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Title: Estimating escapement of Western Alaskan sockeye salmon for WASSIP reporting groups, 2006 to 2008
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Introduction

The Western Alaska Salmon Stock Identification Program (WASSIP) was initiated to identify the stock contributions of western Alaska sockeye and chum salmon to fisheries in and around western Alaska from Chignik northward to Kotzebue Sound. The WASSIP MOU specifically recognizes the desires of signatories to extend stock contribution estimates, *where possible*, to stock-specific harvest rates in the study areas**.** For WASSIP, regional and sub-regional reporting groups approved by the Advisory Panel (Technical Document (TD) 14) will serve as “stocks” for estimating stock-specific parameters for sockeye salmon. As such, the reporting groups (i.e. stocks) in WASSIP may consist of groups of populations that spawn within single drainages or across multiple drainages. To accomplish this, estimates of reporting group escapements and harvests, with associated uncertainty, must be generated. This document deals exclusively with the escapement (E) component of the denominator of the harvest rate estimation equation described below. The purpose of this document is to outline how escapements and associated uncertainties are estimated for sockeye salmon in each of the WASSIP sockeye salmon reporting groups. The 2006 to 2008 escapement data and coefficient of variation (CV) are presented for each WASSIP sockeye salmon regional and sub-regional reporting group that will be used in the harvest rate estimation. The information summarized in this document combined with a future technical document on sockeye salmon harvest estimates will be used to estimate reporting group-specific harvest rates where possible.

Regional Fishery Model

We propose a statistical approach for estimating reporting group-specific harvest rates within the WASSIP fisheries. These harvest rates do not account for fish harvested in fisheries outside the WASSIP area, including terminal and inriver fisheries. Reporting group-specific harvest rates are calculated for each regional fishery which consists of multiple interacting fisheries collectively exploiting multiple reporting groups. Each reporting group may occur to some extent in each of the component fisheries of the region. This approach will be applied to reporting group-specific harvest estimated from WASSIP studies and to estimates of reporting group-specific terminal harvest and escapements.

In a regional fishery there are a number of component fisheries (f) and a number of reporting groups (y), with each reporting group occurring to some extent in all component fisheries. A sub-regional reporting group may consist of several assessed drainage- or area-wide groups of populations, in which case the

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assessed population(s) or escapements and terminal harvests for the reporting group must be aggregated. Sub-regional reporting groups are aggregated into regional reporting groups. From here forward, the term “reporting groups” without the “sub-regional” or “regional” prefix will refer generically to both regional and sub-regional reporting groups.

The key elements necessary are annual estimates (and associated CV) of each run component of the y^{th} reporting group (N_y):

$$N_y = T_y + E_y + \sum_f C_{f,y}$$

where T_y is the terminal harvest of the y^{th} reporting group, E_y is the escapement of the y^{th} reporting group, and $C_{f,y}$ is the harvest in WASSIP fisheries of the y^{th} reporting group in the f^{th} fishery. Terminal harvest occurs for reporting groups exploited in non-sampled fisheries within the WASSIP area where it is assumed that 100% of the fish harvested belong to a single regional or sub-regional stock (e.g. inriver subsistence, recreational fishing, or commercial fisheries).

A measurement error model was used to express the uncertainty in each component (O) of the reporting group’s run (N_y). Each run component (O) is modeled as a lognormal random variable,

$$O \sim \text{lognormal}\ (\mu_o, \lambda^2{}_o), \text{ and}$$

$$\mu_o = \ln(\hat{O}) - \lambda_o^2/2$$

$$\lambda_o^2 = \ln(CV^2(\hat{O}) + 1)$$

where $\hat{O}$ is the estimated value of the quantity O, and $CV(\hat{O})$ is the coefficient of variation of the estimate. These relationships were derived from Evans et al. (1993).

Estimates of the distribution of harvest rate ($HR_{f,y}^*$) in a given regional fishery, for each reporting group (y) and component fishery (f) can be obtained by Monte Carlo simulation. Here, a number of independent realizations of the state of the regional fishery is determined by reporting group-specific catches ($C_{f,y}^*$), terminal harvests (T_y^*) and reporting group-specific escapement ($E_{f,y}^*$). Each realization of the regional fishery is drawn randomly from the lognormal probability distribution associated with the measurement error for each of the individual run components:

$$N_y^* = T_y^* + E_y^* + \sum_f C_{f,y}^*$$

$$HR_{f,y}^* = {C_{f,y}^*}\Big/{N_y^*}$$

Estimates of escapement CVs are not routinely reported in ADF&G escapement and management reports. CVs for escapement estimated by counts (e.g., weir, tower and sonar) are generally quite low and can easily be calculated by applying estimators based on systematic sampling (Reynolds et al. 2007) to the counts. CVs of escapements from mark-recapture (MR) experiments are available for most scenarios. CVs for escapements based on expanded aerial counts are unknown and problematic. However, reasonable approximations will be presented based on summary of historical studies where paired peak aerial counts and more exact estimates of escapement (i.e., weir counts, tower counts, and MR experiments) are compared.

