Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2009 - 2010

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Cover: Image of DIDSON control and display software showing fish in display between 4 and 7 m range.

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Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2009 - 2010

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Abstract

During 2009 - 2010 Dual Frequency Identification Sonar (DIDSON) was used to assess the population abundance of adult fall chum salmon *Oncorhynchus keta* in the Chandalar River, a tributary of the Yukon River. In 2009, DIDSON operations began on August 8, but were discontinued early, on August 23, due to concerns for crew safety and logistic constraints. This accounted for approximately 31% of the usual time period of operation, and counting ended before the majority of the run normally passes. A total of 748 hours of data was collected on both banks, with 6,078 upriver fall chum salmon enumerated. During 2010 DIDSON operations began on August 8 and continued until September 26. Of the available 2,400 hours of sample time during the season (1,200 on each bank) 1,942 hours of data were collected, with 149,371 upriver fall chum salmon enumerated. After adjustments were made for missed time, the fall chum salmon passage estimate for 2010 was 157,744. This estimate represents a conservative estimate of total passage because it only included fish that passed during the dates of sonar operation and within the ensonified portion of the river. The passage on the first day of counting was 173 upriver chum salmon. The passage on the final day of counting was 2,545 upriver chum salmon. The first quartile, median, and third quartile passage dates were September 4, 13, and 18 respectively. Fish target positional data suggested that most fish were within the detection range of the DIDSON with most fish being shore-oriented, and few fish observed near the outer range limits of the ensonified zone.

Introduction

Accurate salmon escapement counts on Yukon River tributaries are important for assessing the results of annual harvest management decisions, predicting run strength based on brood year returns, and monitoring long-term population trends. Weirs, counting towers, mark-recapture programs, ground surveys, and hydroacoustics are methods used to obtain escapement estimates of specific Yukon River salmon stocks (Bergstrom et al. 2001).

The Yukon River drainage encompasses 854,700 km² and is among the largest producers of wild Chinook salmon *Oncorhynchus tschawytscha* and chum salmon *O. keta* in North America (Daum and Osborne 1995). The salmon resources of this unique river support important subsistence and commercial fisheries throughout the drainage. The U.S. Fish and Wildlife Service (USFWS), through Section 302 of the Alaska National Interest Lands Conservation Act, has a responsibility to ensure that salmon populations within federal conservation units, including National Wildlife Refuge lands, are conserved in their natural diversity, international treaty obligations are met, and subsistence opportunities are maintained. Accurate spawning escapement estimates for the major salmon stocks in the drainage is one important component for addressing these mandates. The fall chum salmon population in the Chandalar River is one of the largest in the Yukon River drainage and is an important wildlife and subsistence resource.

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The use of fixed-location hydroacoustics to count migrating salmon in Alaska began during the early 1960s. Their use provided counts in rivers where limited visibility or sample volume precluded other sampling techniques (Gaudet 1990). A five year study, (from 1986 to 1990) using fixed-location Bendix salmon counters to enumerate adult fall chum salmon in the Chandalar River was conducted by the USFWS. Results of that study revealed that the Chandalar River fall chum salmon stock was one of the largest populations of fall chum salmon in the entire Yukon River drainage. Annual Bendix sonar counts of fall chum salmon during this period averaged 58,628 fish, with a range of 33,619 to 78,631 fish (Appendix 1). These early “Bendix salmon counters” were not acoustically calibrated, used factory-set echo-counting criteria to determine fish counts, had limited acoustic range (<33 m), and could not determine direction of target travel (upriver or downriver). It is now suspected that due to these technological limitations of the Bendix sonar system, it yielded very conservative estimates of actual salmon passage.

A study was initiated in 1994 to reassess the Chandalar River fall chum population status using the then newly developed split-beam sonar technology. This sonar system was acoustically calibrated, had user-defined echo-tracking techniques to count fish, and had extended acoustic range (>100 m). The split-beam sonar also provided three-dimensional positioning for each returning echo, allowing the determination of direction of travel and swimming behavior for each passing target (Daum and Osborne 1998). Operations during 1994 were used to develop site-specific operational methods, evaluate site characteristics, and describe possible data collection biases, even though activities ended prematurely due to flooding (Daum and Osborne 1995). In 1995, daily and seasonal estimates of fall chum salmon passage were calculated post season and in situ target strength evaluations were collected (Daum and Osborne 1996). Since 1996, the project has provided daily in-season counts to managers and a total estimate of passage post season. Sonar passage estimates from 1995 – 2008 averaged 185,910 ranging from 65,894 to 496,484 fish (Appendix 1).

A more recently developed sonar technology, Dual Frequency Identification Sonar (DIDSON) offers advantages over the previous sonar technologies used on the Chandalar River. These advantages include deployment over a wider range of site conditions, production of a more straightforward visual image, requires less training for technicians due to the more intuitive operation and image interpretation, easier setup and deployment, and the potential to have increased capacity for species determination under some conditions. The major limitations of DIDSON, relative to split-beam sonar, include a more limited range capability, lack of vertical position data, and large data files requiring large hard drives to store or archive data.

