Imaging sonar deployment in the lower Copper River to enhance early season management.

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Executive Summary/Abstract

In order to enumerate up-migrating Copper River Salmon, a DIDSON imaging sonar was deployed for the month of May 2016 in the Copper River, at a site by the confluence of the Clear Martin and Copper rivers, approximately 10 river miles north of the open ocean. Hourly and daily counts of upriver passage were determined, and the results posted multiple times per day via internet for use by ADF&G managers and the general and fishing public. An early pulse of fish moving up river was captured beginning on May 10, followed by lower counts for the rest of the month. A post-deployment analysis of the difference between the Clear Martin sonar and the ADF&G sonar site at Miles Lake showed that the Clear Martin site counted considerably fewer fish than were counted at Miles Lake. The differences may have been due to deploying on only one bank at the Clear Martin site, and because stage heights in the Copper River in 2016 were above average. Lagged correlations suggest that the salmon took 2 to 3 days to transit between the two points, which is within the range of swim speeds by Sockeye salmon observed elsewhere.

Background/Rationale

The Copper River salmon fishery is managed in part with an acoustic weir operated by the Alaska Department of Fish and Game (ADF&G) at the Million Dollar Bridge/Miles Lake at mile 50 of the Copper River Highway. ADF&G operates two sonar systems at the site (one on each bank), and fish are counted by technicians from 10 minute subsets done at two frequencies. The sonar systems used by ADF&G are highly specialized imaging multibeam sonars that produce a video-like image by scanning at high frequencies. This allows individual fish to be counted as the pass the sonar, which results in very good estimates of escapement.

The ADF&G sonar site is located at the first point above the Copper River delta where the river is confined to a single channel, and is approximately 35 miles from the nearest ocean entry point to the Copper River Delta at Kokenhenik Bar. Direct measurement of the swimming velocity of up-migrating salmon has not been done in the Copper River, but estimates from matching up abundance peaks between the fishery, a site at Flag Point (~15 miles from the ocean) and the Miles Lake site suggest that it takes at least 3 to 5 days for salmon to transit through the delta (Degan et al., 2005). The lag between the time when the fish enter the river (and are no longer available to the fishery) and when they pass the counters at Miles Lake complicates timely management of effort by the fishery, and can lead to escapements in excess of expectations.

The main channel of the Copper River has been transitioning from having the bulk of the flow through the western side of the delta at Flag Point (mile 27 of the Copper River Highway), towards the east (Brabets and Conaway, 2009). Those changes in flow regime lead to significant damage to a number of the bridges of the Copper River Highway in the early 2000's. After being almost completely undermined by the new main channel, bridge 339 at mile 37 was closed in

2011 and became the new terminus of the Copper River Highway. In the years since the channel has continued to migrate eastward.

Presently, during periods of low discharge, essentially all the water in the river passes through the main channel at bridge 339; as discharge increases and water levels rise, other channels begin to come on-line (Jeff Conaway, USGS Hydrologist, personal communication). Landsat imagery also suggests that during low water, the river is confined to a relatively small number of channels until a point near where the Clear Martin River enters the delta (~10 miles from Kokenhenik Bar), and is heavily braided below that (figure. 1). A pilot study done in 2015 for the CR/PWSMA indicated that the channel near the Clear Martin River was the lowest possible point in the Copper River delta where fish might be counted with acoustic methods: a 720 kHz imaging sonar deployed at the site in late June observed fish passage in the main channel.

In 2016, the CR/PWSMA board funded a proposal submitted by the Prince William Sound Science Center (PWSSC) to deploy an imaging sonar at the Clear Martin site for the early portion of the Copper River salmon run (approximately for the month of May). PWSSC technicians deployed a sonar at the site from May 4th to June 1st; this report will outline the

