In-season Harvest and Effort Estimates for the 2018 Kuskokwim River Subsistence Salmon Fisheries During Block Openers

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Abstract

Management of the Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*) subsistence fishery has historically been conducted with minimal in-season information about harvest and run strength. Because of this lack of information, it is challenging to make well-supported and defensible decisions regarding fishing opportunities to simultaneously achieve conservation and subsistence harvest objectives, particularly during years of weak runs. In response to an anticipated weak 2018 Kuskokwim River Chinook salmon run, the United States Fish and Wildlife Service in collaboration with the Kuskokwim River Inter-Tribal Fish Commission, the Orutsararmiut Native Council, and the Alaska Department of Fish and Game collected data to produce in-season subsistence salmon harvest estimates from the portion of the main stem Kuskokwim River within the boundaries of the Yukon Delta National Wildlife Refuge between and including the villages of Tuntutuliak and Akiak. Using methods developed in 2016 and further refined in 2017, the estimated total subsistence salmon harvest in this area was 87,750 (75,670 – 101,230) during five fishing opportunities between June 12 and July 5, 2018. Most salmon harvested were chum salmon (*O. keta*; 43,570; 35,840 – 52,000), followed by sockeye salmon (*O. nerka*; 23,320; 19,020 – 28,110), and Chinook salmon (20,870; 17,670 – 24,630). Methodologies refined during this study should be useful to structure future efforts to estimate subsistence salmon harvest in-season on the Kuskokwim River as well as other fisheries with similar characteristics.

1 Introduction

In order to manage in a fully-informed way, a manager of a Pacific salmon (*Oncorhynchus* spp.) fishery would require an accurate pre-season run size forecast, as well as accurate and continuous information on run timing and at least one of either harvest or escapement. With knowledge on these components, it would then be possible to know how much of the run is yet to come, how much escapement potential remains, and how many more fish may be harvested.

In-season management of Kuskokwim River salmon harvest has historically been conducted with very little of this information (due in a large part to the size and remoteness of the system), and has instead relied largely on a single index (the Bethel Test Fishery[1]; BTF; Bue and Lipka, 2016) of run abundance, run timing, and species composition to inform decision-making. Work is underway to develop and evaluate methods of obtaining more detailed information regarding run timing (Staton et al., 2017) and run size (e.g., a relatively new main stem sonar project and a Bayesian approach to update run size forecasts with in-season data daily; Staton and Catalano, unpb) and delivering it to managers and stakeholders in a timely manner for decision-making. However, even with perfect information on these run characteristics, the manager would still be left wondering about how many fish have been harvested to date, which is important for structuring future fishing opportunities.

Timely in-season subsistence harvest estimates have only recently been available in the Kuskokwim River (2015 – 2017) for in-season management consideration. The primary need for producing in-season harvest estimates has been to to track the progress towards a season-wide target harvest of Chinook salmon chosen to ensure the escapement goal will be met. In 2015, relatively simple harvest estimates were produced based on aerial boat counts and completed trip interview data collected during short-duration block openings (unpublished data). For the 2016 season, a more complex harvest estimation method was developed to better-interpret the data (Staton and Coggins, 2016); this approach was again applied in 2017 (Staton and Coggins, 2017). The method was relatively consistent with the existing literature regarding harvest estimation from fisheries in Alaska (Bernard et al., 1998). The primary difference between the standard methods presented in Bernard et al. (1998) and those used by (Staton and Coggins, 2016, 2017) is the extent of temporal and spatial scales that are considered. Standard methods are designed to obtain estimates using structured sampling programs covering extended periods of time (several weeks or months) over relatively small areas (several lakes or streams), whereas Staton and Coggins (2016, 2017) were concerned with estimating harvest from short bursts of fishing activity (ranging from 6 to 72 hours) spread over a large spatial area (spanning > 300 kilometers of the main stem Kuskokwim River from the villages of Tuntutuliak to Aniak; Figure 1).

In response to an anticipated weak 2018 Kuskokwim River Chinook salmon run (pre-season forecast of 133,000 fish), the United States Fish and Wildlife Service (USFWS), by delegation from the Federal Subsistence Board, assumed primary management authority of the Kuskokwim River Chinook subsistence fishery within the boundaries of the Yukon Delta National Wildlife Refuge (YDNWR; Figure 1). The Federally-designated in-season manager, along with YDNWR staff and in collaboration with the Kuskokwim River Inter-Tribal Fish Commission (KRITFC), designed and implemented a management strategy based on explicit objectives informed by the best available scientific information, and the Alaska Department of Fish and Game (ADF&G) provided input throughout the process. In pre-season management meetings, the Federal in-season manager

[1] http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareakuskokwim.btf

and the KRITFC agreed that the subsistence fishery should target 16,000 Chinook salmon considering an anticipated run size of approximately 133,000 fish and a fundamental objective to ensure a spawning escapement of at least 110,000 fish with a 53% chance. The probabilistic framing of objectives was a new introduction to the management process in 2018, facilitated by a Bayesian method to update the pre-season run forecast with index data from the BTF (Staton and Catalano, unpb) and a risk assessment tool, known commonly as the P^* model[2]. The BTF index suggested the run was approximately 10% smaller than forecast for nearly all of June, but managers did not adjust the harvest objective. This decision was in response to the updated run forecast, which suggested that if the pre-season strategy was loosely followed, there would be a 90% chance of having escapement fall above the lower bound of the drainage-wide goal (65,000).

During June and July 2018, there were five subsistence fishery openings within the YDNWR boundaries (those limited to no larger than 6-inch mesh gillnets and implemented by Federal Special Action):

- 6/12/2018 (12 hours; 10:00–22:00[3])
- 6/16/2018 (12 hours; 10:00–22:00[4])
- 6/24/2018 (12 hours; 10:00–22:00[5])
- 6/29/2018 (6 hours; 12:00–18:00[6])
- 7/5/2018 (12 hours; 9:00–21:00[7])

Harvest and effort estimates were produced for each of these openers and the data were analyzed as quickly as possible (generally within 24 – 48 hours) for review by managers when the next opener was considered. Shortly after the fifth opener, managers decided that further restrictions to the subsistence fishery would have negligible effects on Chinook salmon escapement because of (1) the abundance of chum (*O. keta*) and sockeye (*O. nerka*) salmon that were running at that time and (2) the small fraction of the Chinook salmon run that was likely yet to come.

[2]https://bstaton.shinyapps.io/BayesTool/
[3]Federal Special Action 3-KS-04-18
[4]Federal Special Action 3-KS-05-18
[5]Federal Special Action 3-KS-06-18
[6]Federal Special Action 3-KS-08-18
[7]Federal Special Action 3-KS-09-18

2 Methods

The in-season harvest estimation framework that was developed and applied to the 2016 – 2018 Kuskokwim River salmon seasons required two primary types of information:

(1) an estimate of the total number of fishing trips each day and
(2) completed trip interview information from fishers documenting gear, fishing location, fishing time, and catch.

The methods used to estimate harvest in 2018 were identical to those used in 2017, except for one additional interview data source (see Section 2.2).

2.1 Aerial Net Counts

For each opener, two or more aerial survey flights were flown to count the number of drift boats and set nets fishing within the YDNWR boundaries (Figure 1). Flights were scheduled to capture boat counts between low and high tide when the tides were moving the strongest, which are the most popular times to fish, and such that the flights were spaced relatively equally throughout the opener. Oftentimes, this resulted in approximately 3 – 4 hours between the end of one flight and the start of the next flight (Table 1). Flight missions involved a USFWS pilot and at least one observer flying at an altitude of 500 – 700ft and using predominately YDNWR aircraft (most frequently Cessna 185 n714 and Cessna 2016 n740).

Flight missions involved departing Bethel, following the river downstream and southwest toward

Kuskokwim Bay to the village of Tuntutuliak, then turning upstream and northeast to fly to the village of Akiak by following the river (Figure 1). This path took approximately 1.5 hours to complete, including the flight back to the Bethel airport. All sections of the flight path along the main stem Kuskokwim River excluding below Loumavik Slough (which is just downstream of of the Johnson River confluence) and Kuskokuak Slough (off of which the Kwethluk and Kisaralik Rivers branch) were counted twice (i.e., once flying downstream, once flying upstream), and the maximum of the two counts was used as the boat count for that section. Below Loumavik Slough, the river is too wide to see both banks entirely so each bank was counted once and the counts were summed. The very small amount of nets (typically <5) observed in Kuskokuak Slough were not included in the count given the coverage of the harvest estimation was limited to the main stem Kuskokwim River only.

Drift boat and set net counts were recorded into approximately 10 river regions demarcated by major landmarks (e.g., villages or tributaries) and then assigned to four strata (Figure 1, denoted by the letters A – D). Boats were counted if they were actively fishing or if a net could be seen in the boat. If there was any doubt about whether boats were fishing boats (such as below Loumavik Slough, where large distances made it difficult to look for nets inside boats in transit), they were counted as fishing boats. On two occasions, inclement weather prevented USFWS from flying scheduled effort surveys: 6/16/2018 and 7/5/2018. Both of these canceled flights were the first of three scheduled flights for 12-hour openers, though the later two flights each day were flown with no issues.

2.2 Completed Trip Interviews

Information from fisher trips was obtained from five sources:

(1) the Bethel boat harbor,
(2) Bethel area fish camps,
(3) several main stem villages other than Bethel,
(4) several tundra villages, and
(5) from USFWS law enforcement personnel during routine roving compliance checks.

Interview data from sources (1) and (2) were collected by personnel from the Orutsararmiut Traditional Native Council (ONC) and were the predominate sources used by Staton and Coggins (2016). Data from source (3) were collected beginning in 2017 as part of a community-based monitoring project established by the Bering Sea Fisherman's Association (BSFA) to, among other things, provide interview data from areas of the YDNWR other than solely the Bethel area. The BSFA village monitors in 2018 were located in the villages of Tuntutuliak, Napaskiak, Kwethluk, Akiachak, and Akiak and reported data in a timely manner so that they could be included into the estimates. Data from source (4) were collected by ADF&G Division of Subsistence staff stationed in the tundra villages of Atmautluak and Kasigluk — data from this source were a new addition for 2018. Data from source (5) have been available since 2015, but have been of varying quality. The data from source (5) collected in 2018 were very high quality and were included when available (all openers except the final one on 7/5/2018 before restrictions were lifted). It should be noted, however, that because the law enforcement interviews were not completed trips, the only information that was used from these interviews was the catch rate and the net length (see Section 2.3.3).

Interviewees sampled by these five sources were asked the same questions (with the exception of interviews conducted by USFWS law enforcement) and the interviewers were trained as thoroughly as possible in a formal setting (in Bethel; 5/29 – 5/30 of 2018) to ensure the questions were asked in a consistent fashion. Interviewers were instructed to spend as much time as possible collecting data during openers, which during the short openers (none longer than 12 hours) allowed for nearly complete coverage at interview locations. Interviews were intended to be minimally intrusive yet still gain accurate and meaningful information regarding the fishing trip. The key pieces of information collected in each interview (indexed by i) included:

- The day fishing occurred (indexed by d)
- The location of the trip (used to place the trip in a geographic stratum, indexed by j; Figure 1)
- The type of net used (drift *versus* set net)
- The start and end times of the trip ($T_{1,i,d}$ and $T_{2,i,d}$, respectively)
- The total number of hours the net was fishing (referred to as "soak time"; $h_{i,j,d}$)
- The length of the net used (in feet; $L_{i,j,d}$)
- The total harvest by species of each Chinook, chum, and sockeye salmon ($C_{i,j,s,d}$; species indexed by s)

2.3 Analytical Methods

Although the analytical methods used in 2018 were nearly identical to those presented in Staton and Coggins (2016), a full description will be provided here for completeness.

2.3.1 Boat Effort Expansion Model

When interpreting aerial survey counts, it is important to consider two facts which result from the counts being instantaneous surveys rather than complete censuses. First, some active drift boat trips counted during one flight were likely also active in subsequent flights (i.e., some boats were double- or triple-counted). Second, surely some number of drift boat trips started and ended during times that were not flown (i.e., some boats fished but were not counted). Thus, to obtain an estimate of the total number of drift boat trips in an opener, a method was needed to correct for these two issues.

It is possible to derive an estimator for the number of boat trips on day d based on:

(1) the boat counts made on each flight c ($A_{c,d}$),
(2) the start ($F_{1,c,d}$) and stop ($F_{2,c,d}$) times of flight c on the same day, and
(3) the start ($T_{1,i,d}$) and stop ($T_{2_i,d}$) times of each of the n_d completed trip interviews.

