In-season Harvest and Effort Estimates for the 2017 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 harvest and run strength information. Because of this lack of information, it is challenging to make well-supported and defensible decisions regarding fishing opportunities to simultaneously achieve conservation and harvest objectives, particularly during years of weak runs. In response to an anticipated weak 2017 Kuskokwim River Chinook salmon run, the United States Fish and Wildlife Service in collaboration with the Kuskokwim River Inter-Tribal Fisheries Commission, the Orutsararmiut Native Council, and several other villages on the Kuskokwim River, collected data to produce in-season subsistence salmon harvest estimates from that portion of the 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, we estimated the total subsistence salmon harvest in this area was 87,130 (73,520 – 102,350) during four fishing opportunities between June 12 and July 3, 2017. Most salmon harvested were chum salmon (*O. keta*; 54,420; 44,650 – 65,420) followed by sockeye salmon (*O. nerka*; 24,080; 18,540 – 30,360), and Chinook salmon (8,630; 6,920 – 10,550). Methodologies refined during this study should be useful to structure future efforts to estimate subsistence salmon harvest on the Kuskokwim River as well as other fisheries with similar characteristics.

INTRODUCTION

In-season management of Kuskokwim River salmon fisheries is undertaken in the face of a severe lack of information (due in a large part to the size and remoteness of the system). In order to manage in a fully-informed way, a manager would require continuous and accurate information on run timing, harvest, and escapement. With knowledge on these three 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 has historically been conducted with very little of this information, and has instead relied largely on a single index (the Bethel Test Fishery) of run abundance, run timing, and species composition to inform decision-making. Work is being done to develop and evaluate methods of obtaining more detailed information regarding run timing (Staton et al. 2017) and run size (e.g., a new main stem sonar project and unpublished preliminary analyses involving updating run size forecasts with in-season data) 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 is still 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 rarely been available

(i.e., 2015 and 2016) for in-season management consideration, and are arguably the most critical information source necessary to successfully manage weak salmon runs. This document presents in-season salmon harvest estimates from short-duration Kuskokwim River subsistence fishing opportunities during the 2017 season using a recently developed harvest estimation technique (Staton and Coggins 2016).

In response to an anticipated weak 2017 Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*) run, the United States Fish and Wildlife Service (USFWS), by delegation from the Federal Subsistence Board (Federal Special Action 3-KS-02-17), assumed primary management authority of the Kuskokwim River Chinook subsistence fishery within the boundaries of the Yukon Delta National Wildlife Refuge (YDNWR). The Federally-designated manager, along with Refuge staff and in collaboration with the Kuskokwim River Inter-Tribal Fisheries Commission (KRITFC), designed and implemented a management strategy based on explicit objectives informed by the best available scientific information. The Alaska Department of Fish and Game (ADFG) was given the opportunity to provide input throughout the process. In pre-season management meetings, the Federal manager and the KRITFC agreed that the subsistence fishery should target 40,000 Chinook salmon considering an anticipated run size of approximately 150,000 fish and a fundamental objective to assure a spawning escapement of at least 110,000 fish. Thus, going into the 2017 season, a targeted subsistence harvest of 40,000 Chinook salmon was used as the primary means objective; subject to further revision should in-season assessment information suggest a larger or smaller harvest would be warranted. It was further decided that the use of fishing time, area, and gear restrictions would provide an adequate means to manage the fishery. These "block openings" would allow for limited harvest opportunity, with periods between openings allowing for harvest estimation and decision-making to identify the nature of subsequent fishing opportunities.

Early in the 2017 Chinook salmon run, it became clear to biologists and managers that the in-season assessment projects (i.e., the Bethel Test Fishery, sonar, and harvest monitoring) were suggesting a substantially smaller run than forecasted. Following these realizations, the Federal in-season manager and the KRITFC abandoned the pre-season means objective of harvesting 40,000 Chinook salmon, and determined that future harvest of Chinook salmon during the 2017 season should be minimized in order to maximize the probability of meeting the lower bound of the drainage-wide escapement goal (65,000 fish).

As this management strategy (i.e., explicit harvest objective) to the in-season management problem is relatively novel to the Kuskokwim River salmon fisheries, in-season harvest estimates had not been required or produced prior to 2015. In 2015, relatively simple harvest estimates were produced based on boat counts and trip interview information collected during short-duration block openings that year (unpublished data). For the 2016 season, a more complex harvest estimation method was developed (Staton and Coggins 2016) that 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) was the temporal and spatial scales they pertain to. The 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) were concerned with estimating harvest from short bursts of fishing activity (ranging from 12 to 72 hours) spread over a large spatial area (spanning > 300 kilometers of the main stem Kuskokwim from the villages of Tuntutuliak to Aniak; Figure 1).

There were four subsistence fishery openers during June and July 2017 within the YDNWR boundaries. The first opener was 12 hours in duration starting at 12:01pm 6/12/2017 and ending at 11:59pm 6/12/2017 (Federal Special

Action 3-KS-03-17). The second opener was 12 hours in duration starting at 12:01pm 6/24/2017 and ending at 11:59pm 6/24/2017 (Federal Special Action 3-KS-04-17). The third opener was 6 hours in duration, starting at 3:00pm 7/1/2017 and ending at 9:00pm 7/1/2017 (Federal Special Action 3-KS-05-17). The fourth opener was 12 hours in duration, starting at 12:01pm 7/3/2017 and ending at 11:59pm 7/3/2017 (Federal Special Action 3-KS-06-17). Shortly after the fourth opener, managers decided that further restrictions to the subsistence fishery would have negligible effects on Chinook salmon escapement.

METHODS

The in-season harvest estimation framework that was developed and applied to the 2016 and 2017 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 their gear, fishing location, fishing time, and catch.

The methods to estimate harvest used in 2017 were identical to those used in 2016, with the exception of two important points. First, due to the finding in 2016 that a very small fraction (3%; Staton and Coggins 2016) of the salmon harvest within the YDNWR occurred upstream of Akiak, harvest and effort were not estimated for this section of river in 2017. Second, the 2016 analysis relied almost entirely on interviews from the Bethel boat harbor and Bethel area fish camps, however, other data covering a broader geographical area were available in addition to these sources in 2017 (described in *Completed Trip Interviews*, below).

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 high and low tide when the tides are moving the strongest, which are the most popular times to fish (Greg Roczicka, Orutsararmiut Native Council [ONC] Natural Resource Director, pers. comm.), and such that the flights were spaced relatively equally throughout the opener. This resulted in in no more than 3 hours between the end of one flight and the start of the second flight.

Flights involved departing the Bethel airport, 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 (Figure 1). This flight path took approximately 1.5 hours to complete, including the flight back to the Bethel airport. Boat 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; strata indicated by letters A-D). All river regions excluding below Loumavik Slough and Kuskokuak Slough 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 region. Below Loumavik Slough, the river is too wide to see both banks entirely so each bank was counted once and the counts were summed. Kuskokuak Slough was counted only once on the return flight from Akiak to Bethel. Set nets were counted in the same fashion. Boats were counted only if they were actively fishing or if a net could be seen in the boat. No inclement weather prevented a scheduled flight from occurring.

Completed Trip Interviews

Information from fisher trips was obtained from 4 sources: (1) the Bethel boat harbor, (2) Bethel area fish camps, (3) several villages other than Bethel, and (4) from USFWS law enforcement personnel during routine compliance checks. Interview data from sources (1) and (2) were collected by personnel from ONC and were the predominate sources used by Staton and Coggins (2016). Data from source (3) were collected by KRITFC staff in cooperation with the Bering Sea Fisherman's Association (BSFA) as part of a new project that was designed to, among other things, provide interview data from areas of the YDNWR other than solely the Bethel area. Village monitors were placed in the

villages of Tuntutuliak, Napakiak, Napaskiak, Kwethluk, and Akiak and reported the data in a timely manner so that they could be included into the estimates. Data from source (4) were available in 2015 and 2016, though in 2016 they were of poor quality and were therefore discarded. In 2017, law enforcement officers participated more fully in the data collection process and the data were of higher quality allowing them to be included into the 2017 estimates. 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 *Harvest Expansion Model* below).

Interviewees sampled by these four sources were asked the same questions and the interviewers were trained as thoroughly as possible in a formal setting (in Bethel; 6/1/2017) 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 trip. The key pieces of information collected in each interview included:

- The day fishing occurred
- The location of the trip (used to place the trip in a geographic stratum)
- The type of net used (drift vs. set)
- The start and end times of the trip
- The total number of hours the net was fishing (referred to as "soak time")
- The length of the net used (in feet)
- The total harvest by species of each Chinook, chum, and sockeye salmon

Analytical Methods

Given that the analytical methods in 2017 were nearly identical to those used in 2016 and are fully described in Staton and Coggins (2016), they will not be presented in full here. Instead, a brief overview will be provided.

Boat Trip 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). Staton and Coggins (2016) presented methodology to handle these two problems by making use of the reported start and end times of the interviewed trips. The number of drift boat trips that would have been double counted on multiple flights was calculated and was discounted from the total. Then, the known drift boat trips per interview was calculated and expanded by the number of interviews that reported fishing during times that were not flown (similar to the Peterson two-sample abundance estimator; Seber 1982). Through simulation, Staton and Coggins (2016) reported that averaging the unexpanded and expanded estimates provided the least biased estimator for total drift boat trips. However, through subsequent simulation efforts we have found that the expanded estimator is unbiased conditional on reasonably good interviewer coverage throughout the opener. Thus, only expanded boat counts were used as the estimate of total drift boat trips during 2017. Total estimated drift boat trips were then post-stratified into the four geographic strata based on the average proportion of all boats that were counted within each geographic stratum.