When the escapement of a reporting group is an aggregate of assessed populations or groups of populations, the aggregate escapement (O_A) can be estimated as:

$$\hat{O}_A = \sum_i \hat{O}_i,$$

where, $\hat{O}_i$ is the assessed escapement for each component in terms of total number of fish (see below for details about expanding escapement indices). Note that each assessed escapement component is a lognormal random variable, with coefficient of variation ($CV(\hat{O}_i)$) and mean ($\hat{O}_i$). The uncertainty in the estimate of the aggregate escapement component ($CV(\hat{O}_A)$) is estimated by summing the variances of the individual components (assuming independence among the components):

$$Var(\hat{O}_A) = \sum_i Var(\hat{O}_i).$$

Therefore, to express this in terms of CV, we use the formula:

$$CV(\hat{O}_A) = \sqrt{\sum_i (CV^2(\hat{O}_i) * \hat{O}_i^2) \Big/ \sum_i \hat{O}_i^2}.$$

Escapement Based on Weir and Tower Counts

Sockeye salmon escapements are enumerated from weirs and towers for many of the WASSIP area reporting groups. Weirs are deployed in Kuskokwim Bay rivers, several tributaries on the Kuskokwim River, several rivers in the North and South Alaska Peninsula, and on the Chignik River. Generally, all salmon are counted that pass through the weir. Towers are used to count sockeye salmon on 8 river systems in Bristol Bay. For tower projects, counts are made for 10 minutes of every hour on each bank of the river and then expanded.

Uncertainty and bias in count-based escapement estimates can be introduced by a number of factors related to counting and sampling methods. Due to the protracted nature of salmon runs, underestimate of escapement (i.e. downward bias) is introduced because counting projects generally cannot be deployed for the entire portion of the run. However, this bias is small because counts at the end date of the project are at most a small percentage of the counts during the peak of the run. For some systems, escapements after the assessment project is terminated for the season are estimated (e.g. Chignik River late-run). Additional downward bias may be introduced when weirs are inoperable during the main part of the migration due to flooding, debris or mechanical issues. These periods when fish cannot be counted are generally minor, but can be substantial (e.g., 51% of escapement past the Kanektok weir in 2008 was estimated; Taylor and Clark 2010b). Counts during these inoperable periods may be estimated through interpolation or from other years when run timing and abundance are similar (e.g., Taylor and Clark, 2010b). Uncertainty in the estimates is also introduced by simple errors in counting. Furthermore, with tower projects uncertainty (sampling error) is introduced because of the incomplete counting associated with the systematic 10-minute counting period.

For tower counts, sampling error (i.e. counting 10 minutes out of each hour) can be estimated using the V5 estimator for variance in systematic sampling proposed by Wolter (1984, 1985) and recommended by Reynolds et al. (2007) because it was found to be the least biased variance estimator. The average CV observed in 2004 and 2005, among 9 Bristol Bay tower projects was 0.02 (T. Baker, ADF&G, pers. comm.). This CV estimate assumes no errors in the counts over the 10 minutes sampled. The accuracy of the no counting error assumption can be examined with data from historical experiments designed to test the efficiency tower counts based on the systematic 10-minute counts sampling. These experiments were conducted in 1965 and 1966 on several tower counting projects (Seibel 1967). In these experiments, counts were conducted for a full hour, counts during the first 10-minute of the hour were expanded and compared to the total hourly count. The errors here reflect both the sampling error and the counting errors. This study indicated that the relative error in the 10-minute counting over the season were unbiased and low; with relative errors generally less than 10 percent and bias not significantly different from zero. Note that in Seibel (1967), a limited number of hours were fully counted. In the suite of tower project experiments only 12 to 80 hours were included in the experiments. Tower projects generally run a month or longer. Estimated escapements and associated variance (assuming errors in absolute numbers) can be made given the set of paired hourly counts and expanded 10-minute counts, but these reflect the total escapements over the period of full hourly counts. Hence estimates of total escapement and associated variance cannot be estimated from the full count data. A quasi-estimate of the variance and CV of the total escapement can be made by expanding the set of full hourly counts to a month period (set of 1440 counts) by boot strapping the set of observed full hourly counts. The total escapement and associated CV were estimated from the expanded data set (1440 observations) and were computed assuming errors in absolute numbers. The CVs of the escapement estimates based on expanded 10-minute counts were very low, averaging less than 0.02 over the entire suite of experiments. These were consistent with the CVs for tower counts estimated from systematic sampling.

In the following, a CV of 0.02 was used as an estimate of uncertainty for weir and tower counts when estimating escapement within the sub-regional and regional reporting groups.

Escapement Based on Sonar Counts

Nushagak River is the only system within the WASSIP area that uses sonar to assess escapement of sockeye salmon. The variance of the escapement estimates are routinely provided in project reports (e.g., Brazil and Buck 2011). The estimated CV for the Nushagak River sockeye salmon escapement was 0.031 in 2006 (Brazil and Buck 2011), 0.026 in 2007, and 0.033 in 2008 (T. Baker, ADF&G, unpub. data). Bias in the escapement estimate based on sonar counts can be introduced if fish migrate beyond the range of detection of the sonar units (or behind the units). However, measures are taken to minimize these biases, such as using newer sonar technology (i.e. DIDSON), as is the case with the Nushagak River sonar project.

