 1). Acoustic receivers were generally anchored with a cement block or sand bag and were tethered to a rope extending up to a sub-surface buoy. Receivers were tested prior to deployment and a subset of receivers were range tested. Range testing was completed at each site by placing a V16 range test transmitter at set distances from each receiver for a set time interval (generally 12 minutes or 100 potential detections). Range test results are presented in Appendix 1. Additionally, Chinook Salmon movement was monitored beyond Marsh Lake and into the Southern Lakes by the 20-receiver array maintained by Environment Yukon for their Lake Trout (*Salvelinus namaycush*) study in the Southern Lakes. These receivers will be retrieved in spring 2018, providing data on any tagged Chinook Salmon that visited these areas.

Figure 1: Locations of acoustic receivers deployed in 2018 and the two gill net fishing sites.

Figure 2: Locations of acoustic receivers deployed around the WHP in 2018.

Table 1: Description of 2018 acoustic receiver locations and rationale.

Receiver #	Location	Rationale
1	Fallback site at mouth of Takhini River	To detect post-gill netting fallback and other fish at the confluence of the Takhini River and Yukon River
2	6-11 km upstream of fishing sites	Similar distances upstream of the Takhini River tagging sites as Schwatka Lake is to the Yukon River tagging site. Confirms that fish travel as far as the WHP after capture and handling.
3	Alaska Highway Bridge on the Takhini (km 57)	Adult salmon have been seen surfacing between the Alaska Highway bridge and the Ibex River mouth late in the spawning season
4	Alaska Highway Bridge on the Takhini (km 57)	To confirm upstream movement to the most downstream known potential spawning areas and evaluate whether there are effects of capture and handling
5	Takhini River mainstem upstream of Stoney Creek (km 87)	Lowermost extent of major spawning areas in the Takhini River downstream of Kusawa Lake.
6	Takhini River mainstem upstream of Stoney Creek (km 87)	To detect movement upstream of known primary Takhini River spawning areas
7	Industrial boat launch (6 km from tagging site on Yukon River)	To detect fish that moved upstream from Yukon River gill netting locations, confirming initial post-tagging recovery.
8	Rotary Park (11 km from tagging site on Yukon River)	To detect fish that moved upstream from gill netting locations to approach the WHP. Locations further upstream were unsuitable because of river noise or braided channels.
9	Robert Service Way flats (11 km from fishing site on Yukon River)	To detect fish that terminate on the spawning grounds near Robert Service Way
10	~500 m downstream of ladder	To detect fish that approach the WHP
11	Eddy immediately downstream of the ladder	To detect fish that approach the WHP and identify which areas fish are holding in downstream of the WHP.
12	Eddy immediately downstream of the ladder	To detect fish that approach the WHP and identify which areas fish are holding in downstream of the WHP.
13	Eddy immediately downstream of the ladder	To detect fish that approach the WHP and identify which areas fish are holding in downstream of the WHP.
14	Ladder entrance	To detect fish holding at the ladder entrance (attraction efficiency)
15	Lower ladder	To detect fish in the lower ladder and to separate attraction/entrance/passage elements of ladder efficiency
16	Ladder turning basin	To detect progress between the ladder entrance and viewing chamber, and identify a potential holding location

17	Viewing chamber	To confirm detections in or adjacent to the viewing chamber
18	Downstream of the spillway	To detect fish that breached the weir or fell back after passing the ladder
19	Schwatka Lake	To confirm ladder passage success and timing
20	Wolf creek entrance	A known spawning tributary
21	Wolf creek upstream of the fish ladder	To evaluate use of the fish ladder in Wolf Creek at the Alaska Highway
22	Downstream of Lewes Dam	To detect passage at the Lewes Dam
23	Mouth of the M’Clintock River	To identify entrance to the Michie Creek - M’Clintock River system
24	M’Clintock River, downstream of Michie Creek	To identify movement direction at the confluence of the M’Clintock River and Michie Creek
25	M’Clintock River, upstream of Michie Creek	To identify movement direction at the confluence of the M’Clintock River and Michie Creek
26	Michie Creek, upstream of M’Clintock River	To identify movement direction at the confluence of the M’Clintock River and Michie Creek
27	Michie Creek, downstream of Byng Creek	To identify movement direction at the confluence of Michie and Byng creeks
28	Byng Creek	To identify movement direction at the confluence of Michie and Byng creeks
29	Michie Creek, upstream of Byng Creek	To identify movement direction at the confluence of Michie and Byng creeks
30	Michie Creek, upstream of Michie Lake	To identify movements upstream of Michie Lake

Tagging methods

Chinook Salmon were gastrically implanted with Vemco V16 acoustic transmitters. A PVC pipe was used to apply transmitters, the end of which was coated in PlastiDip to prevent injury to the viscera. A transmitter was placed in the pipe, which was inserted into the fish’s mouth and pushed to the stomach. A wooden dowel was then inserted into the pipe to release the transmitter, and the pipe and dowel were withdrawn from the stomach. Subjects were then externally tagged behind the dorsal fin with a coloured Floy tag and marked with a hole punch through the caudal fin (genetic sample). External tags and markings allowed visual identification of treatment groups to avoid double tagging with acoustic transmitters. Sex, origin (hatchery or wild), and fork length to the nearest cm were recorded. Fish were kept in the water during sampling except during acoustic tagging and length measurements.

Tagging in the Whitehorse Rapids Fishladder Viewing Chamber

Fifty Chinook Salmon were tagged at the Whitehorse Rapids Fishladder. Tagging was completed by ladder and hatchery staff. Fish were selected based on size, sex, origin, and run timing, in an attempt to mimic the characteristics of an average run (Table 2). Hatchery staff used their discretion to determine the number of acoustic tags applied daily in the viewing chamber, while also ensuring that a sufficient number of fish were kept as broodstock. Most tagged fish were of medium size (82%), given that the run consisted mostly of fish between 70 and 100 cm fork length. Large fish are rare, and were generally avoided for tagging at the viewing chamber. The majority of fish tagged were male (72%), given that there is generally a 2:1 ratio of males to females in the run. A greater portion of wild-origin fish (78%) was selected for tagging to better understand the post-passage movements of wild fish and identify any potential unknown terminal locations. Fish that were selected for tagging were dip netted from the viewing chamber. Total handling time was ~2 min and air exposure was generally <20 s. Fish were released past the upstream gate of the viewing chamber. All tagging was completed by August 26th, 2018 to ensure that fish condition, which degrades rapidly toward the end of the run, was suitable to support acoustic tagging.

Tagging downstream of the WHP

A gill net was used to capture fish downstream of the WHP approximately 9 km upstream of the confluence of the Yukon and Takhini rivers. The cable-laid gill net measured 30.5 m (100 ft) long, 3.05 m (10 ft) tall, and had a 3:1 hang ratio and 16.5-cm mesh size. The hang ratio encouraged entanglement over gilling to minimize harm and facilitate removal. Nets were set along eddy lines and were constantly watched over a 30-min soak period. Nets were checked immediately if the float line indicated a fish capture, and were otherwise checked at the end of the soak period. Fish were lifted on board and were quickly unrolled. Scissors were used to cut the net (typically 1-2 panels per fish) to decrease the amount of time spent entangled. Soak times averaged 123 s and air exposures averaged 45 s. Fish were immediately placed into a tote filled with river water and an oxygen pump set at 25 mg/L. Fish were sampled as described above (scales sampled from a subset) while a boat driver moved upstream approximately 800 m to a release site. Fish were released upstream to reduce the likelihood of recapture in the gill net. The total tagging period from entry in the gill net to release upstream was just under 8 min. No captured fish were released without transmitters (i.e., there was no bycatch).