The estimator operates by determining if each interviewed trip i was actively fishing during a period when it could have been counted on flight c using numerical logic (i.e., Boolean operators). For example, trip i would have been counted on flight c if the trip started before the flight started and ended after the flight ended (i.e., if both conditions $T_{1,i,d} < F_{1,c,d}$ and $T_{2,i,d} > F_{2,c,d}$ were met). This can be expressed more simply by determining if each trip was not available to be counted, i.e., if it started and ended either before or after the flight:

$$T_{1,i,d} < T_{2,i,d} < F_{1,c,d}, \tag{1}$$

$$F_{2,c,d} < T_{1,i,d} < T_{2,i,d}. \tag{2}$$

If either of the conditions (1) or (2) is met, trip i was not available to be counted *via* aerial survey flight c. These conditions were tested for each flight c for each of the n_d interviews and the following summaries were calculated:

- The number of interviewed trips available to be counted on flight c ($B_{c,d}$)
- The number of interviewed trips available to be counted on two consecutive flights c and $c+1$ ($B_{c,c+1,d}$)
- The number of interviewed trips available to be counted during at least one flight ($B_{y,d}$)
- The number of interviewed trips not available to be counted during any of the flights that occurred on day d ($B_{n,d}$)

Based on these quantities, the effort expansion model corrected each aerial count ($A_{c,d}$) by how many trips were also counted on the previous flight of the day. First, the proportion of interviewed boat trips counted on flight $c+1$ that were also counted on flight c (denoted $p_{old,c}$) was calculated:

$$p_{old,c} = \frac{B_{c,c+1,d}}{B_{c+1,d}}, \tag{3}$$

which is an estimator of the joint probability of a boat being counted on two consecutive flights c and $c+1$. The quantity $p_{old,c}$ should be a function of (a) the magnitude of $F_{1,c+1,d} - F_{2,c,d}$ and (b) the magnitude of the average $T_{2,i,d} - T_{1,i,d}$ (openers with closely-spaced flights and long trips will have higher values of $p_{old,c}$, i.e., rates of double-counting). The number of trips that were counted on flight $c+1$ that were not counted on flight c is then:

$$\hat{A}_{c+1,d} = A_{c+1,d}(1 - p_{old,c}). \tag{4}$$

Note that Equation (4) need only be calculated for flights $c > 1$, as all trips counted on flight $c = 1$ were new entries to the fishery as far as the estimator is concerned. The total number of boat trips that were counted during a flight is:

$$\hat{B}_d = A_{1,d} + \sum_{z=2} \hat{A}_{z,d}. \tag{5}$$

To correct the count for trips that occurred between flights (it is known that at least $B_{n,d}$ such trips occurred), a simple scaling method based on the Petersen estimator (Seber, 1982) was applied and the result was added to $\hat{B}_d$ to obtain the total number of drift trips during the opener:

$$\hat{\hat{B}}_d = B_{n,d}\left(\frac{\hat{B}_d}{B_{y,d}}\right) + \hat{B}_d. \tag{6}$$

Given some geographic strata were frequently lacking in interviews, this estimator was applied by aggregating all completed trip interviews regardless of stratum. The total estimated drift boat trips ($\hat{\hat{B}}_d$) was post-stratified into geographic strata based on the average proportion of boats counted in each stratum across all flights that day:

$$p_{j,d} = \frac{\sum_c A_{c,j,d}}{\sum_c \sum_j A_{c,j,d}}, \tag{7}$$

and

$$\hat{\hat{B}}_{j,d} = p_{j,d}\hat{\hat{B}}_d. \tag{8}$$

2.3.2 Set Net Effort Expansion Model

Due to a severe lack of interviews from set net fishers, the procedure described above for drift boat fishers was not possible for set nets. To account for daily set net effort, the sum of the maximum set net aerial count from each geographic stratum was used as the effort for that day.

2.3.3 Harvest Expansion Model

The harvest expansion model used the two pieces of information (trip characteristics from interviews and total effort estimates) to estimate the total harvest by geographic stratum and opener. An index of trip-specific effort was obtained:

$$e_{i,j,d} = L_{i,j,d}h_{i,j,d}, \tag{9}$$

where the units of trip-level effort are in net-foot-hours, and was used to account for the observation that fishers use different lengths of net. Then, a catch rate was calculated for each species to standardize catch numbers across trips:

$$\text{CPUE}_{i,j,s,d} = \frac{C_{i,j,s,d}}{e_{i,j,d}}. \tag{10}$$

The quantities $L_{i,j,d}$, $h_{i,j,d}$, and $\text{CPUE}_{i,j,s,d}$ were averaged across all interviews available in a geographic stratum to obtain the characteristics of the average trip occurring on day d in geographic stratum j ($\bar{L}_{j,d}$, $\bar{h}_{j,d}$, and $\overline{\text{CPUE}}_{j,s,d}$). Total estimated harvest of species s for stratum j on day d is then:

$$\hat{H}_{j,s,d} = \hat{\hat{B}}_{j,d}\bar{L}_{j,d}\bar{h}_{j,d}\overline{\text{CPUE}}_{j,s,d}. \tag{11}$$

This expansion was conducted separately for drift net fishers and set net fishers, using only the interview data from each gear type. It was conducted as geographically-explicitly as possible. As a general rule, if a stratum had fewer than 15 interviews, interview data from the nearest stratum were were aggregated with the data-poor stratum when calculating the average quantities $\bar{L}_{j,d}$, $\bar{h}_{j,d}$, and $\overline{\text{CPUE}}_{j,s,d}$.

Total harvest by species on day d was calculated by summing the strata-specific estimates:

$$\hat{H}_{s,d} = \sum_j \hat{H}_{j,s,d}, \tag{12}$$

and total salmon harvest for day d was calculated by summing across species-specific estimates:

$$\hat{H}_d = \sum_s \hat{H}_{s,d}. \tag{13}$$

2.3.4 Uncertainty Estimation

Variability in among-interview quantities was quite high (particularly for $\text{CPUE}_{i,j,s,d}$ and $h_{i,j,d}$), necessitating the consideration of statistical uncertainty in the estimates. Uncertainty was quantified using a non-parametric bootstrap. Bootstrapping involves randomly sampling (with replacement) from the observed trip interviews, producing a harvest expansion estimate following the above method for each randomized data set (Equations 9 – 13), and repeating the process many times (10,000 in this case) to form a distribution of possible harvests given the observed sample of interviews. To summarize the resulting variation, the 2.5^{th} and 97.5^{th} quantiles were used as the lower and upper confidence limits (CL), respectively, and the mean of all bootstrapped estimates was used as the point (i.e., most likely) estimate.

While there are other methods to estimate uncertainty in the harvest estimates, it was determined that the non-parametric bootstrap was the most appropriate method because other methods make a variety of tenuous assumptions (Efron and Tibshirani, 1993). It is important to recognize that the harvest estimates contained in this report do not account for sampling variability in the process of estimating effort (i.e., boat trips; Equations 3 – 8) during aerial surveys. Thus, uncertainty in the harvest estimates is smaller than if uncertainty in effort was fully considered.

2.3.5 Computation

All analyses were conducted in the statistical programming environment R (R Core Team, 2018) using custom code. During the season, summary documents for consideration by managers and stakeholders were produced using the R package `{rmarkdown}` (Allaire et al., 2018). This report was written and formatted using LaTeX and the `{bookdown}` package (Xie, 2016).

3 Results

3.1 6/12/2018: Opener #1

An estimated total of 466 drift boat trips and 31 set net trips occurred between Tuntutuliak and Akiak (hereafter, "study area") on 6/12/2018 during the 12-hour opener (Table 3; Figures 2 and 3). The estimated total salmon harvest was 7,250 (95% CL: 6,020 – 8,650). The majority of this harvest (72%) was Chinook salmon (5,230; 4,390 – 6,260), followed by chum salmon (24%; 1,770; 1,260 – 2,450), and the remaining 4% was sockeye salmon (250; 160 – 360) (Table 4; Figure 4).

Interestingly, nearly twice as many boats fished in stratum C as in stratum A (Table 3; Figure 2), but these two areas showed similar harvests of Chinook salmon and stratum A showed higher total salmon harvest (Table 4). This likely resulted from the allowance of 300ft nets downstream of the Johnson River confluence (stratum A, compared to 150ft upstream), as well as from higher catch rates and/or soak times.

Harvest estimates were produced from 274 trip interviews, of which 97 (35%) came from the Bethel boat harbor, 17 (6%) from Bethel area fish camps, 74 (27%) from BSFA village monitors, 10 (4%) from ADF&G staff stationed in Kasigluk, and 76 (28%) from USFWS law enforcement officers (Figure 5). Eleven interviews were from set net fishers and the remaining 263 interviews were from drift boat fishers. This represented an estimated sampling rate of 56% and 35% of drift boat and set net trips, respectively.

Based on the distribution of relevant interview quantities from the first opener (Figure 6), there seemed to be two pulses of fishery entry times: one with the vast majority of fishers entering before noon and a second starting at 16:00 and lasting until 19:00. Most trips lasted between 2 and 8 hours (average of 5.7 hours), and soak time was skewed towards shorter soaks of 1 to 6 hours (average of 3.6 hours). Very few fishers caught more than 15 total salmon (average of 8.3) or more than 10 Chinook salmon (average of 6). The average fisher interviewed by the BSFA village monitors caught more total salmon, started their trips earlier, and spent more time actively fishing than the average fisher interviewed at either the Bethel boat harbor or the Bethel area fish camps (Figure 6). Overall, Chinook salmon made up approximately 75% of catches across all interviews. Between 6/10/2018 and 6/12/2018, the BTF catches were composed of 54% Chinook salmon on average (unpublished ADF&G data), possibly indicating that the fishery was able to target Chinook salmon over the other species.

3.2 6/16/2018: Opener #2

An estimated total of 488 drift boat trips and 20 set net trips occurred within the study area on 6/16/2018 (Table 3; Figures 2 and 3). The estimated total salmon harvest was 8,620 (7,420 – 10,010). As in the first opener, most of this harvest was Chinook salmon (64%; 5,490; 4,670 – 6,490), followed by chum salmon (31%; 2,680; 2,170 – 3,380) and sockeye salmon (5%; 450; 300 – 620) (Table 4; Figure 4).

Harvest estimates were produced from 248 completed trip interviews, of which 90 (36%) came from the Bethel boat harbor, 24 (10%) from Bethel area fish camps, 85 (34%) from BSFA village monitors, 7 (3%) from ADF&G staff, and 42 (17%) from USFWS law enforcement officers (Figure 5). Eight of these interviews were from set net fishers and the remaining 240 were from drift boat fishers. This represented an estimated sampling rate of 49% and 40% of drift boat and set net trips, respectively.

Based on the distribution of relevant interview quantities from the second opener (Figure 7), most trips started before noon and lasted between 2 and 8 hours. Average soak time was the same as in the first opener (3.6 hours), few fishing more than 7 hours. Few fishers caught more than 30 total salmon or more than 20 Chinook salmon. The relative catch of Chinook *versus* chum/sockeye salmon was more even, evident from the average percent Chinook catch of 58% across all interviews. Between 6/14/2018 and 6/16/2018, the BTF catches were composed of 33% Chinook salmon on average (unpublished ADF&G data), once again indicating that fishers may target Chinook salmon over other species.

3.3 6/24/2018: Opener #3

An estimated total of 410 drift boat trips and 18 set net trips occurred within the study area on 6/24/2018 (Table 3; Figures 2 and 3). The estimated total salmon harvest was 18,680 (16,740 – 20,710). Most of this harvest was chum salmon (48%; 8,910; 7,650 – 10,120), followed by Chinook salmon (33%; 6,110; 5,310 – 6,930), and sockeye salmon (20%; 3,670; 3,150 – 4,230) (Table 4; Figure 4).

Harvest estimates were produced from 208 completed trip interviews, of which 67 (32%) came from the Bethel boat harbor, 28 (13%) from Bethel area fish camps, 74 (36%) from BSFA village monitors, 16 (8%) from ADF&G staff, and 23 (11%) from USFWS law enforcement officers (Figure 5). Nine of these interviews were from set net fishers and the remaining 199 were from drift boat fishers. This represented an estimated sampling rate of 49% and 50% of drift boat and set net trips, respectively.

Based on the distribution of relevant interview quantities from the third opener (Figure 8), most trips started before noon and lasted between 2 and 8 hours. Average soak time was slightly shorter than in the second opener, with very few fishers actively fishing more than 4 hours (average 3.1 compared to 3.6 in the second opener). Few fishers caught more than 75 total salmon or more than 20 Chinook salmon. Chum and sockeye salmon were the dominant species caught (but not by a substantial margin), evident from the average percent Chinook catch of 37% across all interviews. Between 6/22/2018 and 6/24/2018, the BTF catches were composed of 17% Chinook salmon on average (unpublished ADF&G data), once again indicating that fishers may have the ability to target Chinook salmon over other species.