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. 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.

Harvest Expansion Model

The harvest expansion model used the two pieces of information (catch rates from trip interviews and total effort estimates) to estimate the total harvest by geographic stratum and opener. The interview information was used to quantify the qualities of the average trip in each stratum including the average soak time, the average net length, and the average salmon catch rate by species (catch/net-foot-hour). These quantities, when multiplied, gave the average salmon catch by species for the typical trip in each geographic stratum. Salmon harvest by geographic stratum was estimated as the average salmon harvest per trip multiplied by the estimated number of trips in that stratum. Geographic stratum-specific harvests were then summed to obtain total salmon harvest for each opener.

Uncertainty Estimation

Variability in between-interview quantities (particularly catch rates and soak times) was quite high, necessitating the consideration of statistical uncertainty in the estimates. Variation in between-interview quantities (i.e., net length, soak time, and catch rate) was included in the analysis using non-parametric bootstrapping (10,000 bootstrapped iterations). 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, and repeating the process many times to form a distribution of possible harvests. To summarize the resulting variation, the 2.5th and 97.5th percentiles were used as the lower and upper confidence limits (CL), respectively, and the mean of all bootstrapped estimates was used as the point 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 error in the process of estimating effort (i.e., boat trips) during aerial surveys. Thus, uncertainty in the harvest estimates is smaller than if uncertainty in effort was fully considered.

Computation

All analyses were conducted in the statistical programming environment R using custom code. During the season, summary documents were produced using RMarkdown for consideration by managers and stakeholders.

RESULTS

First Opener (6/12/2017)

We estimated that a total of 523 drift boat trips and 61 set net trips occurred between Tuntutuliak and Akiak (hereafter, "study area") on 6/12/2017 during the 12 hour opener (Table 3; Figures 2, 3). The mean estimated total salmon harvest was 5,620 (95% CL: 4,520–6,910). The majority of this harvest (86%) was split evenly between Chinook salmon (2,400; 1,920–2,950) and chum salmon (2,430; 1,720–3,320), and the remaining 14% was sockeye salmon (800; 530–1,090) (Table 4, Figure 4). Most of this harvest came from geographic strata A (downstream of the Johnson River mouth), as that is where the majority of boats were fishing (Tables 3, 4; Figure 2). These harvest estimates were produced from 191 completed trip interviews, of which 94 (49%) came from the Bethel boat harbor, 8 (4%) came from Bethel area fish camps, 44 (23%) came from KRITFC village monitors, and 45 (24%) came from USFWS law enforcement officers (Figure 5). Four interviews were from set net fishers and the remaining 187 interviews were from drift boat fishers. This represents an estimated sampling rate of 36% and 7% 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 majority of fishers entering close to noon and a second that was more prolonged starting at 3:00pm and lasting until 7:00pm. Most trips lasted between 2 and 8 hours, and soak time was fairly uniform between 1 and 6 hours. Very few fishers caught

more than 15 total salmon or more than 5 Chinook salmon. Interestingly, the average fisher interviewed by the KRITFC 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, relatively equal numbers of Chinook versus chum and sockeye were caught, as evident from the average percent Chinook catch of 44% across all interviewed fishers. Between 6/10/2017 and 6/12/2017, the Bethel test fishery catch was comprised of 27% Chinook salmon on average, possibly indicating that the fishery was able to target Chinook salmon over the other species.

Second Opener (6/24/2017)

We estimated that a total of 447 drift boat trips and 38 set net trips occurred within the study area on 6/24/2017 (Table 3, Figures 2, 3). The mean estimated total salmon harvest was 33,370 (29,160–37,860). Most of this harvest was chum salmon (20,360; 17,650–23,270), followed by sockeye salmon (8,460; 6,910–10,170) and Chinook salmon (4,550; 3,780–5,390) (Table 4, Figure 4). Much of the harvest came from geographic strata B and C, (spanning the Johnson River mouth to Akiachak), and accounted for 72% of the total salmon harvest and 64% of the Chinook salmon harvest. These harvest estimates were produced from 272 completed trip interviews, of which 97 (36%) came from the Bethel boat harbor, 32 (12%) came from Bethel area fish camps, 63 (23%) came from KRITFC village monitors, and 80 (29%) came from USFWS law enforcement officers (Figure 5). Sixteen of these interviews were from set net fishers and the remaining 256 were from drift boat fishers. This represents an estimated sampling rate of 57% and 42% 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 around noon and lasted between 1 and 5 hours. Average soak time was shorter than in the first opener, with very few fishers actively fishing more than 4 hours (average 2.43 compared to 3.56 in the first opener). Very few fishers caught more than 100 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 17% across all interviews. Between 6/22/2017 and 6/24/2017, the Bethel test fishery catch was comprised of 10% Chinook salmon on average.

Third Opener (7/1/2017)

We estimated that a total of 320 drift boat trips and 19 set net trips occurred within the study area on 7/1/2017 (Table 3, Figures 2, 3). The mean estimated total salmon harvest was 30,190 (24,290–37,030). Most of this harvest was chum salmon (19,640; 15,380–24,490), followed by sockeye salmon (9,550; 7,100–12,300) and Chinook salmon (990; 700–1,340) (Table 4, Figure 4). These harvest estimates were produced from 113 completed trip interviews, of which 42 (37%) came from the Bethel boat harbor, 21 (19%) came from Bethel area fish camps, 39 (35%) came from KRITFC village monitors, and 11 (9%) came from USFWS law enforcement officers (Figure 5). Seven of these interviews were from set net fishers and the remaining 106 were from drift boat fishers. This represents an estimated sampling rate of 33% and 37% 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 between 3:00pm and 4:00pm and lasted between 1 and 3 hours. Average soak time was shorter than in the second opener, with very few fishers actively fishing more than 2 hours (average 1.25 compared to 2.43 in the second opener). Few fishers caught more than 75 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 4% across all interviews. Between 6/29/2017 and 7/1/2017, the Bethel test fishery was comprised of 3% Chinook salmon on average.

Fourth Opener (7/3/2017)

We estimated that a total of 250 drift boat trips and 12 set net trips occurred within the study area on 7/3/2017 (Table 3, Figure 2, 3). The mean estimated total salmon harvest was 17,950

(15,550–20,550). Most of this harvest was chum salmon (11,990; 9,900–14,340), followed by sockeye salmon (5,270; 4,000–6,800) and Chinook salmon (690; 520–870) (Table 4, Figure 4). These harvest estimates were produced from 109 completed trip interviews, of which 41 (38%) came from the Bethel boat harbor, 8 (7%) came from Bethel area fish camps, 43 (39%) came from KRITFC village monitors, and 17 (16%) came from USFWS law enforcement officers (Figure 5). Eleven of these interviews were from set net fishers and the remaining 98 were from drift boat fishers. This represents an estimated sampling rate of 39% and 98% 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 between 12:00pm and 4:00pm and lasted between 1 and 4 hours. Average soak time was very similar to the third opener, with few fishers actively fishing more than 2 hours (average 1.44 compared to 1.25 in the second opener). Few fishers caught more than 50 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 6% across all interviews. Between 7/1/2017 and 7/3/2017, the Bethel test fishery was comprised of 3% Chinook salmon on average.

Total Harvest across All Openers

Across all openers, we estimated that a total of 87,130 (73,520–102,350) salmon were harvested. Of this, most was chum salmon (54,420; 44,650–65,420), followed by sockeye salmon (24,080; 18,540–30,360), and Chinook salmon (8,630; 6,920–10,550) (Table 4, Figure 10). Fishers within geographic strata B and C (spanning Johnson River to Akiachak) harvested the most total salmon, together accounting for 67% of all salmon harvested. Fishers in stratum C caught fewer chum salmon and more sockeye salmon than fishers in stratum B (Figure 11). 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 2, 4, Figure 11). In general, there was a very clear and linear decline in drift boat and set net effort across the four openers (Figures 2, 3). The proportion of drift boats fishing in stratum A (below the Johnson River mouth) declined across the four openers, though the decline was largest between the first and second openers, presumably because allowable net length in stratum A was reduced from 300ft to 150ft following the first opener, though other factors may have contributed.

DISCUSSION

The in-season salmon harvest estimates presented within this document, and the associated information (e.g., number of drift boats, total salmon catch per boat, and species ratios), proved to be invaluable to the decision-making process used by YDNWR and KRITFC in the 2017 season. ADFG management staff were also interested in seeing the estimates as were area fishers and Kuskokwim River Salmon Management Working Group members. Harvest estimates were even mentioned in several KYUK articles (the public radio news outlet for the Yukon-Kuskokwim Delta region), and were the focus of one such article (MacArthur 2017). Information gleaned from this analysis not only provided critical harvest and effort estimates, but has also contributed substantially to the understanding of the behavior of the fishery. For example, because aerial surveys were flown so often, it was possible to precisely monitor the decline in effort both within a fishing day and as the season progressed.

