January 2015

BERNARD HARBOUR PROJECT

Arctic Char Run Baseline Report - 2014 Results

Submitted to:
Sabina Gold & Silver Corp.

#202-930 West First Street
North Vancouver, BC
V7P 3N4

Report Number: 14-1373-0004

REPORT

Golder Associates

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1.0 INTRODUCTION

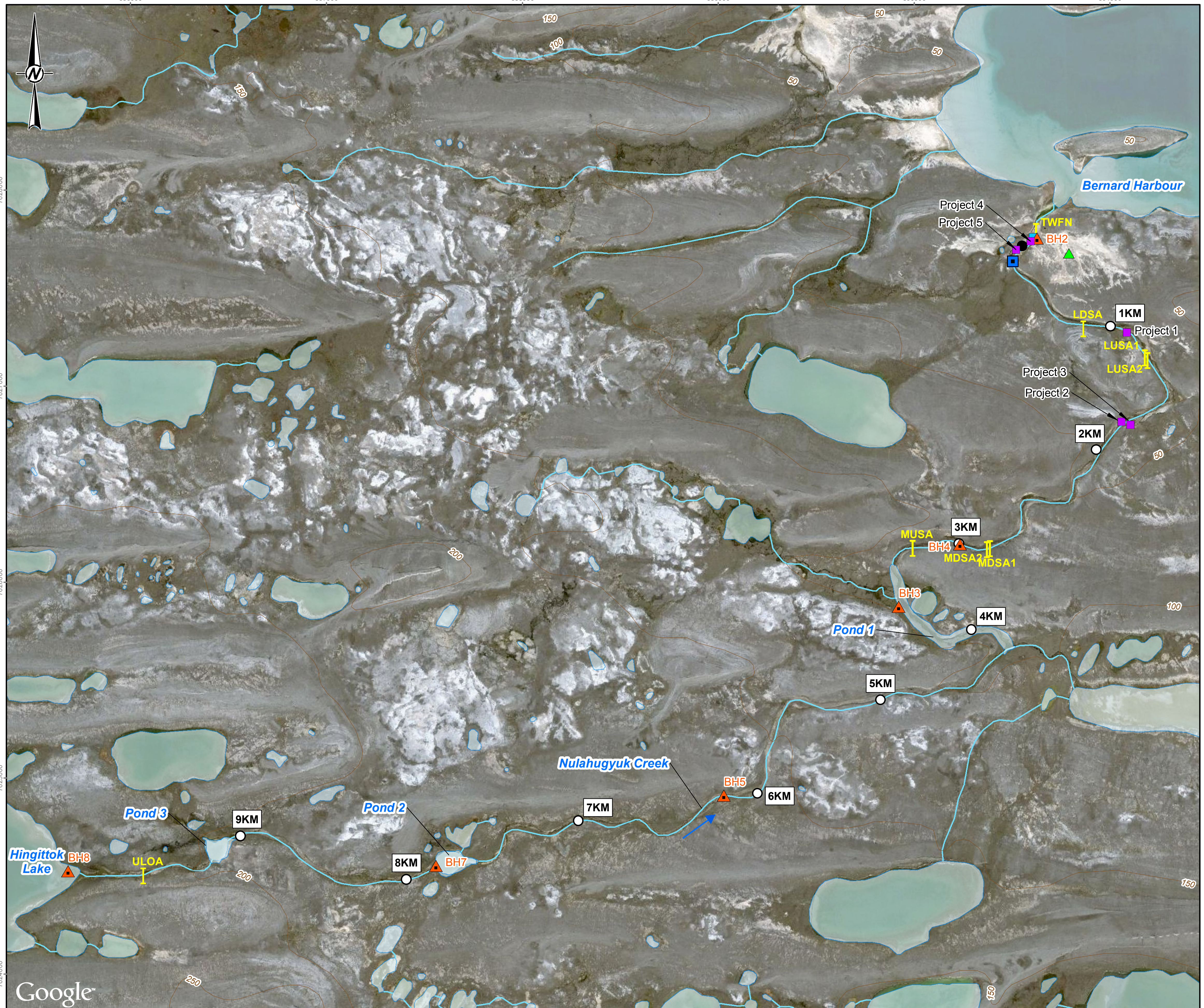
1.1 Background and Scope

The Hingittok Lake-Nulahugyuk Creek (HLNC) system at Nulahugyuk (Bernard Harbour), Nunavut (Figure 1) was once the site of a traditional domestic fishery for Arctic Char (*Salvelinus alpinus*; char). Records from the Canadian Arctic Expedition indicate that HLNC supported a large migration of anadromous char in the early 1900s (Jenness and Jenness 1991). Local knowledge, however, suggests that the number of migrating char has declined markedly over the past 30 to 40 years.

In response to local concerns, members of the Kugluktuk Hunters and Trappers Organization (HTO), and Golder Associates Ltd. (Golder) biologists, performed a preliminary assessment of the size and timing of the char run, and habitat conditions for fish passage during 2004 and 2005 (ANL and Golder 2005; Golder and ANL 2007), and again in 2012 (Golder 2013). Although the previous work reflected only a short window (i.e., less than 2 weeks) within an assumed longer migratory window per study year, the results suggested a decline in the size of the char run. In addition, the timing of the upstream char migration appeared to have shifted to earlier in the summer. It was hypothesized that the char run was affected by lower flows and poor channel conditions in mid to late summer when char generally undertake a return migration from the sea.

During the earlier investigations (ANL and Golder 2005; Golder and ANL 2007; Golder 2013) site-specific blockages (e.g., channel crossover locations) at several sites which appeared problematic for migrating adult char were identified. Upstream movements by char were particularly restricted during low discharge periods. As a possible corrective measure, it was proposed that low-flow channels (i.e., unobstructed flow paths with sufficient depths within the larger channel) be constructed to facilitate fish passage during low discharge periods in a season (e.g., late July to extend the migration window). The low-flow channels would be particularly beneficial during drier than normal years.

In 2012, a stream enhancement and community stewardship project aimed at understanding and enhancing the use of the HLNC system by char was successfully undertaken. Five low-flow channels were constructed with guidance from local Traditional Knowledge to assess the feasibility of applying this approach on a wider scale to increase fish production at HLNC (Figure 1). The project occurred through collaboration between local partners (i.e., students and residents of Kugluktuk, Nunavut, the Kugluktuk HTO, and the Nunavut Department of Environment), the University of Alberta, and Golder Associates Ltd. (Golder 2013).



LEGEND

ELEVATION CONTOUR

WATERCOURSE

WATERBODY

CAMP

CHANNEL MANIPULATION PROJECT 2012

FYKE NET

KILOMETRE MARKER

STAFF GAUGE

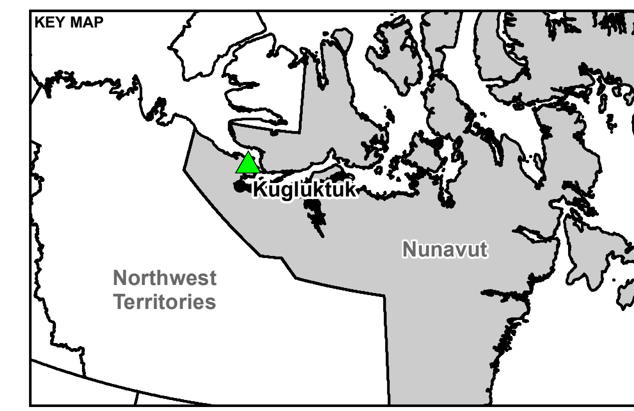
TEMPERATURE LOGGER

WATER VELOCITY STATION

PIT TAG ARRAY

LDSA - LOWER DOWNSTREAM ARRAY
MUSA - MIDDLE UPSTREAM ARRAY
ULOA - UPPER LAKE OUTLET ARRAY
LUSA1 - LOWER UPSTREAM ARRAY 1
LUSA2 - LOWER UPSTREAM ARRAY 2
MDSA1 - MIDDLE DOWNSTREAM ARRAY 1
MDSA2 - MIDDLE DOWNSTREAM ARRAY 2
TWFN - TWO WAY FYKE NET (ARRAY)

KEY MAP



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NOTES

1. THE LOW-FLOW CHANNELS (CHANNEL MANIPULATION PROJECTS) WERE CONSTRUCTED IN 2012 (GOLDER 2013)
2. FOR TEMPERATURE LOGGERS LABELS, BH=BERNARD HARBOUR

REFERENCE

GOOGLE EARTH IMAGERY: © 2014 DIGITAL GLOBE
CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.
NAD 83 UTM ZONE 11N

CLIENT
SABINA GOLD & SILVER CORP.

PROJECT
BERNARD HARBOUR PROJECT

TITLE
LOCATION OF BASELINE PROGRAM
BERNARD HARBOUR, 2014

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-01-26
PREPARED	LMR
DESIGN	KD
REVIEW	JPO
APPROVED	CES

PROJECT No.	PHASE	Rev.	FIGURE
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Path: G:\2014\1373\14-1373-0004 Sabina Gold and Silver\Figures\FIG 1 Bernard Harbour Gen Location - IMAGERY.mxd

In 2014, Golder was contracted by Sabina Gold & Silver Corp. (Sabina) to design and undertake a comprehensive study of the migratory char population at HLNC. The focus of the work was to provide rigorous baseline data in support of a potential Offsetting Plan for Sabina's Back River Project (DFO 2013). The baseline information would provide a reference for future quantification of the potential benefits of using "low-flow channel" methods. Specifically, the 2014 field study was designed to address four general objectives:

1) Monitor the timing and size of the annual migratory char run in Nulahugyuk Creek using two-way fyke net traps installed for the duration of the migration period; data was collected for the three migratory phases, including:

    a. the downstream (seaward) outmigration of adults (assumed to be spawners from the previous fall), which were predicted to be the first migratory fish captured in the trap during the spring freshet;

    b. the adult upstream (lakebound) migration (consisting of char that would spawn in the year following the sampling year); and

    c. the downstream (seaward) outmigration of juveniles, which were assumed to be 4 or 5 years old and migrating later in the summer as occurred in 2012 (Golder 2013).