Experimentation to evaluate DIDSON for enumeration of fall chum salmon in the Chandalar River began in 2004 and continued through 2006. During this time, up to three DIDSONs were set up at different locations, both adjacent to the split-beam sonar, and at independent locations. Conclusions from these evaluations indicated that the DIDSON was well suited to enumerate fall chum salmon on the Chandalar River. Therefore, DIDSON has been used to enumerate fall chum salmon on the Chandalar River since 2007. Project objectives remained the same as when split-beam sonar was used: (1) provide daily in-season counts of Chandalar River fall chum salmon to fishery managers, (2) estimate annual passage of fall chum salmon, and (3) describe annual variability in run size and timing.

**Study Area**

The Chandalar River is a fifth-order tributary of the Yukon River draining the southern slopes of the Brooks Range. It consists of three major branches, the East, Middle, and North Forks (Figure
1). Principal water sources include rainfall, snowmelt, and, to a lesser extent, melt water from small glaciers, and perennial springs (Craig and Wells 1975). Summer water turbidity is highly variable, depending on rainfall. The region has a continental subarctic climate characterized by the most extreme temperatures in the state, -41.7° to 37.8° C (U.S. Department of the Interior 1964). Precipitation ranges from 15 to 33 cm annually with the greater amount falling between May and September. The river is typically ice-free by early June and freeze-up occurs in late September to early October.

The lower 19 km of the Chandalar River is influenced by a series of slough systems connected to the Yukon River. River banks are typically steep and covered with overhanging vegetation and downed trees caused by active bank erosion. Gravel bars are absent in this area and the bottom substrate is primarily sand and silt. Water velocities are generally less than 0.75 m/s. Approximately 21 to 22.5 km upriver from its confluence with the Yukon River, the Chandalar River is confined to a single channel with steep cut-banks alternating with large gravel bars. Substrate in this area primarily ranges from small gravel to cobble with some sand/silt in slow current areas. Upstream from this area, the river becomes braided with many islands and multiple channels. The sonar study area located at river km 21.5 was previously described by Daum et al. (1992; Figure 2).

The DIDSON deployment locations were 150 - 200 m downriver from the sites where the split-beam was deployed in previous years. The left bank site (left determined while facing downriver) has a bottom slope of approximately 5° out to approximately 40 m where it flattens out (Figure 3). On the right bank the bottom slopes at approximately 7° out to approximately 27 m before it flattens out. Substrate on both banks consists of mainly large gravel. Overall river width at the site ranged from approximately 130 m to 150 m, depending on water level, (excluding during the high water event during August 9-17, 2010, when measurements were unable to be obtained due to the flooding).

Methods

Site Selection and Sonar Deployment

A deployment site for each bank was selected from cross-sectional river profiles of the area (Figure 3), which were developed using a Lowrance (Tulsa, Oklahoma) HDS-7 depth sounder/GPS. Requirements for site selection included: (1) single channel, (2) uniform non-turbulent flow, (3) gradually sloping bottom gradient without sudden inflections, (4) absence of structure or debris that could impede fish detection, (5) location downriver from known salmon spawning areas, and (6) active fish migration past the site (no milling behavior).

The Sound Metrics DIDSON system (Lake Forest Park, Washington) is a high frequency 12° X 29° multiple beam sonar (Belcher et al. 2001; 2002). Two models are available. The standard DIDSON operates at frequencies of 1.8 or 1.1 MHz and has an effective range for confidently enumerating fall chum salmon on the Chandalar River of approximately 30 m, based on the detection of known targets drifted through the sonar, and on analysis of fish data. The long range version operates at frequencies of 1.2 MHz or 700 KHz with effective range of approximately 60 m. DIDSON specifications are available in the DIDSON operation manual V5.11 (Sound Metrics Corp. 2007). The DIDSON units were deployed in fixed locations in the river and communicated with laptop computers for control and data management.

A long range DIDSON was deployed on the left bank and a standard range DIDSON was used on the right bank. Both DIDSON models were operated in the low frequency mode (1.1 MHz
for the standard and 700 KHz for the long range). Partial weirs were installed approximately 1 m downriver of the DIDSONs to direct fish through the beams. Both DIDSONs had a window start setting of 0.75 m, and window length settings were 20 m and 70 m on right and left banks respectively. Both DIDSONs began operation on August 8 during 2009 and 2010.

The DIDSON units were mounted to aluminum frames with brackets allowing manual adjustments to vertical and horizontal aim. The DIDSONs were oriented perpendicular to river flow. The aim was adjusted by placing targets (liter plastic bottles half filled with lead shot) on the river bottom at varying ranges within the ensonified area, and drifting targets through the ensonified area from a boat and verifying that the targets were detected by the sonar.