Fish were captured and tagged from gill nets in the Takhini River to control for the potential impacts of capture-tagging-and-release on the ability for Chinook Salmon to complete their migration. Though Eiler et al. (2014) observed a 98% post-tagging recovery rate using similar methods in the lower Yukon River, there was concern that Chinook Salmon in the upper Yukon River would be less resilient to handling because of their longer migration and proximity to spawning grounds. The Takhini River is unimpounded (no physical barriers to migration), so an inability to complete their migration would be attributed to the combination of natural pre-spawn mortality and instantaneous or latent mortality from gill netting and handling. Conversely, if fish complete their migration in the Takhini River after gill net capture, tagging, and handling, then migratory outcomes at the Whitehorse Rapids Fishladder could be assumed to be unaffected by tagging. Chinook Salmon were caught in gill nets as part of the Takhini River Chinook Salmon Restoration Investigation – 2018 conducted by Fisheries and Oceans Canada (DFO), which used gill net catch composition to calibrate sonar estimates (DFO 2018). Project staff from the Canadian Wildlife Federation and Carleton University worked with DFO field technicians to implant eight Chinook Salmon caught in DFO gill nets with acoustic transmitters. The cable-laid gill net used by DFO measured 15.2-m (50 ft) long, 2.44-m (8 ft) tall, had a 3:1 hang ratio, and 13.3-19.1-cm mesh size depending on the net. Fish were sampled similarly to those tagged in the

Yukon River, though soak times were up to 30 min (actual times are unknown as nets were not monitored) and air exposure durations averaged 58 s. Additionally, we captured and tagged two fish in the Takhini River using the same fishing and sampling protocols used in the Yukon River.

Data analysis

Terminal reaches were assigned based on the receiver that fish were detected at by September 5th, 2018. However, if a fish spent 5 or more days in an upstream reach, followed by downstream movement late in the season, the upstream reach was designated as the terminal location. Single downstream movements were observed for a few fish after September 5th, but these movements likely represented downstream carcass drift and were not included in analyses. Travel times were calculated using the first detection at the downstream receiver of each reach and the first detection at the upstream receiver. Migration rates were calculated as the distance divided by the travel time. The distance between receivers was estimated by manually tracing a path along the thalweg of each reach in Google Earth. Differences in migration rates (in the Yukon River, M'Clintock River, and Michie Creek) across sex and origin of fish were assessed using separate analysis of variance tests. The relationships between migration rates (in the Yukon River, M'Clintock River, and Michie Creek) and continuous variables (length of fish, date of arrival at the viewing chamber) were assessed using separate linear regression models. Finally, the relationship between migration rates in the Yukon River, M'Clintock River, and Michie Creek were also modeled by linear regression. Survival of fish that moved back through the WHP was based off detection patterns. Fish that moved upstream were designated as alive, as were fish that were inconsistently detected at any of the downstream receivers over the span of several hours (indicating active movement in and out of a receiver's detection range). Detection efficiency was calculated as the number of fish successfully detected by a receiver divided by the number of fish known to have passed upstream of this receiver (Appendix 2). Data from scale and genetic samples were not available prior to report submission.

Results

Chinook Salmon were acoustically tagged at the ladder viewing chamber (n=50) and by gill net in the Yukon River (n=10) and Takhini River (n=10; Table 1). One transmitter inserted into a fish at the viewing chamber appears to have failed despite testing at activation, given that no signals were detected for this fish, and is not considered further. In contrast, all other fish released at the viewing chamber were detected multiple times by both the viewing chamber and Schwatka Lake (detected 95% of fish) receivers. The last upstream movement of any fish was detected on September 5th, though downstream movement occurred after this date. After August 30th, 93% of fish detected were male, despite males comprising just 68% of tagged fish overall. We suspect these detections reflect post-spawn movements and carcass drift given that males live longer after spawning (Lawrence Vano, pers. comm.).

Table 2. Origin, sex, and length of fish implanted with acoustic transmitters in 2018 for three treatments. Small Chinook Salmon were defined as having a fork length between 60 and 70 cm, medium as between 70 and 100 cm, and large as >100 cm.

Fish type	**Viewing chamber**	**Gill net - Yukon**	**Gill net - Takhini**
Large wild male	1	1	1
Medium wild male	21	2	6
Medium wild female	11	5	3
Small wild male	6	-	-
Medium hatchery male	6	2	-
Medium hatchery female	3	-	-
Small hatchery male	2	-	-
Mean fork length (cm±SD)	79±9	83±9	90±8

<u>Fish migrating beyond the WHP</u>

A total of 55 tagged Chinook Salmon migrated beyond the WHP via the ladder. Fish took an average of 2.1 hours to ascend the ladder and reach Schwatka Lake upon leaving the viewing chamber.

Most fish (80%) terminated in the Michie Creek - M’Clintock River system (Table 3). Half of these fish terminated in Michie Creek upstream of Byng Creek (50%), 41% terminated in Michie Creek between Byng Creek and the M’Clintock River, and 9% in the M’Clintock River upstream of Michie Creek (Figure 3. Three out of four fish terminating in the M’Clintock River upstream of Michie Creek were of hatchery origin. Travel rates were highest from the mouth of the M’Clintock River to the mouth of Michie Creek, and slowest from the mouth of Michie Creek to the mouth of Byng Creek (Table 4).