2) Monitor rates of movement and successful upstream passage to Hingittok Lake using Passive Integrated Transponder (PIT) tag methods (e.g., Puffer et al. 2014); the movement data complement data on the size and timing of the run by providing a direct measurement of the effects of migrations conditions on char in the creek for the study year under examination.

3) Assess the feasibility of using low-flow channels to improve upstream passage for fish; this objective is a direct follow-up of work initiated in 2012 and includes:

    a. Assessments of the structural integrity and performance of low-flow channels previously constructed; and

    b. Scoping-level assessments of the number of problem locations and total length of the creek where low-flow channels could be constructed to effectively increase fish production.

4) Assess fish habitat and the relative abundance of fish species in Hingittok Lake using standard inventory methods to gain some understanding of the carrying capacity of the lake for Arctic Char as it relates to enhancement efforts being made to improve fish access in the creek.

In addition to the objectives outlined above, the 2014 work was intended to complement and integrate objectives of the HTO. This was to be achieved by incorporating students, organizations, and community members and by designing a study that fosters education, stewardship and community involvement in conservation initiatives. Past studies (e.g., Stern et al. 2008) have demonstrated a lasting positive change in environmental attitude, action, and knowledge following environmental education programs, such as the one implemented at Bernard Harbour.

1.2 Study Area

The HLNC drainage is located approximately 100 kilometres (km) directly north of the hamlet of Kugluktuk, Nunavut, along the south coast of Dolphin and Union Strait (Figure 1). The project site is about 4.5 hours (h) travel time by boat from the community. Nulahugyuk Creek, the outflow from Hingittok Lake (882 hectares [ha] in size), flows north for approximately 10 km before entering the sea at 68°44'52"N, 114°45'27"W, approximately 5 km south east of the abandoned DEW-Line site at Bernard Harbour. The contributing basin area at the mouth of creek is approximately 125 square kilometres (km^2) in area, and may be characterized by limited groundwater derived flows punctuated by precipitation-driven peak flows. It is expected that most of the precipitation falls as rain during the open water season. Based on 1981 to 2010 Canadian climate normal station data for Kugluktuk, mean total precipitation is approximately 247 millimetres (mm), of which 144 mm falls during June, July, August, and September (see http://climate.weather.gc.ca). Daily maximum temperatures, on average, are above zero for June through September, peaking in July at 15.6 degrees Celsius (°C), and below zero for the remaining months of the year.

2.0 METHODS

The field study began on June 13, 2014 and was strategically planned to allow the field team to capture the first char moving through the HLNC system once the ice had melted enough to allow passage for fish. The commencement date was selected based on data collected during 2012 (Golder 2013), anecdotal information from the Canadian Arctic Expedition in 1916 (Jenness and Jenness 1991), as well as information from Kugluktuk residents. Field personnel remained on site until July 17. The field crew comprised fisheries biologists and technicians from Golder (Ryan Popowich, Davin Swift, Kent Nuspl, and Ashley Eckford), camp monitors and assistants from the Kugluktuk HTO (Larry Adjun, Jonathon Niptanatiak, Johnny Nivingalok, and Adrian Kadlack) and a graduate student from the University of Alberta who volunteered to assist with field work (Matthew Gilbert).

2.1 Fish Capture and Sampling

2.1.1 Fyke Net Trap

Fish were captured in Nulahugyuk Creek using a two-way fyke net trap installed on June 16, operating continuously until July 17, 2014 (Figure 2; Appendix A, Photos 1 to 3). The fyke net was installed 0.3 km upstream from the mouth of the creek in a shallow run area (an R3 class habitat as defined in Appendix B, with a mean width of about 18 metres (m). The wings of the fyke net were installed across the creek such that all fish moving upstream or downstream would be directed into the 1.8 m by 1.9 m opening. Once they had entered the trap they were directed through a series of five funnels with openings ranging between 0.85 m by 0.85 m at the widest end and 0.19 m by 0.29 m at the narrow end. Captured char were directed for a total distance of about 6.4 m prior entering a holding basket at the base of the net (Appendix A, Photos 4 to 6). The trap was checked several times daily and fish were removed and processed accordingly. The frequency of checks increased with water temperature and capture success to reduce crowding and potential stress to fish.

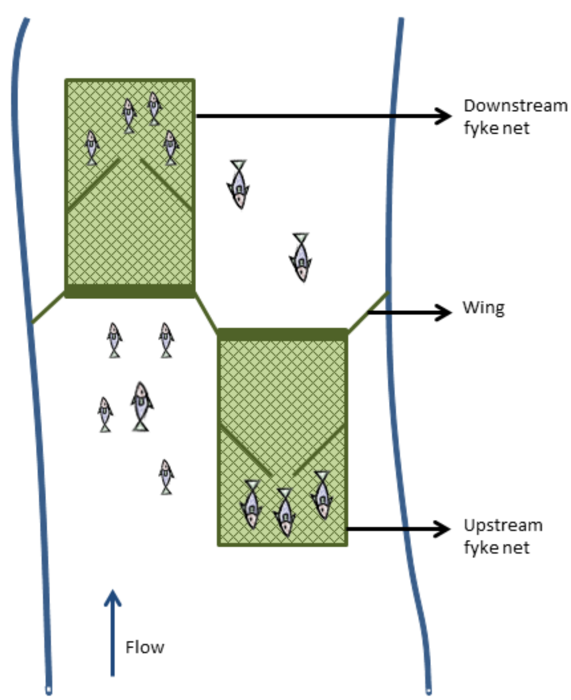


Figure 2: Schematic Showing Two-Way Fyke Net Trap Configuration at Nulahugyuk Creek

2.1.2 Index Gill Nets and Angling

Twenty nine gill net sets (short-duration sets) and two angling events were used to provide information on fish species composition and abundance in Hingittok Lake. Gill net mesh size and configuration were based on Broad Scale Monitoring (BSM) techniques for North American (NA1) and Ontario small mesh (ON2) gill nets (Sandstrom et. al. 2013). A series of bottom-set gill nets were deployed over four days in July 2014 (July 8, 11, 13, and 14). Large mesh nets were 49.6 m by 1.8 m (89.3 square metres [m^2]) with eight mesh sizes (38, 51, 64, 76, 89, 102, 114, 127 mm stretched measure) per gang. Small mesh nets were 25.0 m by 1.8 m (45 m^2) with 5 mesh sizes (13, 19, 25, 32, 38 mm stretched measure) per gang. Each set consisted of either two large (NA1) or two small (ON2) gangs joined for a double-gang configuration. The nets were checked frequently (maximum soak time was approximately four hours) to minimize mortalities. Angling at Hingittok Lake was also performed on July 11 and 13, 2014 using a variety of unbaited, spoon-type lures.

2.1.3 Individual Fish Measurements

Fish captured at the two-way fyke net trap were enumerated, identified to species, and released on the side of the trap that corresponded to their direction of travel. Most fish were weighed (grams [g]) and measured (fork length [FL] [mm]), and a small number of representative individuals were photographed. To minimize stress during periods of warm water temperatures (>17°C), a small number of fish were enumerated but not processed at the fyke net trap (i.e., were allowed to pass without measurement). When possible, otoliths (the calcified structure from the inner ear) were removed from observed mortalities (e.g., from stranding at upstream locations), folded in parafilm, and stored in a labelled coin envelope for age analysis at a later date. Fish captured from Hingittok Lake using gill nets were also enumerated, identified to species, weighed (g) and measured (fork length) then released back into Hingittok Lake. Char smaller than 300 mm were classified as 'juveniles', fish between 300 and 550 mm were classified as 'immature' (or sub-adults), and fish larger than 550 mm were classified as adults (Appendix A, Photos 7 to 11) (Golder 2013).

2.2 Habitat Assessments

2.2.1 Nulahugyuk Creek

About 9.6 km of Nulahugyuk Creek habitat was assessed from July 10 to 14, 2014. It was broken into four stream sections bounded by Hingittok Lake (upstream) and Bernard Harbour (downstream) and divided by three ponds (Pond 1, Pond 2 and Pond 3) along the length of the creek (Table 1; Figure 1).

Table 1: Description of Stream and Pond Sections Assessed in Nulahugyuk Creek, July 10 to 14, 2014

Section	Length (km)	Upstream Bound (UTM)	Downstream Bound (UTM)
Stream Section 1 (outlet of Pond 1 to the mouth of Bernard Harbour)	3.5	589901 E 7626102 N	590739 E 7627908 N
Pond 1	1.1	590309 E 7625468 N	589901 E 7626102 N
Stream Section 2 (outlet of Pond 2 to inlet of Pond 1)	3.4	587763 E 7624574 N	590309 E 7625468 N
Pond 2	0.2	587548 E 7624547 N	587763 E 7624574 N
Stream Section 3 (outlet of Pond 3 to inlet of Pond 2)	0.7	586459 E 7624644 N	587548 E 7624547 N
Pond 3	0.2	586399 E 7624568 N	586459 E 7624644 N
Stream Section 4 (outlet of Hingittok Lake to inlet of Pond 3)	0.5	585742 E 7624519 N	586399 E 7624568 N

Notes:
km = kilometres; UTM = Universal Transverse Mercator

Major habitat types within the sections were described in accordance with the classification system outlined in O'Neil and Hildebrand (1986). Barriers at all problem locations along the entire length of the creek were identified and described late in the program when flow levels had decreased (Appendix G). To prepare for future remedial works global positioning system (GPS) coordinates were obtained for each problem location, and each problem location was rated according to level of adult char upstream impassibility.

2.2.1.1 Water Temperature and Velocity Measurements

A water velocity measurement station with staff gauge was established approximately 0.5 km upstream from the mouth of Nulahugyuk Creek (Table 2). Water velocities were measured at 0.75 m intervals along a transect set perpendicular to flow of water at the station. Each point velocity was measured at 0.6 times the depth from the creek bed, which is representative of the mean velocity at that vertical profile. Velocity was measured using a direct read-out Swoffer™ Model 2100 velocity meter and top-setting wading rod. Stream flows were measured 22 times between June 13 and July 15; the staff gauge was read an additional 28 times between June 13 and July 16. Discharge was then calculated based on the point measurements of velocity, depth, and creek width.