Escapement Based on Expanded Aerial Counts

Sockeye salmon escapements are enumerated from aerial counts for some of the reporting groups within the WASSIP area. This is particularly true for reporting groups in areas with multiple small spawning streams and rivers that drain directly into the ocean (e.g., Alaska Peninsula). Here, assessments of escapement are based on aerial surveys of a number of streams that encompass most of the spawning habitat within the area. The index of escapement is the peak count, which is the largest count observed among surveys conducted during the season. For populations that spawn in coastal areas and use a large number of streams it is not feasible to implement enumeration programs that provide absolute abundance estimates. It is recognized that peak counts are escapement indices and are biased low relative to the actual escapement.

In a typical salmon population, entry to the natal stream occurs over a protracted period on the order of weeks. During the period of entry, salmon are continuously spawning and dying and consequently lost to aerial observers. Because the residence time (i.e., the stream life) of salmon in the stream is short relative to the period of entry (c.f., Dangel and Jones 1988, Fried et al. 1998) the number of fish present in the stream at any given time is below the total escapement. Even with perfect (i.e., without error) aerial observation, the observed peak count is a highly conservative estimate of escapement. The peak live abundance, derived from the temporal pattern of entry (i.e., from daily weir counts) and stream-life, are at most one half of the escapement (c.f., Dangel and Jones 1988). Other factors such as observer bias and poor visibility further affect the bias in peak aerial counts as an escapement estimate.

The department has conducted many studies that pair aerial count data from multiple aerial surveys during the course of a spawning period with escapement enumeration based on weir counts, mark-recapture, and tower counts. Many of these studies are coupled with direct measurement of steam life, and data can be used to derive the pattern of live fish in the stream. Rather than model the pattern of live fish in the stream and compare to the aerial count data to evaluate the bias (e.g., Hilborn et al. 1999, Bue et al. 1998, Quinn and Gates 1997, Adkison and Su 2001, Su et al. 2001) an empirical approach will be used to estimate a relevant expansion factor and CV for sockeye salmon that scale peak aerial counts to total escapement and provide an estimate of uncertainty associated with the escapement estimate. The empirical approach of comparing peak aerial counts to actual estimates of escapement integrates both the variation in stream life and errors in the aerial counts (e.g. observer bias, visibility of the fish, etc.). Therefore, the CV of expanded escapement is equivalent to the CV of the estimated expansion factor:

$$CV(\hat{O}_i) = CV(\hat{x}I_i) = CV(\hat{x}).$$

Where, $\hat{O}_i$ is the expanded escapement estimate and I_i is the index count, which in this case is assumed to be known without error (i.e. a constant) because any observation error is integrated into the expansion factor ($\hat{x}$).

Paired aerial counts and absolute estimates of escapement for sockeye salmon from the WASSIP area are summarized in Table 1. The data include observations of sockeye salmon above the Chignik River weir (Anderson 2011), Alagnak River tower (Clark 2005), Middle Fork of the Goodnews River weir (Taylor and Clark 2010a), Glacial Lake weir, and Pilgrim River weir (Menard et al. 2011). Aerial surveys were conducted at or around peak spawning and consisted of 1 to 3 surveys. If multiple surveys were flown then the survey with the highest count was considered the peak survey.

Data for Chignik aerial surveys and weir counts are available from 1960 to present, but for this document were limited to the 9 years in which surveys were completed for all 12 sites that are typically surveyed in the Chignik River system (1995-2000 and 2006-2008). Similarly, data used from the Alagnak River were limited to years in which all of the 4 major spawning aggregations within the system were assessed (Clark 2005). For the Pilgrim River, data were limited to weir and aerial survey comparisons even though a tower was used to assess escapement prior to switching to a weir. However, only 3 years of paired tower/aerial survey data were available and there were issues with species identification early on in the tower project (Menard 2011). Aerial survey and weir data for the Kanektok River were also available (Taylor and Elison 2010), but were not included in calculation of the mean expansion factor and CV because of the limited years with acceptable aerial surveys and higher mean expansion factor (6.40) than the other systems (1.94 to 2.99), which suggests that this system is particularly difficult to assess.

An expansion factor of 2.47 with a CV of 0.54 (Table 1) will be used to expand sockeye salmon aerial survey indices for the purposes of estimating escapement within the sub-regional and regional reporting groups. The CV estimate reflects the between-observation variation in the peak count expansion.

