Model Description

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September 4, 2018

## State-Space Model

The state-space model (Appendix A1) specifies how population parameters lead to the data that are observed. The process model component describes how natural population processes generate true annual abundance by age, and the observation model component describes how the observed data are generated.

### Process Component

Abundance of Susitna River Chinook salmon in each stock group is generated by a spawner-recruit (SR) relationship, which describes the number of fish expected to return (the “recruitment”) from a given “escapement” (number of spawning fish). The total recruitment produced from fish spawning in year by stock follows the Ricker (1975) formulation:

where is the number of spawners, parameter (number of recruits per spawner in the absence of density dependence) is a measure of productivity for each stock group, and parameter is a measure of density dependence for each stock group.

In the model, productivity is allowed to vary among brood years, fluctuating around a central tendency. Time-varying productivity often manifests as serially correlated model residuals, so an lognormal error term with a lag of one year (MA[1]) was included in the linearized form of the spawner-recruit relationship (Noakes et al. 1987)

where is the lag-1 moving average coefficient, are model residuals

and the are independently and normally distributed process errors with “white noise” variance . The natural log of the productivity parameter for each stock is drawn from a normal distribution .

Expected age at maturity is allowed to trend through time and fluctuate annually. Age-at-maturity vectors from year returning at ages 3-6 were drawn from a distribution. The Dirichlet parameters are expressed in an alternate form where

is the (inverse) dispersion of the annual age-at-maturity vectors, reflecting consistency of age at maturity among brood years. The location parameters are

The abundance in stock group of age Chinook salmon in calendar year is the product of the age proportion scalar and the total return (recruitment) $R\_$ in stock group from year :

Total run for stock group during calendar year is the sum of abundance at age across ages:

Annual harvest of Susitna-origin Chinook salmon below (downstream of) Susitna RM 34 and Yenta RM 6 was modeled as the product of the annual harvest rate below in the area and total run:

Inriver run of stock group during calendar year at Susitna RM 34 and Yenta RM 6 was modeled as follows:

Annual harvest of stock group above Susitna RM 34 and Yenta RM 6 was the product of the annual harvest rate for each stock in the area and inriver run abundance:

Finally, spawning escapement was inriver run abundance minus harvest above Susitna RM 34 and Yenta RM 6:

Multiple tributaries contribute to the spawning escapement in some stock groups. Expected stock composition is allowed to trend through time and fluctuate annually. Stock composition vectors from year were drawn from a distribution. The Dirichlet parameters are expressed in an alternate form where

is the (inverse) dispersion of the annual stock composition vectors, reflecting consistency of stock composition among calendar years. The location parameters are

### Observation Component

Observed data (Appendices B1-B#) include estimates of annual harvest below and above Susitna RM 34 and Yenta RM 6, age composition data from carcass surveys, creel surveys, fishwheel catches and weir projects throughout the Susitna drainage, single aerial survey data for 16 tributaries, MR estimates of inriver run, radio telemetry data, and length composition data. Sampling distributions for the data follow.

Estimated inriver runs of Chinook salmon from mark-recapture were

where the and

The number of age-3 and age-4 fish that were less than 500mm MEFT were

so that inriver runs of fish 500 mm MEFT or greater were

where is the proportion of the run that is age in calendar year . Estimated annual harvest of Susitna River Chinook salmon below Susitna RM 34 and Yenta RM 6 was

where the and the variances followed Equation with an assumed CV of 0.05 reflecting reported commercial and subsistence harvest.

Estimated annual harvest of Susitna River Chinook salmon above Susitna RM 34 and Yenta RM 6 was

where the and the variances followed Equation with an assumed CV of 0.2 reflecting estimated harvest.

Single aerial surveys were available for sixteen tributaries. Each comprised an independent measure of relative abundance for the stock group within which it was located:

where the and where is the median of the distribution of .

Radio telemetry final destinations within each stock group were partitioned into categories with categories representing tributaries within the stock group that are counted during aerial surveys and one category representing all tributaries that were not counted during aerial surveys. Fish within tributaries that were not counted during aerial surveys were

Fish within tributaries that were counted during aerial surveys were

Stock composition was calculated as

The proportion of the spawning escapement counted during single aerial surveys was

Three weirs counts were available. Each comprised an independent measure of relative abundance for the stock group within which it was located:

where the .

The scale-age counts were modeled as multinomially distributed

The location parameters are

where is a bias correction for the type of age sample . Estimated annual age composition is then

## Model Fitting

### Prior Distributions

### Sampling from the Posterior Distribution

## Reference Points and Optimal Yield Profiles

Reference points were calculated for each individual MCMC sample. Spawning abundance providing maximum sustained yield (MSY) was approximated

Sustained yield at a specified level of was obtained by subtracting spawning escapement from recruitment:

Other relevant quantities include harvest rate leading to maximum sustained yield, approximated by (Hilborn 1985)

escapement leading to maximum sustained recruitment (MSR)

and equilibrium spawning abundance, where recruitment exactly replaces spawners:

The quantity

in Equations , , , and adjusts for the difference between the median and the mean of a right-skewed lognormal error distribution autocorrelation.

The probability that a given spawning escapement would produce average yields exceeding X% of MSY was obtained by calculating at incremental values of for each MCMC sample, then comparing with X% of the value of MSY for that sample. The proportion of samples in which exceeded X% of MSY is an estimate of the desired probability, and the plot of proportion versus is termed an optimal yield profile (OYP; Fleischman et al. 2013).

The probability that yield would be reduced to less than X% of MSY by supplying too few spawners was obtained by calculating at incremental values of and tallying the number of MCMC samples for which was less than X% of MSY and was less than . A plot of the fraction of samples in which this condition occurred versus is termed an overfishing profile (Bernard and Jones III 2010).

The probability that a given spawning escapement would produce average recruitments exceeding X% of MSR was obtained by calculating (Equation 1) at incremental values of for each MCMC sample, then comparing with X% of the value of MSR for that sample. The proportion of samples in which exceeded X% of MSR is an estimate of the desired probability, and the plot of the proportion versus is termed an optimal recruitment profile (ORP; Fleischman et al. 2013).

OYPs Overfishing profiles and ORPs were used to quantify the yield (or recruitment) performance of prospective escapement goals, taking into consideration the uncertainty about the true abundance, productivity, and capacity of the stock.

## Escapement Goals Standardized To

For purposes of comparing escapement goals across stocks, we divided the lower and upper bounds of 21 published goals for Alaska Chinook salmon (Munro and Volk 2016) by point estimates of for each stock, thereby expressing all goal ranges in terms of multiples of . These values were multiplied by estimates of for each stock group to provide a graphical comparison of the recommended goals with those from other stocks.

## Escapement Goal Review Process

An interdivisional escapement goal review team was convened to review the available data, discuss analyses and results, and make escapement goal recommendations. The escapement goals recommended in this report are the product of several collaborative meetings of the review team and other ADF&G staff. The final recommendation was reached by consensus of fisheries scientists and regional research coordinators from both fisheries divisions.