Due to the value of the harvest estimates and the corresponding information to in-season management, we suggest that in-season harvest estimates be produced in years where a block-opener management tactic is implemented to meet a specific harvest objective. In order to make the decision to have another opener (and how long to make it), managers need to know (1) how much harvest to anticipate in the proposed opener and (2) how much harvest had been taken to date. At the very least, (1) should be available – how can a decision be justified with no informed predictions as to the likely consequences? Without this information, the decision becomes much less informed and is thus subject to substantial pitfalls (e.g.,

optimism) and criticisms by stakeholders. The data collected and estimates obtained during this study contributed substantially to informing these decisions: managers could feel reasonably confident in harvest predictions because previous predictions aligned closely with what actually happened in past openers. We believe that the robustness of these predictions was a function of the wealth of empirical information provided to managers and the expert knowledge the managers have about the fishery dynamics (particularly on the part of KRITFC). However, in years of higher abundance where meeting the escapement goal is of less concern, a block-opening management structure is not likely necessary as the subsistence fishery may not be able to harvest enough fish to prevent the escapement goal from being met. In these cases, it could be argued that estimates of in-season harvest have little value as there would be no active management decisions to be made based on them.

Despite the utility of the information gained in the harvest estimation process, it came at a substantial cost, in terms of both fiscal and personnel resources. Each aerial survey flight cost an estimated $750 in aircraft expenditures and required a USFWS pilot and at least one observer. Additionally, substantial time was spent by ONC personnel conducting the completed trip interviews at the Bethel boat harbor (for which they currently have no direct funding), which oftentimes involved upwards of 40 man hours per day on the part of ONC (3 – 4 interviewers for 10+ hours per day). Costs were also incurred by the KRITFC as part of their community-based monitoring project, though there were directed funds for this purpose. Besides the data collection efforts, substantial time was spent in the analysis of the data, including data entry, writing custom code, and preparing summary documents. Due to this, the availability of the information for incorporation into decision-making was somewhat delayed (estimates were typically finalized within 12 to 24 hours following the conclusion of the opener). However, because the method was developed in 2016 and only needed to be revised slightly for use in 2017, these time requirements and delays were less than in 2016.

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 2017 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 we 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. We attempted to account for this in several ways. First, although we treated the information as though it was random, each time harvest estimates were presented to stakeholders and decision-makers, we attempted to make them fully aware of the limitations and problems with the analysis. Second, we 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.

Efforts were put forth in 2017 to improve what was done in 2016. The first and most substantial change was the addition of a large amount of interview information from areas within the YDNWR outside of the Bethel area. This change occurred in a large part due to the community-based monitoring project led by KRITFC. Collecting the same information from these other villages not only increased the sample size, but also provided information on fisher behavior in these areas, which oftentimes was somewhat different than the information collected near Bethel. Additionally, the utility of the information collected by USFWS law enforcement officers should not be understated (even though the interviews were not for

completed trips) as it certainly increased the sample size and improved the precision of the estimates.

A second improvement in the 2017 methodology was that instead of averaging expanded and non-expanded drift boat counts, we used the expanded count as the estimator. Recent simulation work shows that this is an unbiased estimator as long as interview coverage is designed to not miss large sections of the day (even with only one flight during a 24 hour period).

Third, we investigated the sensitivity of the estimates to violations in assumption by producing effort and harvest estimates using data from only a single source (e.g., Bethel boat harbor interviews) at a time. Results of these analyses showed that the estimates were generally robust to leaving out information (i.e., making the information used less representative), and resulted in relatively small changes in point estimates of 10% to 30% in most cases. In most cases, the point estimate of the analysis with left-out data fell within the CL of the original estimate and in no cases did the qualitative conclusion change (e.g., Chinook salmon harvest was small relative to chum salmon and sockeye salmon harvest).

Fourth and lastly, YDNWR staff had the opportunity to present the information and estimates to technical advisors from ADFG and the KRITFC shortly before making them public. While this review was relatively informal and abbreviated by necessity to allow nearly-immediate consideration by managers for subsequent decisions, we felt that 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, we believe that the review bolstered the credibility and reliability of our work. In our opinion, these four steps represent substantial improvements to our 2016 work in developing and refining the method. We also anticipate that this approach is likely to improve further as interested and collaborating parties recognize the value of in-season harvest and effort estimates and the information necessary to produce valid and robust estimates.

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

Opener	Date	Flight Times		Geographic Stratum[1]				Total
		F_1	F_2	A	B	C	D	
1	6/12/2017	13:00	14:30	122	114	114	25	375
1	6/12/2017	17:40	19:10	145	101	96	25	367
1	6/12/2017	19:40	21:10	75	52	97	29	253
2	6/24/2017	13:00	14:30	85	131	112	31	359
2	6/24/2017	17:00	18:10	57	71	62	23	213
2	6/24/2017	22:10	22:10	16	28	21	14	79
3	7/1/2017	16:00	17:15	45	86	106	19	256
3	7/1/2017	19:00	20:15	25	47	30	17	119
4	7/3/2017	13:00	14:20	5	32	44	10	91
4	7/3/2017	17:00	18:20	11	36	33	10	90
4	7/3/2017	20:30	22:00	13	24	20	9	66

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

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

Opener	Date	Flight Times		Geographic Stratum[1]				Total
		F_1	F_2	A	B	C	D	
1	6/12/2017	13:00	14:30	2	9	8	4	23
1	6/12/2017	17:40	19:10	5	16	19	9	49
1	6/12/2017	19:40	21:10	2	15	28	12	57
2	6/24/2017	13:00	14:30	2	3	11	3	19
2	6/24/2017	17:00	18:10	3	8	21	2	34
2	6/24/2017	22:10	22:10	0	2	23	4	29
3	7/1/2017	16:00	17:15	0	1	7	1	9
3	7/1/2017	19:00	20:15	4	3	2	5	14
4	7/3/2017	13:00	14:20	0	0	0	0	0
4	7/3/2017	17:00	18:20	4	1	2	2	9
4	7/3/2017	20:30	22:00	0	3	1	3	7

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

Gear	Opener	Date	Duration[2]	Geographic Stratum[1]				Total
				A	B	C	D	
Drift Boat	1	6/12/2017	12	177	137	165	43	523
	2	6/24/2017	12	105	157	129	55	447
	3	7/1/2017	6	62	117	106	35	320
	4	7/1/2017	12	31	93	96	30	250
Set Net	3	6/12/2017	12	5	16	28	12	61
	3	6/24/2017	12	3	8	23	4	38
	3	7/1/2017	6	4	3	7	5	19
	4	7/1/2017	12	4	3	2	3	12

[1]Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Akiak
[2]Duration is the number of hours in the opener

Table 4. Salmon harvest from both drift nets and set nets from all four openers by species and geographic stratum.

Opener	Species	Geographic Stratum[1]				Total
		A	B	C	D	
6/12/2017	Chinook	1,280 (880-1,760)	410 (280-560)	390 (250-550)	320 (160-490)	2,400 (1,920-2,950)
	Chum	1,110 (470-1,960)	510 (330-720)	600 (400-840)	200 (150-250)	2,430 (1,720-3,320)
	Sockeye	480 (260-750)	140 (60-240)	110 (50-190)	70 (10-160)	800 (530-1,090)
	Total	2,880 (1,920-4,020)	1,060 (740-1,420)	1,100 (770-1,500)	590 (440-790)	5,620 (4,520-6,910)
6/24/2017	Chinook	880 (570-1,240)	1,580 (1,130-2,120)	1,340 (1,030-1,640)	760 (360-1,230)	4,550 (3,780-5,390)
	Chum	3,410 (2,230-4,860)	8,320 (6,560-10,210)	6,630 (5,370-8,080)	2,000 (1,060-3,100)	20,360 (17,650-23,270)
	Sockeye	1,640 (1,030-2,380)	2,790 (2,030-3,660)	3,220 (2,260-4,420)	800 (350-1,480)	8,460 (6,910-10,170)
	Total	5,930 (4,070-8,120)	12,690 (10,140-15,390)	11,190 (9,100-13,670)	3,560 (2,200-5,180)	33,370 (29,160-37,860)
7/1/2017	Chinook	360 (150-640)	230 (110-390)	180 (70-320)	230 (130-350)	990 (700-1,340)
	Chum	4,490 (1,980-7,850)	5,680 (4,120-7,750)	7,260 (4,820-10,310)	2,210 (1,550-3,030)	19,640 (15,380-24,490)
	Sockeye	2,560 (1,160-3,790)	2,030 (1,380-2,800)	4,080 (2,230-6,400)	890 (480-1,410)	9,550 (7,100-12,300)
	Total	7,410 (4,080-11,490)	7,940 (5,990-10,300)	11,510 (7,560-16,600)	3,330 (2,500-4,370)	30,190 (24,290-37,030)
7/3/2017	Chinook	70 (40-100)	200 (120-290)	290 (160-440)	130 (80-190)	690 (520-870)
	Chum	1,910 (1,400-2,540)	5,500 (3,990-7,410)	3,120 (2,290-4,120)	1,460 (650-2,550)	11,990 (9, 900-14,340)
	Sockeye	610 (450-790)	1,530 (1,090-2,030)	1,980 (1,370-2,670)	1,150 (330-2,430)	5,270 (4,000-6,800)
	Total	2,590 (2,030-3,270)	7,230 (5,580-9,250)	5,380 (4,170-6,870)	2,740 (1,770-3,620)	17,950 (15,550-20,550)
All Openers	Chinook	2,590 (1,640-3,740)	2,420 (1,640-3,360)	2,200 (1,510-2,950)	1,440 (730-2,260)	8,630 (6,920-10,550)
	Chum	10,910 (6,080-17,210)	20,010 (15,000-26,090)	17,610 (12,880-23,350)	5,870 (3,410-8,930)	54,420 (44,650-65,420)
	Sockeye	5,290 (2,900-7,710)	6,490 (4,560-8,730)	9,390 (5,910-13,680)	2,910 (1,170-5,480)	24,080 (18,540-30,360)
	Total	18,810 (12,100-26,900)	28,920 (22,450-36,360)	29,180 (21,600-38,640)	10,220 (6,910-13,960)	87,130 (73,520-102,350)

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

Table 5. Salmon harvest from drift boat trips from all four openers by species and geographic stratum.