A wireless network was installed for the left bank so all DIDSON communications, data acquisition, and analysis could occur at a single data tent location on the right bank next to the camp. This remote communications network consisted of two D-Link® DWL-2100AP wireless access points, one connected to the DIDSON on the left bank, and the other, connected to the receiving computer on the right bank. A D-Link® ANT24-1800 outdoor directional panel antenna was attached to each access point using an outdoor low loss RF cable.

Data Collection and Analysis

In the data tent, a wired network was set up for each DIDSON to facilitate data collection and analysis. Each of these data networks consisted of a gigabit Ethernet switch, two laptop computers, and a 500 gigabyte Ethernet hard disk. One computer was used to control and communicate with the DIDSON, and saved the collected data to files on the Ethernet hard disk. The second computer was used to analyze the data and manage files.

The sonar systems were operated 24 hours per day, except for intermittent periods for maintenance, repairs, aim adjustments, or relocating the DIDSON as water levels changed. The collected data were saved to files in 30 minute intervals. Data were analyzed using the DIDSON control and display software (version 5.11; Sound Metrics Corp. 2007). Data files were examined in echogram view and when a potential target was encountered it was further evaluated by reviewing that section of data in normal view to verify that the target was a fish and determine direction of travel. Data from these files were then exported to ASCII files, which were compiled and summarized using a Microsoft Excel Visual Basic for Applications macro developed by the author. A staff gauge was used to record changes in water level throughout the season.

All upriver swimming fish that appeared large enough to be a chum salmon on the DIDSON were assumed to be chum salmon. While actual length measurements from the DIDSON are not exact, relative fish sizes can be observed, and fish that were obviously smaller than chum salmon were not counted. Additionally, previous years of beach seining, gill netting, and underwater video monitoring all indicate that the vast majority of fish that are chum salmon sized are chum salmon (Daum and Osborne 1995, 1996, 1998; Melegari and Osborne 2007; Osborne and Melegari 2006).

Count adjustments were made for time lapses in data acquisition. Partial hourly counts (≥ 15 and < 60 minutes) were standardized to 1 hour, using the formula:

\[ E_h = \left( \frac{60}{T_h} \right) \times C_h \]  

(1)
Where \( E_h \) = estimated hourly upriver count for hour \( h \), \( T_h \) = number of minutes sampled in hour \( h \), and \( C_h \) = upriver count during the sampled time during hour \( h \). Counts for hours with < 15 minutes were discarded and treated as missing hours.

Fish counts from missing hours were estimated from mean hourly passage rates from all previous years during the season. During post season analysis counts from missing hours were recalculated from mean hourly passage rates from the 2010 season. Mean hourly passage rates were calculated from days with 24 h of continuous data. Hourly passage rates (fish/h) were calculated for all hours in each day. These hourly passage rates were expressed as proportions (%) of the daily count so high-passage days did not bias results. Then mean passage rates (%) by hour were calculated for the season. Estimated fish counts for missing hours were calculated, using

\[
ed = \frac{\sum R_{di}}{100 - \sum R_{di}} \cdot T_d.
\]

(2)

where \( E_d \) = estimated upriver fish count for missing hours in day \( d \), \( R_{di} \) = mean hourly passage rate (%) for each missing hour \( i \) in day \( d \), and \( T_d \) = adjusted upriver fish count for non-missing hours in day \( d \).

Daily upriver fish counts for each bank were calculated by summing all hourly counts for that day. For the season, total passage was calculated by summing all estimated daily counts. Hourly fish passage rates for each bank were plotted for the season and examined for diel patterns. Range distributions of fish targets were evaluated to assess the likelihood of fish passing beyond the detection range of the DIDSON.

The possibility of undercounting fish that are swimming close together increases with increasing window length (Z axis) due to the decrease in screen resolution along the Z axis. On the left bank a long range DIDSON with a window length of 70 m is used, with these settings the resolution along the Z axis is approximately 140 mm (Sound Metrics Corp. 2007). To determine if fish were being missed due to this lower resolution, a second standard range DIDSON was deployed along side of the long range DIDSON in 2010. The standard DIDSON was deployed the same distance offshore, approximately 1 m upstream of, and aimed parallel to the long range DIDSON. The window start length was the same as the long range (0.75 m), and window length was set at 18.65 m. Hourly counts from the standard DIDSON were compared to hourly counts of fish within the comparable 18.65 m range from the long range DIDSON. Only hours when both DIDSONs counted for the complete hour were compared.

Beach seining was conducted to qualitatively evaluate the presence of non-target species. A beach seine was used instead of gill nets because seining provides a less selective sampling method and does not cause mortality inherent in gillnet sampling (Hayes et al. 1996). A 90 m x 3.7 m, with 2.5 cm mesh seine was set from each bank (Figure 3). Seine sets were made in morning and/or late evening.