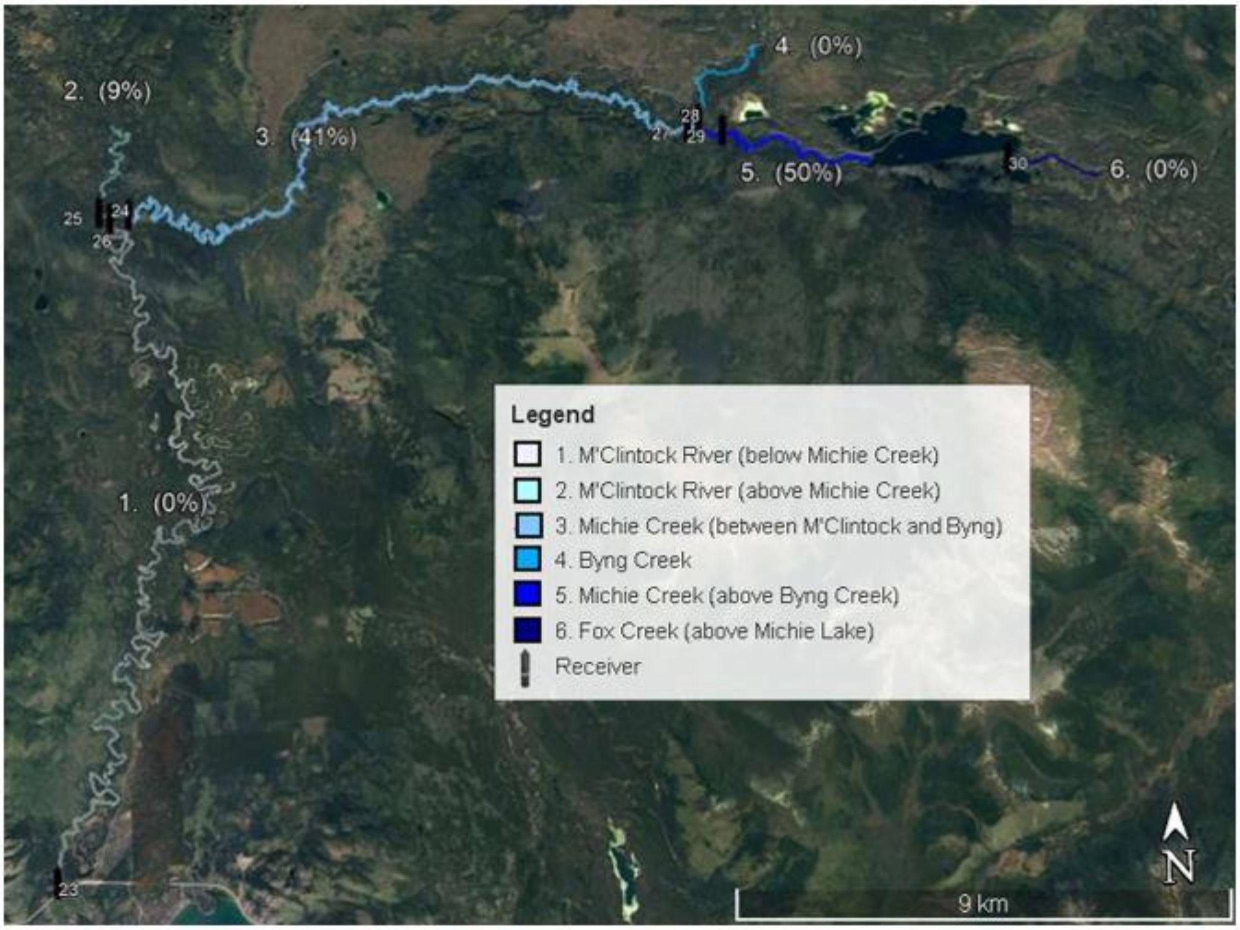

Figure 3. Terminal locations of Chinook Salmon in the Michie Creek - M'Clintock River system in 2018 (n=44 fish implanted with acoustic transmitters). Receiver numbers refer to the numbers listed in Table 2, and percentages refer to the proportion of fish terminating in this system that terminated in each reach.

Five fish terminated in Wolf Creek (9% of total that passed the WHP). These fish were all male and four were of wild origin. Four (80%) of these fish first migrated to the Lewes Dam 15.2 km upstream before returning downstream to Wolf Creek. One of these individuals was detected upstream of the fish ladder operated by the Yukon Fish and Game Association at the Alaska Highway crossing (~3 km upstream) then was detected six days later at the mouth of Wolf Creek. Another three individuals entered Wolf Creek temporarily before moving upstream into the Michie Creek - M'Clintock River system.

Five fish (9%) of both wild (n=3) and hatchery (n=2) origin also returned downstream of the WHP, presumably via the spillway. One of these fish first moved upstream to the Lewes Dam then returned to Schwatka Lake for 3.5 days before moving downstream through the WHP. Three of these fish spent at least 3.5 h in Schwatka Lake before moving downstream through the WHP, and the final fish spent 20 min in the lake before doing so. After moving downstream of the dam, one fish spent approximately seven hours in an eddy downstream of the ladder (receiver #13), whereas another spent approximately three hours near the Rotary Centennial Bridge before moving further downstream. All other fish that moved downstream through the WHP moved more quickly away from the WHP. All fish returning downstream survived and appeared on the Robert Service Way spawning grounds, though two of these fish remained there for less than three hours. Of the two fish that spent less than 3 h on these spawning grounds, both were detected briefly at the confluence of the Yukon and Takhini rivers. One of these was a hatchery fish that spent approximately 3-6 days near the industrial boat launch receiver before moving downstream (Figure 4).

Figure 4. Three receivers downstream of the WHP. Six fish terminated near receiver 9 on the Robert Service Spawning Grounds. One fish terminated near the mouth of the Takhini River after spending six days near the Industrial boat launch receiver (#7). One other fish was last detected at receiver 7.

One fish (2%) tagged on August 10th at the viewing chamber was last detected at the Lewes Dam but did not enter the M'Clintock River or Wolf Creek. This fish moved to the Lewes Dam, returned downstream to Schwatka Lake, and then moved back upstream to the Lewes Dam. It was last detected there on August 16th.

Table 3. The proportion of Chinook Salmon migrating upstream of the WHP that terminated at various locations in the Upper Yukon River (n=55) in 2018.

Fate	Count	%
Robert Service Way*	3	5%
Wolf Creek	5	9%
M'Clintock River upstream of Michie Creek	4	7%
Michie Creek between the M'Clintock River and Byng Creek	18	33%
Byng Creek	0	0%
Michie Creek upstream of Byng Creek	22	40%
Michie Creek upstream of Michie Lake	0	0%
Unknown^	1	2%
Mainstem Yukon River upstream of McIntyre Flats+*	1	2%
Takhini River at the Yukon River	1	2%

*These fish fell back down through the WHP spillway.
^Wild male; moved between the Lewes Dam and Schwatka Lake but was last detected at the Lewes Dam.
+Hatchery male; spent three to six days near the industrial boat launch but was detected at the confluence of the Yukon and Takhini rivers.

Migration rates

Fish tagged later in the season had significantly faster migration rates from Schwatka Lake to the Mouth of the M'Clintock River (n=40, R^2=0.14, P=0.01; Figure 5), within the M'Clintock River (n=43, R^2=0.23, P<0.01), and tended to be faster in Michie Creek (n=28, R^2=0.11, P=0.07) compared with fish tagged earlier in the season. There was a strong correlation between migration rates of individual fish in the Yukon River and M'Clintock River (n=40, R^2=0.25, P<0.01; Figure 6). For example, a fish that migrated quickly between Schwatka Lake and the mouth of the M'Clintock River also migrated quickly up the M'Clintock River to Michie Creek. Fish that migrated quickly up the Yukon River also tended to migrate quickly in Michie Creek but this relationship was not significant (n=28, R^2=0.12, P=0.07). Migration rates were similar for males and females in the Yukon River (n=40, F<0.01, P=0.99), and Michie Creek (n=28, F<0.01, P=0.98), though males (1.7 km/h) moved faster than females (1.3 km/h) in the M'Clintock River (n=43, F=5.68, P=0.02). No significant relationships existed between the size of fish (FL) or origin (wild vs. hatchery) and their migration rates in the Yukon River (n=40, R^2<0.01, p=0.16; n=39, F=1.24, P=0.27 respectively), M'Clintock River (n=43, R^2=0.05, P=0.87; n=42, F=0.46, P=0.50 respectively), or Michie Creek (n=28, R^2<0.01, P=0.90; n=27, F=0.91, P=0.35).