3.4 6/29/2018: Opener #4

An estimated total of 387 drift boat trips and 13 set net trips occurred within the study area on 6/29/2018 (Table 3; Figures 2 and 3). Although this was a 6-hour opener, the amount of drift boat effort did not substantially differ from the 6/24/2018 opener, which was 12 hours in duration (a decline of only 6%). The estimated total salmon harvest was 28,430 (24,240 – 32,990). Most of this harvest was chum salmon (62%; 17,750; 14,500 – 21,460), followed by sockeye salmon (27%; 7,660; 6,160 – 9,450), and Chinook salmon (11%; 3,020; 2,470 – 3,700) (Table 4; Figure 4).

Harvest estimates were produced from 190 completed trip interviews, of which 60 (32%) came from the Bethel boat harbor, 22 (12%) from Bethel area fish camps, 61 (32%) from BSFA village monitors, 17 (9%) from ADF&G staff, and 30 (16%) from USFWS law enforcement officers (Figure 5). Seven of these interviews were from set net fishers and the remaining 183 were from drift boat fishers. This represented an estimated sampling rate of 47% and 54% for drift boat and set net trips, respectively.

Based on the distribution of relevant interview quantities from the fourth opener (Figure 9), most trips started around noon and lasted between 1 and 5 hours. Average soak time was much shorter than previous openers, with few fishers actively fishing more than 3 hours (average 2 hours compared to 3.1 – 3.6 in previous openers). Few fishers caught more than 75 total salmon or more than 10 Chinook salmon. Chum and sockeye salmon were the dominant species caught, evident from the average percent Chinook catch of 15% across all interviews. Between 6/27/2018 and 6/29/2018, the BTF catches were composed of 13% Chinook salmon on average (unpublished ADF&G data). Unlike previous openers, the fishery was not substantially skewed toward Chinook salmon relative to the BTF.

3.5 7/5/2018: Opener #5

An estimated total of 276 drift boat trips and 13 set net trips occurred within the study area on 7/5/2018 (Table 3; Figures 2 and 3). The estimated total salmon harvest was 24,770 (21,250 – 28,870). Most of this harvest was chum salmon (50%; 12,460; 10,260 – 14,690), followed by sockeye salmon (46%; 11,290; 9,250 – 13,450), and Chinook salmon (4%; 1,020; 830 – 1,250) (Table 4; Figure 4).

Harvest estimates were produced from 94 completed trip interviews, of which 29 (31%) came from the Bethel boat harbor, 20 (21%) from Bethel area fish camps, 43 (46%) from BSFA village monitors, and 2 (2%) from ADF&G staff (Figure 5). Thirteen of these interviews were from set net fishers and the remaining 81 were from drift boat fishers. This represented an estimated sampling rate of 29% and 100% for drift boat and set net trips, respectively.

Based on the distribution of relevant interview quantities from the fourth opener (Figure 10), most trips started at or before noon and lasted between 1 and 5 hours. Average soak time was even shorter than in the fourth opener, with few fishers actively fishing more than 2 hours (average 1.6 hours compared to 2 hours in the fourth opener). Few fishers caught more than 80 total salmon or more than 5 Chinook salmon. Chum and sockeye salmon were the dominant species caught, evident from the average percent Chinook catch of 5% across all interviews. Between 7/3/2018 and 7/5/2018, the BTF catches were composed of 6% Chinook salmon on average (unpublished ADF&G data). Like the fourth opener, the fishery was not substantially skewed toward Chinook salmon relative to the BTF.

3.6 Season summary

Across all openers, an estimated total of 87,750 (75,670 – 101,230) salmon were harvested. Most harvested salmon were chum salmon (50%; 43,570; 35,840 – 52,000), followed by sockeye salmon (27%; 23,320; 19,020 – 28,110), and Chinook salmon (24%; 20,870; 17,670 – 24,630) (Table 4; Figure 11).

Fishers within geographic stratum C (spanning Napaskiak to Akiachak; Figure 1) harvested the most total salmon, accounting for 35% of all salmon harvested. The number of Chinook salmon harvested in each stratum was remarkably similar (with the exception of stratum D), despite differences in the number of estimated drift boat trips between strata (Tables 3 and 4; Figure 11).

In general, there was a decline in drift boat and set net effort as the season progressed, though it was less pronounced than in previous years (Figures 2 and 3). Unlike in 2017, the proportion of drift boats fishing in stratum A (below the Johnson River mouth) did not decline as the season progressed but instead stayed at a constant of approximately 20% (Figure 2; in fact, the spatial distribution of effort stayed quite constant all season). This observation is possibly a function of the gear restrictions between these two years. In 2017, early-season fishers downstream of Johnson River were permitted to use 300ft drift nets while those fishing upstream were limited to 150ft, though all fishers were limited to 150ft approximately halfway through the season. In 2018, the difference in net lengths was maintained all season, which may explain why a constant fraction of fishers were counted there all season.

4 Discussion

The in-season salmon harvest estimates obtained in June and July 2018 and presented within this document, proved to be useful to the management of the Kuskokwim River subsistence salmon fishery, as they were in 2016 and 2017. The ADF&G management staff were also interested in seeing the estimates as were area stakeholders and Kuskokwim River Salmon Management Working Group members. The specific ways in which the in-season harvest data have been used for fishery management, as well as a synthesis of the important findings from the previous three seasons, are presented in a separate document (Staton and Stahlnecker, unpb).

4.1 Reliability of Assumptions

All reported analyses assumed the interview information was a random sample from the population of fishers during the opener. This assumption is not unique to this analysis, or even creel surveys in general, but is made in every statistical analysis where samples are used to make inference on a population. It cannot be overemphasized that the sampling design for the 2018 completed trip interviews was not implemented in a random sense, but could be much more accurately described as opportunistic. This issue of non-randomness certainly brings to question the validity of the resulting harvest estimates in terms of accuracy and precision. If the information obtained was systematically biased (e.g., fishers in the sample fished longer and had higher catch rates than non-sampled fishers), then the resulting estimates would also be biased. I attempted to account for this in several ways. First, although the information was treated as though it was random, each time harvest estimates were presented to stakeholders and decision-makers, I attempted to make them fully aware of the limitations of the analysis. Second, I produced estimates of uncertainty and emphasized that the estimates be interpreted in the full context of their uncertainty. To embrace this level of uncertainty, decisions were often made by considering both a “most likely” and a “worst case” scenario, using the point estimate and the upper bound of the estimates, respectively. Third, I performed sensitivity analyses (described in the next section), which provided insights about how the estimates were influenced by different data sources. The rest of this section is devoted to speculation about how representative the data collected in 2018 are likely to have been.

Even though the samples were taken opportunistically, I think the interview data provide a good representation of the fishery in the locations they correspond to. For example, I think the Bethel boat harbor samples provide an adequate snapshot of the population of fishers that fished from that location, and the same for the BSFA village monitor data collected in the outlying villages. This belief is supported by the fact that monitors sampled so intensively at each of the locations during the short-duration openers. For example, interviewers at the Bethel boat harbor were typically present for 10 of the 12 hours in an opener, and the two hours that were missed were at the very start, when it was unlikely that fishers would be returning to be interviewed regardless. Indications are that the BSFA village monitors spent similar amounts of time conducting interviews. These figures indicate that the majority of the fishing period was sampled at each location, which should provide a random sample of the fishers at these locations. If the assumption that the data were representative within each data source is valid, then the remaining considerations regarding the representativeness of the data are:

(1) whether samples from the various sources were taken in proportion to the part of the fishery they were sampled from and

(2) whether unsampled locations exhibited similar behavior as the sampled locations.

As an example of item (1), suppose that fishers starting their trips from the Bethel boat harbor make up 50% of all drift boat trips in an opener. If that is the case, then interviews from the Bethel boat harbor should make up approximately 50% of the sampled interviews used in the analysis. Data for comparison on this topic are available in Shelden et al. (2016): Table 3 therein shows the number fishing households by village in the lower Kuskokwim River. Bethel makes up approximately 70% of all fishing households categorized as either light, medium, or high harvesting households. In this study, trips originating from the Bethel boat harbor made up approximately 30% of the interviewed trips, and it is safe to assume that the vast majority these interviews were from Bethel residents. It is reasonable to expect that half of the trips interviewed by the USFWS law enforcement officers to have interviewed Bethel residents, and some of the ONC fish camp interviewees were Bethel residents. These sources bring the estimated average Bethel contribution to the interview data to approximately 60%, which is reasonably close to the 70% contribution of Bethel fishing households to the population of such households within the study area. This suggests that fishers from the village of Bethel may be underrepresented in the interview data, but that the sample is not far off from what it should be according to this measure of representation (i.e., using the data from Shelden et al., 2016, this way).

Regarding (2), it is reasonable to expect that fishing behavior of the non-sampled villages within the study area was represented by the sampled villages. There are 11 villages in the lower Kuskokwim River with fishers that were likely counted by aerial surveys in 2018. These villages include (in general order of downriver to upriver) Tuntutuliak, Kasigluk, Nunapitchuk, Atmautluak, Napakiak, Napaskiak, Oscarville, Bethel, Kwethluk, Akiachak, and Akiak. In 2018, BSFA placed village monitors in five of these villages, ADF&G had monitors in two villages, and efforts by ONC added Bethel to this list, bringing the total of monitored villages in the study area to eight out of eleven. This represents the majority of the areas within the lower river, and it seems unlikely that fishers from the other three villages would exhibit vastly different behavior than those in the eight that were sampled.

4.2 Sensitivity of Estimates

I investigated the sensitivity of the estimates to violations in assumption by producing effort and harvest estimates using data from only a smaller subset of all the available interviews (e.g., removing Bethel boat harbor interviews). Results of these analyses showed that the estimates were generally robust to leaving out information (i.e., making the information used presumably less representative), and the results ranged from small changes (<5%) in point estimates to larger changes (25-50%). Typically, when Bethel boat harbor data were removed, the harvest estimates increased, but decreased when the BSFA village monitors interviews were removed. In most cases, the point estimate of the analysis with left-out data fell within the 95% CL of the original estimate and in no cases did the qualitative conclusion change (e.g., Chinook salmon harvest being small relative to chum salmon and sockeye salmon harvest).

4.3 Review of Estimates

Staff from the YDNWR had the opportunity to present the information and estimates to technical advisors from ADF&G, KRITFC, and ONC shortly before making them public, similar to what was done in 2017. While this review was relatively informal and abbreviated by necessity to allow timely consideration by managers for subsequent decisions, I believe the additional review was helpful to allow for screening of gross errors in data analysis and interpretation. Though no major alterations were suggested by these reviewers, I believe that the review bolstered the credibility and reliability of the work.

4.4 Scalability of the Method

End-of-season estimates of Chinook salmon harvest from the in-season method have agreed well with independent estimates of harvest in both 2016 and 2017 (i.e., those obtained during standardized surveys for post-season total harvest estimation; *unpublished analysis*). Additionally, the method can produce final estimates within 24 – 48 hours, making it useful for making fast-paced in-season management decisions. It is reasonable to conclude that the method developed by Staton and Coggins (2016) will be effective (timely and accurate) when applied to years with similar fishery conditions as those experienced in 2016-2018 (i.e., relatively few openers and each short in duration). The short duration (frequently 12-hours) has allowed:

(1) aerial effort surveys to be flown every 3 – 4 hours and
(2) monitors to be placed at various fishery access sites for essentially the entire opener.

These two aspects of the current sampling program have prevented the need to develop a rigorous random sampling design: because the sampling was so complete, has been reasonable to assume the opportunistic sampling generated random samples from the fishery (see Section 4.1 for a discussion of this topic). More carefully-designed random sampling programs are applied to cases in which the fishery is open for long periods of time (Bernard et al., 1998). If at some point the Kuskokwim River salmon fishery management becomes less restricted by increasing abundances of Chinook salmon, then it is likely the fishery will be opened for more and longer periods of time, which is a scenario the current harvest sampling program is not designed for. Unlike for a 12-hour opener, it is unreasonable to keep a monitor at an access site for the majority of an opener several times as long. In 2016, comparatively longer openers were implemented and fishers were sampled at the Bethel boat harbor and Bethel area fish camps. By necessity, the interview coverage each day was less than for 12-hour openers and monitors were placed to obtain the greatest number of interviews possible, rather than to sample the entire opener. However, the longer the openers become, the harder it will be to justify the assumption of random sampling. Thus, if the fishery management becomes less restrictive and managers wish to have harvest estimates, then a more rigorous sampling program will be required.