Water temperatures were measured at 0.25 h intervals at six locations (BH2 to 5, BH7 and 8) along Nulahugyuk Creek using Onset® HOBO Water Temperature Pro V2 Data Loggers (Figure 1; Table 2). The loggers collected data every 15 minutes and ran continuously for the duration of the field study.

Table 2: Water Temperature and Velocity Measurement Locations, Nulahugyuk Cree, 2014

Site	Location (UTM), zone 11W		Distance Upstream from Nulahugyuk Creek Mouth (km)
	Easting	Northing	
Water velocity measurement station	590504	7627637	0.50
Staff gauge	590551	7627716	0.40
BH2	590627	7627754	0.33
BH3	589922	7625874	3.70
BH4	590234	7626192	3.12
BH5	589029	7624910	6.26
BH7	587558	7624550	7.96
BH8	585681	7624524	10.03

Note:
Onset® HOBO Water Temperature Pro V2 Data Logger BH1 could not be recovered to download the temperature data and BH6 recorded air temperature during the 2014 study period, therefore; BH1 and BH6 are not included in these results.

UTM = Universal Transverse Mercator; km = kilometre; BH = Bernard Harbour.

2.2.2 Hingittok Lake

Bathymetry at Hingittok Lake was determined while gill nets were in place as part of the lake fish inventory. Bathymetry transects were completed from July 8 to July 11, 2014 using a Garmin GPSMAP 298 sounder (Garmin, Olathe, KS) coupled with a Global Positioning System (GPS). Transect layout consisted of longitudinal transects in a north/south orientation along the lake, bisected by lateral transects across the width of the lake. Longitudinal and lateral transects were approximately equally spaced to provide as much coverage of the lake as possible. Although limited data was collected in the two northwest arms of the lake, these areas were relatively shallow based on a reconnaissance survey (i.e., less than 6 m; Appendix A, Photo 12). Data were stored in the boat-mounted sonar/GPS and downloaded onto a computer as ‘gpx’ file. Bathymetry data (i.e., depth and GPS position) were then transcribed onto a 1-m bathymetric contour map using ArcGIS (ArcMapTM v9.3.1, 2009) ‘topo to raster’ tool (3D Analyst v. 9.3). Erroneous points were screened out by eliminating any unrealistic depths with the visual aid of georeferenced aerial imagery provided by Google Earth. The volume of Hingittok Lake was calculated using Global Mapper (Version 14.0.2).

2.3 Movement Assessments

Upstream movements of Arctic Char were monitored using implanted PIT tags and Radio Frequency Identification (RFID) antenna-reader arrays installed at strategic locations on the creek (Table 3; Figure 1) (e.g., Puffer et al. 2014). PIT tag methods are ideal for monitoring movements of fish in shallow streams such as Nulahugyuk Creek (i.e., constricted environments) and because of the low cost of the tags, a high number of individuals can be tracked to reliably describe movements. PIT tags are also ideal for long-term studies since they contain no battery and have indefinite life spans.

Table 3: Location of Radio Frequency Identification Antennae-Reader Arrays, Nulahugyuk Creek, 2014

Array	Location (UTM)		Distance Upstream from Nulahugyuk Creek Mouth (km)[(a)]
	Easting	Northing	
Two Way Fyke Net (TWFN)	590623	7627809	0.30
Lower Downstream Array (LDSA)	590865	7627313	0.75
Lower Upstream Array 1 (LUSA1)	591178	7627164	1.14
Lower Upstream Array 2 (LUSA2)	591192	7627151	1.16
Middle Downstream Array 1 (MDSA1)	590387	7626190	2.73
Middle Downstream Array 2 (MDSA2)	590372	7626185	2.75
Middle Upstream Array (MUSA)	589992	7626191	3.15
Upper Lake Outlet Array (ULOA)	586065	7624520	9.43

Note:
[(a)] Distances upstream were measured from the mouth of Nulahugyuk Creek; UTM = Universal Transverse Mercator
UTM = Universal Transverse Mercator; km = kilometre.

2.3.1 PIT Tagging

Upon capture, char were transferred by dip net from the upstream fyke net to a large container filled with fresh water, and transported to an instream holding pool using an all-terrain vehicle (ATV) and tub trailer. Char were then transferred from the holding pool to a foam surgical bed set in a large container filled with fresh creek water. The char were placed ventral side facing up and a PIT tag needle was used to implant a uniquely coded half duplex (HDX) PIT tag (23 mm length, 3.7 mm diameter, 0.6 g weight) in the char's abdomen. The needle penetrated the fish's belly skin between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle, 1 to 2 mm lateral from the mid-ventral line. The bevel of the needle was oriented toward the ventral surface to minimize the chance of contact with internal organs. The angle of the needle upon insertion was approximately 45°. PIT tag injectors were disinfected between implantations using ethyl alcohol (ethanol) diluted with water to a final concentration of 70% to 80% ethanol. Once the PIT tag was implanted, the char were transferred to an in-stream recovery pool. A block net was set at the downstream end of the pool to prevent fish from entering fast moving water that may push them downstream. The upstream end of the recovery pool was not blocked and fish were free to move out of the recovery pool at will.

2.3.2 Floy Tagging

A Floy tag program was also initiated where a subset of adult char moving downstream from Hingittok Lake was implanted with Floy to allow identification of char captured by local community members as individuals originating from HLNC. The tags were implanted through the dorsal surface of the char lateral to the dorsal fin. The tags were orange and had identification numbers ranging from 0001 and 1882. A total of 475 adult char captured moving downstream were implanted with Floy tags.

Resulting data from recaptures by domestic and recreational anglers, as well as future research teams, will be collected over time through tag return programs initiated by Sabina and the Kugluktuk HTO. This program will contribute valuable information on char movements and possibly the location of overwintering sites. However, the analysis of the return information is beyond the scope of this report.

2.3.3 RFID Antennae Array Configuration

Seven PIT tag antennae-reader arrays were installed strategically in relation to the location of the 2012 low-flow channel project areas and reference sections. An array was also installed near the outlet of Hingittok Lake (Table 3; Figure 1). The arrays were configured using either a single antennae (Lower Downstream Array [LDSA], Middle Upstream Array [MUSA], Upper Lake Outlet Array [ULOA]) or paired antennas (i.e., Lower Upstream Array 1 [LUSA1], Lower Upstream Array 2 [LUSA2] and Middle Downstream Array 1 [MDSA1], Middle Downstream Array 2 [MDSA2]), each of which was constructed from bound T90 cable (Figure 3; Appendix A, Photo 13).

Boulder spurs or weirs were constructed to prevent fish from moving around the arrays and to direct fish through the arrays. Antennas were oriented vertically to increase PIT tag reception range. The bottom of the antenna loop was embedded in the creek substrate and the top of the loop was suspended approximately 5 centimetres (cm) above the water surface. This configuration ensured that char passed through the loop perpendicular to the antenna field. Antennas were connected to individual tuner boxes located creek-side, with twinax cable extending from the tuner boxes to a multi antenna HDX-PIT tag reader box. The arrays were powered by deep-cycle 130 ampere marine batteries which were kept continually charged using solar panels.

Detection probabilities (*p*) were generated for individual antennae by assigning binary detection values for individual char based on whether they were detected (1) or not (0) at a given array. Detection probabilities were calculated for each array based on the mean detection value. Zero values above the furthest upstream detection were excluded from the detectability calculations because these fish were assumed to have been removed from the system. Therefore, detection values for each array were based only on data where detection occurred, or was known to occur further upstream. Detectability for the UOLA array was based on the mean detectability of the downstream arrays, with the exception of MUSA where a technical malfunction reduced detectability at that site.

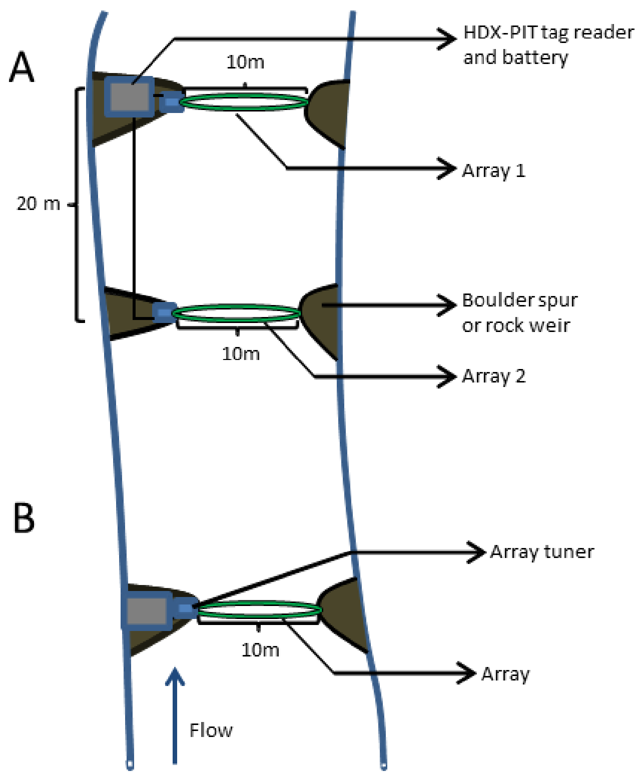


Figure 3: Schematic of Paired (A) and Single (B) RFID Antenna Array Configurations

2.3.4 Mortality Surveys

Mortality data was collected opportunistically as incidental observations, for example, during habitat assessments or while travelling to PIT reader locations. When there was an opportunity field crew members visually surveyed the creek for dead char and when located, carcass information was documented using a hand-held GPS, photographs, and field notes. Carcasses were scanned with a hand-held PIT tag reader and visually assessed for a Floy tag.

2.3.5 Statistical Analyses

Binary logistic regressions were used to explore relationships between upstream migration success (fish detected [1], or not detected [0] at the lake outlet) and environmental and biological parameters including migration date, stream discharge (daily and 4-day mean), water temperature (daily and 4-day mean), length, weight and condition factor. Various models were compared based on their Akaike Information Criterion (AIC) score, with lower values identifying models better representing the data analyzed, and Receiver Operating Characteristic (ROC), with higher values indicating greater sensitivity and specificity of the model.