Opener	Species	Geographic Stratum[1]				Total
		A	B	C	D	
6/12/2017	Chinook	1,270 (870-1,740)	370 (250-510)	310 (200-450)	290 (130-450)	2,240 (1,770-2,780)
	Chum	1,100 (460-1,950)	500 (320-710)	590 (390-820)	190 (140-240)	2,390 (1,670-3,290)
	Sockeye	480 (260-750)	140 (60-240)	110 (50-190)	70 (10-160)	800 (530-1,090)
	Total	2,880 (1,920-4,020)	1,060 (740-1,420)	1,100 (770-1,500)	590 (440-790)	5,420 (4,330-6,700)
6/24/2017	Chinook	840 (530-1,190)	1,480 (1,050-2,020)	1,060 (830-1,320)	710 (320-1,180)	4,090 (3,360-4,900)
	Chum	3,260 (2,080-4,700)	7,900 (6,200-9,790)	5,450 (4,470-6,510)	1,790 (970-2,880)	18,400 (15,830-21,130)
	Sockeye	1,530 (930-2,270)	2,500 (1,810-3,310)	2,390 (1,770-3,140)	660 (240-1,310)	7,080 (5,790-8,500)
	Total	5,630 (3,790-7,820)	11,890 (9,420-14,520)	8,900 (7,390-10,580)	3,160 (1,830-4,750)	29,580 (25,770-33,600)
7/1/2017	Chinook	360 (150-630)	220 (110-390)	170 (70-310)	220 (120-350)	980 (680-1,320)
	Chum	4,410 (1,900-7,760)	5,620 (4,050-7,680)	7,120 (4,680-10,160)	2,110 (1,460-2,920)	19,250 (15,010-24,120)
	Sockeye	2,500 (1,110-3,730)	1,980 (1,340-2,750)	3,970 (2,130-6,300)	810 (410-1,340)	9,270 (6,820-12,030)
	Total	7,260 (3,930-11,350)	7,830 (5,890-10,190)	11,260 (7,320-16,350)	3,140 (2,330-4,190)	29,500 (23,600-36,360)
7/3/2017	Chinook	70 (40-100)	200 (110-290)	290 (160-440)	130 (70-190)	680 (510-860)
	Chum	1,800 (1,300-2,430)	5,420 (3,910-7,330)	3,060 (2,240-4,060)	1,380 (580-2,480)	11,660 (9,570-14,010)
	Sockeye	480 (330-640)	1,430 (990-1,930)	1,910 (1,310-2,600)	1,050 (240-2,330)	4,870 (3,600-6,400)
	Total	2,350 (1,790-3,020)	7,050 (5,390-9,060)	5,260 (4,040-6,740)	2,560 (1,590-3,410)	17,210 (14,790-19,800)
All Openers	Chinook	2,540 (1,590-3,660)	2,270 (1,520-3,210)	1,830 (1,260-2,520)	1,350 (640-2,170)	7,990 (6,320-9,860)
	Chum	10,570 (5,740-16,840)	19,440 (14,480-25,510)	16,220 (11,780-21,550)	5,470 (3,150-8,520)	51,700 (42,080-62,550)
	Sockeye	4,990 (2,630-7,390)	6,050 (4,200-8,230)	8,380 (5,260-12,230)	2,590 (900-5,140)	22,020 (16,740-28,020)
	Total	18,120 (11,430-26,210)	27,830 (21,440-35,190)	26,520 (19,520-35,170)	9,450 (6,190-13,140)	81,710 (68,490-96,460)

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

Table 6. Salmon harvest from set nets from all four openers by species and geographic stratum.

Opener	Species	Geographic Stratum[1]				Total
		A	B	C	D	
6/12/2017	Chinook	10 (0-30)	40 (0-90)	70 (0-150)	30 (0-70)	160 (60-270)
	Chum	0 (0-10)	10 (0-20)	20 (0-30)	10 (0-10)	40 (20-60)
	Sockeye	0	0	0	0	0
	Total	20 (0-30)	50 (0-100)	90 (0-180)	40 (0-80)	200 (80-320)
6/24/2017	Chinook	40 (10-70)	100 (30-180)	280 (80-520)	50 (10-90)	450 (240-720)
	Chum	160 (70-290)	410 (180-760)	1,180 (540-2,190)	210 (90-380)	1,960 (1,190-3,030)
	Sockeye	110 (30-240)	290 (70-640)	830 (210-1,820)	150 (40-320)	1,380 (610-2,440)
	Total	300 (140-540)	800 (370-1,460)	2,290 (1,080-4,160)	400 (190-720)	3,790 (2,370-5,820)
7/1/2017	Chinook	0 (0-10)	0 (0-10)	10 (0-20)	10 (0-20)	20 (10-30)
	Chum	80 (20-140)	60 (20-110)	140 (40-260)	100 (30-180)	390 (220-550)
	Sockeye	60 (30-90)	40 (20-70)	100 (50-160)	70 (40-110)	280 (210-350)
	Total	150 (90-200)	110 (70-150)	250 (160-350)	180 (120-250)	690 (550-830)
7/3/2017	Chinook	0 (0-10)	0 (0-10)	0 (0-10)	0 (0-10)	10 (10-20)
	Chum	110 (50-170)	80 (40-130)	50 (30-80)	80 (40-130)	320 (240-410)
	Sockeye	130 (60-210)	100 (50-160)	70 (30-110)	100 (50-160)	400 (290-520)
	Total	250 (130-370)	190 (100-280)	120 (70-190)	180 (100-280)	740 (560-930)
All Openers	Chinook	50 (10-120)	140 (30-290)	360 (80-700)	90 (10-190)	640 (320-1,040)
	Chum	350 (140-610)	560 (240-1020)	1390 (610-2560)	400 (160-700)	2,710 (1,670-4,050)
	Sockeye	300 (120-540)	430 (140-870)	1,000 (290-2,090)	320 (130-590)	2,060 (1110-3,210)
	Total	720 (360-1,140)	1,150 (540-1,990)	2,750 (1,310-4,880)	800 (410-1,330)	5,420 (3,560-7,900)

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

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.