A few considerations that may be faced in such an effort include:

(1) Longer open periods will almost certainly result in lower fisher density at access points (fewer returning per unit time) because all of the fishery would not be funneled into a short time window. In 2018, estimated interview coverage was frequently around 50%, however with longer openers it seems that the interview efforts would generate fewer samples. This could have the effect of reducing the precision of the estimates.
(2) Because the whole population cannot be sampled, one must decide which time periods and areas should be sampled more frequently than others. It is standard practice in creel surveys to place more sampling effort on the portion of the fishery where most of the effort occurs (e.g., weekends *versus* weekdays; Bernard et al., 1998). Something similar could be developed for the lower Kuskokwim River salmon fishery, but deciding where and when to sample to minimize bias would be a difficult task.
(3) Aerial effort surveys are also resource-intensive, so they would likely need a similar subsampling program (i.e., under current

YDNWR pilot demands, it may be unrealistic to expect to have 3 flights a day for 2-3 consecutive days). Thus, the current effort expansion model would need to be adapted for this more general case.

While these considerations present formidable barriers, they do not seem impassable with directed development efforts if monitoring harvest in years with larger harvest objectives is desired.

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Table 1: Raw boat counts from each flight and geographic stratum.

Flight Times		Geographic Stratum[1]				
F_1	F_2	**A**	**B**	**C**	**D**	**Total**
6/12/2018						
11:00	12:40	80	64	125	36	305
15:00	17:00	93	82	109	31	315
19:00	20:30	31	29	111	31	202
6/16/2018						
12:35	14:00	93	55	148	23	319
19:30	21:20	40	49	71	20	180
6/24/2018						
11:40	13:30	77	57	153	32	319
15:45	17:05	41	46	87	29	203
19:15	20:20	16	6	38	11	71
6/29/2018						
12:30	14:00	74	59	144	40	317
16:15	17:45	16	43	63	21	143
7/5/2018						
14:00	15:30	20	17	38	12	87
18:00	20:00	12	22	47	9	90

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

Table 2: Raw set net counts from each flight and geographic stratum.

Flight Times		Geographic Stratum[1]				
F_1	F_2	**A**	**B**	**C**	**D**	**Total**
6/12/2018						
11:00	12:40	0	1	10	5	15
15:00	17:00	0	3	18	8	29
19:00	20:30	0	0	20	6	26
6/16/2018						
12:35	14:00	0	2	16	2	20
19:30	21:20	0	1	5	0	6
6/24/2018						
11:40	13:30	0	2	3	1	6
15:45	17:05	0	1	12	3	16
19:15	20:20	0	0	5	4	9
6/29/2018						
12:30	14:00	0	1	8	2	11
16:15	17:45	0	1	3	4	8
7/5/2018						
14:00	15:30	0	1	3	3	7
18:00	20:00	0	2	5	3	10

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

Table 3: Estimated drift boat trip and set nets by day and geographic stratum. The derivation of these quantities from the raw counts presented in Tables 1 and 2 is presented in the text in Section 2.3.1.

Date	Duration[2]	Geographic Stratum[1]				Total
		A	B	C	D	
Drift Boats						
6/12/2018	12	110	95	203	57	466
6/16/2018	12	125	108	209	48	488
6/24/2018	12	91	67	197	54	410
6/29/2018	6	67	94	173	53	387
7/5/2018	12	50	61	132	33	276
Set Nets						
6/12/2018	12	0	3	20	8	31
6/16/2018	12	0	2	16	2	20
6/24/2018	12	0	2	12	4	18
6/29/2018	6	0	1	8	4	13
7/5/2018	12	0	3	6	1	13

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

[2]The length of the open period each day, in hours.

Table 4: Salmon harvest from both drift nets and set nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits.

Species	Geographic Stratum[1] A	B	C	D	Total
6/12/2018					
Chinook	1,910 (1,370-2,490)	600 (400-840)	2,010 (1,500-2,630)	710 (420-1,040)	5,230 (4,390-6,260)
Chum	1,250 (760-1,890)	150 (100-210)	290 (180-430)	80 (30-140)	1,770 (1,260-2,450)
Sockeye	90 (40-150)	60 (10-130)	90 (40-140)	20 (0-40)	250 (160-360)
Total	3,250 (2,290-4,310)	810 (560-1,110)	2,390 (1,810-3,120)	810 (480-1,180)	7,250 (6,020-8,650)
6/16/2018					
Chinook	1,570 (970-2,370)	1,240 (940-1,540)	2,020 (1,580-2,490)	670 (360-1,020)	5,490 (4,670-6,490)
Chum	860 (480-1,380)	490 (340-650)	990 (760-1,240)	340 (160-520)	2,680 (2,170-3,280)
Sockeye	100 (20-220)	90 (50-140)	250 (140-390)	10 (0-40)	450 (300-620)
Total	2,520 (1,600-3,770)	1,810 (1,390-2,220)	3,260 (2,660-3,910)	1,020 (780-1,300)	8,620 (7,420-10,010)
6/24/2018					
Chinook	1,450 (1,080-1,860)	1,070 (730-1,440)	2,650 (2,180-3,180)	940 (580-1,390)	6,110 (5,310-6,930)
Chum	2,920 (2,120-3,710)	1,120 (790-1,480)	3,370 (2,810-3,930)	1,500 (930-2,190)	8,910 (7,650-10,120)
Sockeye	1,650 (1,230-2,130)	480 (310-680)	1,270 (1,020-1,530)	270 (180-380)	3,670 (3,150-4,230)
Total	6,020 (4,740-7,310)	2,670 (1,890-3,490)	7,290 (6,260-8,320)	2,710 (1,940-3,670)	18,680 (16,740-20,710)
6/29/2018					
Chinook	520 (310-750)	720 (520-970)	1,170 (790-1,680)	620 (410-850)	3,020 (2,470-3,700)
Chum	5,790 (3,910-8,040)	5,120 (3,340-7,530)	5,600 (3,910-8,040)	1,240 (820-1,730)	17,750 (14,500-21,460)
Sockeye	2,440 (1,260-3,840)	1,720 (1,220-2,340)	2,830 (2,090-3,750)	670 (490-900)	7,660 (6,160-9,450)
Total	8,750 (6,190-11,740)	7,550 (5,420-10,230)	9,590 (7,230-12,770)	2,530 (2,100-3,030)	28,430 (24,240-32,990)

Table 4: Salmon harvest from both drift nets and set nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits. *(continued)*

	Geographic Stratum[1]				
Species	**A**	**B**	**C**	**D**	**Total**
7/5/2018					
Chinook	230 (160-320)	300 (200-410)	370 (230-550)	120 (60-190)	1,020 (830-1,250)
Chum	3,660 (2,670-4,760)	4,280 (2,900-5,770)	3,340 (2,250-4,600)	1,180 (790-1,580)	12,460 (10,260-14,690)
Sockeye	2,540 (1,660-3,470)	3,230 (2,090-4,400)	4,830 (3,470-6,370)	690 (470-940)	11,290 (9,250-13,450)
Total	6,430 (4,660-8,400)	7,810 (5,390-10,340)	8,540 (6,730-10,720)	1,990 (1,580-2,420)	24,770 (21,250-28,870)
All Openers					
Chinook	5,680 (3,890-7,790)	3,930 (2,790-5,200)	8,220 (6,280-10,530)	3,060 (1,830-4,490)	20,870 (17,670-24,630)
Chum	14,480 (9,940-19,780)	11,160 (7,470-15,640)	13,590 (9,910-18,240)	4,340 (2,730-6,160)	43,570 (35,840-52,000)
Sockeye	6,820 (4,210-9,810)	5,580 (3,680-7,690)	9,270 (6,760-12,180)	1,660 (1,140-2,300)	23,320 (19,020-28,110)
Total	26,970 (19,480-35,530)	20,650 (14,650-27,390)	31,070 (24,690-38,840)	9,060 (6,880-11,600)	87,750 (75,670-101,230)

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

Note: Total means and 95% confidence intervals within an opener were obtained via bootstrapping. Quantities totaled between openers were obtained using the sum of the bootstrapped summaries.

Note: Totals were rounded to the nearest 10 fish after calculating the sum of non-rounded estimates. As a result, the total presented in this table may differ by approximately 10 – 20 fish from the total obtained by summing the rounded estimates.

Table 5: Salmon harvest from drift nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits.

Species	Geographic Stratum[1] A	B	C	D	Total
6/12/2018					
Chinook	1,910 (1,370-2,490)	540 (340-770)	1,600 (1,190-2,050)	540 (310-810)	4,590 (3,820-5,440)
Chum	1,250 (760-1,890)	140 (90-210)	220 (130-320)	50 (20-100)	1,670 (1,150-2,330)
Sockeye	90 (40-150)	60 (10-130)	90 (40-140)	20 (0-40)	250 (160-360)
Total	3,250 (2,290-4,310)	740 (500-1,030)	1,910 (1,440-2,400)	610 (360-900)	6,500 (5,370-7,730)
6/16/2018					
Chinook	1,570 (970-2,370)	1,220 (930-1,530)	1,890 (1,480-2,360)	650 (340-1,000)	5,330 (4,500-6,330)
Chum	860 (480-1,380)	490 (340-650)	980 (750-1,220)	340 (160-520)	2,670 (2,160-3,250)
Sockeye	100 (20-220)	90 (50-140)	240 (130-390)	10 (0-40)	430 (290-610)
Total	2,520 (1,600-3,770)	1,790 (1,370-2,200)	3,110 (2,520-3,770)	1,000 (760-1,280)	8,430 (7,250-9,810)
6/24/2018					
Chinook	1,450 (1,080-1,860)	1,040 (710-1,420)	2,500 (2,050-3,030)	890 (540-1,330)	5,890 (5,110-6,720)
Chum	2,920 (2,120-3,710)	1,120 (780-1,470)	3,320 (2,760-3,880)	1,480 (910-2,170)	8,820 (7,560-10,030)
Sockeye	1,650 (1,230-2,130)	450 (290-660)	1,130 (890-1,380)	230 (140-330)	3,460 (2,940-4,030)
Total	6,020 (4,740-7,310)	2,610 (1,820-3,430)	6,950 (5,970-7,970)	2,600 (1,820-3,560)	18,180 (16,230-20,200)
6/29/2018					
Chinook	520 (310-750)	710 (510-970)	1,130 (750-1,650)	600 (390-830)	2,970 (2,410-3,670)
Chum	5,790 (3,910-8,040)	5,110 (3,330-7,520)	5,530 (3,860-7,960)	1,210 (790-1,700)	17,640 (14,400-21,380)
Sockeye	2,440 (1,260-3,840)	1,680 (1,180-2,300)	2,550 (1,860-3,410)	530 (370-720)	7,200 (5,690-8,880)
Total	8,750 (6,190-11,740)	7,510 (5,400-10,190)	9,210 (6,890-12,410)	2,340 (1,930-2,840)	27,810 (23,560-32,390)

Table 5: Salmon harvest from drift nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits. *(continued)*

Species	Geographic Stratum[1]				Total
	A	B	C	D	
7/5/2018					
Chinook	230 (160-320)	290 (190-400)	340 (220-510)	100 (50-170)	970 (780-1,190)
Chum	3,660 (2,670-4,760)	4,180 (2,790-5,640)	3,150 (2,080-4,310)	1,040 (700-1,400)	12,030 (9,960-14,310)
Sockeye	2,540 (1,660-3,470)	3,060 (1,960-4,250)	4,490 (3,190-5,990)	460 (290-640)	10,550 (8,570-12,630)
Total	6,430 (4,660-8,400)	7,530 (5,140-10,080)	7,980 (6,230-10,080)	1,610 (1,270-2,000)	23,560 (20,090-27,490)
All Openers					
Chinook	5,680 (3,890-7,790)	3,800 (2,680-5,090)	7,460 (5,690-9,600)	2,780 (1,630-4,140)	19,750 (16,620-23,350)
Chum	14,480 (9,940-19,780)	11,040 (7,330-15,490)	13,200 (9,580-17,690)	4,120 (2,580-5,890)	42,830 (35,230-51,300)
Sockeye	6,820 (4,210-9,810)	5,340 (3,490-7,480)	8,500 (6,110-11,310)	1,250 (800-1,770)	21,890 (17,650-26,510)
Total	26,970 (19,480-35,530)	20,180 (14,230-26,930)	29,160 (23,050-36,630)	8,160 (6,140-10,580)	84,480 (72,500-97,620)

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

Note: Total means and 95% confidence intervals within an opener were obtained via bootstrapping. Quantities totaled between openers were obtained using the sum of the bootstrapped summaries.

Note: Totals were rounded to the nearest 10 fish after calculating the sum of non-rounded estimates. As a result, the total presented in this table may differ by approximately 10 – 20 fish from the total obtained by summing the rounded estimates.

Table 6: Salmon harvest from set nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits.

