# Overview:

This program is designed to assess a paired set of post season model runs (one with specified fisheries “turned on” and one with them “turned off”) over a given time series by producing the following outputs:

1. Annual estimates of age 3-5 Chinook abundance available to SRKWs in both inland (Salish Sea) and coastal waters for each pair of runs.
2. Annual estimates of age 3-5 Chinook kilocalories available to SRKWs in both inland (Salish Sea) and coastal waters for each pair of runs.
3. Annual estimates of percent reduction in kilocalories caused by the fisheries of interest.
4. Annual estimates of kilocalorie availability to needs ratio, given a set of caloric needs scenarios.

Below is a description of the required input file, the various output files, and some information specific to the R program itself, in addition to a general overview of how the R program processes the data.

# SRKW\_Inputs.xlsx File:

This is the file used to supply static input data to the SRKW\_Analysis.R program. It contains 5 tabs (shaded red) that get read as tables into the program:

1. **R\_In\_RunID** – this table tells the R program which FRAM model runs to process from the supplied databases. The RunIDs in column B will link to the database identified in path 2 of the R program, while those in column C will link to the database identified in path 3. It is important that the column B/path 2 database is the set of model runs with the action fisheries “turned on.” The column names for columns B/C will be used by the R program in output tables and figures to specify which set of model runs the estimates are associated with. The time series provided in this table (currently 1992 to 2014) will determine the years processed by the R program. Before running the program, ensure that the RunIDs in this table correctly reflect the specific run year and run type (‘Fisheries On’ or ‘Fisheries Off’).
2. **R\_In\_kCal-Age** – this table provides the mean fork length (‘MeanFL’), kilocalories per fish (‘kCal’), and kilocalories per fish given a specified size selectivity of SRKW feeding (‘kCal\_Selectivity’) for each stock-age-time step combination. Mean fork length is based on updated Von Bertalanffy growth parameters from the recently updated Chinook FRAM base period, which no longer differ for immature vs. mature fish (McHugh et al., 2015). Length-to-kilocalorie conversions for three energy tiers are based on O’Neill et al. 2014, and stocks were assigned to energy tiers based on life history characteristics and expert opinions. The size selectivity parameters are currently set to 1 (no size selectivity), however, functionality to include size selectivity does exist – the parameters can be adjusted in the ‘Parameters’ tab. Stock/age specific estimates of kCal/fish for time step 4 were replicated from time step 1.
3. **R\_In\_FishFlag** – this table designates fisheries as either outside Puget Sound (flag = 0), pre-terminal Puget Sound (flag = 1), or terminal Puget Sound (flag = 2). It also contains a ‘Weight’ field, which allows mortalities in a given fishery to be discounted (or excluded) based on the location of the fishery and prior knowledge of SRKW spatial distribution.
4. **R\_In\_Needs** – this table contains SRKW caloric needs information provided by the NWFSC.
5. **R\_In\_Distribution** – this table provides information on the spatial distribution of each stock in the format of the proportion of the total abundance of each stock that occur outside of the SRKW range (‘ppnOutside’), in the Coastal range (‘ppnCoastal’), and in the inland Salish Sea waters (‘ppnInland’). Values were calculated based on the average distribution of fishery catch and escapement for each stock across old FRAM base period years, under the assumption that the catch of a stock across fisheries represents the distribution of that stock because fishing effort in these years was relatively broad and well distributed spatially and temporally. For fishery catch, each fishery was designated as outside, coastal, or inland based on its location. Stock-specific escapements were designated as outside, coastal, or inland based on the location of the stock’s watershed of origin.