Sex, length, and vertebrae for aging were collected from fall chum salmon carcasses on the spawning grounds during October 8 and 9. A helicopter was used to survey the spawning area for concentrations of spawned out fish. Upon location of concentrations of spawned out fish, all fish at a particular site were sampled to reduce possible sampling bias. Fish were measured to the nearest 5 millimeters, mid-eye to the fork of the tail (METF). The sex of specimens was determined, by external morphology or by dissection of the carcass and visual identification of
reproductive organs when sex was not obvious from external morphology. Vertebrae were collected, cleaned, and provided to Alaska Department of Fish and Game for aging.

Results

Site Selection and Sonar Deployment

During each year several cross sectional profiles were recorded on each bank near the identified deployment locations and the DIDSONs were deployed at the river bottom profiles considered best for counting fish with the DIDSONs (Figure 3). The DIDSONs were deployed at the same approximate locations during both years; minimal changes in physical conditions were observed at the locations between years. Counting began on August 8 during both years. During 2009 counting was discontinued early, on August 23, due to concerns for crew safety and logistic constraints. During 2010 operations continued through September 26. The left bank wireless performed well except for a slightly lower maximum frame rate limitation than experienced when wired, and occasional short term interruptions to the wireless connection. Neither one of these conditions substantially impacted the effectiveness of the DIDSON.

Data Collection and Analysis

During the 2009 season, with the early termination of operations, only 748 hours of acoustic data were collected, and 6,321 fish were counted (Table 1). Of these, 6,078 (95% of the total fish counted) were upriver fish (i.e. fall chum salmon). Upriver fish counts were 1,243 and 4,835 for the left and right banks, respectively. The time of operation during 2009 accounted for only 31% of the time normally monitored during this project, and the project ended before the majority of fish usually pass the site.

During the 2010 season, 1,942.1 hours of acoustic data were collected and 150,713 fish were counted (Table 2). Of these, 149,371 (99% of the total fish counted) were upriver fish. On the left bank, 958.2 h (80% of the possible 1,200 h) were monitored, with 196.1 hours missed due to high water during August 9 to 17, and 45.7 hours due to intermittent disruptions to the remote communications network, generator refueling, and maintenance/repairs. On the right bank, 983.9 h (82% of the possible 1,200 h) were monitored, with 196.1 hours missed due to high water during August 9 to 17, and 20 hours missed for maintenance/repairs. Upriver fish counts were 34,479 and 114,892 for the left and right banks, respectively.

After adjusting for the missed time, the estimated fall chum salmon passage for 2010 was 157,744 (Table 3). The left bank estimate was 38,539 accounting for 24% of the total. The right bank estimate was 119,892, accounting for 76% of the total. The adjusted count was 173 upriver fish on the first day of sonar operation (0.1% of the total), and 2,545 fish on the final day of counting (1.7% of the total). Peak daily passage occurred during September 15 (Figure 4). The first quartile of the run occurred during September 4, the median during September 13, and the third quartile during September 18.

During 2010, hourly passage rates (number of fish for each hour expressed as a proportion of the daily count) of upriver fish showed a strong diel pattern on the left bank, and a slight pattern on the right bank. These patterns displayed higher passage rates during late night or early morning hours (Figure 5). During 2009 mean hourly passage rates were not calculated due to the limited data collected.
Upriver migrating chum salmon were shore-oriented and most fish were well within the range of acoustic detection for both banks (Figures 6 and 7). More than 95% of upriver fish were within 17 m on the left bank, and 13 m on the right bank. Downriver fish, while still shore oriented, were slightly more dispersed across the full detection range of the DIDSONs.

During October 5-6, 2009, a helicopter was used to identify locations with concentrations of chum salmon carcasses on the Chandalar River. Sex, length, and vertebrae for aging were collected from carcasses at two sites. The GPS locations of the sites were: N 67° 05.060′ W 147° 01.640′; N 67° 02.543′ W 146° 51.449′. Samples were collected from 180 carcasses, 104 females and 76 males. After being boiled and cleaned samples were sent to Alaska Department of Fish and Game to be aged. Ages were able to be determined for all of the samples. There were two primary age classes, 0.3 and 0.4, from brood years 2005 and 2004, respectively (Table 4). Age class 0.3 was predominant overall, accounting for 63% of the total samples, while age class 0.4 accounted for 26% of the total. Females and males were both predominantly age class 0.3 (67% and 57% respectively). Also included were age classes 0.2, 0.5 and one fish in age class 0.6 accounting for 9%, 2%, and <1% of the total samples respectively. The sex ratio of the samples was 58% female. Females ranged from 500 to 660 mm METF and males ranged from 510 to 660 mm METF (Table 5). For length-at-age measurements, mean lengths of male fish were generally larger than females.