	Geographic Stratum[1]				
Species	**A**	**B**	**C**	**D**	**Total**
6/12/2018					
Chinook	0 (0-0)	60 (10-140)	410 (100-880)	170 (40-370)	640 (280-1,170)
Chum	0 (0-0)	10 (0-30)	70 (10-170)	30 (0-70)	110 (30-220)
Sockeye	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Total	0 (0-0)	70 (20-170)	480 (120-1,030)	200 (50-440)	750 (320-1,370)
6/16/2018					
Chinook	0 (0-0)	20 (10-30)	130 (50-230)	20 (10-30)	160 (80-270)
Chum	0 (0-0)	0 (0-0)	10 (0-40)	0 (0-0)	20 (0-40)
Sockeye	0 (0-0)	0 (0-0)	10 (0-30)	0 (0-0)	10 (0-30)
Total	0 (0-0)	20 (10-30)	150 (70-250)	20 (10-30)	190 (110-290)
6/24/2018					
Chinook	0 (0-0)	20 (10-40)	150 (70-210)	50 (20-70)	220 (140-290)
Chum	0 (0-0)	10 (0-10)	60 (20-90)	20 (10-30)	80 (50-120)
Sockeye	0 (0-0)	20 (10-30)	140 (80-190)	40 (30-60)	200 (140-260)
Total	0 (0-0)	60 (30-80)	340 (200-460)	110 (70-150)	500 (360-640)
6/29/2018					
Chinook	0 (0-0)	0 (0-10)	30 (10-70)	20 (0-40)	60 (20-100)
Chum	0 (0-0)	10 (0-20)	70 (10-170)	30 (10-90)	110 (40-220)
Sockeye	0 (0-0)	40 (20-70)	280 (120-520)	140 (60-270)	460 (260-740)
Total	0 (0-0)	50 (20-80)	380 (180-620)	190 (100-320)	620 (390-920)

Table 6: Salmon harvest from set nets from all five openers by species and geographic stratum[1]. Numbers within parentheses are 95% confidence limits. *(continued)*

	Geographic Stratum[1]				
Species	**A**	**B**	**C**	**D**	**Total**
7/5/2018					
Chinook	0 (0-0)	10 (0-20)	20 (0-50)	20 (0-30)	50 (20-90)
Chum	0 (0-0)	100 (10-270)	190 (20-540)	130 (20-340)	420 (90-840)
Sockeye	0 (0-0)	170 (70-320)	340 (130-660)	230 (90-420)	740 (450-1,090)
Total	0 (0-0)	280 (140-460)	560 (260-940)	370 (180-590)	1,210 (820-1,720)
All Openers					
Chinook	0 (0-0)	110 (30-240)	740 (230-1,440)	280 (70-540)	1,130 (540-1,920)
Chum	0 (0-0)	130 (10-330)	400 (60-1,010)	210 (40-530)	740 (210-1,440)
Sockeye	0 (0-0)	230 (100-420)	770 (330-1,400)	410 (180-750)	1,410 (850-2,120)
Total	0 (0-0)	480 (220-820)	1,910 (830-3,300)	890 (410-1,530)	3,270 (2,000-4,940)

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

Note: Total means and 95% confidence intervals within an opener were obtained via bootstrapping. Quantities totaled between openers were obtained using the sum of the bootstrapped summaries.

Note: Totals were rounded to the nearest 10 fish after calculating the sum of non-rounded estimates. As a result, the total presented in this table may differ by approximately 10 – 20 fish from the total obtained by summing the rounded estimates.

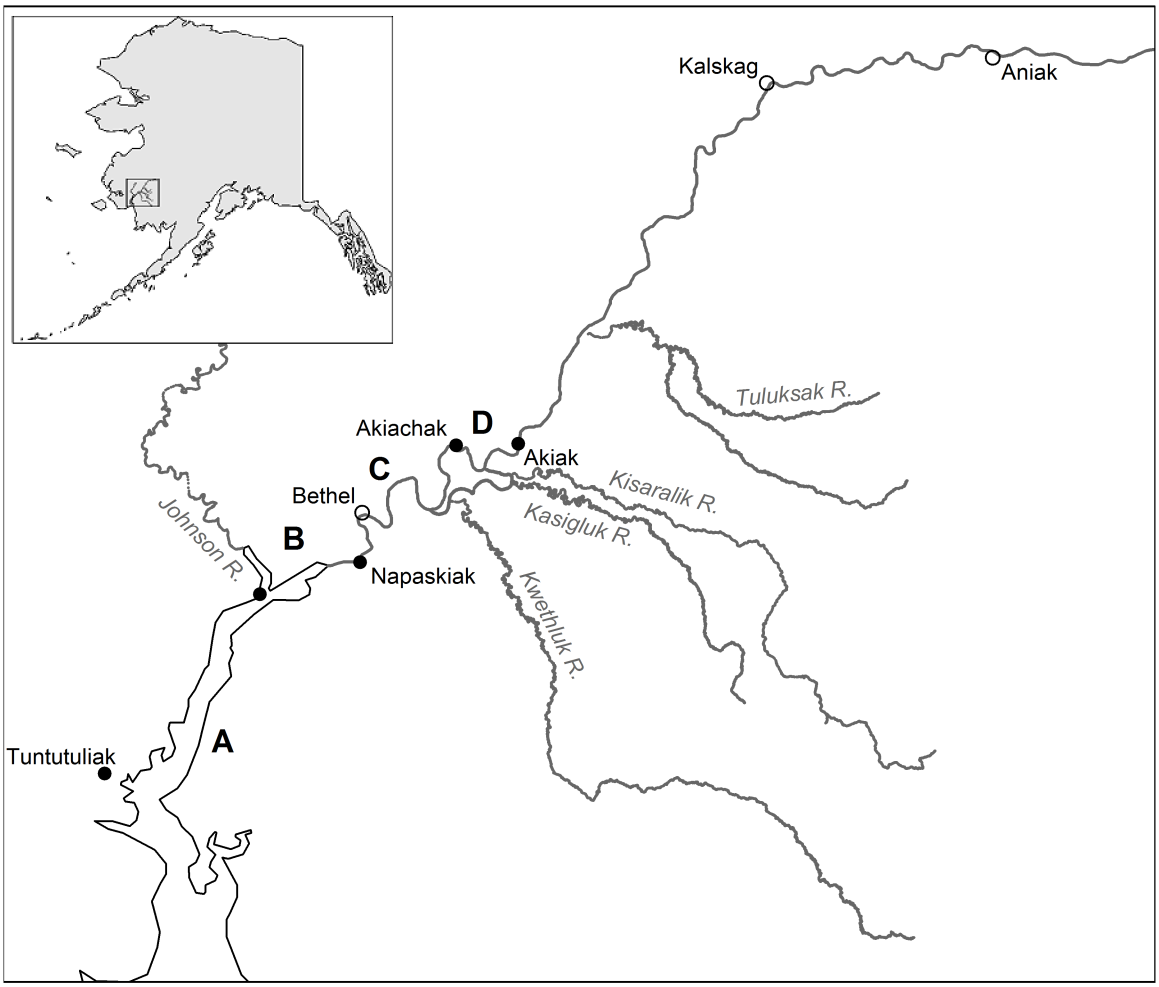

Figure 1: Map of the Yukon Delta National Wildlife Refuge waters with geographic strata noted (A-D). Solid circles indicate strata boundaries; hollow circles indicate other points of interest.

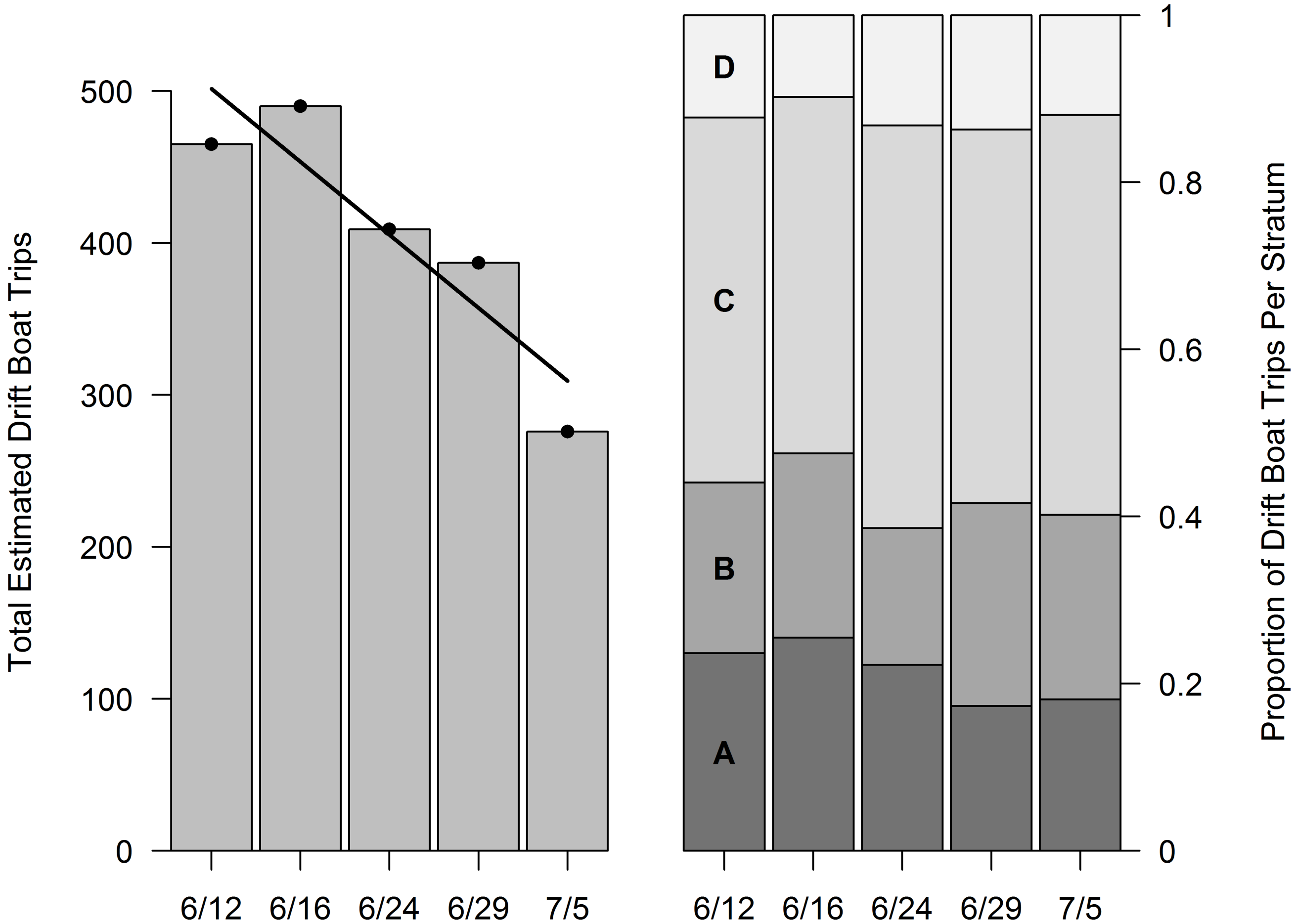

Figure 2: *Left*: total estimated drift boat trips by opener, with a fitted linear trend showing the consistent decline in effort. *Right*: the proportion of all estimated trips that occurred in each geographic stratum[1] by opener.