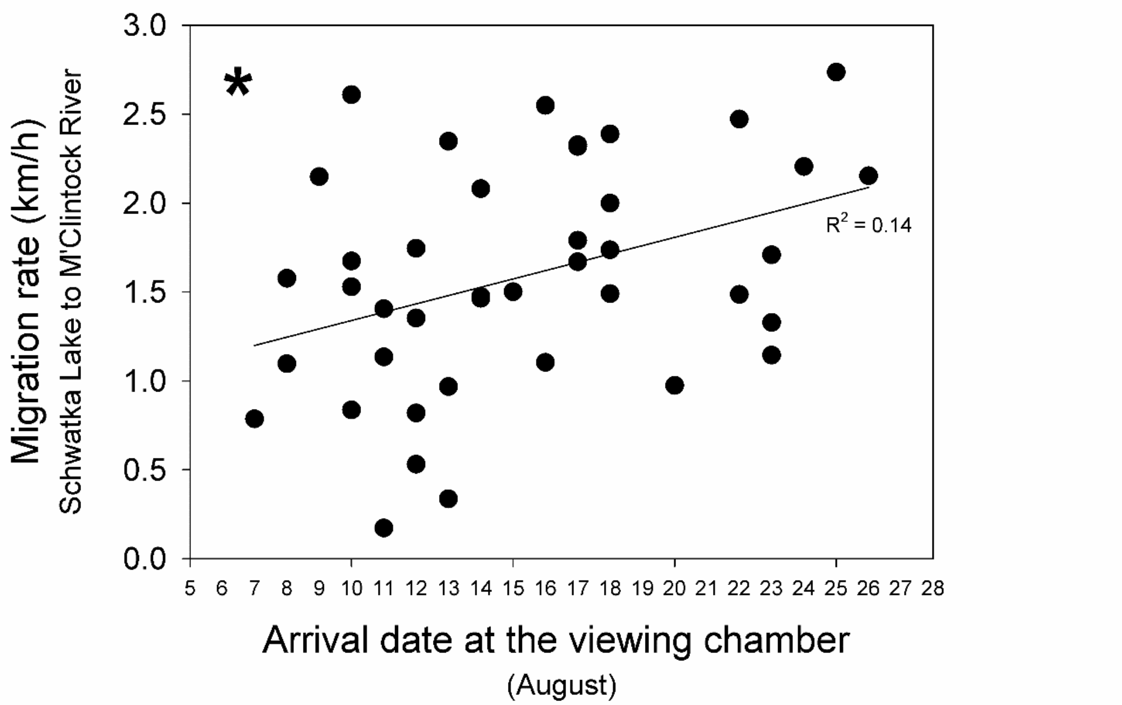

Figure 5. The migration rates of Chinook Salmon in the Yukon River upstream of the WHP, in relation to their arrival date at the viewing chamber (P=0.01).

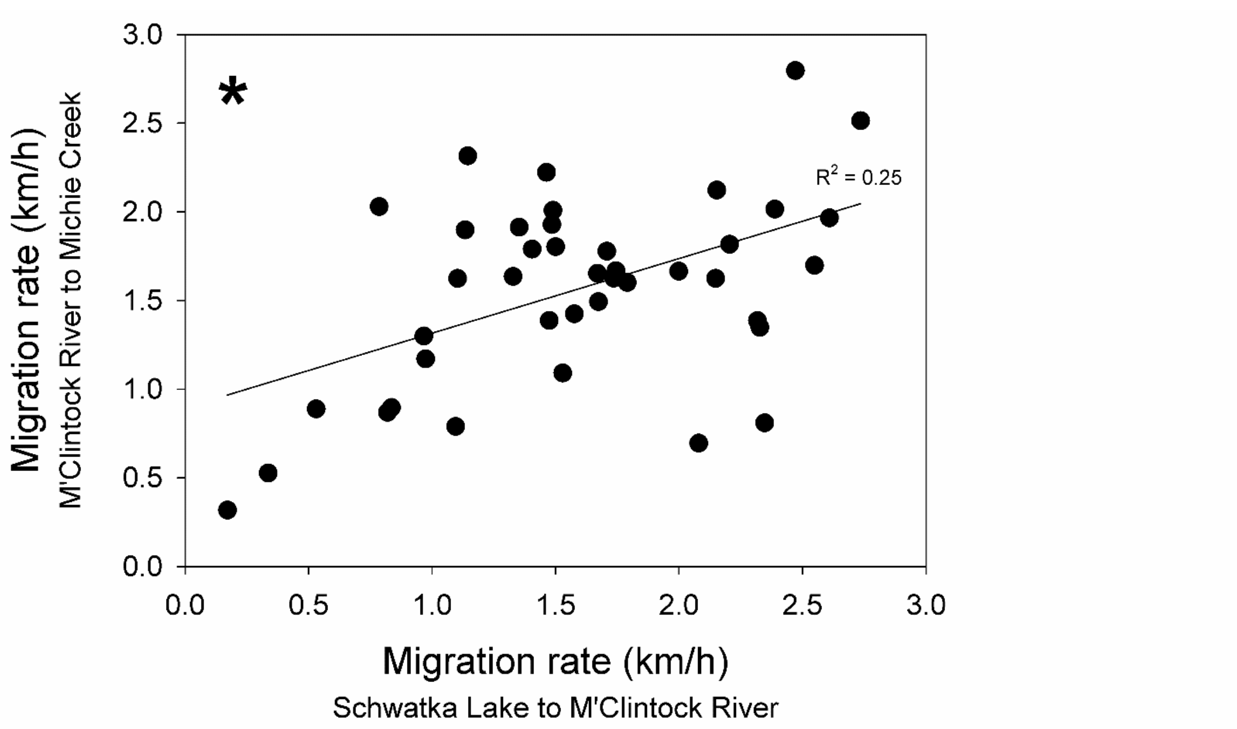

Figure 6. The relationship between Yukon River migration rates (upstream of the WHP) and M'Clintock River migration rates for individual Chinook Salmon (P<0.01).

Table 4. Travel times, distances, and migration rates for Chinook Salmon in the upper Yukon River, 2018. The average movement rate represents the minimum movement rate, had fish traveled directly between receivers, and is based on the first detection at each receiver. For the viewing chamber, the last detection was used to control for potential time spent recovering after tagging. Sample sizes differ from terminal location counts due to fish occasionally passing receivers undetected. Data reflects all fish that passed between receivers, and where applicable data for fish captured by gill net is presented in parentheses for comparison.

Tagging location	Reach	Sample size	Distance (km)	Average time (hours)	Standard deviation(hours)	Min time (hours)	Max time (hours)	Average rate (km/hr)
Viewing chamber								
	Viewing chamber to Schwatka Lake	46 (6)	0.3	2.1 (1.0)	1.4 (0.6)	0.6 (0.6)	6.8 (2.2)	<0.1 (0.3)
	Schwatka Lake to mouth of M'Clintock River	41 (4)	46.0	40.3 (19.9)	42.2 (1.7)	16.8 (18.1)	267.1 (22.1)	1.6 (2.3)
	Mouth of M'Clintock River to mouth of Michie Creek	44 (4)	32.3	24.5 (28.2)	15.5 (12.4)	11.6 (19.0)	101.7 (46.4)	1.6 (1.3)
	Mouth of Michie Creek to Byng Creek	29	21.5	80.1	30.1	44.0	175.8	0.3
Gill net (Yukon River)								
	Release site to industrial boat launch	10	6.2	25.3	25.5	4.2	71.1	0.7
	Rotary Centennial Bridge to viewing chamber	5	0.6	81.2	63.1	31.5	185.1	0.1
	Rotary Centennial Bridge to ladder entry	5	0.5	>75	~63	>25	>180	<0.1
	First step of ladder to viewing chamber	1	0.1	2.1	NA	NA	NA	<0.1
	Ladder turning basin to viewing chamber	2	0.05	0.6	NA	0.5	0.7	<0.1
Gill net (Takhini River)								
	Release site to Takhini River (km 15)	10	6.9-11.4	29.2	20.3	6.9	66.6	0.5
	Takhini River (km 15) to Alaska Hwy crossing (km 57)	10	41.7	34.1	19.4	15.4	80.3	1.5

	Alaska Hwy crossing (km 57) to Stoney Creek (km 87)	6	30.2	30.4	17.3	14.1	61.8	1.3