During October 8-9, 2010, sex, length, and vertebrae for aging were collected from carcasses at three sites. The GPS locations of the sites were: N 67° 03.862′ W 146° 57.790′; N 67° 02.591′ W 146° 46.556′; N 67° 02.628′ W 146° 52.094′. Samples were collected from 180 carcasses, 124 females, 53 males, and 3 where sex was undetermined. After being boiled and cleaned samples were sent to Alaska Department of Fish and Game to be aged. Ages were able to be determined for all of the samples. There were three primary age classes in the samples, 0.3, 0.2, and 0.4, from brood years 2006, 2007 and 2005, respectively (Table 6). Age class 0.3 was predominant overall, accounting for 58% of the total samples, age class 0.2 accounted for 21% of the total, and age class 0.4 accounted for 17% of the total. Female samples were predominantly age class 0.3 (56%) followed by age class 0.2 then age class 0.4 (24% and 15% respectively). Male samples were also predominantly age 0.3 (62%) but the second most abundant was 0.4 then 0.2 (21% and 13% respectively). Also included were age classes 0.5 and one fish in age class 0.6 accounting for 3%, and <1% of the total samples respectively. The sex ratio of the samples was 70% female overall. Females ranged from 490 to 650 mm METF and males ranged from 530 to 720 mm METF (Table 7). For length-at-age measurements, mean lengths of male fish were generally larger than females.

Beach seining was not conducted in 2009 due to the early discontinuation of the project. Beach seining during 2010 began in early September since that is historically when least cisco Coregonus sardinella, the only other species historically abundant enough to seriously impact sonar counts, began showing up in the catch. Between September 4 and September 23 a total of 42 beach seine hauls, 21 on each bank, were made (Table 8). Similar to previous years of seining catch rates were very low. Chum salmon were the dominant species in the catch (72%), with 31 being caught. Other fish caught included four northern pike Esox lucius, two Arctic grayling Thymallus arcticus, two humpback whitefish Coregonus pidschian, one least cisco and one round whitefish Prosopium cylindraceum.

For the 2010 standard – long range DIDSON comparison on the left bank, the standard DIDSON was operated from August 28 through September 25. This resulted in 533 hours of data where the standard and long range DIDSON concurrently counted full hours. The standard DIDSON
counted 20,815 fish during those hours, while the long range DIDSON counted 20,104 fish within the same range window as the standard DIDSON (0.75 m – 18.65 m), a difference of only 3.5%. When comparing hourly counts, the long range DIDSON produced lower counts then the standard DIDSON for 285 (53%) of the hours compared; larger counts then the standard DIDSON for 187 (35%) of the hours compared; and the same counts as the standard DIDSON for 61 (11%) of the hours compared. However the magnitude of the differences between counts was small, and the average difference in hourly counts was 0.7%. Counts from the two DIDSONs were highly correlated, ($R^2=0.97$), and the fitted line had an intercept of -0.78 and a slope of 1.056 (Figure 8), indicating that the rate of error does appear to increase slightly at higher densities.

Discussion

Site Selection and Sonar Deployment

The greater tolerance for site conditions of the DIDSON relative to the split-beam sonar previously used on this project has allowed operations to continue over a wider range of water levels than previously possible. The 2010 season was the first year since switching to DIDSON in 2007 that operations were interrupted for any notable time due to high water. Since the project began in 1994 similar water levels have only been observed on two other occasions.

Proper aim of the sonar remains a primary concern; however, the wider beam angles of the DIDSON and the ability to continue enumeration of fish while the beams are hitting the substrate, make small precise adjustments to aim less critical than with the split-beam system. Additionally, the images provided by the DIDSON allow for a quicker, more confident evaluation of the aim and aiming adjustments than with the split-beam sonar. This has allowed us to forego the use of the remote controlled underwater rotators that were used with the split-beam sonar and aim the DIDSONs manually. Manual adjustment of the aim has worked well, with two way radios used to facilitate communication between the DIDSON operator and the person adjusting the aim. Furthermore, not using the rotators has reduced the power requirements of the system.

Few problems with the remote communications network were encountered and were primarily limited to brief interruptions to the connection. Maximum achievable frame rates, however, were slightly more limited with the remote communications network than with hard wiring. Data were collected at two frames per second on the left bank with the long range DIDSON and the remote communications network. During previous years and under similar conditions, we were able to operate the long range DIDSON at three to four frames per second when hard wired. However, two frames per second was considered sufficient to capture fall chum salmon migrating upriver past the site. This is supported by the data, in which nearly all fish were captured in several frames. If substantial numbers of fish were not being detected because the frame rate was too low, then more fish would be expected to be almost missed, or captured in only one or two frames.

Data Collection and Analysis

Run timing during 2010 in the Chandalar River was later than average. Both the first and third quarter passage dates, September 4 and 18 respectively, were four days later than the average for 1995 - 2008. The mid point, September 13, was six days later than the average for 1995 - 2008. Considering that the estimated passage on the last day was 1.6% of the cumulative, it is probable that the actual quarter point dates for the run are slightly later than the dates indicated.
Preliminary data from other fall chum salmon projects in the Yukon River drainage also suggest later than average run timing (Alaska Department of Fish and Game unpublished data; Fisheries and Oceans Canada unpublished data). Attempting to extend the project beyond the normal shut down day of September 26 was unfeasible due to logistic constraints and weather conditions.