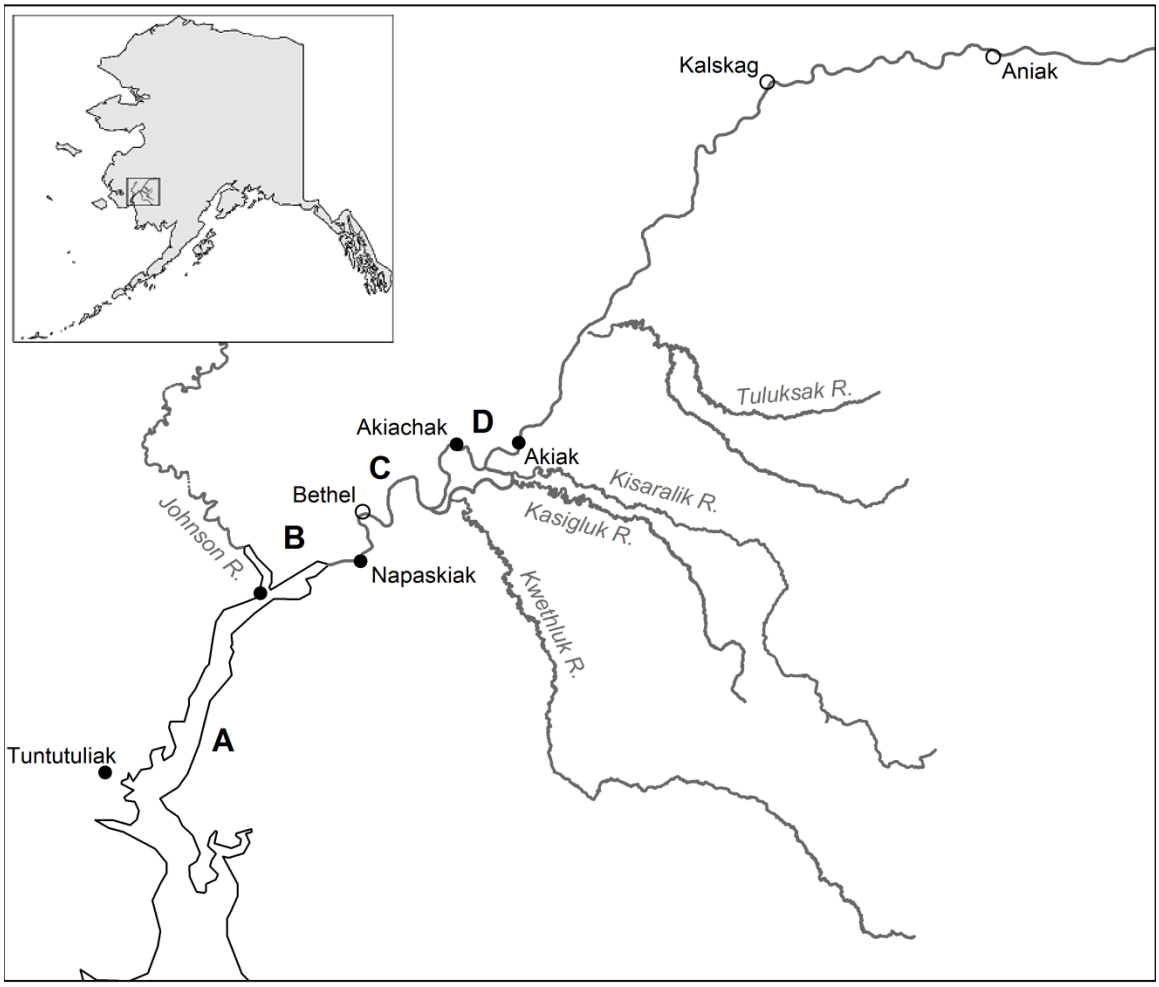
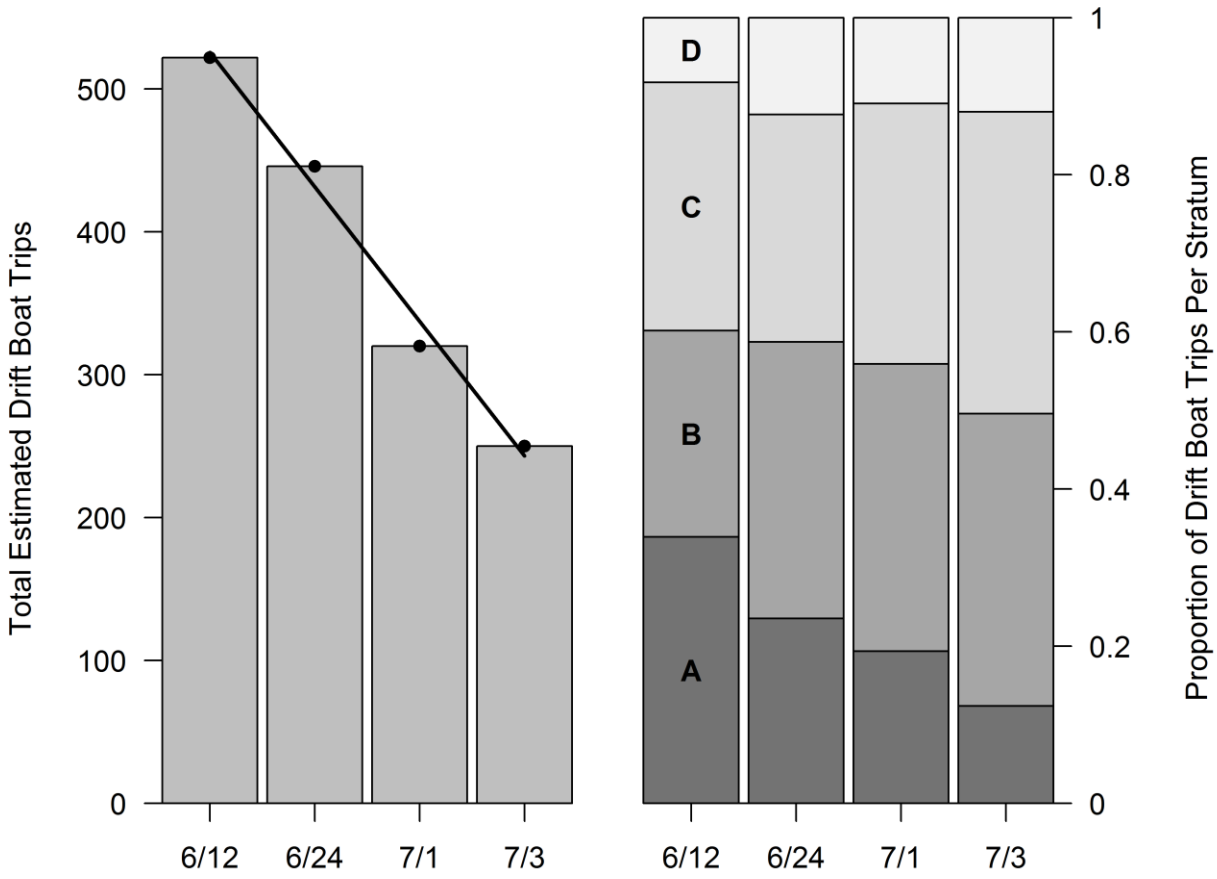
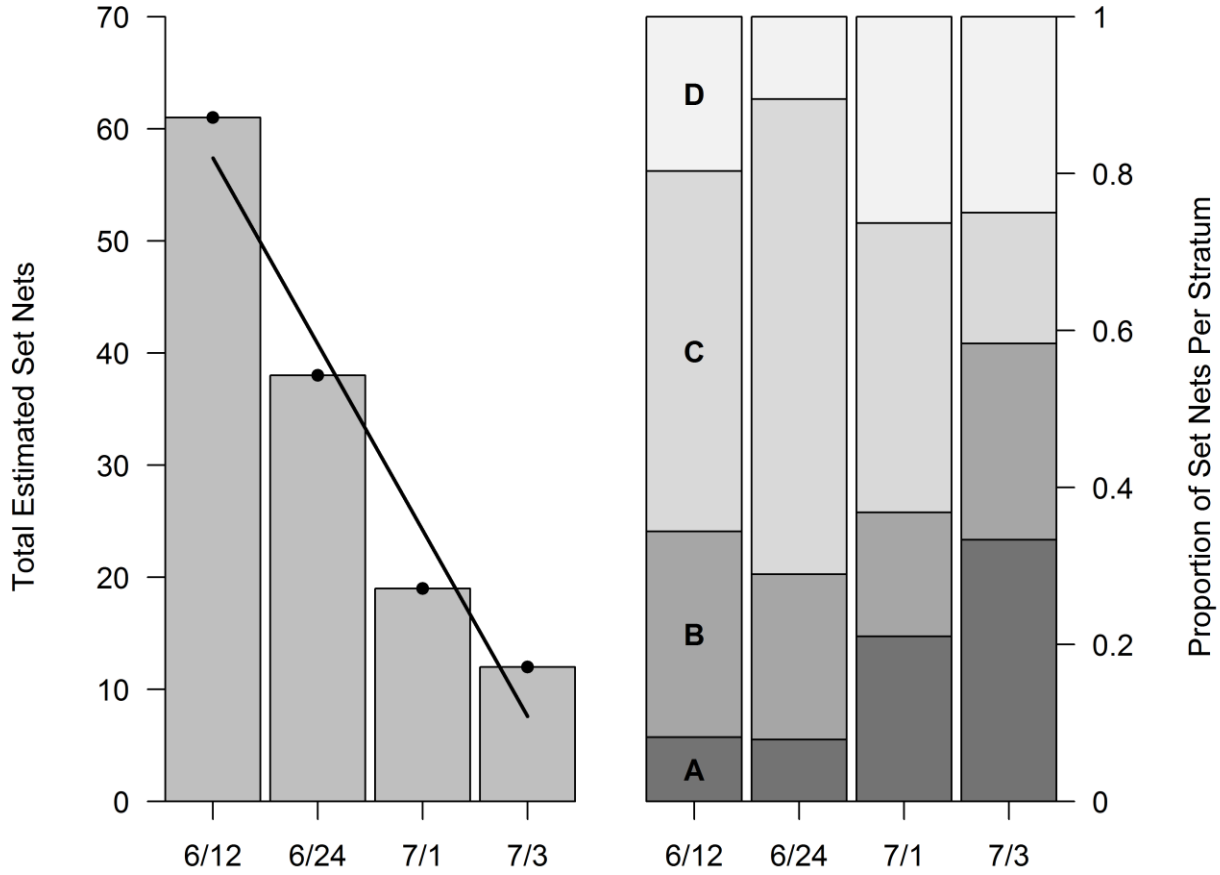


Figure 2. *Left*: Total estimated drift boat trips by opener, with a fitted linear trend showing the consistent decline in effort. *Right*: the proportion of all estimated trips that occurred in each geographic stratum[1] by opener.



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

Figure 3. *Left*: Total estimated set net trips by opener, with a fitted linear trend showing the consistent decline in effort. *Right*: the proportion of all estimated set net 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 = Akiakchak to Akiak

Figure 4. Estimated salmon harvest by species in each of the four openers. Estimates include harvest from both drift nets and set nets.