<u>Tagging by gillnet</u>

All fish captured by gill net in the Yukon River moved upstream after capture. The migration rates of these fish were slowest immediately after capture (0.7 km/hour). Gill netted fish had similar migration rates to fish tagged in the viewing chamber over the remainder of the migration (Table 4). All but one fish tagged in the Yukon River downstream of the WHP approached the facility (i.e., visited one or more locations upstream of the Rotary Centennial Bridge), with 66% of these fish successfully passing the WHP and arriving at spawning grounds (Table 5). Data for 5 of these fish indicated they spent an average of at least 75 hours between Rotary Centennial Bridge and the ladder entrance, and then spent an average of 6 hours or less moving through the ladder to reach the viewing chamber (Table 3). Fish that approached the WHP but did not successfully pass spent an average of 86 hours between the Rotary Centennial Bridge and the WHP on their first attempt. Two of three fish that did not pass the WHP on their first attempt moved back downstream several kilometres before returning to the WHP for a second attempt. Second attempts were considerably shorter in duration, lasting 5 and 15 hours respectively. The total searching time (defined as the time between when these fish first passed the Rotary Centennial Bridge upstream and last passed it downstream) was ~8 days for the two fish that approached the WHP twice. One fish that did not pass the WHP was detected near the viewing chamber for two hours (8:30-10:30 pm) but returned downstream. All three fish unsuccessful in passing the WHP spent at least 24 hours on the Robert Service Way spawning grounds. Two of these fish terminated at this location, the other moved downstream to the mouth of the Takhini River by August 23rd.

Table 5. The number of Chinook Salmon tagged by gill net downstream of the WHP that terminated at various locations in the Upper Yukon River in 2018 (n=10).

Fate	#
Yukon River downstream of the industrial boat launch*	1
Robert Service Way*	3
Wolf Creek	2
M'Clintock River upstream of Michie Creek	1
Michie Creek between the M'Clintock River and Byng Creek	2
Michie Creek upstream of Byng Creek	1

*Three of the fish terminating downstream of the WHP first approached the WHP (visited sites upstream of the Rotary Centennial Bridge).

All Chinook Salmon tagged following gill net capture in the Takhini River were successful in migrating >10 km upstream of the tagging site (a similar distance as the WHP is from the Yukon River tagging site). All salmon successfully migrated to the second Alaska Highway crossing of the Takhini River, located approximately 50 km upstream of the tagging site (Table 4). Most fish (60%) were last detected in the mainstem Takhini River upstream of Stoney Creek (Table 6; Figure 7). Migration rates were slowest immediately after capture, but increased beyond the first receiver, 15 km upstream of the tagging site. One fish each from both the Yukon River and Takhini River gill net tagging groups returned downstream to the confluence of the Yukon and Takhini rivers (~7 km downstream) after tagging. These fish had unusual capture conditions (one fish was bleeding moderately from the gills and the other was recaptured in another gill net after release). Both fish terminated in known spawning grounds suggesting eventual recovery from capture. One fish was last detected at the confluence of the Yukon and Takhini rivers, but first moved upstream to Takhini River km 57, back downstream to the confluence, and back upstream to km 57 where it spent a day before moving downstream to the confluence again.

Table 6. The number of Chinook Salmon tagged by gill net in the Takhini River that terminated at various locations in the Takhini River (n=10) in 2018.

Fate	#
Between Takhini River km 57 and km 87	4
Upstream of Takhini River km 87	5
Confluence of the Yukon and Takhini rivers*	1

*Male migrated upstream to Takhini River km 57, returned to the confluence of the Yukon and Takhini rivers, migrated back to km 57, remained there for one day, then returned to the confluence of the Yukon and Takhini rivers.

Discussion

Spawning sites

The distribution of terminal locations in 2018 confirms traditional ecological knowledge and other scientific studies stating that the majority of Chinook Salmon that pass upstream of Whitehorse appear to spawn throughout the Michie Creek - M'Clintock River system (Cox 1997). Cleugh and Russel (1980) observed 88% of the run entering Michie Creek, whereas in 1993 and 1994, 56% and 44% of the run counted at the ladder were counted entering Michie Creek. Our results in 2017 and 2018 suggest that 74% of fish that pass the WHP enter Michie Creek. Within Michie Creek, Cleugh and Russell (1980) observed that 100% of radio tagged fish migrating into the Michie Creek - M'Clintock River system terminated in the upper reach of Michie Creek upstream of Byng Creek. In 1998, 0% of 35 radio tagged Chinook Salmon reached Byng Creek (Matthews 1999a). Corresponding foot and aerial surveys indicated that a beaver dam (~7 km downstream of Byng Creek) was likely blocking fish migration (Matthews 1999b). Our results from 2017 and 2018 suggest that closer to 50% of fish entering the Michie Creek - M'Clintock River system terminate in Michie Creek upstream of Byng Creek.

In 2017 and 2018, 11% then 7% of tagged fish migrating upstream of the WHP terminated in the M'Clintock River upstream of Michie Creek, compared to 20% in 1998 (Matthews 1999a). Over the two years, five of nine fish terminating here were of hatchery origin, despite that no fry were released in this reach. This, along with other observations of hatchery-origin fish terminating in reaches where fry were not released suggests that release site fidelity is not as strong as previously assumed.

A substantial number of Chinook Salmon terminated in Michie Creek between Byng Creek and the M'Clintock River (36% of those that passed the WHP in 2017, and 33% in 2018). Over two years of study, no Chinook Salmon terminated in the M'Clintock River downstream of Michie Creek, indicating that this reach may not have suitable or favourable spawning habitat. Further acoustic telemetry research or visual observations are required to identify specific spawning habitats in the lower reaches of Michie Creek, and in the M'Clintock River upstream of Michie Creek.

Fish also terminated in Wolf Creek, which has been the site of fry stocking by the Whitehorse Rapids Fish Hatchery every year since its founding in 1986 (Joint Technical Committee of the Yukon River U.S./Canada Panel 2017). Five male fish (9% of all tagged fish that passed the WHP) were last detected in Wolf Creek; four of wild origin and one of hatchery origin. The return of wild fish in 2017 and 2018 suggests natural recruitment within this system, though it is unclear whether it contains a self-sustaining population or if these are only the direct descendants of returning hatchery-origin fish (i.e., acts as an ecological sink). These could also be wild fish straying from their natal stream. Most fish that terminated in Wolf Creek first moved upstream to the Lewes Dam (i.e., overshot their terminal location), a behaviour that has been observed in both 1998 and 2017 for Wolf Creek (Matthews 1999a; Sebes and Lapointe 2017). Another 5% (3) explored the creek before continuing upstream to the M'Clintock River. The number of fish terminating in Wolf Creek is consistent with our results from 2017, which showed that 8% of fish passing the ladder terminate in Wolf Creek. Previous studies based on stream counts estimated that 1.9%, 3%, and 11.5% of fish passing the WHP terminated in Wolf Creek

(Matthews 1999b). In 2018, one fish entering Wolf Creek was detected upstream of the fishway installed in Wolf Creek at the Alaska Highway, approximately 2.5 km upstream of the mouth of the creek. It is possible that other tagged fish used this fishway without being detected, given that the detection range of this receiver was very low (~1 m) due to shallow depths and acoustic conditions within the creek. Continued deployment of receivers in Wolf Creek will provide greater insight into the proportion of wild- and hatchery-origin fish that terminates in Wolf Creek and whether use of the small fish ladder there is common.