Char movement speed (metres per hour [m/h]) was compared between arrays using analysis of variance (ANOVA). Movement speed was square root transformed to meet assumptions of normality. The significance level, alpha (α), was defined *a priori* as $\alpha = 0.05$. Normality was assessed graphically by examining the distribution of residuals using normal probability plots (Zar 1999). All analyses were conducted using Systat 13 (Systat Software, San Jose, CA).

2.3.6 Low-Flow Channels

The integrity of previously completed low-flow channels was visually assessed and photographed during low discharge conditions (July 18, 2014). Supporting information on channel width, velocity and depth within the assumed thalweg (deepest area of channel) was collected every 2 m for the length of each project. Mean values and standard deviations of channel characteristics are reported.

3.0 RESULTS

3.1 Fish Capture and Sampling

3.1.1 Nulahugyuk Creek

The fyke net was in place for a total of 35 days, 16 hours and 17 minutes beginning the evening of June 12, 2014 (18:15) and ending July 17, 2014 (10:32). Char catch-per-unit-effort (CPUE) for the upstream fyke net was 0.388 fish/hour, while CPUE for the downstream fyke net was 1.168 fish/hour. The combined CPUE for upstream and downstream fyke nets was 1.556 fish per hour. Three Ninespine Stickleback were also captured but not included in CPUE calculations.

A total of 1,332 char were captured from Nulahugyuk Creek. Of the char captured, 332 were adults moving upstream (Appendix A, Photos 10 to 11); 478 were adults moving downstream (Appendix A, Photos 8 and 9); one was immature, and 521 were juveniles (Appendix D, Table D1). Maximum daily upstream CPUE for adults was 1.167 fish/hour on July 4, 2014; whereas maximum downstream CPUE for adults was 3.167 fish/hour on June 24, 2014; and maximum daily juvenile CPUE (migrating downstream) was 4.417 fish/hour on July 11, 2014.

Char length and weight measurements and condition factor for the three migratory groups and one immature individual are summarized and described in Table 4 and Figure 4 (not every individual was measured). The largest captured char was 887 mm in length with a weight of 6,645 g. Adult char moving upstream had the highest average condition factor (± standard deviation [SD]) of the three migratory groups (K_{us} = 1.09 [± 0.1]); whereas, downstream-moving juveniles had lowest average condition factor (K_{juv} = 0.81 [± 0.1]). Adult char moving downstream had an average condition factor of 0.84 (± 0.1). Adult char moving downstream from Hingittok Lake were approximately 27% lighter in weight than char moving upstream from the ocean. It was noted by the field crew that although none appeared obviously ripe for spawning, many char moving upstream were developing spawning colours had better condition (visual judgment of weight to length ratio) than adults moving downstream.

Table 4: Summary of Arctic Char by Size Class Captured in Fyke Nets on Nulahugyuk Creek, June 16 to July 17, 2014

Migratory Group	Number of Char	Length Range (mm)	Mean Length (mm) ± SD	Weight Range (g)	Mean Weight (g) ± SD	Mean Condition Factor ± SD
Adults moving upstream	329	602 to 887	728.8 ± 53.9 *(n = 328)*	2,250 to 7,545	4,271.2 ± 991.3 *(n = 329)*	1.09 ± 0.1
Adults moving downstream	476	509 to 859	717.0 ± 54.3 (*n* = 475)	1,545 to 5,080	3,134.6 ± 747.6 (*n* = 473)	0.84 ± 0.1
Immature fish moving downstream	1	305	-	243	-	0.86
Juveniles moving downstream	521	145 to 261	192.5 ± 19.1 *(n = 347)*	25 to 140	60.3 ± 18.2 *(n = 313)*	0.81 ± 0.1

Note:
mm = millimetres; ± = plus or minus; SD = standard deviation; g = grams; *n* = number of fish; - = no data

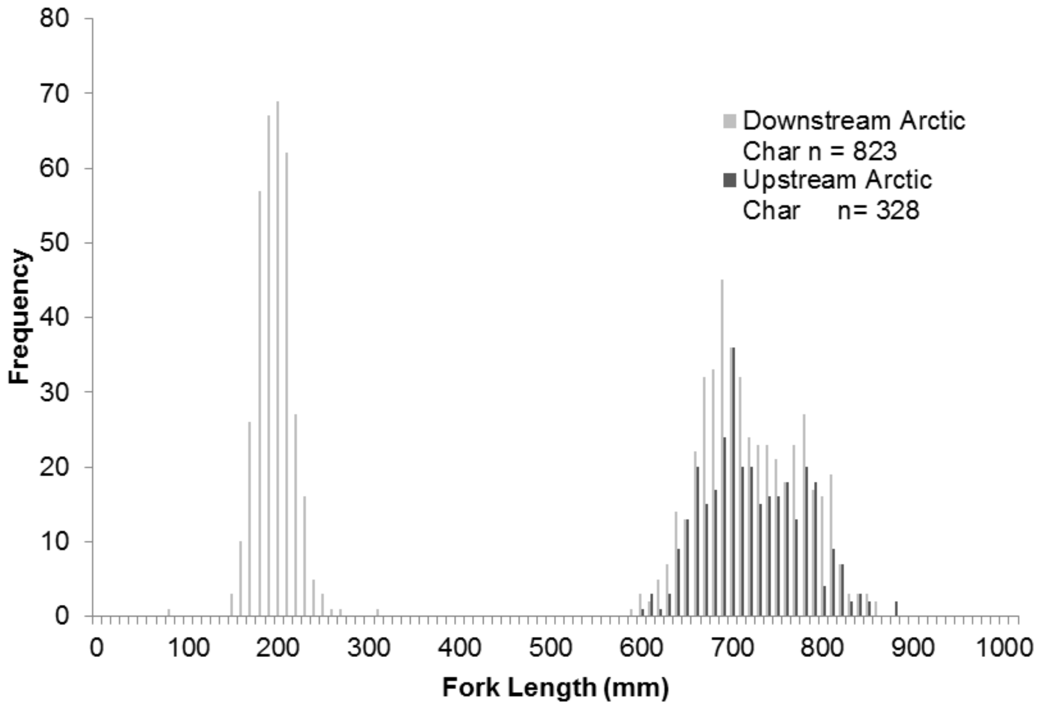
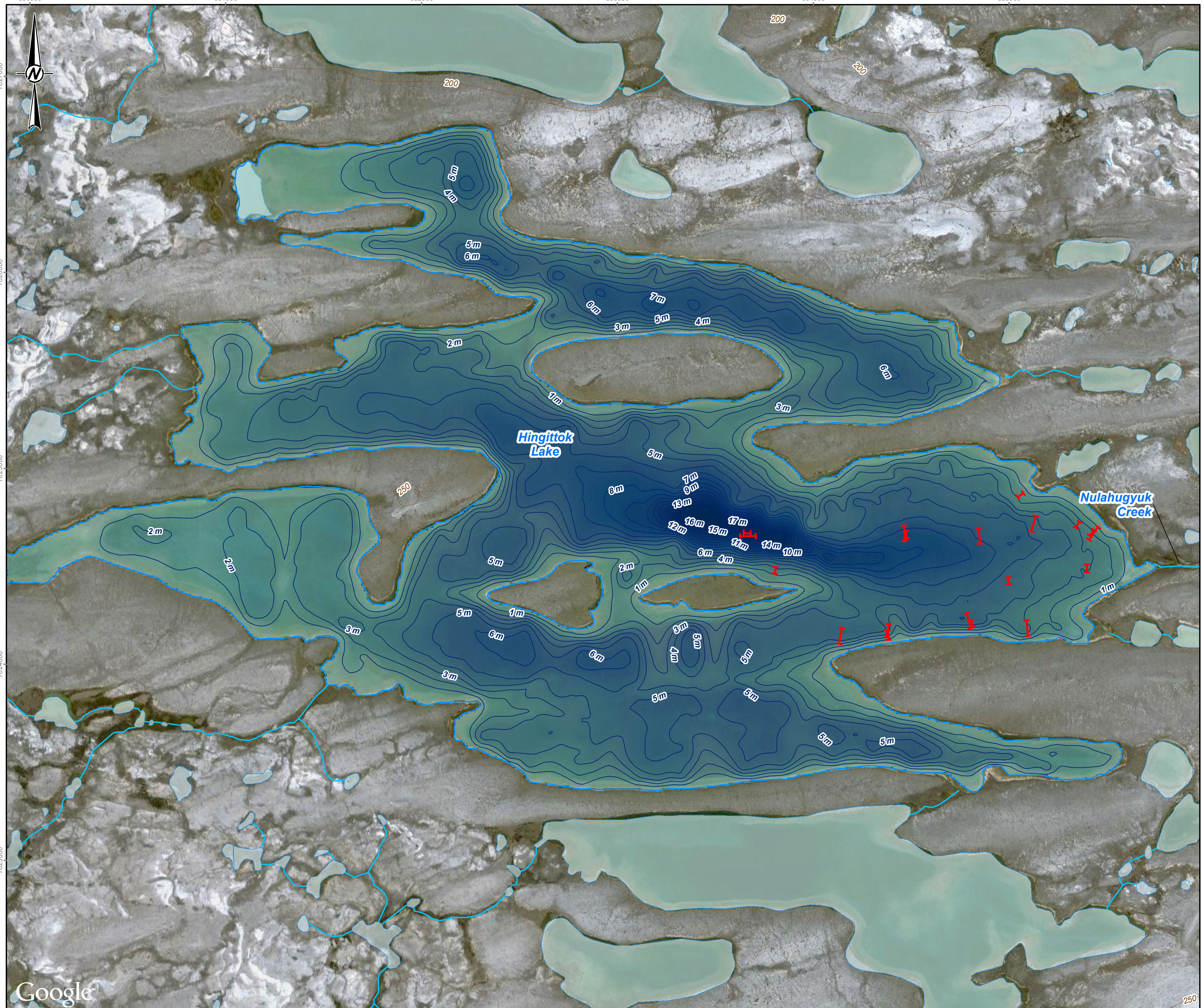


Figure 4: Length-Frequency Distribution of Arctic char Captured in the Fyke Net Trap.