The 2010 passage estimate of 157,744 fish was 85% of the average from 1995 - 2008 (Figure 8). Preliminary data from other fall chum salmon enumeration projects during 2010 also indicate lower than average/expected escapements (Alaska Department of Fish and Game unpublished data; Fisheries and Oceans Canada unpublished data).

Generally, the Chandalar River sonar passage estimate is a conservative estimate. This is because counts did not include fish that passed before or after the sonar was in operation, e.g. passage on the final day of operations was still 1.6% of the total. Additionally, while chum salmon are generally considered shore and bottom oriented during migration, which is supported by our data that suggest most fish passed well within the ensonified zone, it is likely that a small number of fish passed undetected outside of the ensonified zone.

The observed diel patterns in upriver fish passage were similar to patterns seen during previous years (Daum and Osborne 1998; Osborne and Melegari 2006). During most years, the left bank has had a strong diel pattern, while the right bank generally displays a weaker, or sometimes an undistinguishable diel pattern. Also of note is the general pattern of the peak daily passage rate occurring later in the morning on the right bank then on the left, which is also common during previous years. The fact that these similar patterns were observed at the new locations, where the physical conditions of the river on the right bank closely resemble those of the old split-beam left bank location, highlights the complexity of behaviors in migrating fish, and indicates that factors other than in-river physical conditions at the sonar site may be influencing the diel patterns.

During 2010, the right bank accounted for 76% of the total passage. This is similar to that observed in previous years. The pattern of higher right bank counts has been observed during all years of operation (Appendix 1) however, the differences have tended to be greater in more recent years. This could be due to natural variation, or changing river conditions. The differences in counts during recent years of the project have generally tended to be larger and a little more variable than during the earlier years of the project. Another possible reason for the larger differences in counts could be the relocation of the site 150 - 200 m down river. A larger proportion of the fish may be migrating on the right bank at this location. There is a sand/gravel bar that extends into the river from the right bank between the new downriver site and the previous site. This bar could be affecting migration patterns, causing fish to crossover between the new and old sites.

Fish range data collected with the DIDSONs were similar to data collected during previous years and suggested that most upriver fish passing the sonar site were within the ensonified zone. Upriver fish were found close to shore with few fish near the range limits of acoustic detection. This shore orientation is consistent with previous behavioral observations of upriver-migrating fall chum salmon on the Chandalar (Osborne and Melegari 2006), Sheenjek (Barton 1995) and mainstem Yukon rivers (Johnston et al. 1993). Unlike the split-beam sonar, the DIDSON does not obtain vertical position data. However, the much larger vertical angle of the DIDSON’s beams (12° vs. 2.1° and 4.8° used with the split-beam on the Chandalar River) reduced the potential of fish passing above or below the beams. This is further supported by the DIDSON
data, where surface waves were usually detected on windy days, and the river bottom was normally visible throughout most or all of the range.

Beach seine catches were similar to previous years, with chum salmon making up the vast majority of the catch. Additionally, more than half of the catch that was not chum salmon were species that were much smaller than the chum salmon (Arctic grayling and whitefish), which should be distinguishable on the DIDSON. Previous seine catches and information from underwater video (Melegari and Osborne 2007; Osborne and Melegari 2006) have shown increased catches and observations of least cisco beginning in early September. However, only one least cisco was caught in 2010. While certainly not conclusive, this could be an indication that the abundance of least cisco in the Chandalar River is cyclic or highly variable.

The standard – long range comparison indicated that the number of fish that were sometimes missed with the long range DIDSON relative to the standard DIDSON, was small (3.5% overall), and in nearly half the hours compared (47%) the long range counts were the same or greater than the standard range counts. The standard range counts were completed post season (one to two months later) by the same technicians who counted the long range counts during the season. Because of this, and the large number of hours compared (533 hours) potential errors or biases due to different counters, or concerns that counts from one DIDSON may have influenced the other are not an issue.

The most likely solution to address possible issues of reduced resolution when shooting out to longer ranges would be to divide the covered range into two range windows and subsample from each range, allowing the use of shorter window lengths. However, we do know from our passage data that fish passage, even within a single hour, is not evenly distributed and most fish pass in clusters or groups. Our data also indicate that, at our site, the overall number of fish missed when counting with the long range DIDSON opposed to the standard range DIDSON is relatively small. Therefore, under these circumstances estimates derived from such subsamples of fish passage could have errors or bias that would be greater than those derived from the long range DIDSON, although the actual size of this error or bias would be unknown.

**Conclusions**

The DIDSON performed well and while counts were interrupted by the very high water experienced in 2010 operations were reinitiated much sooner than what would have been possible with the split-beam. Less down time resulted in fewer adjustments to raw counts, which should correspond to more accurate passage estimates.