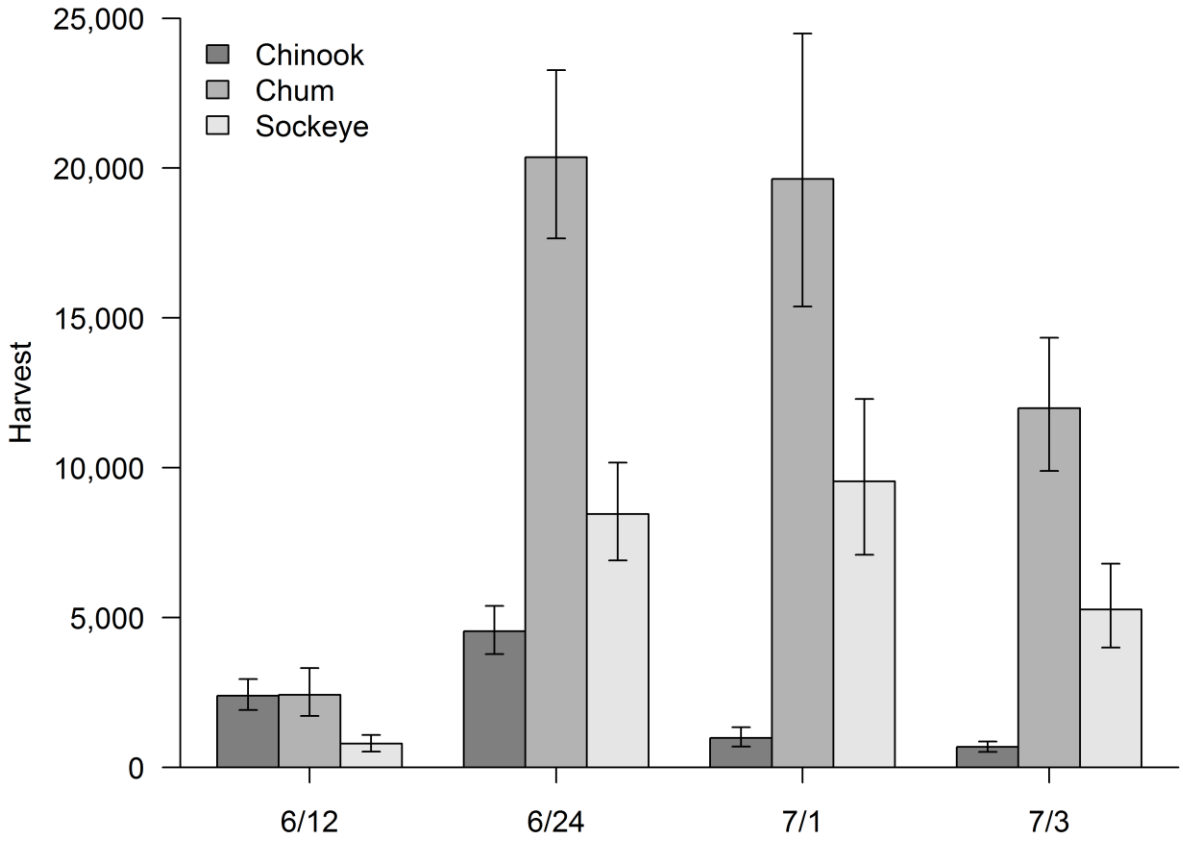
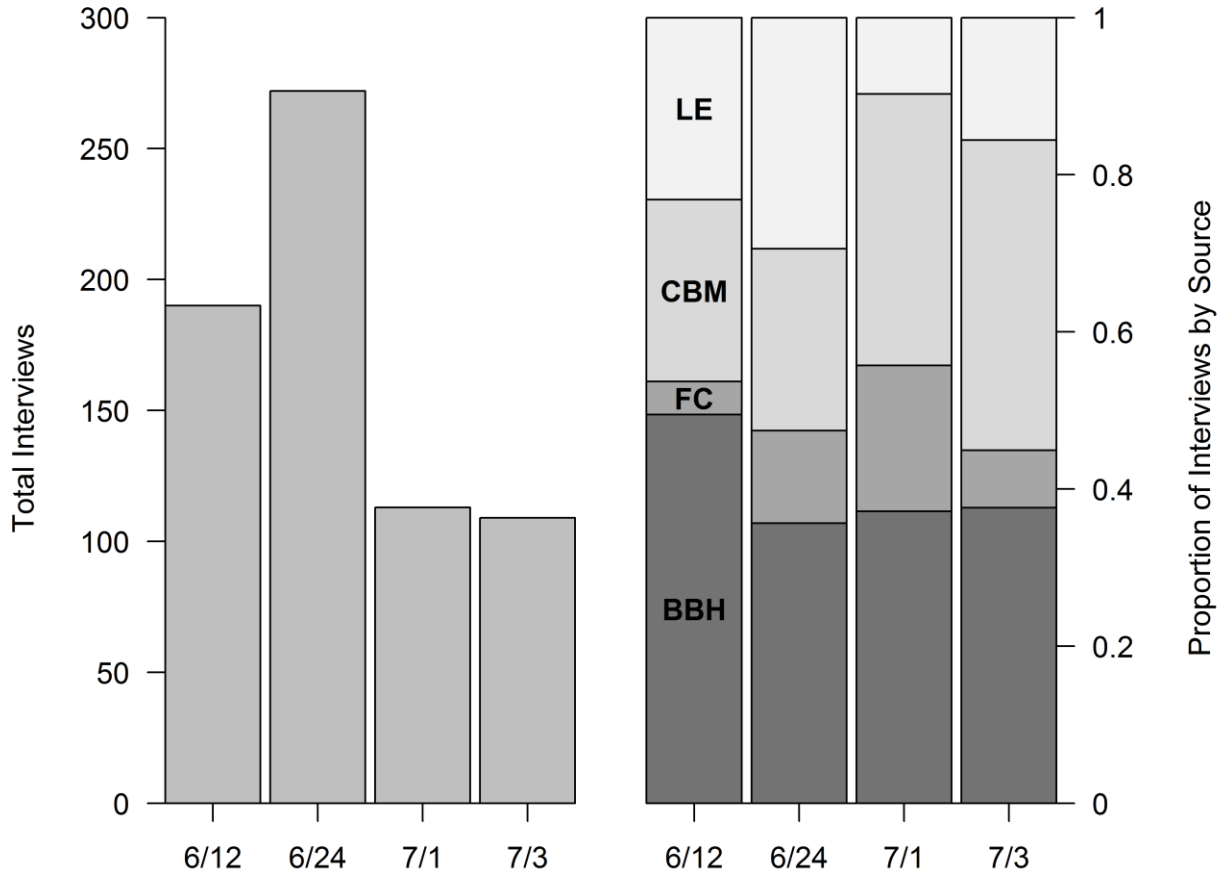
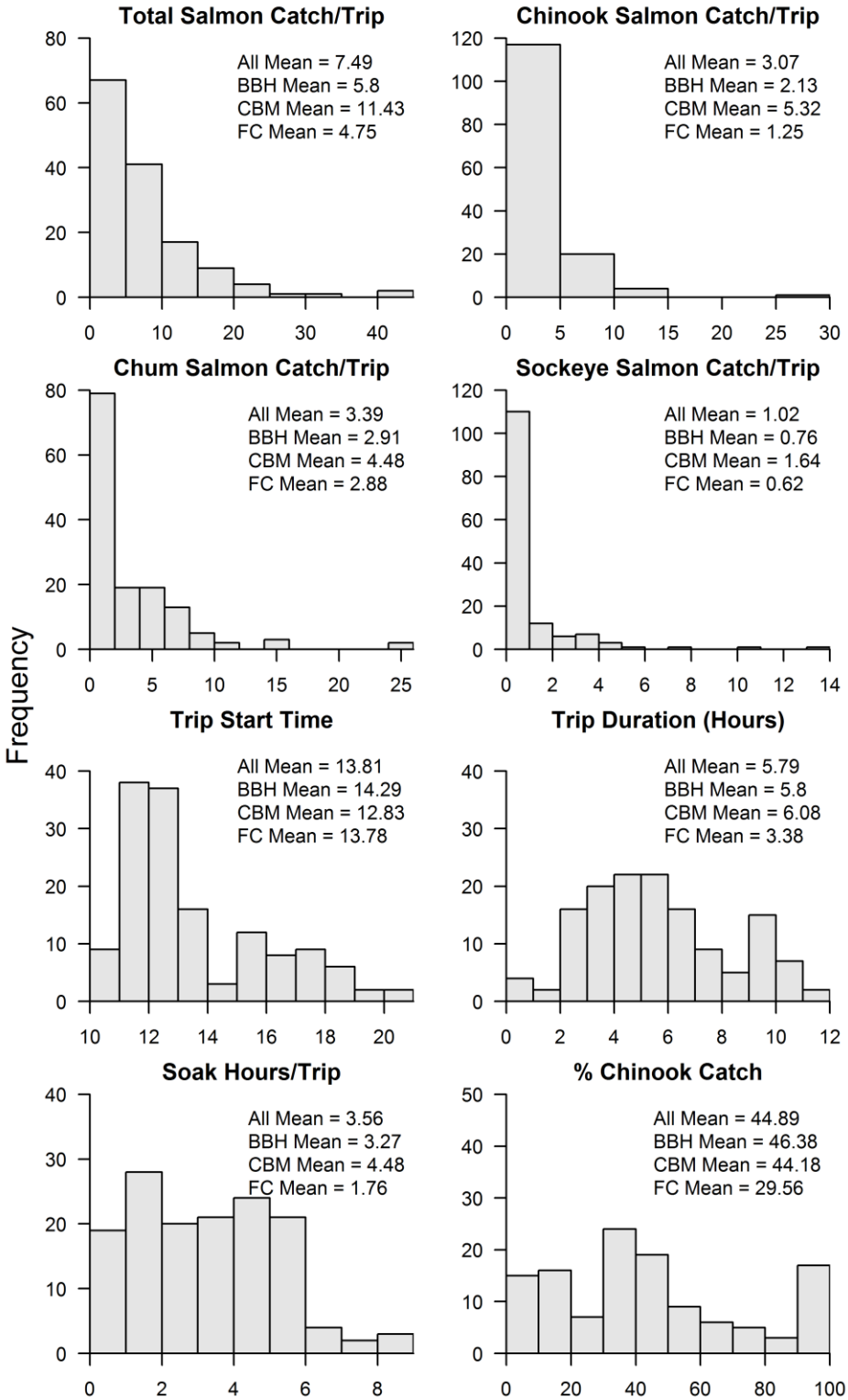


Figure 5. *Left*: total number of interviews used to inform the harvest estimates from each opener. *Right*: the proportion of all interviews that came from each source[1] by opener.