3.1.2 Hingittok Lake

Twenty-nine short-duration gill net sets were deployed for a total of approximately 65 hours in Hingittok Lake (Figure 5; Appendix E, Table E1). Gill netting efforts in Hingittok Lake captured a total of 54 fish including 36 Lake Trout (*Salvelinus namaycush*; Appendix A, Photo 14), 10 Arctic Char (*Salvelinus alpinus alpinus*), 7 Cisco (*Coregonus artedi*; Appendix A, Photo 15), and 1 Ninespine Stickleback (*Pungitius pungitius;* (Appendix E, Table E1). Of the 10 char captured, 7 were adults and 3 were juveniles. Mean CPUE for large mesh nets was 2.16 fish/hour/100 m; approximately twice that of small mesh nets which was 1.07 fish/hour/100 m (Appendix E, Table E2). It is noteworthy that two of the captured char were PIT tagged in 2014.

A total of 2.5 hours, mid to late afternoon, were spent angling by two crew members in the lake, resulting in the capture of eight Lake Trout (CPUE of 1.5 fish/angler hour; Appendix E, Table E1). Overall, Lake Trout was the dominant species captured from Hingittok Lake (based on gill netting and angling combined), contributing 71% to the total catch (Figure 6).



LEGEND

- ELEVATION CONTOUR
- WATERCOURSE
- WATERBODY
- GILL NET
- BATHYMETRIC CONTOUR (1 METRE INTERVAL)

DEPTH (METRES)

18.4

0

0 400 800

1:20,000 METRES

REFERENCE

GOOGLE EARTH IMAGERY: © 2014 DIGITAL GLOBE
CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.
NAD 83 UTM ZONE 11N

CLIENT
SABINA GOLD & SILVER CORP.

PROJECT
BERNARD HARBOUR PROJECT

TITLE
BATHYMETRY AND GILL NET LOCATIONS IN HINGITTOK LAKE, JULY 8 TO 13, 2014

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-01-26
PREPARED	LMR
DESIGN	KD
REVIEW	JPO
APPROVED	CES

PROJECT No.	PHASE	Rev.	FIGURE
14-1373-0004	2200	D	5

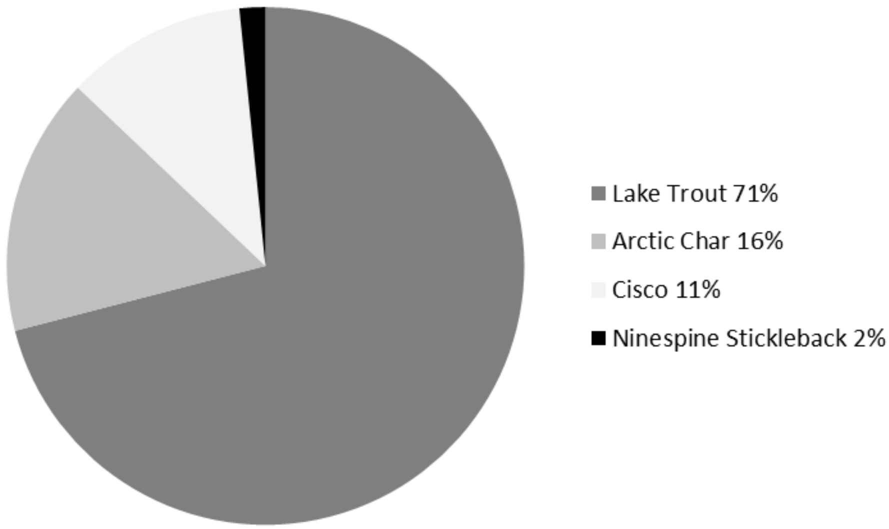


Figure 6: Fish Species Composition in Hingittok Lake, 2014

3.2 Habitat Assessments

3.2.1 Nulahugyuk Creek

A habitat survey was completed on 9.5 km of Nulahugyuk Creek between July 10 and July 14, (Appendix B; Appendix C). Nulahugyuk Creek transitions from faster moving riffles near its confluence with the sea to runs and pools near Hingittok Lake. Although about 82% of the lower section of the creek to the first pond was riffle habitat (Appendix A, Photo 16), char were observed using the vertical and undercut banks, slower moving sections and small pools as resting areas in the lower section of the creek (Appendix A, Photos 17 and 18). The creek transitioned from riffle (44%) to run (53%) between the first and second ponds. It was largely R3 run (>90%) from the second pond to the outlet of Hingittok Lake (Appendix A, Photos 19 and 20; Appendix B; Appendix C). Substrate was predominantly cobble (usually >60%) and boulder (~5 to 19%) and gravel (~5 to 13%) with small amounts of sand and silt, for the most part in ponds and large pools. The maximum depth in most stream reaches (excluding the three ponds on the creek) was less than 0.75 m, indicating that Nulahugyuk Creek does not provide overwinter habitat, as it freezes to the bottom in most areas. The habitat characteristics observed in July 2014 indicate little cover for large fish with only small patches of intermittent (or discontinuous) cover provided by boulder and undercut banks.

3.2.1.1 Water Temperature and Velocity

The water temperatures in Nulahugyuk Creek increased steadily as the season progressed with mean daily temperatures rising from 2.7°C on June 14 to 12.3°C on July 17 (Figure 7). The warmest temperatures occurred during the latter half of the study period exceeding 17°C at the downstream site (BH2) for 24.3 hours. Diurnal variation in water temperature was evident with a mean difference of 8.8°C between daily minimum and maximum values. A temperature gradient was also observed between the upstream and downstream sites (BH2 and BH7; Figure 1) with a consistent mean difference of 2.4°C across the sampling period, indicating a rate of change of 0.3°C/km downstream.

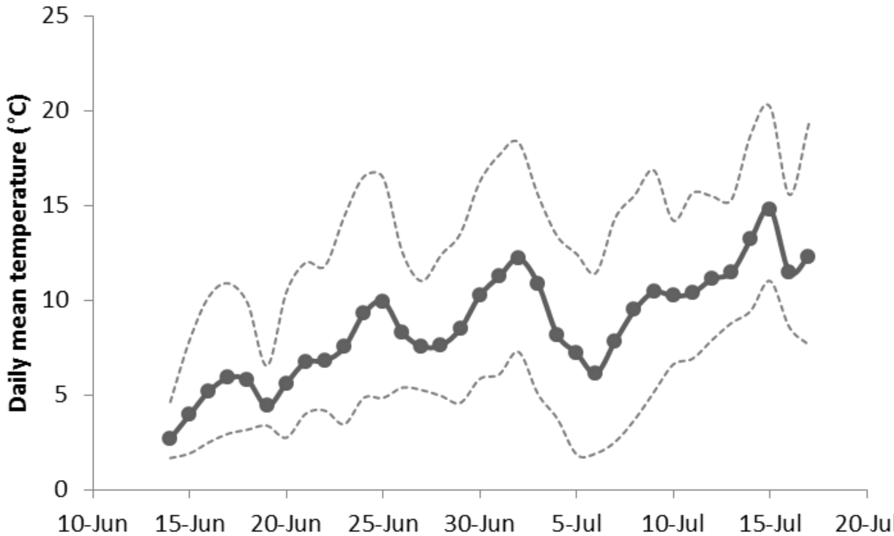


Figure 7: Daily Mean Temperature (°C) Recorded at Nulahugyuk Creek from June 10, 2014 to July 17, 2014. Maximum and Minimum Daily Values Indicated by Upper and Lower Dotted Lines Respectively. Warm Water Temperatures (>17°C) Delineated by the Dashed Line.

Creek discharge declined over the study period ranging from a high of 6.0 cubic metres per second (m^3/s) on June 15 to a low of 0.5 m^3/s on July 15 (Figure 8). Discharge was strongly correlated with water depth at the staff gauge (r = 0.97). A 5.5 m^3/s decline in discharge corresponded to a 28.5 cm decrease in water depth over that period.

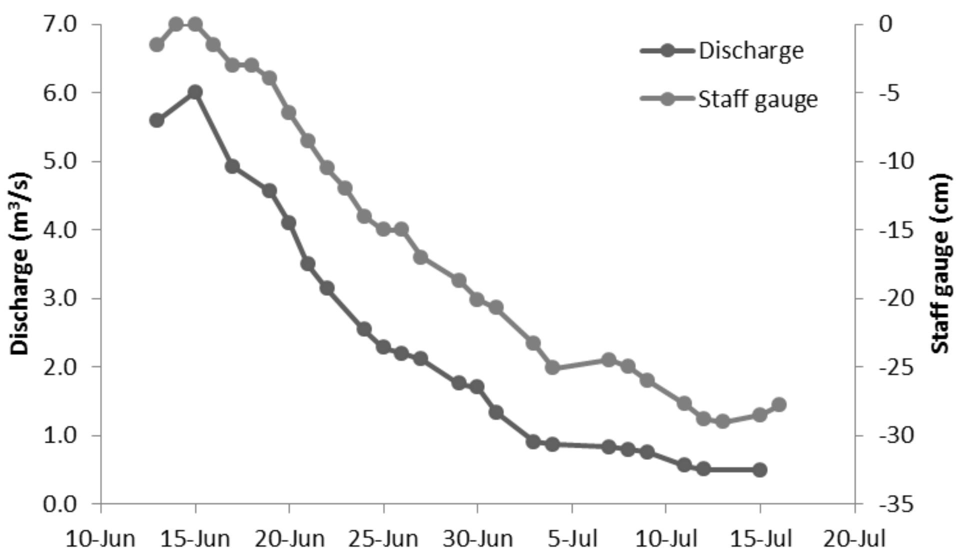


Figure 8: Stream Discharge (m^3/s) and Staff Gauge Depth (cm) Recorded at Nulahugyuk Creek Between June 13, 2014 and July 15, 2014

3.2.2 Hingittok Lake

Based on 1:50,000 CanVec data, Hingittok Lake is 982.3 ha in area and features numerous peninsulas and bays around three large islands in the centre of the lake (Figure 5). Shoreline length (38,085 m including islands) was extensive relative to the size of the lake and the shoreline development factor (the ratio of a lake's perimeter to surface area that provides a measure of irregularity of shoreline) was approximately 12.3. The higher the ratio, the more irregular the shoreline is, and thus, more shoreline habitat is potentially available (a perfect circle would have a shoreline development factor of 1). The bathymetry data derived a lake volume of 30,553,274 m^3 (Table 5). The maximum depth was approximately 18 m and mean depth was 3.7 m (Table 5; Figure 5).