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

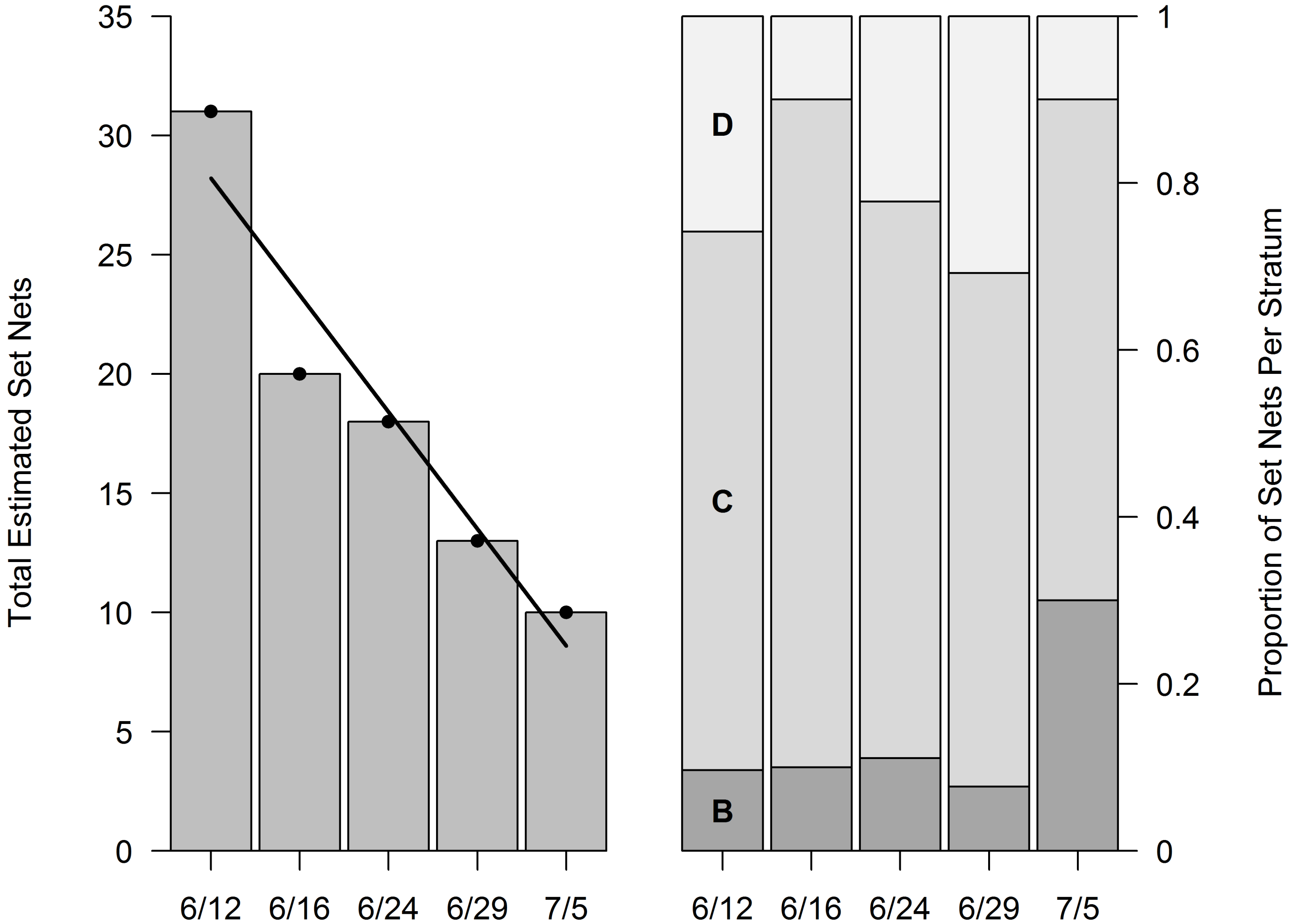

Figure 3: *Left*: total estimated set nets fishing during each opener, with a fitted linear trend showing the consistent decline in effort. *Right*: the proportion of all estimated nets that were set in each geographic stratum[1] by opener.

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak

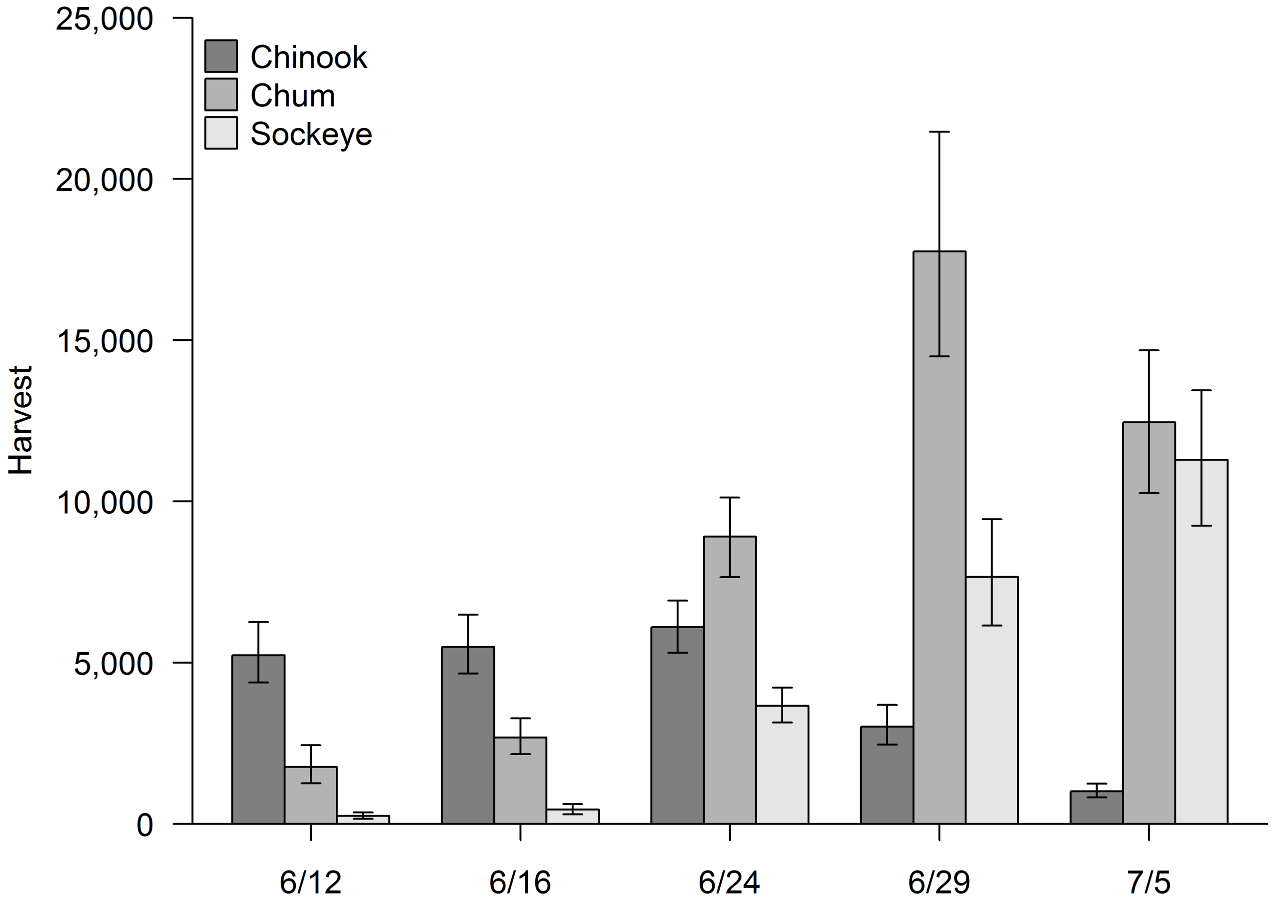

Figure 4: Estimated salmon harvest by species in each of the five openers. Estimates include harvest from both drift nets and set nets. Error bars represent 95% confidence limits.

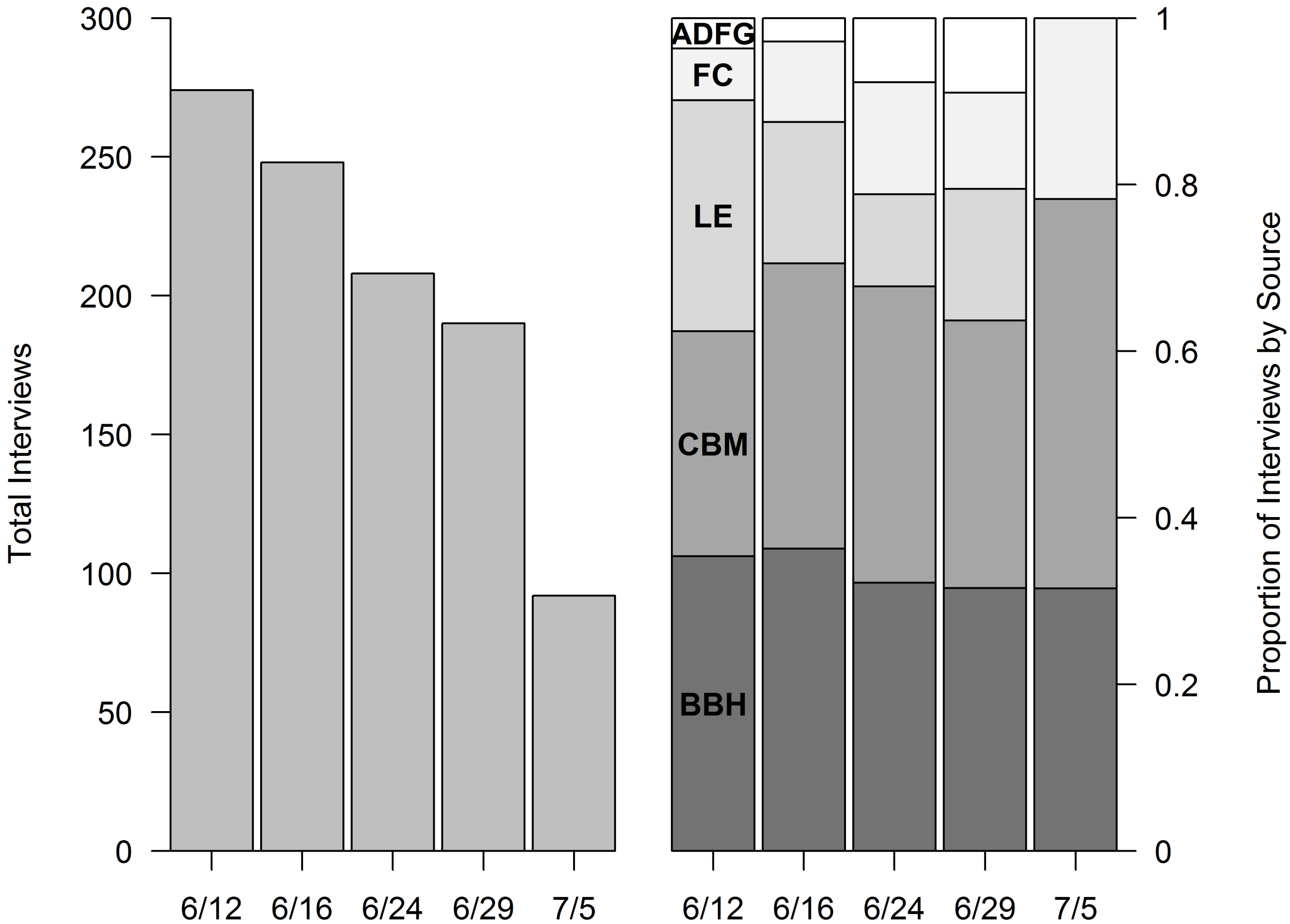

Figure 5: *Left*: total number of interviews used to inform the harvest estimates from each opener. *Right*: the proportion of all interviews that came from each source[1] by opener.

[1]**Data source**: BBH = Bethel boat harbor (ONC), CBM = community-based monitoring (BSFA), LE = Law Enforcement (USFWS), FC = Bethel area fish camps (ONC), ADFG = tundra village interviews (ADF&G).

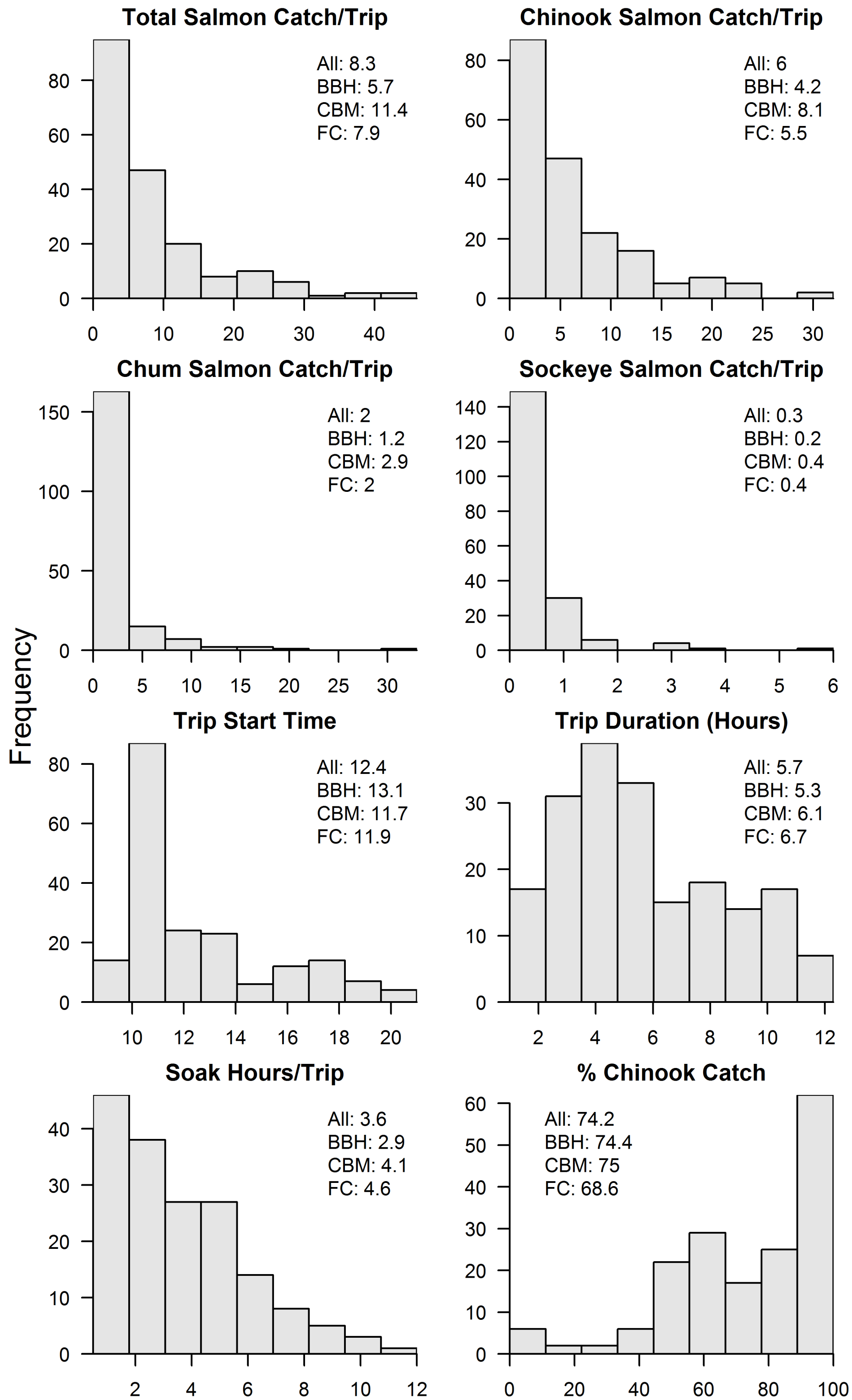

Figure 6: Distribution of relevant quantities from completed drift boat trip interviews during the first opener (6/12/2018), with means for all available interviews and by data source[1].