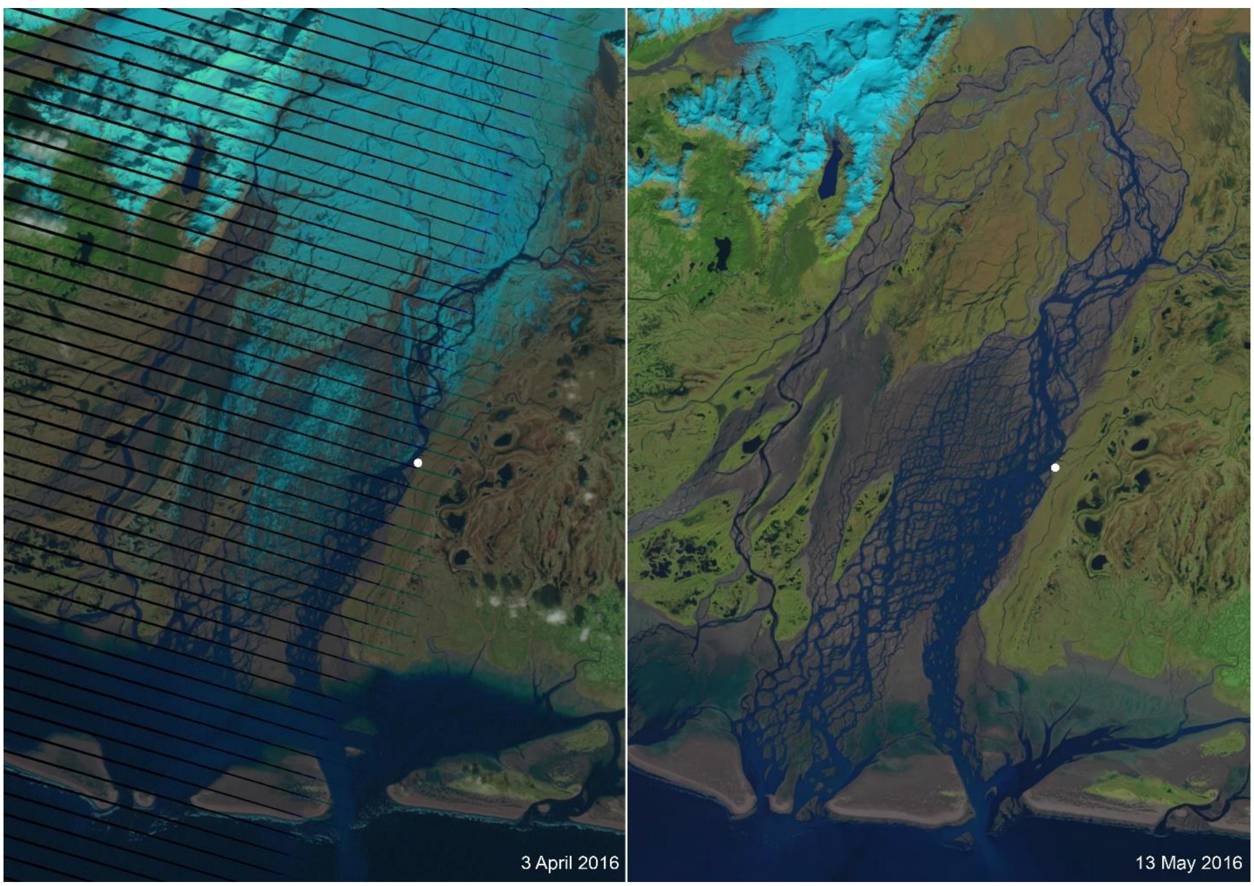


Figure 1: LANDSAT images of the Copper River delta taken on April 3 (left) and 13 May 2016 (right). The black bands in the April 3 image are from a failure in the LANDSAT 7 imager. The position of the sonar camp is denoted by a white dot.

results of that effort.

Narrative of camp activities and sonar methods

Two sonar systems were rented from the Fisheries Ecology and Acoustics laboratory at Florida International University. A Sound Metrics DIDSON (**D**ual frequency **ID**entification **SONa**r) of the same type used by ADF&G at the Miles Lake site, and a Kongsberg M3 multibeam sonar. The M3 sonar operates at a lower frequency than the DIDSON (500 kHz versus 1.1 and 1.8 MHz) and should theoretically have a longer range.

The winter of 2015/2016 was unusually rainy, and the Copper River delta was mostly clear of snow by late April. A field crew of two technicians was deployed at the previously identified site near the Clear Martin River (60° 22.254' N 144° 53.908'W, figure. 1) on May 2nd, and the sonars were deployed at the narrowest part of the channel and recording by noon on May 4th. The sonars were initially sited at a shallower portion of the cutbank that was slightly set back from the main channel (so that the sonars would not be in danger of being hit by floating debris). A 40' long x 20' deep net weir made from seine web (donated by Mike Maxwell at LFS) was set up just downstream of the sonar frame to move up-migrating fish away from the bank so that they might be better ensonified.