Table 5: Approximate Lake Area and Volume for Various Depth Intervals in Hingittok Lake, July 10 to 14, 2014

Depth (m)	Volume (m^3)	Area (ha)	Depth (m)	Volume (m^3)	Area (ha)
>0	30553274	982.25	>10	553638	14.69
>2	15767454	607.66	>12	308168	10.19
>4	6214620	352.37	>14	138401	6.89
>6	2002020	95.61	>16	32068	3.67
>8	964592	28.86	>18	335	0.16

Note:

m = metres; m^3 = cubic metres, ha = hectares; > = greater than.

3.3 Movement Assessments

The first char captured was moving downstream on June 16 (Figure 9). Three distinct groups of migratory char were described including adults moving downstream after overwintering in Hingittok Lake (*n* = 478), adults moving upstream (*n* = 332) to overwinter, potentially spawning first, and juveniles[1] moving downstream from Hingittok Lake (*n* = 522). Downstream movement by adults was largely completed by July 4 (Figure 9). Upstream movement attempts by adults began on June 25 and continued through to the completion of the field study. Downstream movement by juveniles began on June 25 and also continued to the completion of the field study. Migration successes were quantified for adult char migrating upstream from the ocean to Hingittok Lake (see below – Migration Success).

[1]For simplicity, one individual classed as "immature" based on length (300 to 550 mm) was included in juvenile group (300 mm or less) and was 305 mm long.

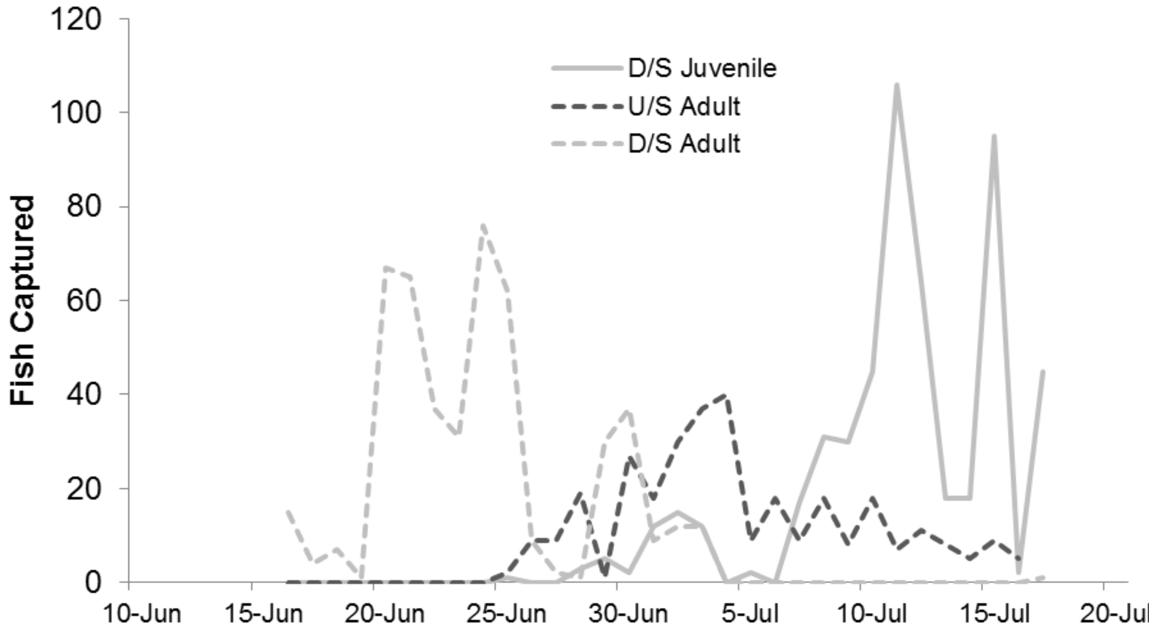


Figure 9: Daily Captures of Migratory Char in Nulahugyuk Creek, 2014. D/S = downstream travelling fish and U/S = upstream travelling fish

3.3.1 Migration Success

A total of 315 upstream migrating adult char were implanted with PIT tags with identification numbers ranging between 228000152003 and 228000152325. Selected char for PIT tag monitoring were a representative sample of the population moving upstream, and characterized by an average length (± SD) of 726.8 (± 52.4) mm, weight of 4229.8 (± 949.8) g and condition factor or 1.09 (± 0.1) (Appendix D, Table D1).

A high degree of detectability was obtained at most antennae-reader arrays (Table 6). The only exception was MUSA which suffered from a series of technical issues including a malfunctioning battery from July 8 to July 9, and suboptimal tuning prior to July 11, resulting in reduced detectability.

Of the 315 char tagged, 103 were detected at the ULOA indicating the completion of a successful upstream movement from the sea. Adjusted for array detectability, this equated to 110 tagged fish, or a success rate of 34.9% between June 25 and July 17, 2014 (Table 6). Although migratory success was relatively high early on in the study (93%), it declined rapidly over time with none of the fish tagged after July 6 detected at the ULOA (Figure 10). This indicates that a threshold was reached and stream conditions became impassable for char after this date. Any remaining fish either perished, likely from exhaustion, predation, or stranding, or remained in the deep pools located in the upper reaches of the creek (average depth exceeding 1.0 m and maximum depth exceeding 3 m, Appendix B and C). Incidental mortalities observed for tagged fish are presented in Appendix F, Table F1.

Table 6: Location of Radio Frequency Identification (RFID) Arrays and Detection Information

Array	Location (UTM)		Distance Upstream from Nulahugyuk Creek Mouth (km)[(a)]	Detection Probability	Detected Total	Corrected Total
	Easting	Northing				
TWFN	590623	7627809	0.30	1.00	315	315
LDSA	590865	7627313	0.75	0.90	263	293
LUSA1	591178	7627164	1.14	0.93	261	280
LUSA2	591192	7627151	1.16	0.91	255	279
MDSA1	590387	7626190	2.73	0.97	205	212
MDSA2	590372	7626185	2.75	0.96	202	211
MUSA	589992	7626191	3.15	0.59	94	158
ULOA	586065	7624520	9.43	0.93	103	110

Note:
(a) Distances upstream were measured from the mouth of Nulahugyuk Creek.

TWFN = two way fyke net; LDSA = Lower Downstream Array; LUSA1 = Lower Upstream Array 1; LUSA2 = Lower Upstream Array 2; MDSA1 = Middle Downstream Array 1; MDSA2 = Middle Downstream Array 2; MUSA = Middle Upstream Array; ULOA = Upper Lake Outlet Array; UTM = Universal Transverse Mercator

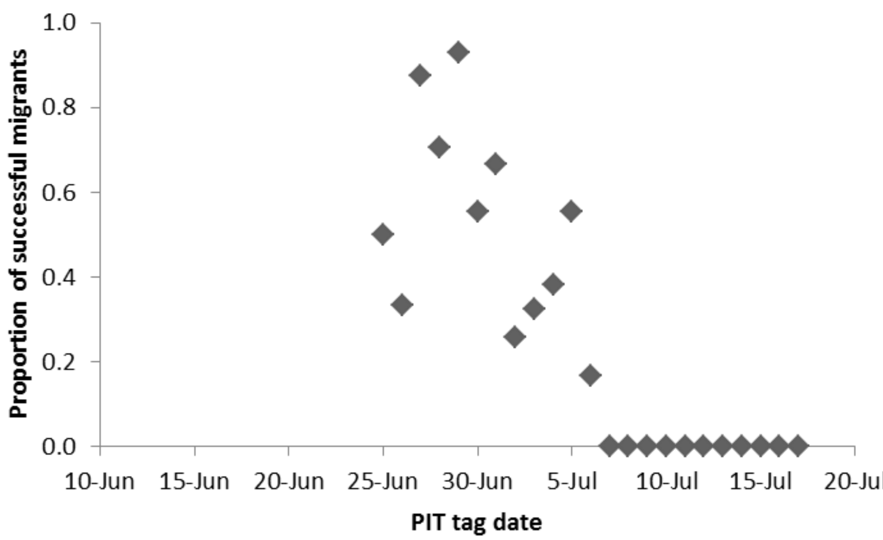


Figure 10: Proportion of Successful Migrants Plotted Against Passive Integrated Transponder Tag Implantation Date

The number of char observed among the RFID arrays declined sequentially as the fish moved upstream. Prior to July 6, a considerable reduction in detected char occurred over a 0.35 km reach between MDSA2 (2.75 km) and MUSA (3.15 km) with a 24% reduction in individuals occurring in this area (Figure 11). After July 6, a 50% reduction in the number of char detected occurred over a 1.57 km reach between LUDS2 (1.16 km) and MDSA1 (2.73 km), with no fish detected after MUSA (>3.15 km).