Video monitoring and beach seining have been used to evaluate sonar performance and the presence of non-target species. Both methods are greatly impacted by water conditions and only provide qualitative data. However, they do provide beneficial information with very little additional cost. The beach seining should be continued, and video monitoring should be implemented during future years as conditions allow.

Considering the small difference in long range versus standard counts, and the potential and unknown error that could result from passage estimates from subsamples, this data does not support a need to modify data collection at the Chandalar sonar project at this time.

Annual sonar enumeration of fall chum salmon in the Chandalar River is a vital component for effectively managing the complex mixed stock subsistence and commercial fisheries in the Yukon River. The Chandalar River fall chum salmon stock is a crucial stock component of the
total Yukon River fall chum salmon run and is important to users throughout the drainage. Daily in-season counts and post-season passage estimates provide important escapement information to managers and users of this resource, allowing better informed management decisions and evaluation of past actions. This project is an important component in assessing the lower river abundance estimate proportioned by mixed stock genetic analysis. Additionally, this project has provided accurate population status and trend data over a 16 year time series. These time series data will become increasingly important as stressors such as climate change, disease, selective harvest, and overall demand on the fisheries and resources in the Yukon River drainage continue to increase.

Acknowledgements

Special appreciation is extended to the people who participated in this project, and who are largely responsible for its success: crew leaders Jeremy Carlson & Laura Gutierrez, technicians Jennifer Malavasi, Jessica Beecher, Mike Purviance, Jeff Yacevich for field assistance. Aaron Martin, Dave Daum, Jeremy Mears, Fred Bue, and Gerald Maschmann for editorial review. We would also like to thank Yukon Flats National Wildlife Refuge and the Council of Athabascan Tribal Governments for logistics support in Ft. Yukon.
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*a Sonar shut down due to high water.
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<td>52.42</td>
</tr>
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<td>6,538</td>
<td>135,591</td>
<td>85.96</td>
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<tr>
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<td>6,154</td>
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<td>996</td>
<td>3,463</td>
<td>4,459</td>
<td>146,204</td>
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<td>2,804</td>
<td>152,345</td>
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<td>2,854</td>
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<td>1,724</td>
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<td>Totals</td>
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<td>157,744</td>
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<td></td>
</tr>
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</table>

* Partial daily count, missing hours estimated using mean hourly frequencies.
* Sonar shut down due to high water, counts interpolated.
### Table 4
- **Age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska, 2009.**
- Vertebrae aged by Alaska Department of Fish and Game, unknown age indicates numbers of samples that could not be aged and were not included in age calculations.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>Unknown age</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Female</td>
<td>104(58%)</td>
<td>0 (0%)</td>
<td>10 (10%)</td>
<td>70 (67%)</td>
<td>23 (22%)</td>
</tr>
<tr>
<td>Male</td>
<td>76(42%)</td>
<td>0 (0%)</td>
<td>6 (8%)</td>
<td>43 (57%)</td>
<td>23 (30%)</td>
</tr>
<tr>
<td>Total</td>
<td>180(100%)</td>
<td>0 (0%)</td>
<td>16 (9%)</td>
<td>113 (63%)</td>
<td>46 (26%)</td>
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</table>

### Table 5
- **Length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska, 2009.**

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Mean</th>
<th>SE</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>10</td>
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<td>8.8</td>
<td>555</td>
<td>505-590</td>
</tr>
<tr>
<td>0.3</td>
<td>70</td>
<td>557</td>
<td>2.9</td>
<td>558</td>
<td>500-600</td>
</tr>
<tr>
<td>0.4</td>
<td>23</td>
<td>565</td>
<td>6.6</td>
<td>570</td>
<td>470-620</td>
</tr>
<tr>
<td>0.5</td>
<td>1</td>
<td>590</td>
<td>–</td>
<td>590</td>
<td>–</td>
</tr>
<tr>
<td>0.6</td>
<td>0</td>
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<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Total</td>
<td>104</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

### Table 6
- **Age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska, 2010.**
- Vertebrae aged by Alaska Department of Fish and Game, unknown age indicates numbers of samples that could not be aged and were not included in age calculations.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>Unknown age</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Female</td>
<td>124(70%)</td>
<td>0 (0%)</td>
<td>30 (24%)</td>
<td>70 (56%)</td>
<td>19 (15%)</td>
</tr>
<tr>
<td>Male</td>
<td>53(30%)</td>
<td>0 (0%)</td>
<td>7 (13%)</td>
<td>33 (62%)</td>
<td>11 (21%)</td>
</tr>
<tr>
<td>Total</td>
<td>177(100%)</td>
<td>0 (0%)</td>
<td>37 (21%)</td>
<td>103 (58%)</td>
<td>30 (17%)</td>
</tr>
</tbody>
</table>

### Table 7
- **Length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska, 2010.**

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Mean</th>
<th>SE</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
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<tr>
<td>0.3</td>
<td>70</td>
<td>558</td>
<td>3.2</td>
<td>560</td>
<td>500-650</td>
</tr>
<tr>
<td>0.4</td>
<td>19</td>
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<td>570</td>
<td>500-630</td>
</tr>
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<td>0.5</td>
<td>4</td>
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<td>11.9</td>
<td>585</td>
<td>560-610</td>
</tr>
<tr>
<td>0.6</td>
<td>1</td>
<td>630</td>
<td>–</td>
<td>630</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>124</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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Table 7 — Length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska, 2010.
Table 8 — Beach seine catches at the Chandalar River sonar site, 2010.