Both of the sonars transmit data by an Ethernet connection, and data logging was done through a small standalone network set up in the main tent of the camp. Data logging was done by a dedicated laptop (a Dell Latitude 14 rugged), and processing and fish counting was done with a Lenovo 420S laptop also connected to the network. Network address translation and data transmission was done through a Sierra Wireless RV50 cellular modem connected to the Cordova Wireless cellular network. Two directional antennas were connected to the modem, and pointed at the Flag Point cell site. Connection quality was generally very good, in the -60 to -70 db range (-50 db is an excellent "5 bar" connection, and a very poor connection is in the -100 to -110 db range), but the Flag Point site has 3G cellular hardware, which was the limiting factor in the connection (limiting transfer rates to < 40 kilobytes/second).

The DIDSON sonar was run on a schedule set in the control software, and the technicians would monitor the sonar first and last thing every day, and from time to time during daylight hours to ensure that it was operating correctly. The sonar and laptops were powered by two 4D batteries that were charged daily with a 2kw gas generator. The M3 sonar was not used operationally: it did not allow automated recording, and tended to have difficultly remaining connected on the network. It would often stop recording for unknown reasons after a short period of time. The M3 software also tended to interfere with the operation of the DIDSON software. When it was working, it did not obtain good sonar images of passing fish. Following initial trials, it was decided to focus on the DIDSON sonar, since it returned better results, and is the same system used by ADF&G.

The DIDSON software allows automated recording, and the recording laptop was initially set to automatically record the first 10 minutes out of every hour on the high frequency setting (1.8 MHz, as is done by ADF&G at Miles Lake); as of May 7th, a second low frequency run (1.1 MHz, also as done by ADF&G) was done every hour as well, for 10 minutes starting at 15 minutes after the hour.

Following recording, the videos were automatically processed with a number of routines scripted in the AutoIT programming language. The routines did the following:

1. Transfer raw DIDSON files from the recording laptop to the processing laptop.
2. Run the DIDSON processing software (DIDSONv5 revision 6) on the DIDSON files to produce an uncompressed video file (.avi).
3. Convert the .avi video file to a compressed .mp4 file using FFMPEG (ffmpeg.org). FFMPEG is a free, open source media compression library. Files were compressed with an H.264 encoder (libx264) with a Constant Rate Factor of 36, which was chosen as a compromise between final file size and video quality. The compressed .mp4 files were generally 10-20 MB in size.
4. Transfer the compressed .mp4 files to the PWSSC server (sonar.pwssc.org) via File Transfer Protocol (FTP) with WinSCP.

The above processing routines were run at least twice daily, who then manually counted fish passage on the processing laptop. During times of low fish passage, the video files could be used for counting (they could be sped up to reduce counting times), and during times of high fish passage, the raw DIDSON files were counted with the DIDSON software (which had better resolution, and better allows “backing up” to double check fish targets). Counts from each subset were converted to hourly counts by multiplying the number of counts in the subset by the fraction of each hour that was recorded. Hourly counts were posted several times per day, and each day’s hourly counts summed up to produce a daily count. Spreadsheets with the hourly and daily counts were posted to the PWSSC lower Copper Sonar website (http://pwssc.org/lower-copper-sonar/**)** directly by the technicians several times per day as the counts were finished.

Counts of salmon-sized targets were initially low, and lasted for the first week of the deployment (figure 2, top panel), a large Eulachon run was observed, but those fish were excluded by virtue of their size. Two large peaks of fish were observed passing on May 12-13th.

Fish counts had somewhat declined by mid-May, and a mid-channel bar began to obscure part of the sonar beam. On May 20th, the entire sonar camp, sonars and weir were moved slightly downstream to a less steeply banked location, approximately 200 meters from the original camp site. The new site allowed the sonar to see further out into the channel, though by that time the river had risen considerably. Counts of salmon passage were fairly steady, with several pulses of fish observed. The sonars and camp were removed on July 1st. It would have been preferable to run the sonars for another week, but both technicians had accepted employment elsewhere and were expected at their new positions.

Comparison between the Clear Martin site and the ADF&G Miles Lake site

Hourly counts of fish passage at the Miles Lake site were made available by Stormy Haught at the ADF&G Cordova office (figure 2, bottom panel). Hourly counts from the North and South bank sonars were summed, and then binned into both quarter-day (i.e. 6 hour) counts, and daily (24 hour) counts. The choice of bin size is somewhat arbitrary, the quarter-day counts appear to preserve most of the “pulses” of fish moving through, while removing some of the high frequency variability of the hourly counts.