Five fish (all males) that passed the WHP returned downstream of the WHP, presumably through the spillway. Fallback through spillways was most common in Columbia-Snake River Chinook Salmon that had the longest passage duration through the hydrosystem (Keefer et al. 2004). One of the Chinook Salmon that fell back through the WHP spillway took 17 hours to leave the ladder after tagging (3 times longer than the average) but other Chinook Salmon had even longer transit times to Schwatka Lake and remained upstream of the WHP. Migrating fish are rheotactic (face oncoming current) and can be attracted to the water passing through a spillway upon entering reservoirs (discussed in Boggs et al. 2004); however, most fallback events that we observed occurred after fish had moved upstream away from the spillway. Fallback may also occur for fish that ‘over shoot’ downstream spawning grounds (Ricker 1972). In the Columbia River basin, overshoot averaged 15% for Chinook Salmon populations, and typically lasted less than 5 days (Keefer et al., 2008).

Regardless of the mechanism, fallback through spillways can decrease survival to spawning grounds in Chinook Salmon and lead to injuries such as bruising (Wagner and Hilsen 1992; Bjornn et al. 1998). All Yukon River fish that moved back through the spillway appeared to survive the event based on their detection patterns downstream of the WHP, including detection on the Robert Service Way spawning grounds receiver located beyond the main river channel. It is unclear whether these fish suffered injuries, or whether they spawned successfully at this site, though two of these fish spent less than three hours there suggesting that they did not spawn at this location. Spawning success of fish terminating downstream of the WHP appears variable based on carcass surveys in 2018. These carcasses likely included fish that did not approach the WHP, fish that approached the WHP and did not pass, and fish that passed then fell back. Of 86 carcasses found downstream of the WHP, 80 were female, and most females were wild (80%). Of these, 30% had completely spawned, 69% had partially spawned, and 1% experienced complete pre-spawn mortality (Twardek and Lapointe, 2018). A fecundity model based on broodstock egg counts at the Whitehorse Rapids Hatchery in 2017 and 2018 estimates that fish found downstream of the WHP exuded ~77% of their eggs (full details in Twardek and Lapointe, 2018). One fish returning downstream of the WHP spent 6 days near the industrial boat launch (Figure 6). It is unclear whether this fish spawned in this area, given that no known spawning areas exist in this location; however, the amount of time spent in this reach may be indicative of spawning behaviour. Compared to 2018 (9%), fallback was lower in 2017 (4%) and the two fish that did so first traveled to the Lewes Dam 30.5 km upstream. In 1998, 11% of fish fell back downstream of the WHP, all of which terminated on the Robert Service Way spawning grounds (Matthews 1999a).

One fish in 2018 was not detected again after passing the Lewes Dam. This fish moved upstream to the Lewes Dam, returned to Schwatka Lake, then moved back upstream to the Lewes Dam on

August 16th. It is unclear whether this fish terminated upstream or downstream of the Lewes Dam, but receiver data from Environment Yukon will inform whether this fish moved beyond Marsh Lake (data available in Spring 2019). In 2017, a single fish also terminated outside of our acoustic array. This fish was last detected upstream of the Lewes Dam on August 21st and was detected on an Environment Yukon acoustic receiver located at the entrance to the Tagish River. This fish was not detected beyond this receiver, suggesting that it terminated in Marsh Lake or one of its tributaries. In 1998, one radio tagged Chinook Salmon (3% of the total) moved upstream of the Tagish Bridge but eventually terminated in Michie Creek (Matthews 1999a). It is possible that these fish are spawning in unknown locations or strayed beyond their natal spawning grounds and died without spawning.

Gill netting synopsis

Gill netting was an effective method of capturing Chinook Salmon in both the Upper Yukon River and Takhini River. Fish tagged in the Takhini River were included in this project to assess the effects of gill netting on Chinook Salmon movement in an unimpounded system following an uncharacteristically long (~3000 km) migration. All fish tagged in the Takhini River migrated upstream at least 50 km, indicating long-term recovery from capture and tagging. Two fish (one from each river) fell back to the Takhini River where it meets the Yukon River (7-9 km) immediately after capture; however, each then resumed normal upstream migration behaviour. Migration rates of fish captured by gill net in the Yukon River were comparable to those of fish tagged in the viewing chamber for the sections of river upstream of the WHP (Table 2) indicating recovery of migratory ability soon after capture and before fish approached the WHP. Our results from 2017 and 2018 provide further support that fish captured by gill net and implanted with transmitters resume normal behaviour, provided that care is taken to minimize capture and handling effects (Bernard et al. 1999; Eiler et al. 2014; Sebes and Lapointe 2017).

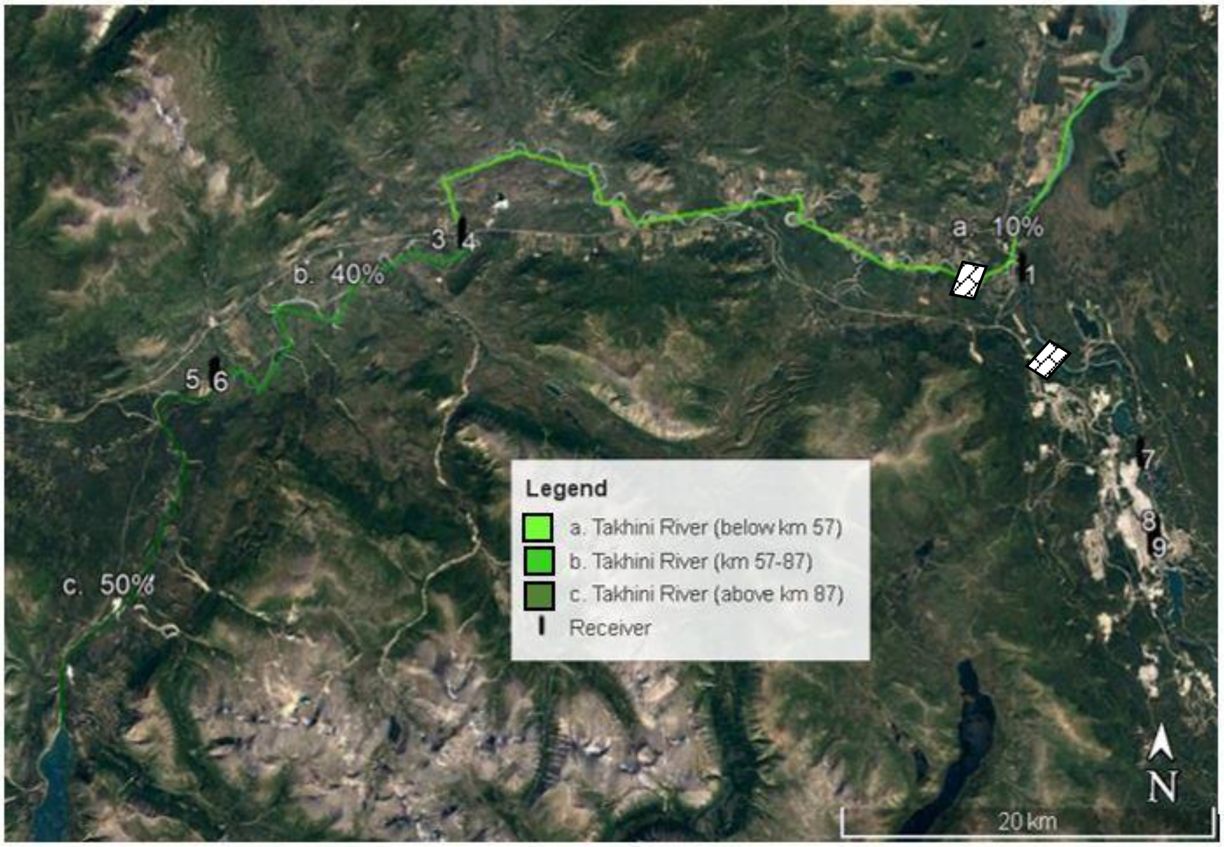

Figure 7. Terminal locations of Chinook Salmon implanted with acoustic transmitters in the Takhini River system in 2018 (n=10). Receiver numbers refer to the numbers listed in Table 2, and percentages refer to the proportion of fish terminating in the system that terminated in each reach. Approximate gill netting locations are marked by the white squares.