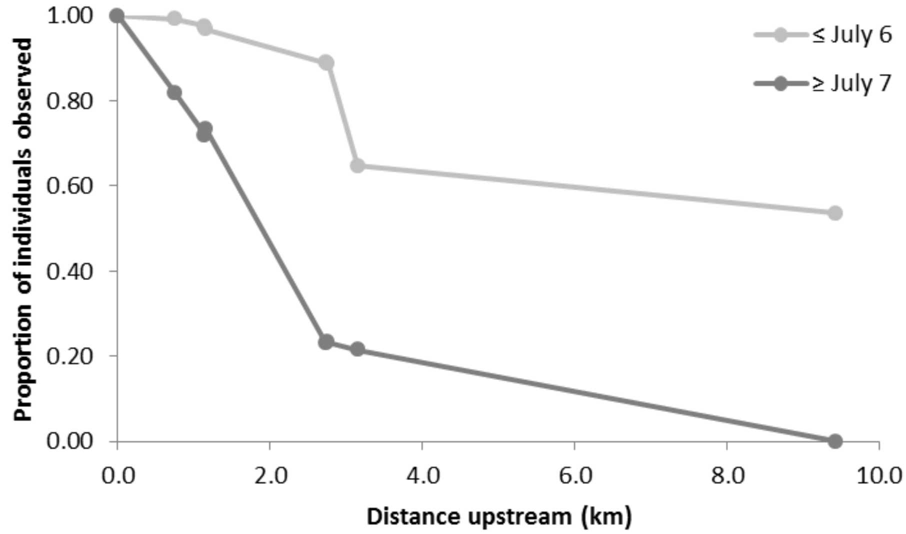


Figure 11: Proportion of Tagged char Observed at RFID Arrays on Nulahugyuk Creek from June 25, 2014 to July 6, 2014, and June 7, 2014 to July 17, 2014, Corrected for Array Detectability

Using a binary logistic regression, the primary factors influencing migratory success were determined to be four day mean discharge and char weight. This relationship was expressed using the formula:

$$P = \frac{e^{-8.398+15.714x-4.612x^2-0.77y}}{1+e^{-8.398+15.714x-4.612x^2-0.77y}}$$

where P was the probability of success, x was the four day mean stream discharge (m^3/s), and y was the char weight in kilograms. Model fit was significant (p <0.001) with an ROC value of 0.84. Parameter estimates are presented in Table 7. The output of the formula was presented graphically in Figures 12 and 13. With respect to the four-day mean discharge, the probability of migration success ranged from a high of 85% at 1.5 m^3/s, declining to a low of 0% at 0.5 m^3/s, when fish weight was held constant at 4.18 kilograms (kg) (Figure 12). Regarding fish weight, the probability of migratory success ranged from a high of 95% for fish that weigh 2.5 kg to a low of 31% in fish that weigh 7.5 kg when discharge was held constant at 1.76 m^3/s (Figure 13).

Table 7: Parameter Metrics for Binary Logistic Regression

Parameter	Estimate	Standard Error	Z	p-Value	95% Confidence Interval	
					Lower	Upper
Constant	-8.398	2.417	-3.48	0.001	-13.134	-3.661
Four day mean discharge (x)	15.714	4.134	3.8	<0.001	7.612	23.815
Four day mean discharge^2 (x^2)	-4.612	1.643	-2.81	0.005	-7.831	-1.392
Weight (kg) (y)	-0.77	0.192	-4.02	<0.001	-1.146	-0.395

Note:

z = z score; p-Value = probability value; % = percent; < = less than; kg = kilograms.

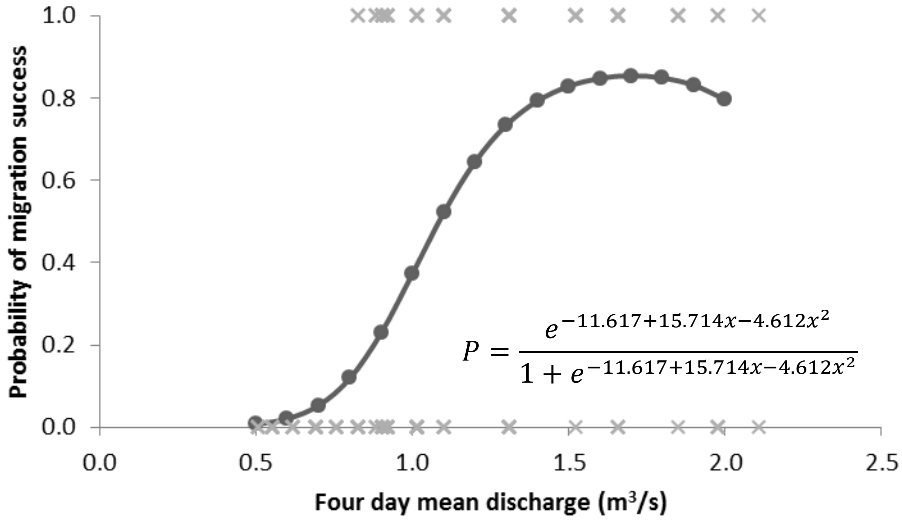


Figure 12: Results of Binary Logistic Regression Plotting the Probability of Migration Success Against Stream Discharge (x), Holding Char Body Weight Constant at 4.18 kg

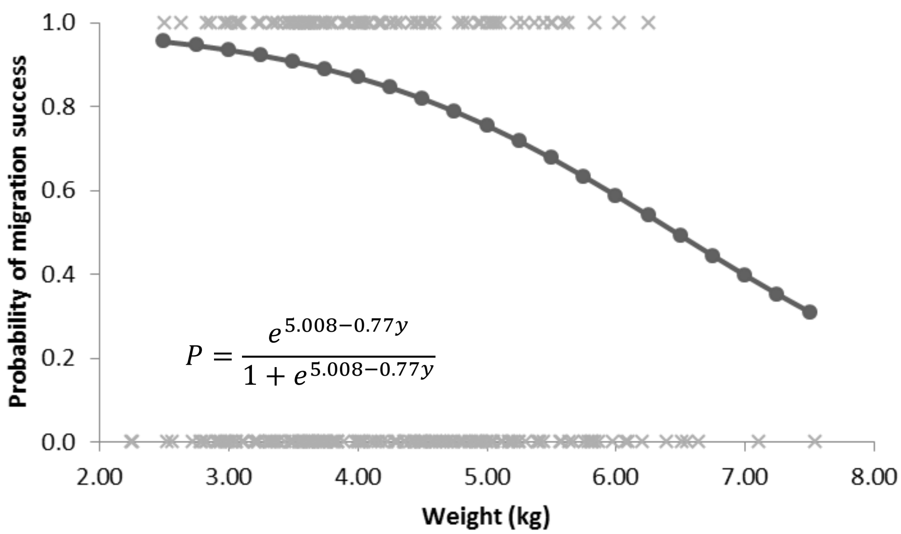


Figure 13: Results of Binary Logistic Regression Plotting the Probability of Migration Success Against Char Body Weight (y) Holding Four Day Mean Stream Discharge Constant at 1.76 m^3/s

3.3.2 Movement Rates

Migration time between the farthest downstream array and the farthest upstream array (distance of 8.68 km) varied among fish and throughout the study period with a mean migration time (± standard error) of 108.3 h (± 4.7) (Figure 14). The fastest fish completed the migration in 34.2 h, and the slowest in 239.0 h. The migration time was generally faster from June 25 to June 30 (79.3 h [± 5.4]) than from June 30 to July 6 (123 h [± 5.8]). Migration time could not be determined after July 6 as none of the tagged fish successfully reached the ULOA; however, travel time between the downstream arrays decreased after July 6 indicating char were traveling at a greater speed (Figure 15).

Char travel speed also varied among creek sections throughout the study period (Figure 16). The highest upstream migration speeds occurred in the shorter array sections where water was shallow and without resting areas and where fish were more exposed (e.g., Sections 0.8 to 1.1 km [LDSA to LUSA1], 1.1 to 1.2 km [LUSA1 to LUSA2], and 2.7 to 2.8 km [MDSA1 to MDSA2]; Figure 1; Figure 16; Appendix C).

The slowest upstream migration speed was recorded in the section of the creek immediately upstream of the fyke net where the recovery pool was located (0.3 to 0.8 km [TWFN to LDSA]; Figure 1; Figure 14). There were also undercut banks in this section of the creek, which provided small pools and cover for refugia.

The next slowest migration speeds were recorded in three sections (1.2 to 2.7 km [LUSA2 to MDSA1], 2.8 to 3.2 km [MDSA2 to MUSA] and 3.2 to 9.4 km [MUSA to ULOA]; Figure 1; Figure 16). The MUSA to ULOA section was the longest section, was largely classified as run habitat (Appendix A, Photos 19 and 20) but also contained three ponds (Appendix C; Figure 1).

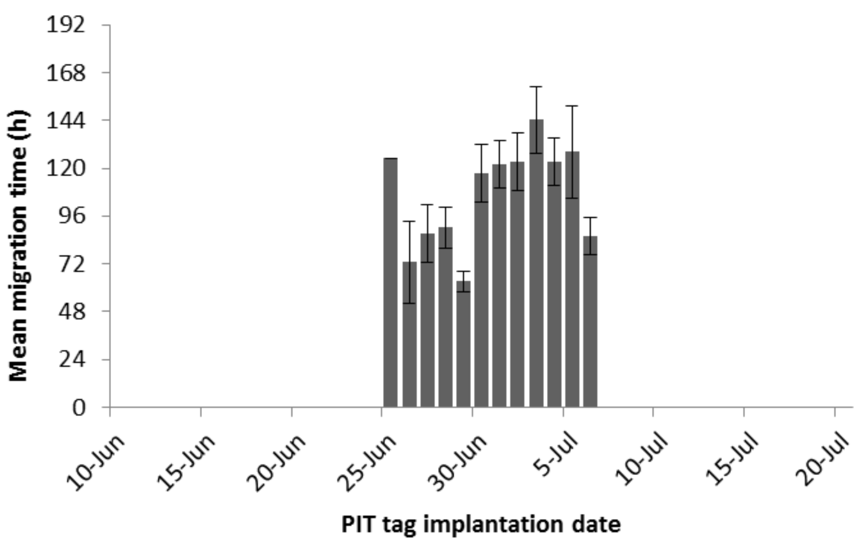


Figure 14: Mean Migration Time ± Standard Error Plotted Against Passive Integrated Transponder Tag Implantation Date. Migratory Time Could Not Be Determined After 6-Jul (dotted line) Due to a Lack of Successful Migrants