Escapement of Sockeye Salmon in Sub-regional and Regional Reporting Groups in the WASSIP Area

Chignik Regional Reporting Group

There are 2 sockeye salmon sub-regional reporting groups within the Chignik regional reporting group – Black Lake and Chignik Lake – that correspond to the early and late runs of sockeye salmon in the system. Escapement of sockeye salmon in the Chignik regional reporting group was estimated based on information available in the annual area management reports (Jackson and Anderson 2009, Stichert 2007, Stichert et al. 2009). Sockeye salmon escapements for the Black Lake (early-run) and Chignik Lake (late-run) sub-regional reporting groups are assessed with the Chignik River weir using underwater video equipment. Fish passing the weir are identified to species and counted during the first 10 minutes of each hour. The counts are expanded to estimate hourly escapements, which are then summed to estimate daily escapement. July 4 is used as the demarcation date for the early and late runs based on historical scale pattern analysis. This is the date after which the number of early-run sockeye salmon is, on average, about equal to the number of late-run sockeye salmon that have already passed the weir (Jackson and Anderson 2009, Stichert 2007, Stichert et al. 2009). There is an unknown error associated with the assessment of early and late run escapements. This error is thought to be small relative to the magnitude of the Chignik escapements. The late-run escapement includes the number of sockeye salmon counted passing the weir plus an estimated escapement that occurs after the weir is removed based on time series analysis. The CVs of the escapement estimates are assumed to be 0.02 (Table 2).

South Peninsula Regional Reporting Group

The South Peninsula reporting group is not subdivided into multiple sub-regional reporting groups. The area from Kupreanof Point to Scotch Cap comprises the South Peninsula sockeye salmon sub-regional and regional reporting group (Technical Document (TD) 14). Total escapement of sockeye salmon in the South Peninsula reporting group was estimated based on information available in the annual area management reports (Poetter 2009, Poetter et al. 2007, 2008). There are several moderate sized sockeye salmon runs in the South Peninsula regional reporting group including Middle Lagoon, Mortensens Lagoon, Thin Point Lake and Orzinski Lake. In addition, there are several small populations that are surveyed by air annually. These small populations, plus Middle Lagoon and Mortensens Lagoon (2007 and 2008) are included in the South Peninsula aerial survey index (Table 3). In general, streams in the South Alaska Peninsula are not obscured by brush or trees and visibility of the spawning grounds are outstanding during normal water flow and clear weather (Poetter 2009, Poetter et al. 2007, 2008). Sockeye salmon escapement in Orzinski Lake and Mortensens Lagoon (2006 only) were assessed with weirs. Aggregate escapement for the South Peninsula reporting group was estimated by adding the weir count(s) and the expanded aerial survey index. An expansion factor of 2.47 was used for the aerial survey index (Table 3). CVs for the aggregate escapements were calculated based on methods described above and assuming CVs for weir counts and expanded aerial counts were 0.02 and 0.54, respectively (Table 3).

North Peninsula Regional Reporting Group

The North Peninsula regional reporting group is comprised of 7 sockeye salmon sub-regional reporting groups for WASSIP and includes: Northwestern District/Black Hills, Nelson, Bear, Sandy, Ilnik, Meshik, and Cinder (TD 14). Total escapement of sockeye salmon in the North Peninsula reporting group was estimated based on information available in the annual area management reports (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007). The Northwestern District/Black Hills sub-regional reporting group includes McLees Lake (located on Unalaska Island), several small systems in the Aleutian Islands, Urilia Bay (including Christianson and Peterson lagoons), Swanson Lagoon, Bechevin Bay, Izembik–Moffet Bay and Caribou Flats–Black Hills (including North Creek). Escapements are a 2.47 expansion of the peak aerial survey indices with an assumed escapement CV of 0.54 (Table 4). McLees Lake is an exception in that sockeye salmon escapement is assessed by weir; therefore, there is no expansion of the escapement estimates and the escapement CV is assumed to be 0.02. The aggregate escapement for the Northwestern District/Black Hills sub-regional reporting group is a sum of the expanded escapements and the McLees Lake weir escapement with an aggregate escapement CV calculated using the methods above. The Nelson sub-regional reporting group includes Nelson River weir counts and aerial survey indices in the Nelson Lagoon, Herendeen Bay and Moller Bay areas (Table 5). Total escapement for the Nelson sub-regional reporting group is the sum of the weir counts, a post-weir escapement estimate (see below), and a 2.47 expansion of the aerial survey counts. Escapement CV is a composite of the weir count CV, post-weir estimate CV and expanded aerial count CV (Table 5). The Bear sub-regional reporting group includes the Bear River weir counts, plus post-weir escapement estimate and the Sandy sub-regional reporting group includes the Sandy River weir counts and post-weir escapement estimate (Table 5). CV for both sub-regional reporting groups is a combination of the weir count CV and the post-weir escapement CV. Total escapement for the Ilnik sub-regional reporting group is the sum of the Ilnik River weir counts, a post-weir escapement estimate and the 2.47 expanded aerial survey index of Ocean River and several streams in the Three Hills area (Table 6). The escapement CV is a composite of weir count CV, post-weir escapement CV and aerial index CV. The Meshik and Cinder sub-regional reporting groups are both assessed using aerial surveys; therefore the total escapement estimates are the 2.47 expansion of the respective aerial survey indices for these systems with an estimated CV of 0.54 (Table 6).

Escapements after the weirs were removed on the Nelson, Bear, Sandy, and Ilnik rivers were estimated and reported in the area management reports. These post-weir estimates are based on aerial surveys, commercial fisheries performance, run timing indicators, effort levels and weather conditions (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007). Because aerial surveys likely had the largest influence on post-weir escapement estimates, it was assumed the CV associated with these estimates were similar to that of aerial surveys (0.54). These post-weir escapement estimates, however, were also assumed to be in terms of total number of fish and not an index since they were typically a small proportion of the escapement.