The two sites showed rather different patterns in fish passage: The Clear Martin site showed an early pulse of fish (several thousand per day), followed by more modest pulses for the rest of the deployment. In comparison, the Miles Lake site showed a steady ramping up of fish passage over time, and less periodicity. A damping of the periodicity in fish passage is to be expected, given that fish will travel up the river at different rates. The number of counts made at the Clear Martin site will also depend on the height of the river: the site is something of a choke point in the early season, but other channels will come on-line as the river rises, and not all fish will be counted. Deploying a single sonar on one bank obviously will under-count fish passage as well, the bank preference of fish at that site is unknown.

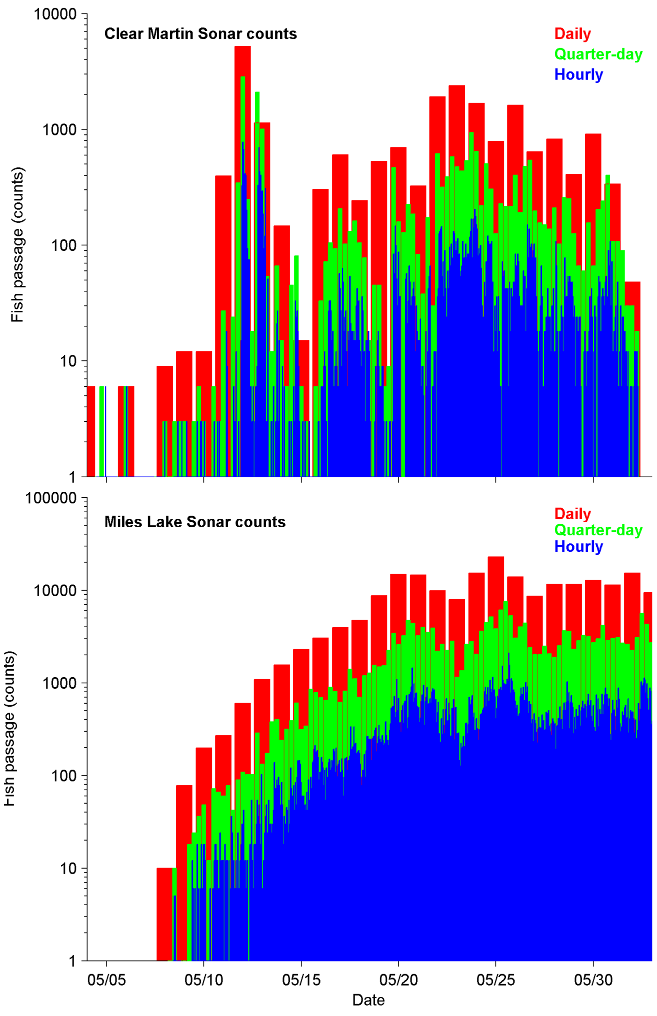


Figure 2: Counts of fish passage made at the Clear Martin sonar site (this sproject, top panel) and the ADF&G sonar site at Miles Lake (bottom panel). Hourly counts (blue bars) were binned into 6 hour (quarter-day) and 24 hour (daily) bins for further analysis. Note that the y-axis scaling differs.

The state of the river during the deployment may be inferred by examining the hydrograph of discharge during the Clear Martin deployment (figure 3). Discharge data from the USGS station at the Million Dollar Bridge were furnished by the USGS office in Anchorage (discharge is derived from stage height observations, and are thus a proxy for water height). The data record at that site is patchy, but includes several years of observations from 1988 to present. To put the 2016 river height (the red line in figure 3) in context, an "average" discharge was calculated with two methods – by averaging all observations for each individual day (the black line in figure 3), or by fitting a fifth order sinusoidal curve through all of the data (the blue line in figure 3). The latter method produces a smooth curve, while the former does not. Both methods indicate that discharges in the latter part of May (May 14-15th onward) were above average. This suggests that the flattening out of fish passage at the Clear Martin site may have partly been due to the river rising more quickly than usual and providing more options to up-migrating fish.