[1]**Data source**: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (BSFA). The relatively small number of ADF&G interviews were grouped with the CBM interviews for the calculation of this mean.

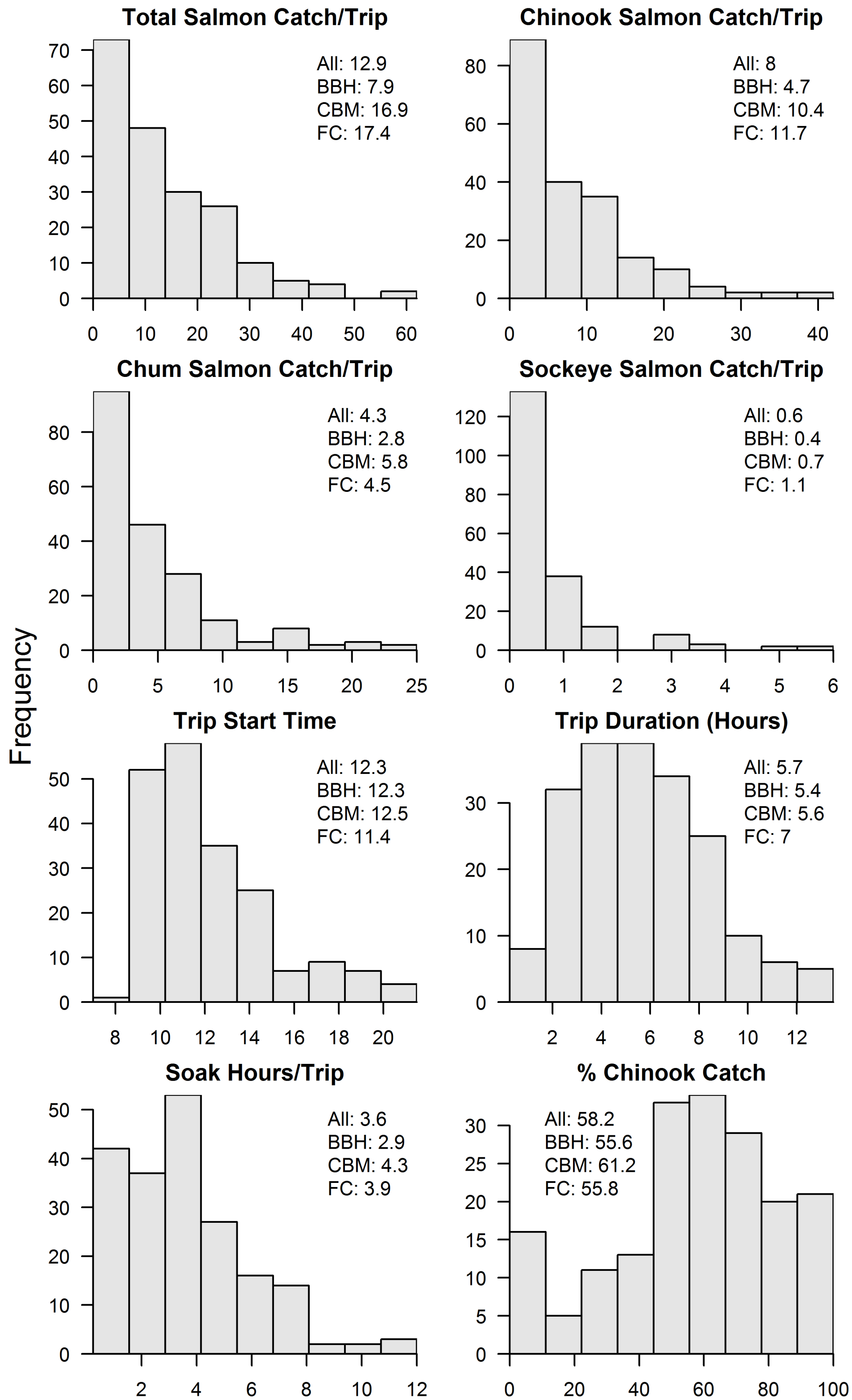

Figure 7: Distribution of relevant quantities from completed drift boat trip interviews during the second opener (6/16/2018), with means for all available interviews and by data source[1].

[1]**Data source**: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (BSFA). The relatively small number of ADF&G interviews were grouped with the CBM interviews for the calculation of this mean.

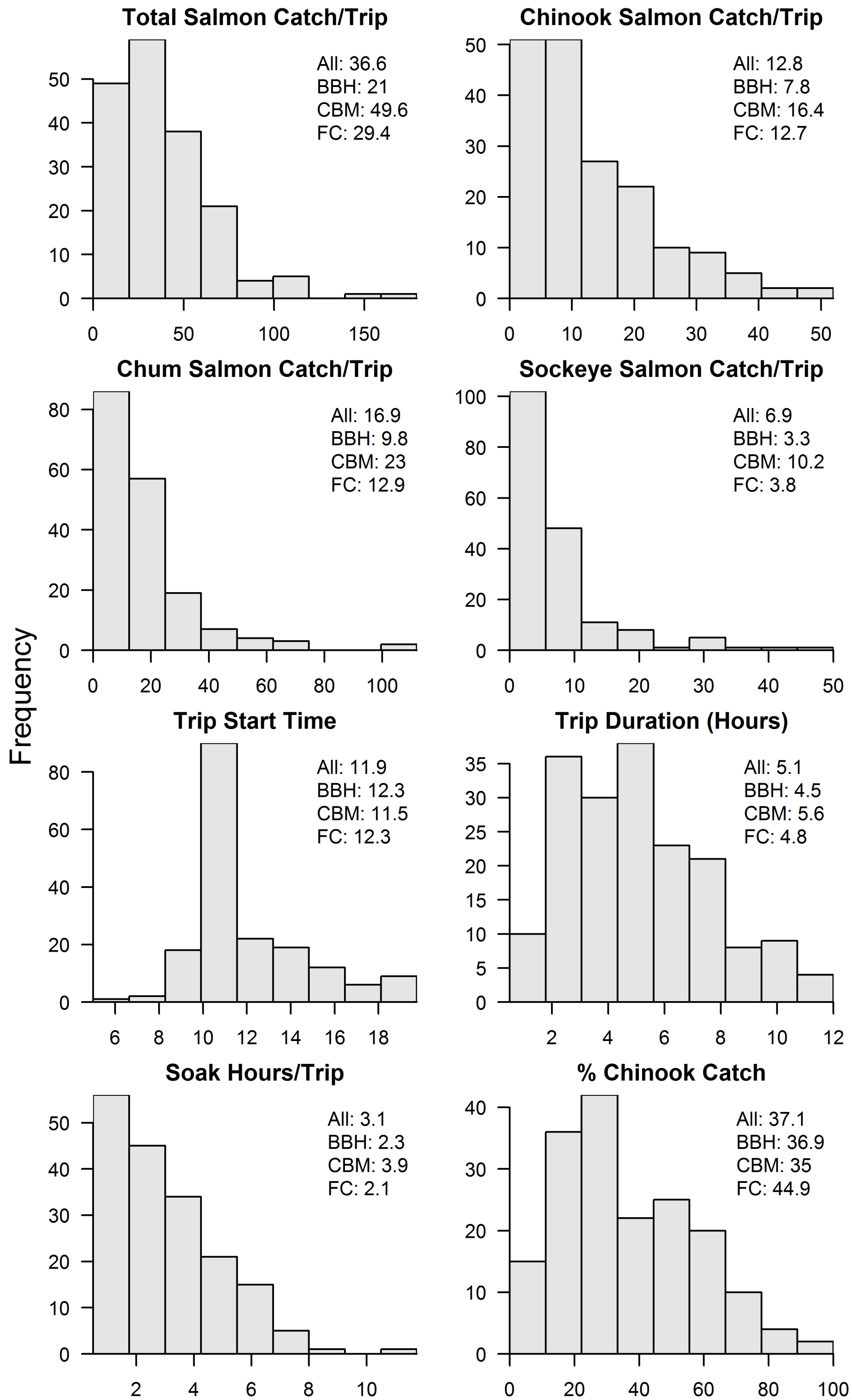

Figure 8: Distribution of relevant quantities from completed drift boat trip interviews during the third opener (6/24/2018), with means for all available interviews and by data source[1].

[1]**Data source**: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (BSFA). The relatively small number of ADF&G interviews were grouped with the CBM interviews for the calculation of this mean.

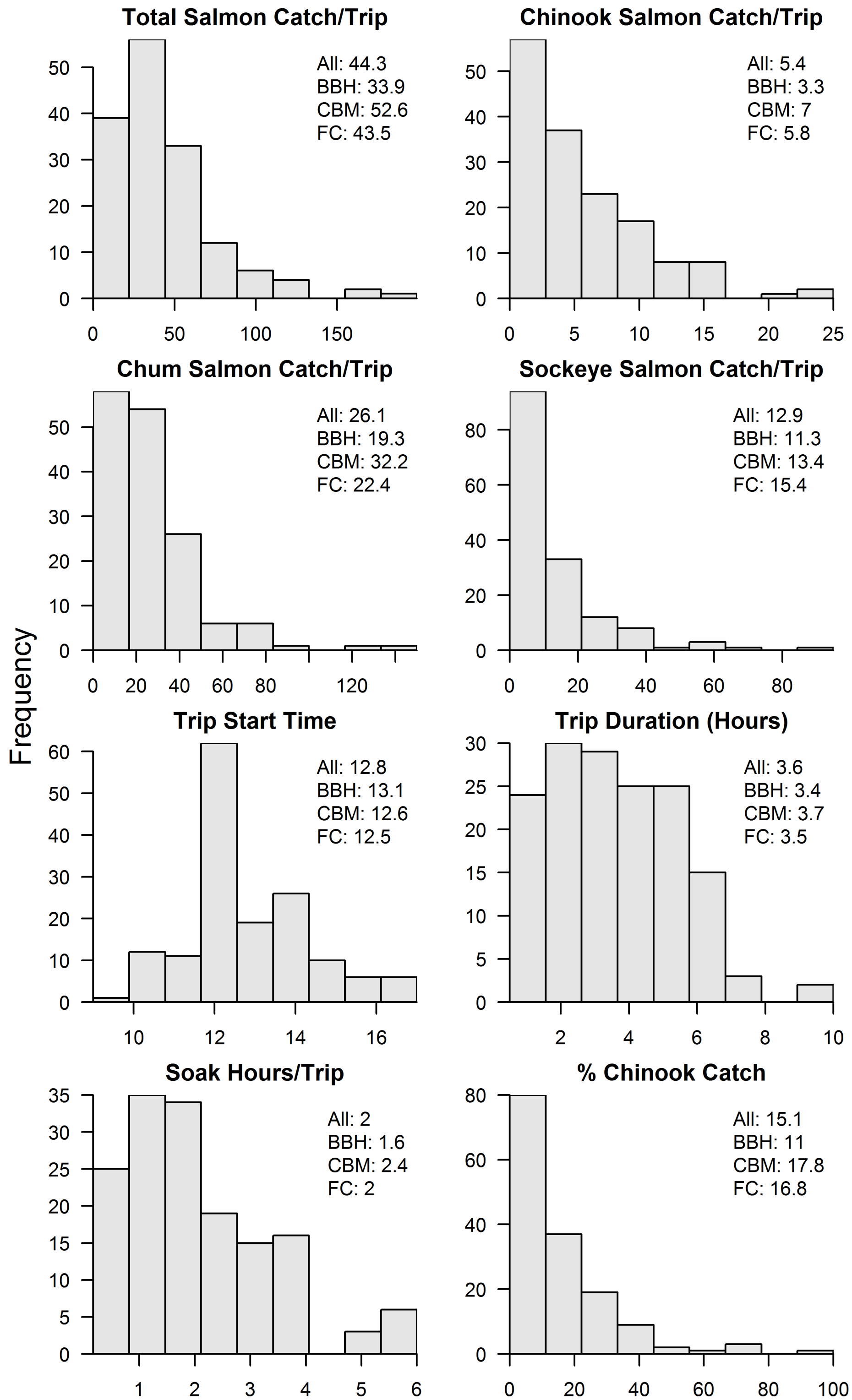

Figure 9: Distribution of relevant quantities from completed drift boat trip interviews during the fourth opener (6/29/2018), with means for all available interviews and by data source[1].