Movement through the ladder

All ten fish captured by gill net in the Yukon River migrated upstream following capture. Nine of these fish (90%) ventured beyond the Rotary Centennial Bridge and visited locations downstream of the WHP including receivers 11, 12, 13, and 14 immediately downstream of the WHP (Figure 2). Fish took an average of 81 h to travel to the viewing chamber once they passed the Rotary Centennial Bridge. Detections at receivers within the ladder suggest short transit times to reach the viewing chamber after entering the ladder. Three fish were detected by receivers within the ladder downstream of the viewing chamber (first step or turning basin). One fish moved from the first step to the viewing chamber in 2 h, whereas the other 2 fish moved from the ladder turning basin to the viewing chamber in <45 min. Fish took an average of 81 hours to travel from the Rotary Centennial Bridge to the viewing chamber, and were detected for an average of 75 hours between this bridge and the eddies downstream of the ladder entrance. This is a minimum estimate of time spent below the ladder given that fish holding at the ladder entrance were infrequently detected at the ladder entrance receiver. This indicates that most of the time spent traveling from the Rotary Centennial Bridge to the viewing chamber is outside of the ladder. It is unclear exactly how long fish were delayed at the viewing chamber because detection efficiency was ~100% both within and upstream of the viewing chamber. One fish reached the viewing chamber at 8:30 pm on August 23rd and remained for two hours before returning downstream. These results should be interpreted with caution, given that sample sizes were small in association with a pilot study.

The average time for fish to enter Schwatka Lake after leaving the vicinity of the viewing chamber was 2.1 hours (Table 2). Fish generally spent a few hours near the viewing chamber after being released there, likely recovering from handling. Four fish remained in the ladder for an extended period of time ranging from 11 hours to over three days. The energetic costs and potential stress of passage did not prevent most fish (at least 89%, depending on reasons for fallback) from completing their migration, though ultimate spawning success was not evaluated.

Range testing and detection efficiency of receivers (Appendices 1 and 2) indicate weak performance of receivers 11-14 downstream of the WHP due to poor acoustic conditions where the river is highly turbulent. This means that several fish could (and did) enter these locations without being detected. The ladder entrance receiver functioned particularly poorly with only 19% of range test transmissions 1 m from the receiver successfully detected.

Three fish tagged downstream of the WHP failed to pass the facility despite spending an average of 86 hours at various locations between the Rotary Centennial Bridge and the WHP. Two of these fish then moved downstream at least 6 km and were detected by the industrial boat launch receiver. Both fish made a second attempt to pass the WHP, one of which arrived at the viewing chamber during this attempt before turning back downstream. All three gill netted fish that approached but did not pass the WHP spent at least 24 hours on the Robert Service Way spawning grounds. This behaviour could reflect exploration upstream of spawning sites (Keefer et al. 2008) or failure to enter and pass the WHP to reach intended upstream spawning sites. Bett et al. (2017) reviewed the causes of straying in salmon populations, including delays/failed passage downstream from dams, but concluded that there was no literature available to assess this potential relationship. They hypothesized that disrupted flow patterns at dams can make olfactory navigation difficult, and that fish may track the conspecific cues of salmon aggregations downstream of a dam (Bett and Hinch 2015; Quinn et al. 1989). The final fish traveled directly from the release site to the spawning grounds by Robert Service Way. Results in 2018 suggest higher passage efficiency (66%) than similar tagging in 2017 (0%). In 2017, 6 fish tagged downstream of the WHP (60%) reached the ladder entrance, though just one reached the viewing chamber and it did not pass further. It is also possible that the four other fish captured by gill net in 2017 also approached the WHP but were not detected, given that fewer receivers were deployed downstream of the WHP in 2017. There are multiple reasons why these differences may be observed between years including sampling bias (small sample sizes each year) and environmental differences (e.g. flow); however, both years consisted of pilot studies with small sample sizes and results should be interpreted with caution.

Conclusions

Acoustic tagging of Chinook Salmon in the Upper Yukon River in 2018 highlighted the importance of multiple spawning areas within Michie Creek, consistent with our findings in

2017. Our work over two years has also demonstrated that a substantial portion of the run terminates in Wolf Creek, including fish of wild origin. In the final two years of this project, there will be an emphasis on increasing the spatial resolution of detections in Michie Creek, estimating the proportion of wild returns in Wolf Creek, and continuing to search for populations outside of known spawning sites. Data from Environment Yukon's acoustic array in the Southern Lakes and further mobile tracking in 2019 will help determine whether one fish in 2018 terminated in unknown spawning areas. Gill net studies were a success in 2018, and ladder attraction and passage efficiency will be assessed with larger sample sizes in 2019 and 2020. Further consideration should be given to the Robert Service Way spawning grounds, given the high proportion of fish that terminated in this area.

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Appendices

Appendix 1. Detection rate of a range test tag placed near each receiver for a fixed period of time.

Receiver #	Location	Rationale	Distance (m)	Detection rate
1	Confluence of the Yukon and Takhini rivers	Directly across from receiver on opposite bank	150	24%
2	Takhini “Dam”	Directly across from receiver on opposite bank	87	74%
7	Industrial boat launch	Upstream of receiver on opposite bank	280	0%
8	Rotary Park	Directly across from receiver on opposite bank	150	0
10	~500m downstream of ladder	Directly across from receiver on opposite bank	71	7%
11	Turbine eddy	Beside receiver	1	70%
11	Turbine eddy	End of the eddy	5	0%
12	Weir eddy	End of the eddy	30	1%
12	Weir eddy	End of the eddy in main channel	35	0%
13	Platform eddy	End of the eddy in main channel	50	0%
14	Ladder entrance	Beside receiver	2	26%, 19%
14	Ladder entrance	Beyond retaining wall within eddy 10m	5	0%
14	Ladder entrance	Beyond retaining wall within eddy	10	0%
14	Ladder entrance	Inside ladder, beyond entry	3	0%
14	Lower ladder (first step)	First step	1	69%
15	Lower ladder (first step)	First step below, first step above	3	0%, 0%
16	Ladder turning basin	Lower end of basin	2	69%
16	Ladder turning basin	Upper end of basi	3	39%
16	Ladder turning basin	First step below, first step above	5	0%
17	Viewing chamber	At lower end of the chamber	5	70%
17	Viewing chamber	First step below	7	44%
17	Viewing chamber	Second step below	10	0%
18	Spillway	Near receiver	3	0%
18	Spillway	Lower end of eddy	30	0%
21	Upper Wolf Creek	Near receiver	1	~25%
21	Upper Wolf Creek	Near receiver	1.5	~25%

21	Upper Wolf Creek	Near receiver	2	~25%
21	Upper Wolf Creek	Downstream run	10	0%
21	Upper Wolf Creek	Downstream run	12	0%
22	Lewes Dam	Upstream of receiver, just downstream of the Lewes Dam	450	48%
23	Mouth of the M'Clintock River	Directly across from receiver on opposite bank	55	75%
30	Michie Creek, upstream of Michie Lake	Same bank	5	42%

Appendix 2. The detection efficiency of fish passing each receiver based on subsequent detection at upstream receiver sites. Fish were counted as having been detected at a receiver if one or more transmissions were detected there, followed by one or more detections at any receivers upstream of that site.