Bristol Bay Regional Reporting Group

The Bristol Bay regional reporting group is comprised of 9 sockeye salmon sub-regional reporting groups for WASSIP (TD 14). Escapement of sockeye salmon in the Bristol Bay regional reporting group was based on information available in the annual area management report (Jones et al. 2009). The escapements are by sub-regional reporting group and include Ugashik, Egegik, Naknek, Alagnak, Kvichak, Igushik, Wood, Nushagak River, and Togiak (Table 7). Escapements are based on tower counts for each sub-regional reporting group except Nushagak, which are based on sonar counts. The CV for tower counts is assumed to be 0.02 and Nushagak sonar counts of sockeye salmon are assumed to be 0.031 for 2006, 0.026 for 2007, and 0.033 for 2008.

Kuskokwim Bay Regional Reporting Group

The Kuskokwim Bay regional reporting group is comprised of 3 sockeye salmon sub-regional reporting groups for WASSIP, including Goodnews, Kanektok, and Kuskokwim River (TD 14). Escapements of sockeye salmon in the Kuskokwim Bay regional reporting group were estimated based on information available in monitoring and assessment reports for the Goodnews River (Taylor and Clark 2010a), Kanektok River (Clark and Linderman 2009, Taylor and Clark 2010b, Taylor and Elison 2010), Kuskokwim River (Schaberg et al. 2010) and Kogrukluk River (Bavilla et al. 2010).

Escapements of sockeye salmon for the Goodnews sub-regional reporting group include the weir counts on the Middle Fork of the Goodnews River and estimated escapement for the North Fork of the Goodnews River (Table 8). North Fork escapement estimates were based on the Middle Fork escapement (weir counts) multiplied by the average of the relative magnitude of paired aerial survey counts ($x = 1.07$, $CV = 0.70$, $n = 12$, range = 0.30-2.37) in the Middle and North forks from 1983 to 2008 (Taylor and Clark 2010a).

Escapement for the Kanektok sub-regional reporting group is based on the Kanektok River weir counts (Clark and Linderman 2009, Taylor and Clark 2010b; Table 8). The weir was not operational in 2006, but a peak aerial survey count was available (Taylor and Elison 2010) and several paired observations of aerial counts and weir counts for the Kanektok River are available. The average ratio of weir counts to aerial counts (i.e. expansion factor) was estimated to be 6.40 ($CV = 0.77$, $n = 4$, range = 2.19-13.12), which is much higher and more variable than the estimated expansion factor for sockeye salmon aerial surveys for the Goodnews River. Expansion of the 2006 Kanektok River aerial survey index by the general expansion factor used in other systems or the Kanektok River-specific expansion factor would result in an unrealistically high escapement estimate for 2006. Therefore, escapement in 2006 was taken to be the unexpanded aerial count with an assumed CV of 0.54 (i.e. the CV associated with aerial survey expansions for sockeye salmon). The 2006 Kanektok River escapement should be considered a minimum estimate.

A basin-wide sockeye escapement estimate was only available for the Kuskokwim River sub-regional reporting group for 2006, which was based on a mark-recapture experiment at Kalskag (Schaberg et al. 2010; Table 8). Long term estimates of sockeye salmon escapement from the Kogrukluk River weir (a tributary of the Kuskokwim River) are available and were paired with mark-recapture estimates of escapement at Kalskag plus down river escapement from 2002 to 2006 in Schaberg et al. (2010) to estimate an expansion factor for Kogrukluk River weir counts for an estimate of total sockeye salmon escapement in the Kuskokwim River. Therefore, estimates of total of sockeye salmon escapement in the Kuskokwim River sub-regional reporting group for 2007 and 2008 were based on expansion of the Kogrukluk River weir counts using an expansion factor of 30.72 with an estimated CV of 0.56 (Table 8). It should be noted that the CV of the expanded escapement estimate is the same as the CV of the expansion factor, using the same error propagation rules that were used for the expanded aerial survey data.

North of Kuskokwim Bay Regional Reporting Group

The North of Kuskokwim Bay regional reporting group for sockeye is represented by the Norton Sound sub-regional reporting group. The Norton Sound sub-regional reporting group extends from Point Romanzof to Cape of Prince of Wales (TD14). Aggregate escapement of sockeye salmon in the Norton Sound sub-regional reporting group for 2006 to 2008 was estimated based on information available in the annual area management reports (Menard et al. 2010, Soong et al. 2008a, b). River systems within this area that are assessed for sockeye salmon escapements include Glacial Lake (Sinuk River), Pilgrim River (Salmon Lake), and Nome, Snake, and Eldorado rivers. Sockeye salmon escapements in all of these systems are assessed using weirs (Table 9). Additionally, escapements in Salmon Lake/Grand Central River and Glacial Lake are assessed using aerial surveys, but because escapements of both systems are also assessed by weirs only the weir counts will be used for estimating the escapement of sockeye salmon in these systems.

Escapement and CV of regional reporting groups

Total escapement and CV for each reporting group was calculated using the same methods used for the sub-regional reporting groups. The estimated sockeye salmon escapement and CV for each regional reporting group in WASSIP for the years 2006 to 2006 are summarized in Table 10.