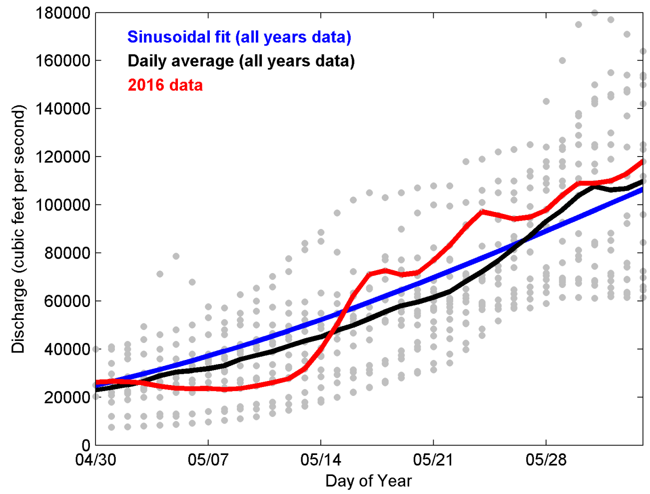
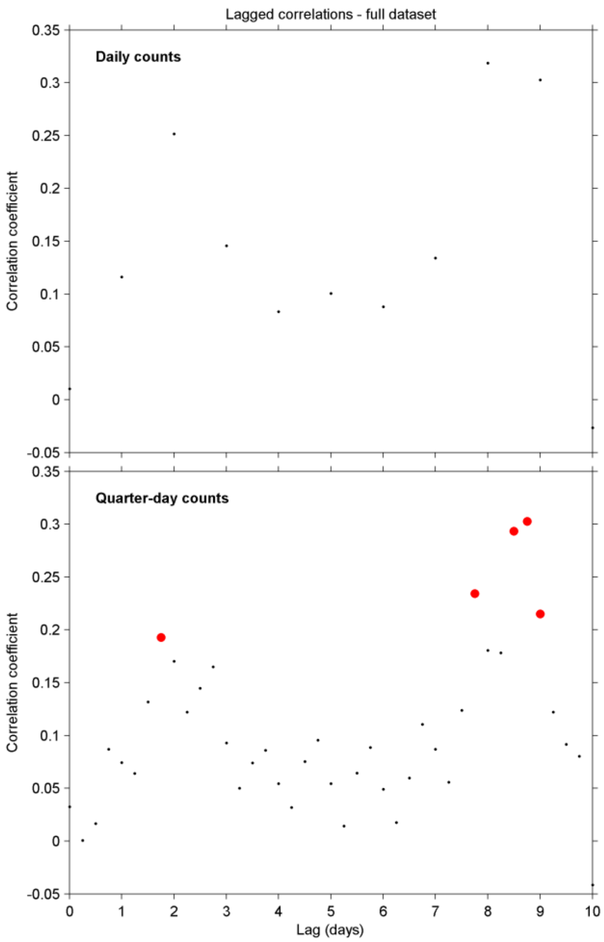


Figure 3: Discharge hydrograph at USGS station 15214000 (Million Dollar Bridge) during May. Grey dots are all observations (i.e. made between 1988 and present), and the red line indicates observations made in 2016. "Average" discharge is indicted as a daily average (black line), which is the average of the discharge for every individual day. A sinusoidal line (blue line) was also fit through the data.

There was an unknown lag time between when fish were counted at the Clear Martin site and when they passed the sonars at Miles Lake. If one assumes that the fish travel at a roughly constant rate, then there may be some coherence between the two sites that will be indicated by the correlational lags between the two sites. The counts made at the Clear Martin site may be correlated against counts made at Miles Lake at some point in the future – this is termed a lag (e.g. counts made at the Clear Martin site at time X can be correlated against counts made at Miles Lake 1, 2 or 3 days later, and so forth). For each correlation, a Pearson's correlation coefficient was determined, and the statistical significance of each correlation tested using a Student's t distribution for a transformation of the correlation. The probability value of the test indicates the probability that a correlation was detected when none exists. Correlations with probabilities < 5% are presented as statistically significant (i.e. there was a 1 in 20 probability that the correlation occurred by chance alone)

The lagged correlations of the entire dataset did not indicate any significant correlations at any lags when daily counts were used (figure 4, top panel), but did find significant correlations at approximately 2 days lag, as well as several correlations at 8-9 day lags when using 6 hour binning (figure 4, bottom panel). However, the two large peaks of fish passing at the Clear Martin site on May 12th and 13th present something of a challenge to this analysis: a correlation implies a linear relationship, but the large counts observed May 12th and 13th may skew that relationship. When the lagged correlations were done with counts from after those two large peaks (May 13th onward), there was a significant correlation detected at ~2 days when using the daily counts (figure 5, top panel), and also when using quarter-day counts (figure 5, bottom panel). Significant correlations also occurred at very long lags (9-10 days), but were negatively correlated (i.e. when counts were high at the Clear Martin, they were low at Miles lake 10 days later). Those correlations are likely a result of aliasing caused by some long term periodicity in fish migration, for instance the stage of the tide determining when the fish chose to enter the river, and are probably not biologically meaningful.