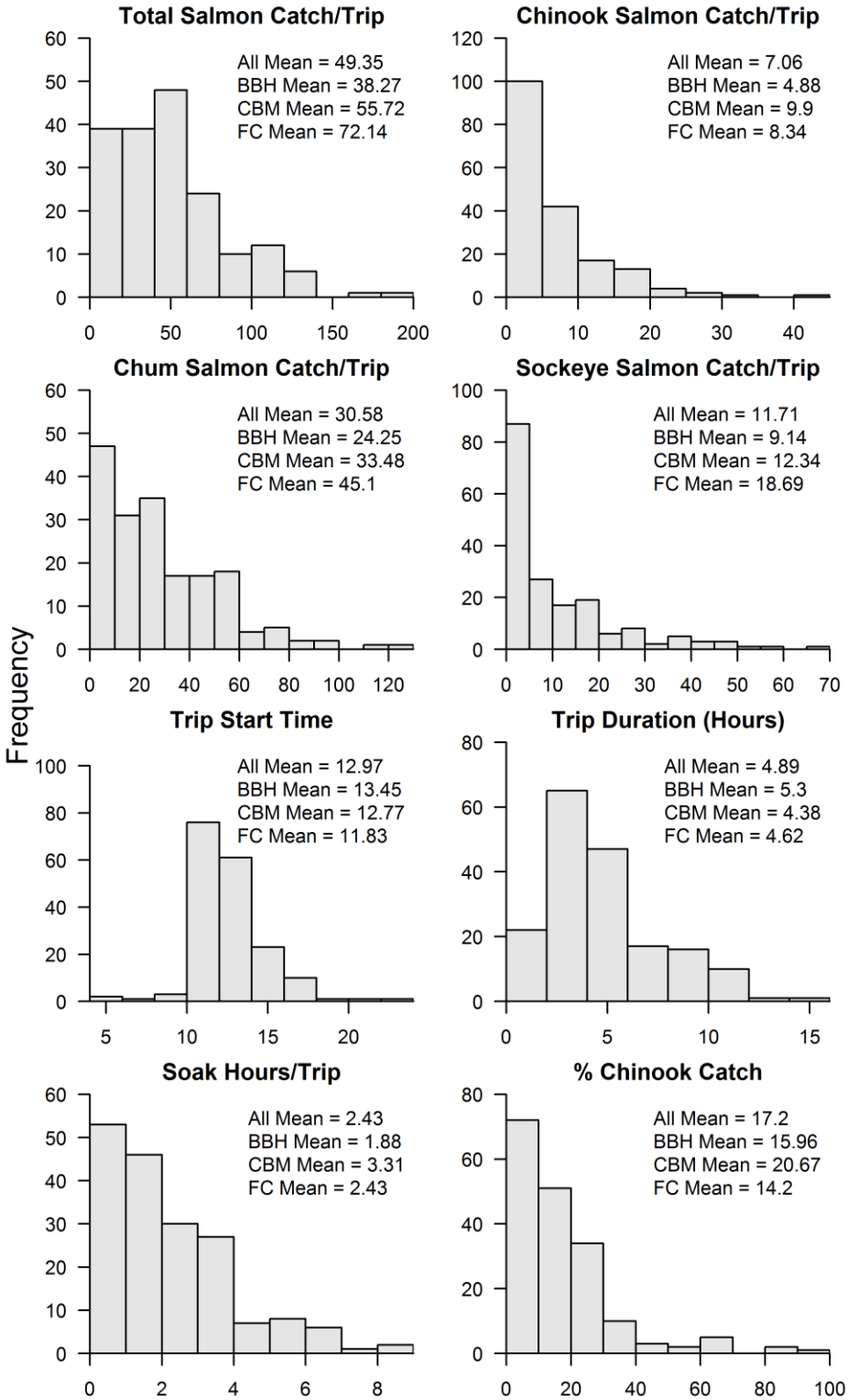
[1]Data source: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (KRITFC), and LE = law enforcement (USFWS)

Figure 6. Distribution of relevant quantities from completed drift boat trip interviews during the first opener (6/12/2017), with means for all available interviews and by data source[1].



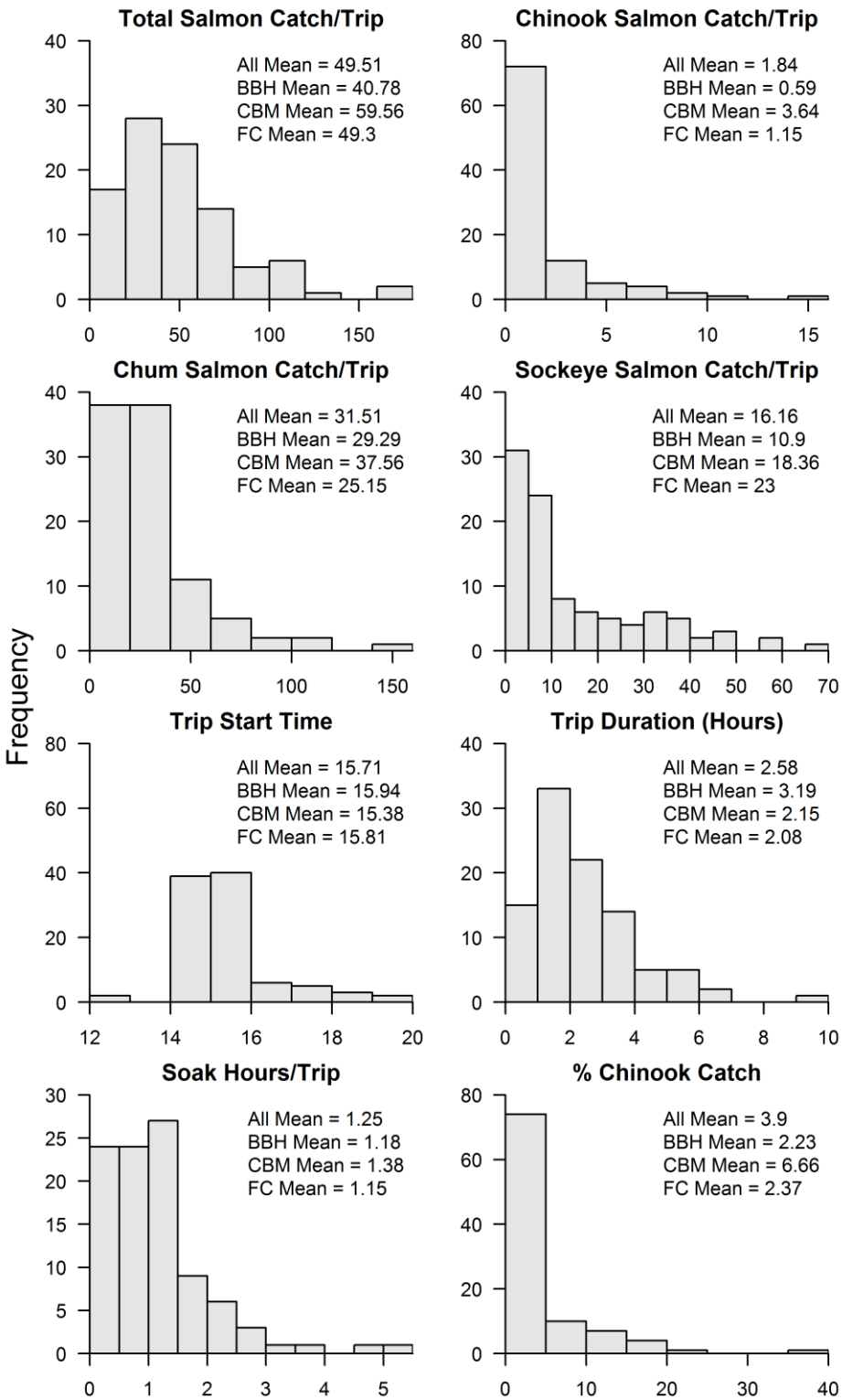
[1]Data source: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (KRITFC)

Figure 7. Distribution of relevant quantities from completed drift boat trip interviews during the second opener (6/24/2017), with means for all available interviews and by data source[1].