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Questions for Technical Committee

1) Is the proposed Regional Fishery Model appropriate for the harvest rate calculation?

2) Are the methods used to estimate the aerial survey expansion factor for sockeye salmon and the associated uncertainty (CV) appropriate and reasonable?

3) Are the estimates of uncertainty for the other assessment methods (weir, tower, and sonar) similarly reasonable?

4) Have we appropriately addressed uncertainties associated with estimates to account for incomplete weir counts?

5) Are the approach and methods used to estimate aggregate escapement and CV for the sub-regional and regional reporting groups appropriate?

6) Have we adequately addressed the biases associated with the various assessment methods used to estimate sockeye salmon escapement?

Technical Committee review and comments

Milo Adkison (Unedited email dated 18 January 2012)

First, I think the simulation method of determining the uncertainty in the estimated harvest rate is appropriate and straightforward. The reliability of the results is going to depend on the reliability of the values that go in.

Unfortunately, the total CVs of the various abundances that go into determining the harvest rates have components that are quantifiable, and components (often larger) that are not objectively quantifiable. I agreed with the general sentiment that CVs of 0.02 for weir and tower escapements were too low except in the most ideal situations. This value was a research-supported estimate of the quantifiable uncertainty (and maybe just one of the potential quantifiable components? I was unclear on this), but it didn't (couldn't) account for things like poor visibility, unobserved weir leakage, crew problems, extrapolation for missing data at the tails, extrapolation during storm blowouts, etc. I think we saw one weir estimate with an assumed CV of 0.02 where the weir had been non-operational for half of the season and the numbers were filled in by extrapolation.

I think there'll be no getting around partially determining CVs using ad hoc rules and/or expert judgement. The people running these data collection programs and the people massaging these numbers to estimate abundances should have a good sense of how reliable the values are, at least in a qualitative sense. As an outside observer who's talked to a lot of people running these projects and using the numbers from these projects, I might expect the CVs to range from 0.02 to 0.15 depending on the project and year, and maybe to have some disastrous years where the CV might be much higher.

On the aerial survey data, I'm a bit more comfortable just because the proposed CV of 0.54 is fairly large. We know that the relationship between counts and the true escapement varies by system, year, and observer. You could consider case-specific CVs here as well, as you have some sense of which systems have high quality data and which don't.

We didn't touch on CV's for terminal catch data. My sense is that the appropriate CVs may depend on how the data are aggregated. Allocation of catch to the appropriate stock is often an issue, but if the terminal catches are aggregated into large regions this is not as important.

Finally, it's not too soon to start thinking about what the likely outcomes of the study are going to be. It's pretty easy to plug in some abundances and CVs into the harvest rate simulations outlined in Tech Doc 18 to see under what circumstances we get reliable estimates of harvest rates. I've attached a spreadsheet that does 20 simulations using the formula. You can plug in stock sizes, bycatch rates, and CVs for the various data components and get a quick sense of when you get reliable results.

Tables

Table 1. Summary of historical data comparing aerial survey counts to independent estimates of escapement for sockeye salmon in WASSIP area.

		Expansion based on peak aerial count			
System	Escapement enumeration method	Mean	CV	No. of obs.	References
Chignik					
Chignik River (early & late-run)	Weir count	1.94	0.71	9	Anderson (2011)
Bristol Bay					
Alagnak River	Tower count	2.55	0.40	9	Clark (2005)
Kuskokwim Bay					
Middle Fork Goodnews River	Weir or tower count	2.48	0.41	12	Taylor and Clark (2010a)
Kanektok River[a]	Weir count	6.40	0.77	4	Taylor and Elison (2010)
North of Kuskokwim Bay					
Glacial Lake	Weir count	2.99	0.66	8	Menard et al. (2011), Banducci et al. (2003, 2007), Kohler (2002), Kohler et al. (2004, 2005)
Pilgrim River	Weir count	2.42	0.57	7	Menard et al. (2011)
Weighted mean[a]		2.47	0.54	45	

[a] Kanektok River data not included in calculation of overall mean expansion factor and CV because of limited years with acceptable aerial surveys and higher mean expansion and CV than other systems.

Table 2. Escapement (thousands of fish) and CV of sockeye salmon in the Black Lake and Chignik Lake sub-regional reporting groups of the Chignik regional reporting group from 2006 to 2008.

	Black Lake		Chignik Lake	
Year	Chignik weir (early-run)	CV	Chignik weir (late-run)[a]	CV
2006	366.50	0.02	369.00	0.02
2007	361.09	0.02	293.88	0.02
2008	377.58	0.02	328.48	0.02

[a] Chignik Lake (late-run) escapement includes an estimate of escapement in September, after the weir is removed: 2006 = 58,942; 2007 = 28,550; 2008 = 27,829.

Table 3. Escapement (thousands of fish) and CV of sockeye salmon in the South Peninsula sub-regional reporting group of the South Peninsula regional reporting group from 2006 to 2008.