If one assumes that up-migrating salmon use the main channel of the river, the distance between the Clear Martin site and Miles lake is approximately 25 miles (figure 6). A transit time of two days between the Clear Martin site and Miles like implies an average velocity of 0.23 m/s (slightly more than a half mile per hour), which is toward the lower end of swimming speeds observed in sockeye salmon migrating up the Fraser River, where speeds have been observed to vary between 0.14 and 3 m/s (Hinch and Rand 1998; Hanson et al 2008).



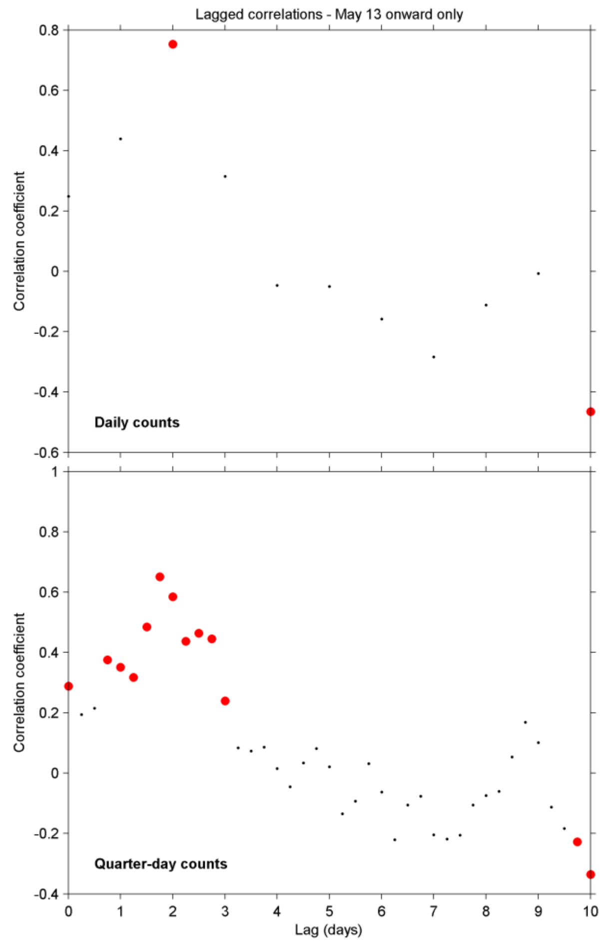


Figure 4: Lagged correlations (Pearson's) between the Clear Martin and ADF&G Miles Lake sonar sites, using daily (top panel) and 6-hour (bottom panel) counts. Correlations were lagged relative to the Clear Martin site (e.g. a lag of 1 day is the correlation between counts made at the Clear Martin site and counts made at Miles Lake on day later). Points denoted in red indicate statistically significant ($p>0.05$) correlations.

Figure 5: Lagged correlations (Pearson's) between the Clear Martin and ADF&G Miles Lake sonar sites, using daily (top panel) and 6-hour (bottom panel) counts, using counts from only May 13 onward. Correlations were lagged relative to the Clear Martin site (e.g. a lag of 1 day is the correlation between counts made at the Clear Martin site and counts made at Miles Lake on day later). Points denoted in red indicate statistically significant ($p>0.05$) correlations.