Receiver	Detection efficiency (%)
Industrial Boat Launch	100% (n=10)
Rotary Park	75% (n=12)
Rotary Centennial Bridge	70% (n=10)
Turbine eddy	71% (n=14)*
Platform eddy	22% (n=9)*
Weir eddy	11% (n=9)*
Spillway	0% (n=4)
Ladder entrance	43% (n=7)
Ladder first step	14% (n=1)
Ladder turning basin	29% (n=7)
Viewing chamber	100% (n=55)
Schwatka Lake	95% (n=55)
Lewes Dam	100% (n=46)
Mouth of M'Clintock River	100% (n=40)
Michie Creek at the M'Clintock River	100% (n=28)
Michie Creek at Byng Creek	100% (n=21)

*Fish that passed an eddy without detection may not have entered that eddy while travelling upstream.

Appendix 3. The terminal locations of each Chinook Salmon tagged with an acoustic transmitter in 2018. Fish were captured and tagged at the Whitehorse Rapids Fishladder viewing chamber (n=50), by gill net downstream of the WHP in the Yukon River (n=10), or by gill net in the Takhini River (n=10). For each fish, the acoustic ID#, date, sex, length (FL; cm), and origin are listed.

Tagging Location	ID #	Date	Sex	FL; cm	Origin	Terminal Location
Whitehorse Rapids Fishladder viewing chamber						
	24438	22/08/2018	m	62	hatchery	Yukon River upstream of McIntyre flats
	24463	09/08/2018	m	81	wild	*Last detected by Lewes Dam*
	24394	18/08/2018	m	89	wild	Michie Creek upstream of Byng Creek
	24398	18/08/2018	f	84	wild	Michie Creek upstream of Byng Creek
	24412	10/08/2018	f	93	wild	Michie Creek upstream of Byng Creek
	24413	13/08/2018	m	80	wild	Michie Creek upstream of Byng Creek
	24417	12/08/2018	m	76	wild	Michie Creek upstream of Byng Creek
	24434	23/08/2018	m	63	wild	Michie Creek upstream of Byng Creek
	24435	22/08/2018	m	92	wild	Michie Creek upstream of Byng Creek
	24437	23/08/2018	m	65	wild	Michie Creek upstream of Byng Creek
	24440	24/08/2018	f	88	wild	Michie Creek upstream of Byng Creek
	24446	13/08/2018	f	89	hatchery	Michie Creek upstream of Byng Creek
	24449	16/08/2018	m	83	wild	Michie Creek upstream of Byng Creek
	24450	14/08/2018	m	81	wild	Michie Creek upstream of Byng Creek
	24452	14/08/2018	m	82	wild	Michie Creek upstream of Byng Creek
	24456	17/08/2018	m	83	wild	Michie Creek upstream of Byng Creek
	24459	15/08/2018	m	82	wild	Michie Creek upstream of Byng Creek
	24460	09/08/2018	m	73	wild	Michie Creek upstream of Byng Creek
	24466	10/08/2018	m	63	wild	Michie Creek upstream of Byng Creek
	24475	7/08/2018	m	88	wild	Michie Creek upstream of Byng Creek
	24479	18/08/2018	f	86	hatchery	Michie Creek upstream of Byng Creek
	24491	10/08/2018	m	70	hatchery	Michie Creek upstream of Byng Creek
	24492	10/08/2018	f	84	wild	Michie Creek upstream of Byng Creek
	24397	20/08/2018	f	80	hatchery	Michie Creek upstream of M'Clintock River
	24416	12/08/2018	m	78	wild	Michie Creek upstream of M'Clintock River
	24420	11/08/2018	f	79	wild	Michie Creek upstream of M'Clintock River
	24429	23/08/2018	m	64	hatchery	Michie Creek upstream of M'Clintock River
	24432	22/08/2018	m	71	wild	Michie Creek upstream of M'Clintock River
	24433	25/08/2018	f	82	wild	Michie Creek upstream of M'Clintock River
	24441	22/08/2018	f	81	wild	Michie Creek upstream of M'Clintock River

24458	13/08/2018	f	86	wild	Michie Creek upstream of M'Clintock River
24472	08/08/2018	f	88	wild	Michie Creek upstream of M'Clintock River
24410	11/08/2018	m	81	hatchery	Michie Creek downstream of Byng Creek
24414	12/08/2018	m	70	wild	Michie Creek downstream of Byng Creek
24427	26/08/2018	m	87	wild	Michie Creek downstream of Byng Creek
24431	25/08/2018	m	73	unknown	Michie Creek downstream of Byng Creek
24455	17/08/2018	m	82	wild	Michie Creek downstream of Byng Creek
24457	18/08/2018	m	87	wild	Michie Creek downstream of Byng Creek
24469	08/08/2018	f	78	wild	Michie Creek downstream of Byng Creek
24411	12/08/2018	m	63	wild	Robert Service Way (Yukon River)
24428	25/08/2018	m	71	wild	Downstream of Yukon-Takhini Confluence
24430	26/08/2018	m	73	wild	Robert Service Way (Yukon River)
24436	25/08/2018	m	82	hatchery	Robert Service Way (Yukon River)
24419	11/08/2018	m	91	hatchery	M'Clintock River upstream of Michie Creek
24447	13/08/2018	m	85	hatchery	M'Clintock River upstream of Michie Creek
24489	12/08/2018	f	82	wild	M'Clintock River upstream of Michie Creek
24453	17/08/2018	m	71	wild	Tag malfunction
24392	20/08/2018	m	68	wild	Wolf Creek
24445	18/08/2018	m	100	wild	Wolf Creek
24476	7/08/2018	m	66	wild	Wolf Creek
Gill net downstream of the WHP in the Yukon River					
24467	13/08/2018	m	83	wild	Michie Creek upstream of M'Clintock River
24470	15/08/2018	m	103	wild	Michie Creek upstream of M'Clintock River
24493	10/08/2018	m	93	hatchery	M'Clintock River upstream of Michie Creek
24423	09/08/2018	m	75	wild	Wolf Creek
24488	14/08/2018	m	74	hatchery	Wolf Creek
24471	14/08/2018	f	84	wild	Michie Creek upstream of Byng Creek
24426	09/08/2018	f	79	wild	Robert Service Way (Yukon River)
24391	11/08/2018	f	87	wild	Yukon River downstream of the industrial boat launch
24461	14/08/2018	f	80	wild	Robert Service Way (Yukon River)
24468	15/08/2018	f	88	wild	Robert Service Way (Yukon River)
Gill net in the Takhini River					
24481	13/08/2018	f	95	wild	Upstream of Takhini River km 87
24484	13/08/2018	m	105	wild	Between Takhini River km 57 and km 87
24487	13/08/2018	m	88	wild	Between Takhini River km 57 and km 87

24480	14/08/2018	f	91	wild	Upstream of Takhini River km 87
24483	14/08/2018	m	80	wild	Upstream of Takhini River km 87
24486	14/08/2018	f	84	wild	Between Takhini River km 57 and km 87
24482	15/08/2018	m	89	wild	Upstream of Takhini River km 87
24485	15/08/2018	m	91	wild	Yukon-Takhini River Confluence
24404	16/08/2018	m	96	wild	Between Takhini River km 57 and km 87
24478	16/08/2018	m	85	wild	Upstream of Takhini River km 87