	South Peninsula				
Year	South Peninsula aerial survey index[a]	Mortensens Lagoon weir[b]	Orzinski Lake weir[b,c]	Sub-region escapement	CV
2006	55.46	14.69	18.00	169.58	0.53
2007	58.37	NA	10.64	154.72	0.54
2008	59.02	NA	36.84	182.52	0.52

Note: NA = Mortensens Lagoon weir was not run in 2007 and 2008, Mortensens Lagoon aerial survey index is included as part of South Peninsula aerial survey index for 2007 and 2008.

[a] Expansion factor = 2.47 and CV = 0.54 is assumed for South Peninsula aerial survey index.

[b] CV = 0.02 is assumed for Mortensens Lagoon and Orzinski Lake weir counts.

[c] The number of jacks that migrated through the Orzinski Lake weir were enumerated and included in the escapement numbers: 2006 = 167; 2007 = 10,643; 2008 = 1,429 (Poetter 2009, Poetter et al. 2008, 2007).

Table 4. Escapement (thousands of fish) and CV of sockeye salmon in the Northwestern District/Black Hills sub-regional reporting group of the North Peninsula regional reporting group from 2006 to 2008.

	Northwestern District/Black Hills								
Year	McLees Lake weir[a]	Aleutian Islands aerial survey index[b]	Urilia Bay aerial survey index	Swanson Lagoon aerial survey index	Bechevin Bay aerial survey index	Izembek-Moffet Bay aerial survey index	Caribou Flats - Black Hills aerial survey index	Sub-region escapement	CV
2006	12.94	0.25	45.06	0.38	7.88	41.20	7.53	265.40	0.54
2007	21.43	0.04	48.08	9.20	2.28	32.60	16.80	290.46	0.54
2008	8.66	0.07	118.60	5.50	3.10	46.60	44.00	546.43	0.54

[a] CV = 0.02 is assumed for McLees Lake weir.

[b] Expansion factor = 2.47 and CV = 0.54 is assumed for aerial survey indices.

Table 5. Escapement (thousands of fish) and CV of sockeye salmon in the Nelson, Bear, and Sandy sub-regional reporting groups of the North Peninsula regional reporting group from 2006 to 2008.

	Nelson					Bear				Sandy			
	Nelson Lagoon - Herendeen Bay aerial survey index[a]	Nelson River				Bear River				Sandy River			
Year		Weir[b,c]	Post-weir[d]	Sub-region escapement	CV	Weir[b,e]	Post-weir[d]	Sub-region escapement	CV	Weir[b,f]	Post-weir[d]	Sub-region escapement	CV
2006	14.00	196.27	18.74	249.56	0.11	404.20	40.81	445.00	0.06	35.79	12.21	48.00	0.17
2007	10.10	174.70	5.30	204.93	0.08	396.54	34.46	431.00	0.05	44.33	0.37	44.70	0.02
2008	38.22	135.45	6.15	235.94	0.31	282.58	38.42	321.00	0.08	29.58	2.60	32.18	0.05

[a] Expansion factor = 2.47 and CV = 0.54 is assumed for Nelson Lagoon-Herendeen Bay aerial survey index.

[b] CV = 0.02 is assumed for weir counts on Nelson, Bear, and Sandy rivers.

[c] The number of jacks that migrated through Nelson River weir were enumerated and included in the escapement numbers: 2006 = 3,717; 2007 = 1,056; 2008 = 918 (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007).

[d] Escapements after weir removal were estimated for Nelson, Bear, and Sandy rivers as well as a pre-weir installation escapement estimate of 10,000 sockeye salmon in 2006 for Sandy River; estimates are based on aerial surveys, commercial fisheries performance, run timing indicators, effort levels and weather conditions (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007). CV of post-weir escapement is assumed to be same as aerial survey (0.54), but escapement estimate is not expanded.

[e] The number of jacks that migrated through Bear River weir were enumerated and included in the escapement numbers: 2006 = 10,198; 2007 = 6,396; 2008 = 6,632 (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007).

[f] The number of jacks that migrated through Sandy River weir were enumerated and included in the escapement numbers: 2006 = 329; 2007 = 2,164; 2008 = 351 (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007).

Table 6. Escapement (thousands of fish) and CV of sockeye salmon in the Ilnik, Meshik, and Cinder sub-regional reporting groups of the North Peninsula regional reporting group from 2006 to 2008.

	Ilnik						Meshik			Cinder		
			Ilnik River									
Year	Three Hills aerial survey index[a]	Ocean River aerial survey index[a]	Weir[b,c]	Post-weir[d]	Sub-region escapement	CV	Meshik aerial survey index[a]	Sub-region escapement	CV	Cinder aerial survey index[a]	Sub-region escapement	CV
2006	1.80	13.00	74.55	0.45	111.53	0.21	142.61	352.00	0.54	101.10	249.55	0.54
2007	1.50	14.00	77.17	1.83	117.26	0.22	58.50	144.40	0.54	142.00	350.50	0.54
2008	2.00	16.00	27.00	1.30	72.73	0.44	86.25	212.89	0.54	129.80	320.39	0.54

[a] Expansion factor = 2.47 and CV = 0.54 is assumed for Three Hills, Ocean River, Meshik, and Cinder aerial survey indices.

[b] CV = 0.02 is assumed for Ilnik River weir counts.