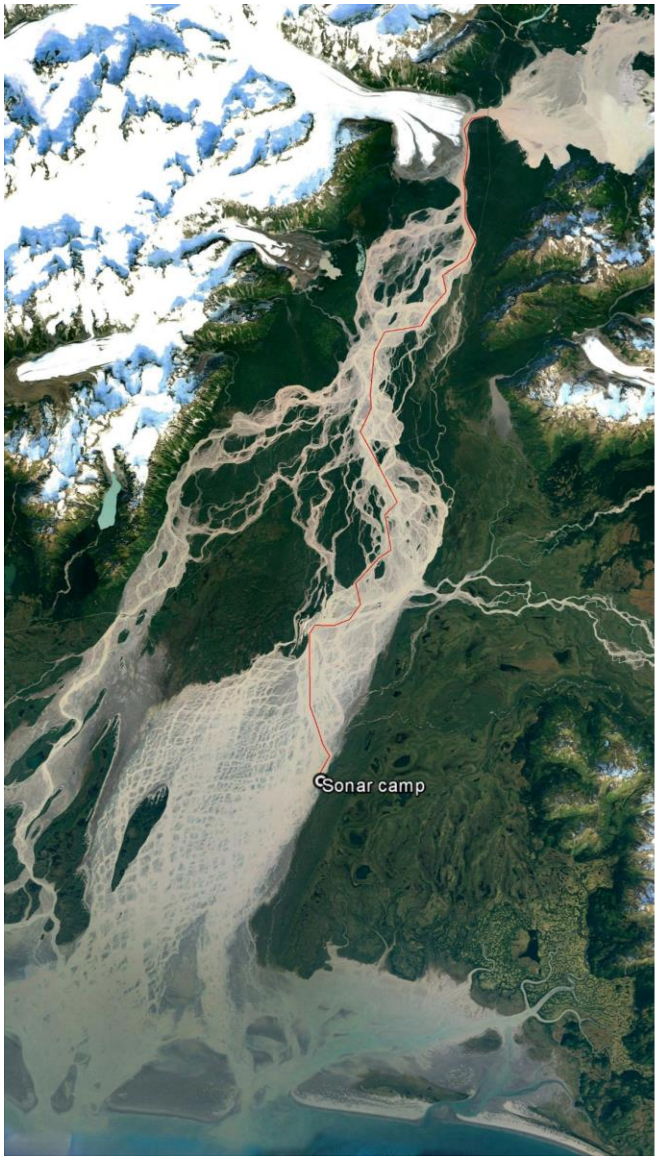


Figure 6: Shortest distance river path used in calculating average salmon swim speeds.

Costs: Budgeted vs Actual

This was the first time this effort had been attempted, and the project proposal budget was a best estimate of the expected costs of the project. As with all projects, the reality of going about doing it was somewhat different than expected; some costs were higher, some lower. A comparison of the original project budget and the actual costs is presented in table 1. Some combining of the original line items has been done where sensible. Overall salary costs were slightly higher than expected: the technicians hired were less expensive than anticipated, and did not work quite as long as expected (the camp was taken down because they had other work obligations). The difference was in Campbell's time, which was under-budgeted. The reason for that was primarily an underestimate of the setup and configuration time for the sonars and networking equipment: time spent on the setup of the logging and analysis computers, and writing the programs to automate the processing and moving of files to the server and website used up most of Campbell's budgeted time before the sonars were even deployed. Once operational, a good deal of Campbell's time was still required, thus the overage.

Table 1: Budgeted vs actual expenses for the 2016 Lower Copper Sonar project. Over-budget lines are denoted by red text.

Item	Budgeted	Actual	Difference
Salary	22125	24160	2035
Data telemetry	1000	451	-549
Supplies			
Food and Incidentals	1200	1269	69
Fuel/Travel	4000	2520	-1480
Misc. camp supplies	1000	618	-382
Equipment			
Sonar rigging	2500	2028	-472
Laptop/computer supplies/network	2000	1825	-175
Cellular modem	500	0	-500
Shelter	0	2662	2662
Other			
Sonar Rental - FIU	10000	9879.96	-120.04
Network, telephone, printing	200	75	-125
Maintenance	1000	0	-1000
Permits	1600	1600	0
Subtotal	47125	47088	-37.04

Most of the other costs were lower than expected, with the exception of food and incidentals which was approximately on budget. Travel costs came in lower by using Campbell's personal jet boat instead of Jack Stevenson for resupply visits. A cellular modem was not purchased as expected, another project conducted by Campbell required a cell modem, so it was purchased early and loaned to the sonar project (the antennas for the setup were purchased under a third project). The only other major unbudgeted purchase was that of two tents. It was advised that the location of the camp could be subject to extreme winds, and that the weatherport originally planned for might not survive a heavy wind event. We were also unable to borrow a floorless tent for use as an outhouse. Therefore, an expedition grade Mountain Hardware "Stronghold" tent was purchased for use as the main camp tent, and a Cascade designs “Twin Sisters” tent purchase for outhouse use.

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