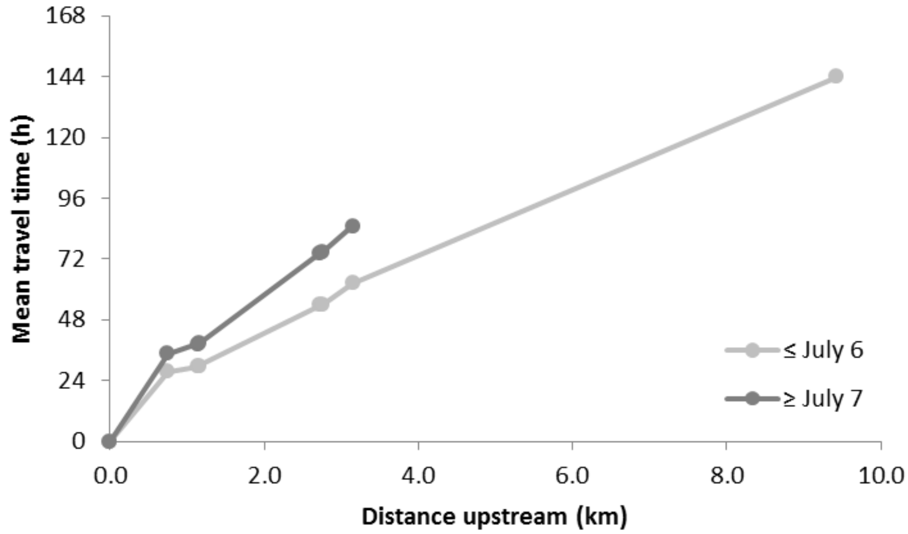


Figure 15: Mean Travel Time (h) of Char Between RFID Arrays on Nulahugyuk Creek From June 25, 2014 to July 6, 2014, and June 7, 2014 to July 17, 2014

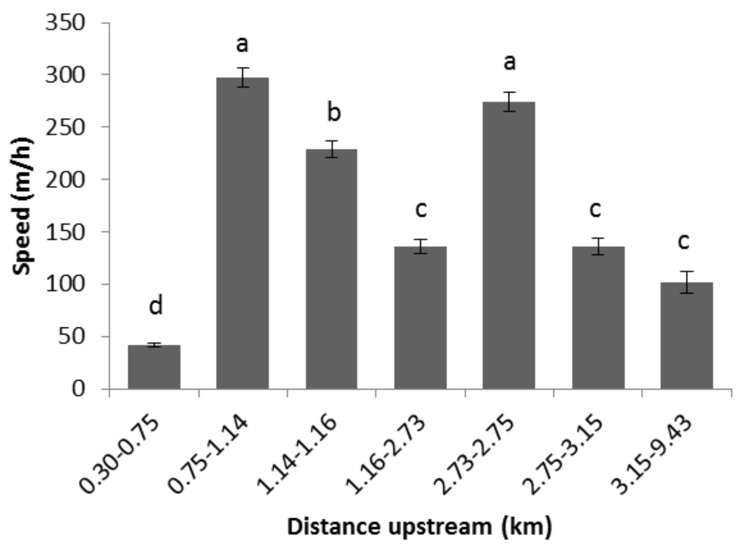


Figure 16: Average Movement Speed (m/h) ± Standard Error of Char Traveling Through Nulahugyuk Creek. Sections Not Significantly Different From Each Other Represented By The Same Letter

3.3.3 Low-flow channels

3.3.3.1 2012 Low-Flow Channel Projects

The integrity of previously completed low-flow channels were visually assessed and photographed during low discharge conditions (July 18, 2014; Appendix A, Photos 21 to 25). Supporting information on channel width, velocity and depth was collected every 2 m for each Project (Table 8). The low flow channels constructed in 2012 were intact in 2014 and would provide char with a migratory path where potential barriers existed in low flow conditions previously (Golder 2013).

Table 8: Summary of Velocity Data from 2012 Project Locations 1 to 5, July 16, 2014

Station	Average Wetted Width ± SD (m)	Average Depth ± SD (m)	Average Velocity ± SD (m/s)
P1	2.34 ± 1.49	0.13 ± 0.03	0.69 ± 0.26
P2	2.48 ± 0.94	0.17 ± 0.04	0.47 ± 0.22
P3	2.37 ± 0.73	0.22 ± 0.03	0.72 ± 0.36
P4	2.42 ± 0.45	0.17 ± 0.06	0.65 ± 0.21
P5	1.96 ± 0.62	0.19 ± 0.10	0.65 ± 0.24

Note:
± = plus or minus; SD = standard deviation; m=metre; m/s=metres per second; P=project

3.3.3.2 Potential Project Locations

Problem locations (locations where char movement may be impeded by lack of depth, boulder barriers, etc.) were identified in 2014 and detailed in Appendix G. These locations are where fishery productivity, characterized by Arctic Char production (i.e., available biomass for harvesting), may benefit from enhancement projects (Table 9).

Table 9: Summary of Potential Locations for Fish Passage Enhancement Projects

Site Name	Approximate Distance Upstream of Bernard Harbour (km)	Easting (UTM)	Northing (UTM)	Estimated Length (m)	Priority for Enhancement
Site 1	1.3	591279	7627006	30	High
Site 2	1.3	591263	7627032	20	Medium
Site 3	1.5	591200	7626876	30	Low to Medium
Site 4	1.6	591165	7626842	60	Medium
Site 5	2.0	590836	7626544	20	High
Site 6	2.0	590876	7626563	20	Medium
Site 7	2.4	590556	7626395	50	High
Site 8	2.9	590214	7626213	10	Low to Medium
Site 9	4.8	589969	7625431	20	Low to Medium
Site 10	5.7	589244	7625128	40	Low
Site 11	7.8	587549	7624548	15	Low

Note:
km = kilometres; UTM = Universal Transverse Mercator; m = metre

4.0 SUMMARY AND CONCLUSIONS

The number of char (n = 1,332) captured at the fyke trap in Nulahugyuk Creek in 2014 was much lower than in 2012 (n = 7,236), especially with regard to juveniles which declined from 6,803 to 522. Possible explanations include differential recruitment success resulting in variable year-class strengths, inter-year environmental differences, or changes in the timing of movements, among others.

There is a small window for adult char migration in HLNC and the first adult char captured were those migrating downstream (June 16 to July 4; about 20 days). The migration of the second adult group (adults moving upstream towards Hingittok Lake) began June 25 and peaked around July 5. Although adults were still captured attempting to migrate upstream near the end of the study, PIT data indicated that adults attempting migration after July 7 would be unsuccessful. In contrast to adult migrations, the window for the juvenile downstream migration is likely longer, due to their smaller size allowing them to migrate through shallow water. Juvenile char were first captured migrating downstream on June 25, peaked around July 11 and (likely) continued past the end of the 2014 study on July 17.

The primary factors affecting char migration success at Nulahugyuk Creek in 2014 were discharge and fish weight. Discharge was strongly correlated with water depth, and as depth declined over time, new impediments to fish passage were created until fish passage was no longer possible. Larger fish were less likely to overcome these impediments to fish passage, presumably due to an increased probability of stranding and predation. Unfortunately larger fish are generally the most productive in a spawning population (Jeuthe et al. 2013), producing greater numbers of more viable offspring, and loss of these individuals could have significant effects on recruitment potential.

A significant barrier to fish passage was created on July 7, 2014 as stream discharge declined to approximately 0.8 m^3/s and water depths declined by 25 cm at the staff gauge. Afterward, fish passage was no longer possible; indicating a brief and discrete window of opportunity exists for the char migration at Nulahugyuk Creek. Between the time fish were initially detected moving upstream (June 25) and passage was no longer possible (July 7), the migration window in 2014 was 13 days. While some of the unsuccessful migrants may have taken temporary shelter in upstream pools eventually retreating to the sea, the majority of the remaining char likely perished through stranding, exhaustion or predation, with only four fish successfully exiting the system by July 17, 2014.

The low-flow channels constructed in 2012 were intact and assumed functional in 2014 and based on the data collected, further enhancement efforts at Nulahugyuk Creek would optimally focus on the 11 problem locations (i.e., Sites 1 to 11) identified within various sections of the creek. For example, in order to augment the current cohort of successful migrants traveling upstream (i.e., those fish traveling upstream while passage remains possible), effort should focus on impediments near Site 8 and the 2.8 to 3.2 km section where losses (i.e., failed movements of PIT tagged fish) were observed in 2014. This approach would have the advantage of focusing restoration efforts over a relatively discrete (approximately 0.4 km) section of Nulahugyuk Creek. Remediation efforts could potentially increase the migration success rate by 44%, or almost 50 individuals for this section alone (based on preliminary analyses not shown). A complementary approach would be to focus on extending the current migration window (i.e., delay the point in time where fish passage is no longer possible) by removing impediments occurring when flows are low, for example, between 1.2 and 2.7 km (including Sites 1 to 7) and after 3.2 km (above MUSA; including Sites 9 to 11). As none of the 12 fish observed at MUSA after July 6, 2014 were detected at the ULOA (Hingittok Lake), it is possible that a significant barrier occurred upstream of this array when flows were low (e.g., Site 9) or that char health was compromised because of downstream migration conditions, precluding a continued successful migration.

It is expected that the char that successfully reach Hingittok Lake overwinter and then spawn during the fall of the next year, migrating downstream to Bernard Harbour the following spring. Both Hingittok Lake and it's connectivity with Bernard Harbour through Nulahugyuk Creek is critical to the local char population, and possibly to the larger fishery in the Coppermine River region. The maximum depth of Hingittok Lake is over 18 m deep, providing overwinter habitat, and there are at least two prey species (Cisco and Ninespine Stickleback) available to adult Arctic Char. Importantly, shoreline length is extensive relative to the size of the lake potentially providing an abundance of shoal habitat for spawning.

5.0 ACKNOWLEDGMENTS

Golder would like to first thank and acknowledge the community of Kugluktuk and the staff at the Hunters and Trappers Organization for their continued support for the project. This project was successful because of their efforts, in particular the support provided by Barb Adjun and David Nivingalok. Golder would also like to acknowledge Matt Gilbert at the University of Albert for his continued enthusiasm and assistance with field work.

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APPENDIX A

Project Photos