[e] The number of jacks that migrated through Ilnik River weir were enumerated and included in the escapement numbers: 2006 = 671; 2007 = 137; 2008 = 88 (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007).

[d] Escapements after weir removal were estimated for Ilnik River; 2006 estimate includes a pre-weir installation escapement estimate of 500 sockeye salmon; estimates are based on aerial surveys, commercial fisheries performance, run timing indicators, effort levels and weather conditions (Murphy and Hartill 2009, Murphy et al. 2008, Murphy and Tschersich 2007). CV of post-weir escapement is assumed to be same as aerial survey (0.54), but escapement estimate is not expanded.

Table 7. Escapement (thousands of fish) and CV estimates of sockeye salmon in the Ugashik, Egegik, Naknek, Alagnak, Kvichak, Nushagak, Wood, Igushik, and Togiak sub-regional reporting groups of the Bristol Bay regional reporting group from 2006 to 2008.

	Ugashik		Egegik		Naknek		Alagnak		Kvichak		Nushagak		Wood		Igushik		Togiak	
Year	Tower	CV	Tower	CV	Tower	CV	Tower	CV	Tower	CV	Sonar	CV	Tower	CV	Tower	CV	Tower	CV
2006	1,003	0.02	1,465	0.02	1,953	0.02	1,774	0.02	3,068	0.02	548.41	0.031	4,008	0.02	305	0.02	312.13	0.02
2007	2,599	0.02	1,433	0.02	2,945	0.02	2,466	0.02	2,810	0.02	518.04	0.026	1,528	0.02	415	0.02	269.65	0.02
2008	596	0.02	1,260	0.02	2,473	0.02	2,181	0.02	2,758	0.02	492.12	0.033	1,725	0.02	1,055	0.02	205.68	0.02

Table 8. Escapement (thousands of fish) and CV of sockeye salmon in the Goodnews, Kanektok, and Kuskokwim River sub-regional reporting groups of the Kuskokwim Bay regional reporting group from 2006 to 2008.

	Goodnews				Kanektok		Kuskokwim River		
Year	Middle Fork weir[a]	North Fork estimate[b]	Sub-region escapement	CV	Sub-region escapement	CV	Kogrukluk weir	Sub-region escapement	CV
2006	126.77	135.14	261.91	0.51	367.30[c]	0.54	60.81	696.21[g]	0.07
2007	72.28	77.05	149.33	0.51	327.74[d]	0.02	16.53[f]	507.60[h]	0.56
2008	50.46	53.79	104.25	0.51	145.76[e]	0.02	19.68	604.33[h]	0.56

[a] CV = 0.02 is assumed for Middle Fork weir counts.

[b] North Fork Goodnews River sockeye salmon escapement is estimated by multiplying escapement at Middle Fork weir by the average ratio of aerial survey indices of North Fork to Middle Fork (1.07). Estimated CV = 0.70.

[c] Kanektok River weir not operational in 2006. Escapement is based on unexpanded aerial survey with assumed CV equal to other sockeye salmon aerial survey escapement estimates.

[d] Includes additional 19,992 sockeye salmon spawned below Kanektok River weir in 2007 (Clark and Linderman 2009).

[e] Includes additional 4,373 sockeye salmon spawned below Kanektok River weir in 2008 (Taylor and Clark 2010b); 72,359 sockeye salmon were estimated to pass weir during inoperable periods in 2008.

[f] Kogrukluk weir operation incomplete in 2007 and > 20% of total escapement is based on daily passage estimates.

[g] Mark-recapture and CV estimate at Kalskag plus 7,717 escapement below Kalskag (see Schaberg et al. 2010).

[h] Kuskokwim River sub-region escapement estimate for 2007 and 2008 are based on expansion of Kogrukluk weir escapements using an expansion factor of 30.72.

Table 9. Escapement (thousands of fish) and CV of sockeye salmon in the Norton Sound sub-regional reporting group of the North of Kuskokwim Bay regional reporting group from 2006 to 2008.

	Norton Sound						
Year	Pilgrim River weir	Glacial Lake weir	Snake River weir	Nome River weir	Eldorado River weir	Sub-region escapement	CV
2006	52.32	6.85	0.30	0.19	0.001	59.66	0.02
2007	43.43	4.53	1.35	0.53	0.022	49.88	0.02
2008	20.45	1.79	0.14	0.09	0.003	22.48	0.02

Table 10. Escapement (thousands of fish) and CV of sockeye salmon within the WASSIP area by regional reporting group from 2006 to 2008.

	2006		2007		2008	
Regional reporting group	Escapement	CV	Escapement	CV	Escapement	CV
Chignik	735.49	0.02	654.97	0.02	706.06	0.02
South Peninsula	169.58	0.53	154.72	0.54	182.52	0.52
North Peninsula	1,721.03	0.40	1,583.24	0.39	1,741.56	0.49
Bristol Bay	14,436.54	0.02	14,983.69	0.02	12,745.80	0.02
Kuskokwim Bay	1,325.42	0.28	984.68	0.47	854.33	0.55
North of Kuskokwim Bay	59.66	0.02	49.88	0.02	22.48	0.02