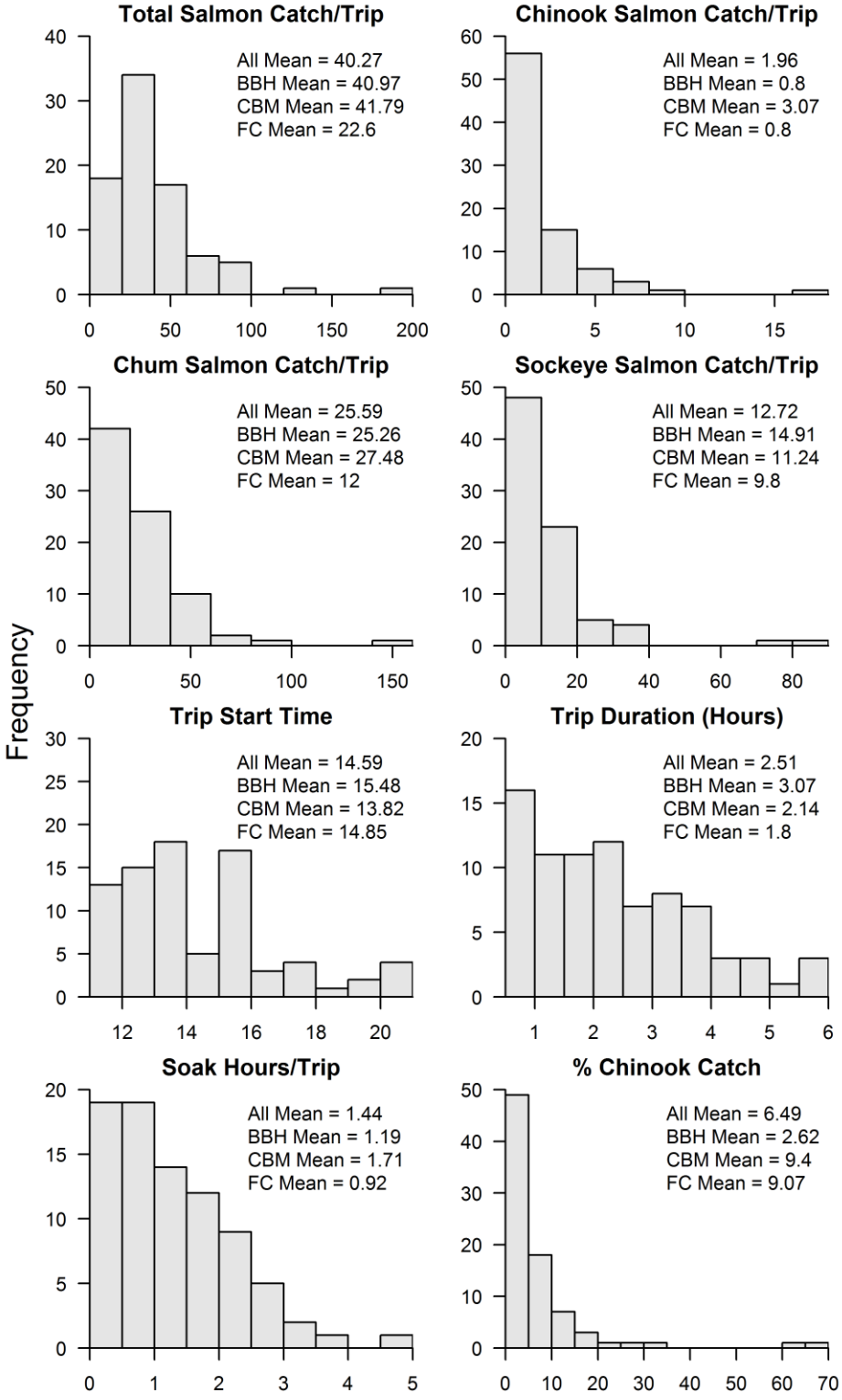
[1]Data source: BBH = Bethel boat harbor (ONC), FC = Bethel area fish camps (ONC), CBM = community-based monitoring (KRITFC)

Figure 8. Distribution of relevant quantities from completed drift boat trip interviews during the third opener (7/1/2017), 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 (KRITFC)

Figure 9. Distribution of relevant quantities from completed drift boat trip interviews during the fourth opener (7/3/2017), 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 (KRITFC)

Figure 10. Total salmon harvest by species across all four openers combined between drift nets and set nets.

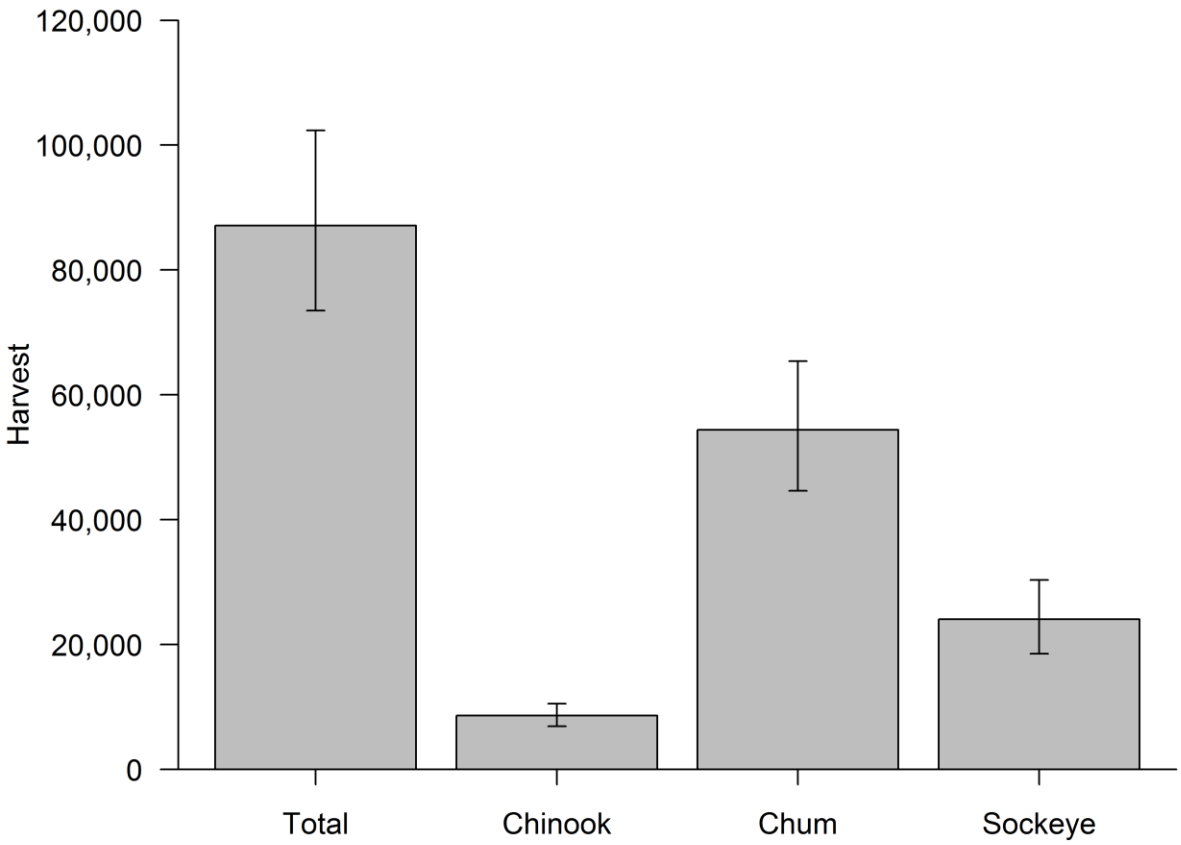
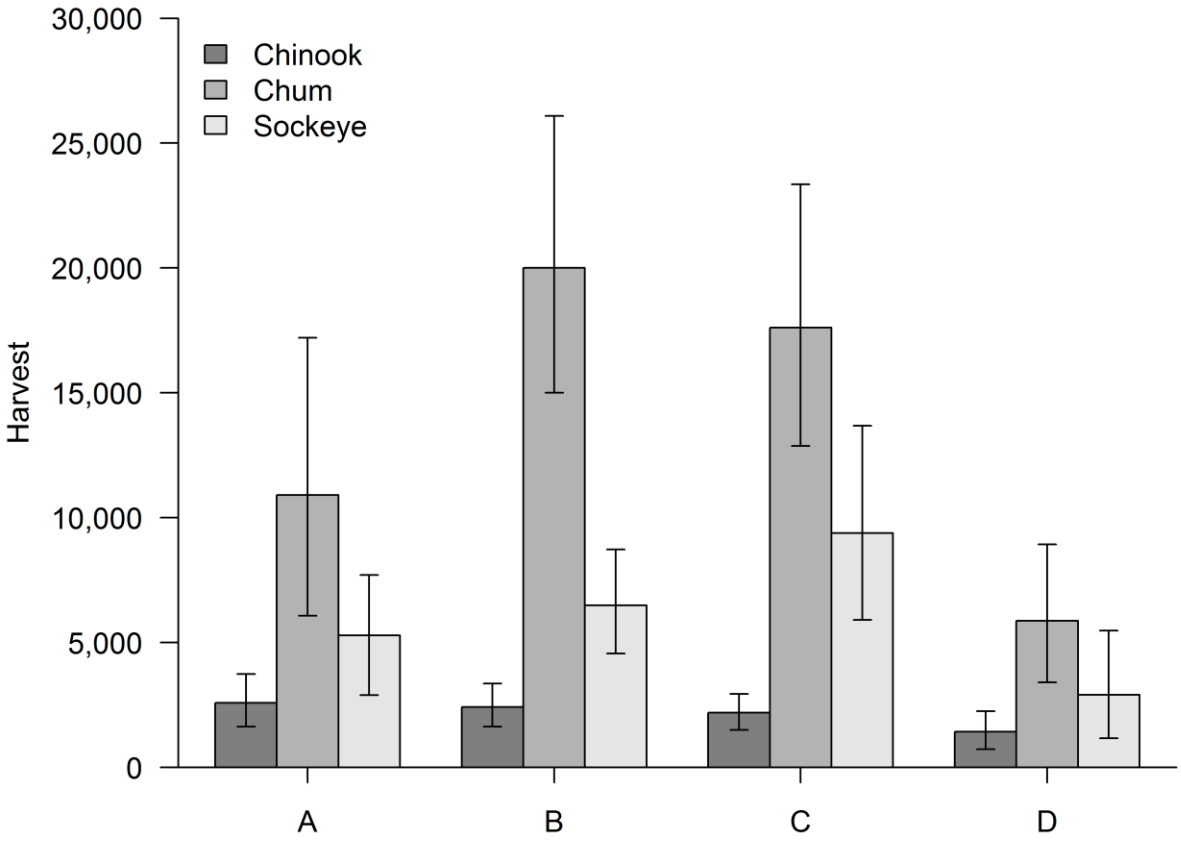


Figure 11. Total estimated salmon harvest by species and geographic stratum across all four openers combined between drift nets and set nets.



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