[1]**Data source**: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (BSFA). The relatively small number of ADF&G interviews were grouped with the CBM interviews for the calculation of this mean.

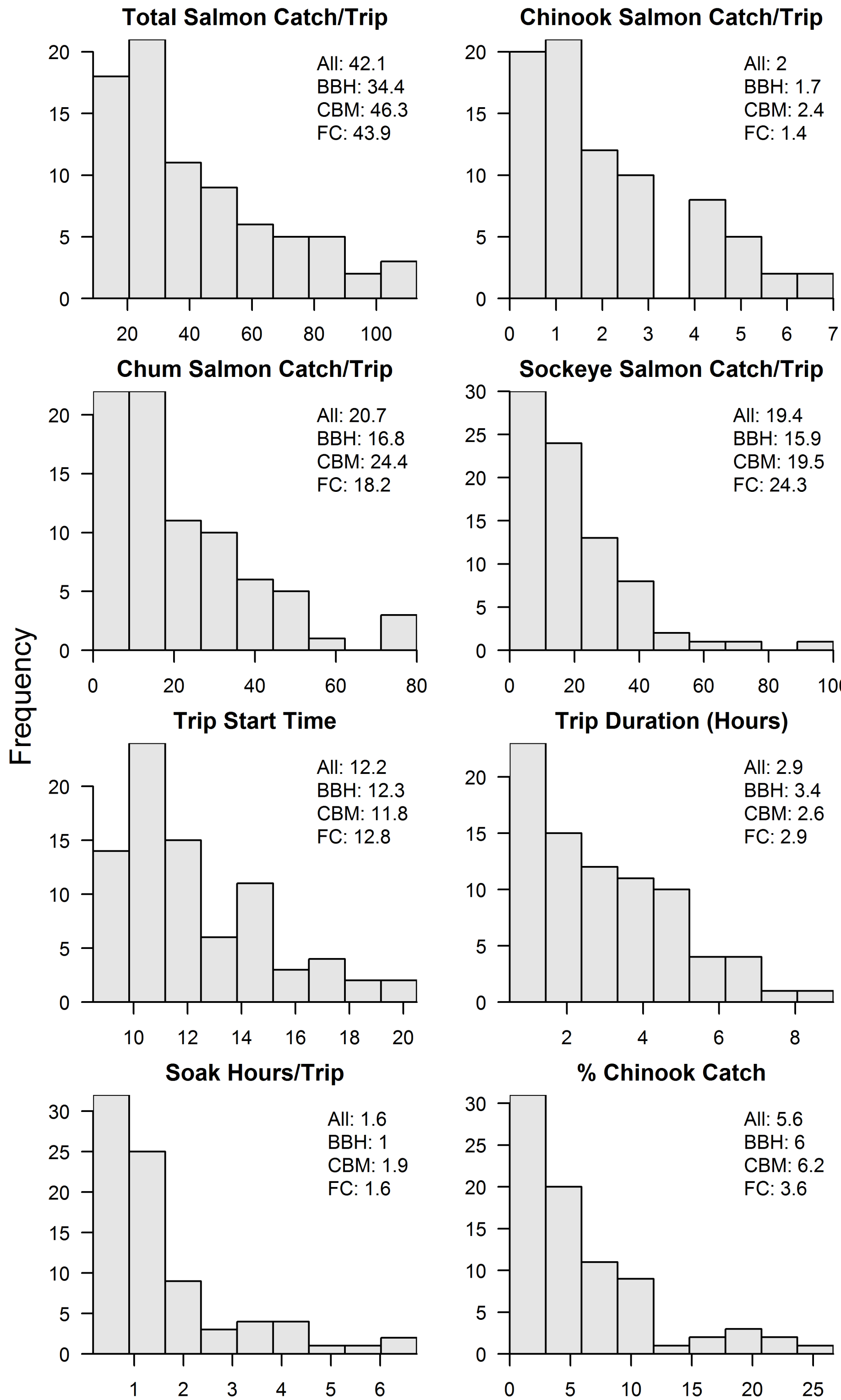

Figure 10: Distribution of relevant quantities from completed drift boat trip interviews during the fifth opener (7/5/2018), with means for all available interviews and by data source[1].

[1]**Data source**: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (BSFA). The relatively small number of ADF&G interviews were grouped with the CBM interviews for the calculation of this mean.

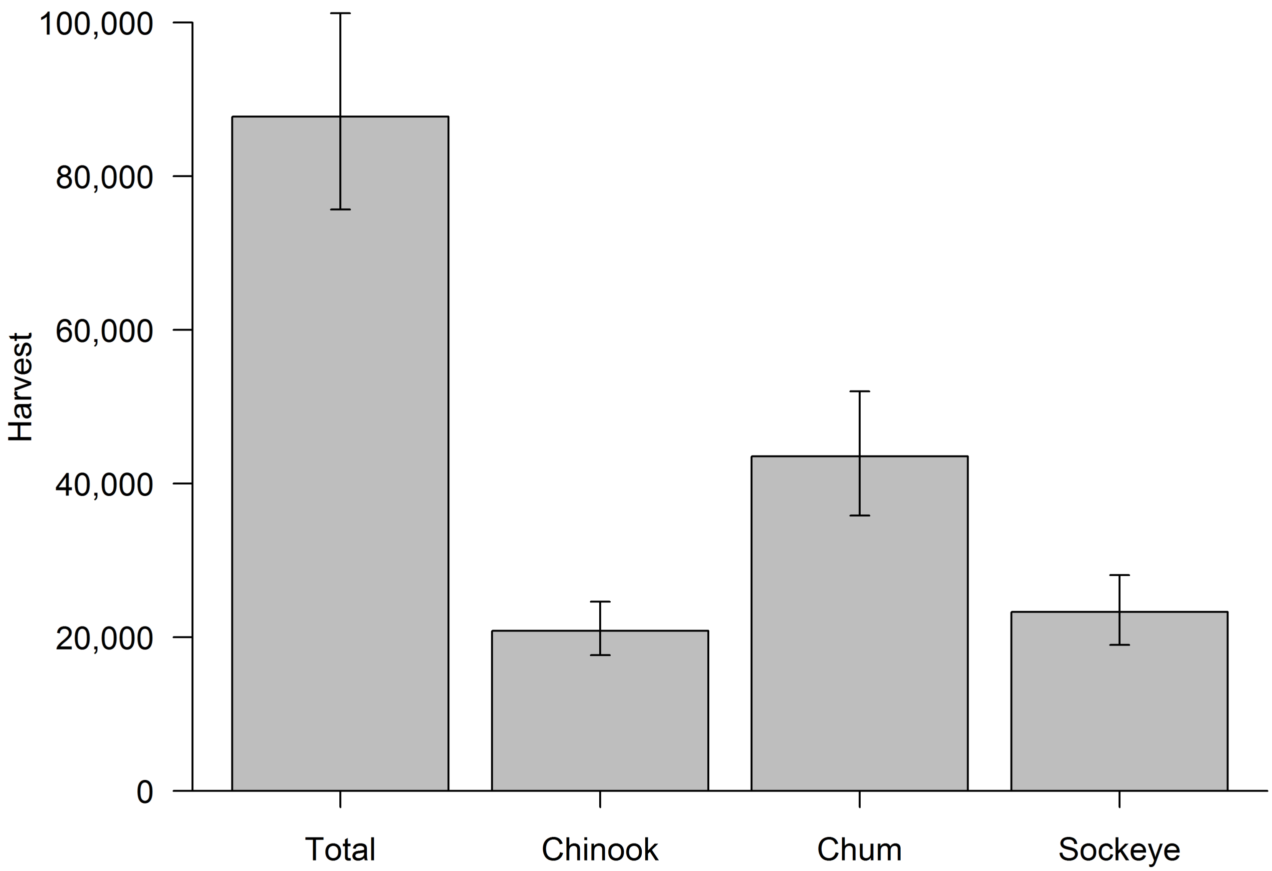

Figure 11: Total salmon harvest and harvest by species across all five openers combined between drift nets and set nets. Error bars represent 95% confidence limits.

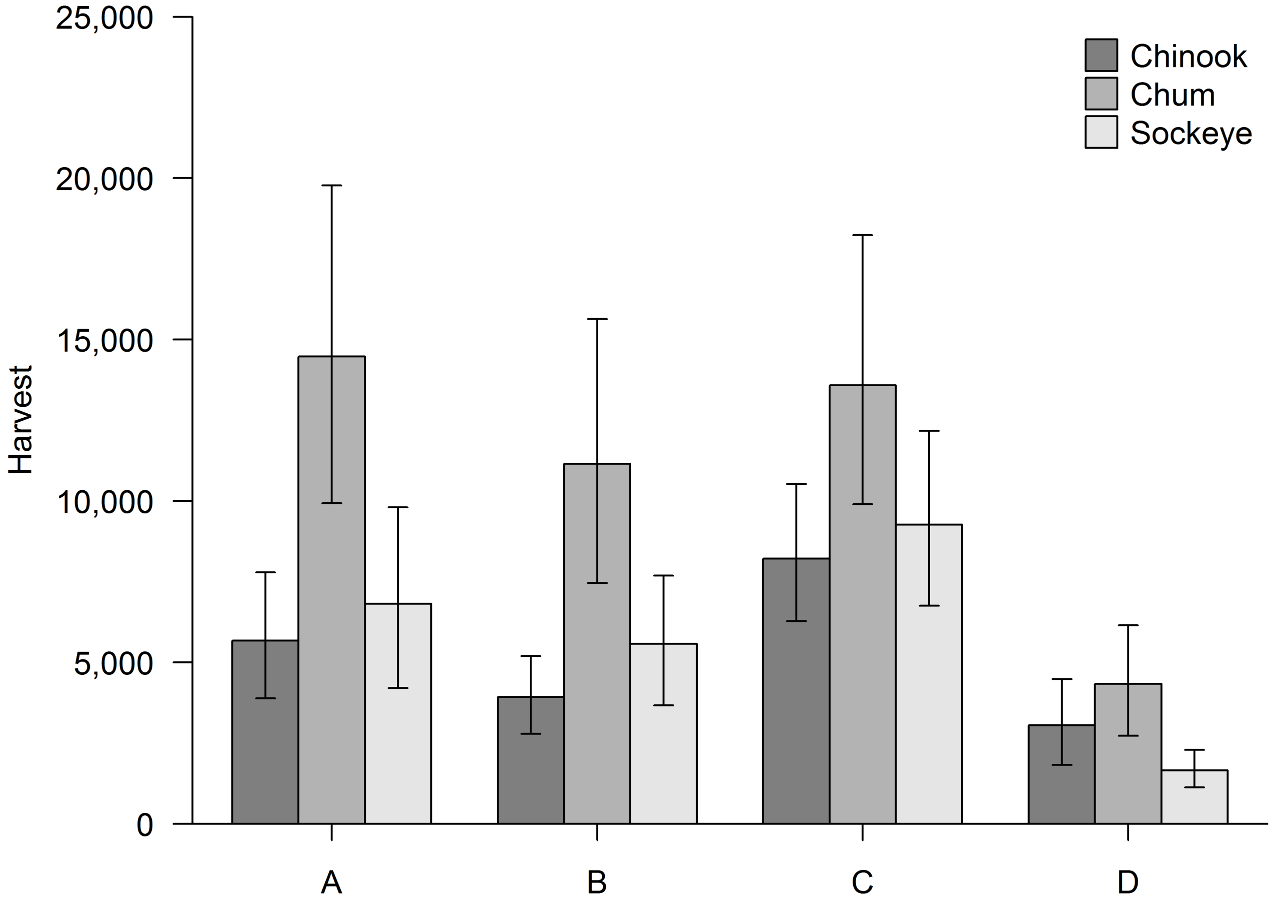

Figure 12: Total estimated salmon harvest by species and geographic stratum[1] across all five openers combined between drift nets and set nets. Error bars represent 95% confidence limits.

[1]**Geographic strata**: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiachak to Akiak