<table>
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<th>Number of sets</th>
<th>Chum salmon</th>
<th>Arctic grayling</th>
<th>Northern pike</th>
<th>Humpback whitefish</th>
<th>Least cisco</th>
<th>Unknown whitefish</th>
<th>Left bank</th>
<th>Right bank</th>
<th>Total LB</th>
<th>Total RB</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
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<td>-</td>
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<td>-</td>
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<td>31</td>
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<tr>
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<td>22-Sep</td>
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<td>23-Sep</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Total RB</td>
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<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total Combined</td>
<td>42</td>
<td>31</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. — Sonar site and major tributaries of the Yukon River near U.S. Canada border.
Figure 2. — Site map of Chandalar River sonar facilities.

Figure 3. — River channel profile and approximated ensonified zones for the left and right bank sonar sites, Chandalar River, 2009. Very little change was detected in channel profile from 2008 - 2010. Different axis scales are used to enhance readability.
Figure 4 — Estimated passage of upriver fall chum salmon by bank and combined, Chandalar River, 2010. Highlighted data points in the top graph indicate the 1st quarter, mid, and 3rd quarter points of passage.
Figure 5. — Mean (±2 SE) hourly frequency of upriver fish, Chandalar River, 2010. Hourly frequency is the hourly passage expressed as a percent of the total daily count. Data from 34 complete days of 24 hour data on the left bank and 37 days on the right bank.
Figure 6. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the left bank Chandalar River, August 8 to September 26, 2010. Note different Y-axis scales.
Figure 7. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the right bank Chandalar River, August 8 to September 26, 2010. Note different Y-axis scales.
Figure 8 — Scatter plot of hourly counts from standard and long range DIDSONs. The black solid line is the fitted regression line, and the red dashed line indicates the one-to-one line.

Figure 9. — Annual passage estimates (in thousands of fish) of fall chum salmon from sonar counts on the Chandalar River, 1995 - 2010. The horizontal line indicates the average of 1995-2008 passage estimates. In 2009 the project was ended early, before the majority of the run normally passes, and that partial count is not included in this chart.
Appendix 1. — Historical fall chum salmon passage estimates from sonar counts on the Chandalar River, Alaska.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sonar type</th>
<th>Left bank</th>
<th>Right bank</th>
<th>Combined</th>
</tr>
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<tbody>
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<td>1987</td>
<td>Bendix</td>
<td>36,089</td>
<td>16,327</td>
<td>52,416</td>
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<td>1988</td>
<td>Bendix</td>
<td>20,516</td>
<td>13,103</td>
<td>33,619</td>
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<tr>
<td>1989</td>
<td>Bendix</td>
<td>36,495</td>
<td>32,666</td>
<td>69,161</td>
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<tr>
<td>1990</td>
<td>Bendix</td>
<td>24,635</td>
<td>53,996</td>
<td>78,631</td>
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<tr>
<td>1995</td>
<td>Split-beam</td>
<td>116,074</td>
<td>164,925</td>
<td>280,999</td>
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<tr>
<td>1996</td>
<td>Split-beam</td>
<td>75,630</td>
<td>132,540</td>
<td>208,170</td>
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<tr>
<td>1997</td>
<td>Split-beam</td>
<td>65,471</td>
<td>134,403</td>
<td>199,874</td>
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<tr>
<td>1998</td>
<td>Split-beam</td>
<td>31,676</td>
<td>44,135</td>
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<td>Split-beam</td>
<td>38,091</td>
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<tr>
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<td>16,420</td>
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<td>65,894</td>
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<td>20,299</td>
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<tr>
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<td>Split-beam</td>
<td>24,188</td>
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<td>Split-beam</td>
<td>68,825</td>
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<tr>
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<td>29,851</td>
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<td>159,937</td>
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<td>Split-beam</td>
<td>63,123</td>
<td>181,967</td>
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<tr>
<td>2007</td>
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<td>22,261</td>
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<td>DIDSON</td>
<td>38,539</td>
<td>119,205</td>
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</tr>
</tbody>
</table>

* Estimates calculated post season.

b Incomplete counts, operations stopped before the majority of the run normally passes.
Appendix 2. — Water temperature and staff gauge readings taken at the Chandalar River Sonar project, 2010.

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