# Excel Output from SRKW\_Analysis.R File:

1. **‘Abundance\_Coastal’ tab** – this file provides the estimated annual abundance of age 3 through 5 Chinook in the coastal region of SRKW distribution (SUS, WCVI, CBC; based on stock specific catch distributions from previous FRAM base period, see ‘R\_In\_Distribution’ above) by time period and run type (with or without “action” fisheries). When ‘AbundType’ variable in R code is set to 0, these abundance estimates include natural mortality (i.e., cohort size after natural mortality and fishing plus natural mortality). Chart included below the table.
2. **‘Kilocalories\_Coastal’ tab** – this file provides the estimated annual number of kilocalories of age 3 through 5 Chinook available to SRKWs in the coastal region of their distribution (SUS, WCVI, CBC) by time period and run type (with or without “action” fisheries). When ‘AbundType’ variable in R code is set to 0, these kilocalorie estimates include natural mortality. Chart included below the table.
3. **‘kCal%Inc\_Coastal’ tab** – this file presents the proportional increase in estimated available kilocalories in coastal waters by year and time period in the set of runs with the fisheries turned off (or reduced) compared to the runs with fisheries turned on. Note that these increases should be considered cumulative across time periods, as the effects of reductions to fisheries in earlier time periods will roll over into the next time period.
4. **‘NeedsRatio\_Coastal’ tab** – this file presents the ratio of kilocalorie availability to kilocalorie needs by time period and year for four different needs scenarios and each run type (with or without “action” fisheries) in the coastal region of SRKW distribution. Chart included to the right of the table.
5. **‘Abundance\_Inland’ tab** – this file provides the estimated annual abundance of age 3 through 5 Chinook in the inland region of SRKW distribution (Salish Sea) by time period and run type (with or without “action” fisheries). For each set of model runs, if terminal fisheries occur in time step 3 in Puget Sound (i.e., sum of mortalities > 0 for fisheries with flag = 2 in ‘R\_In\_FishFlag’ above), these mortalities will be subtracted from the existing time step 3 abundance estimates, which only account for pre-terminal fisheries. Additionally, the column will be renamed to ‘…\_AfterTerm\_T3’ to indicate that terminal mortalities have been removed. When ‘AbundType’ variable in R code is set to 0, these abundance estimates include natural mortality. Chart included below the table.
6. **‘Kilocalories\_Inland’ tab** – this file provides the estimated annual number of kilocalories of age 3 through 5 Chinook available to SRKWs in the inland region of their distribution (Salish Sea) by time period and run type (with or without “action” fisheries). For each set of model runs, if terminal fisheries occur in time step 3 in Puget Sound (i.e., sum of mortalities > 0 for fisheries with flag = 2 in ‘R\_In\_FishFlag’ above), the kilocalories resulting from these mortalities will be subtracted from the existing time step 3 kilocalorie estimates, which only account for pre-terminal fisheries. Additionally, the column will be renamed to ‘…\_AfterTerm\_T3’ to indicate that terminal mortalities have been removed. When ‘AbundType’ variable in R code is set to 0, these kilocalorie estimates include natural mortality. Chart included below the table.
7. **‘kCal%Inc\_Inland’ tab** – this file presents the proportional increase in estimated available kilocalories in inland waters by year and time period in the set of runs with the fisheries turned off (or reduced) compared to the runs with fisheries turned on. Note that these increases should be considered cumulative across time periods, as the effects of reductions to fisheries in earlier time periods will roll over into the next time period.
8. **‘NeedsRatio\_Inland’ tab** – this file presents the ratio of kilocalorie availability to kilocalorie needs by time period and year for four different needs scenarios and each run type (with or without “action” fisheries) in the inland region of SRKW distribution. Chart included to the right of the table.

# SRKW\_Analysis.R File:

This is the R program to process a set of FRAM model runs and assess the amount of Chinook prey (in terms of both abundance and kilocalories) available to SRKWs in both coastal and inland Salish Sea waters. To run properly, there are a few parameters and four paths that must be updated at the beginning of the script:

* ‘RoundFlag’ should be set to zero. This was only set to 1 for testing purposes.
* ‘AbundType’ should be set to zero. This determines whether or not natural mortality is included in the abundance and kilocalorie estimates (0 = included, 1 = excluded)
* ‘outfile\_name’ sets the name of the excel output file. This file does not need to exist, as the program will create it. If the file does exist, it will be overwritten. Also, if it does exist, make sure that the file is not open otherwise it will throw an error in the program.
* Set paths:
  + Path 1 – identifies the location of the SRKW\_Inputs.xlsx file
  + Path 2 – identifies the location of the FRAM database that contains model runs with “action” fisheries turned on and the RunIDs specified in column B of the above R\_In\_RunIDs tab
  + Path 3 – identifies the location of the FRAM database that contains model runs with “action” fisheries turned off and the RunIDs specified in column C of the above R\_In\_RunIDs tab
  + Path 4 – this identifies the directory where output tables and figures will be saved

Below is a description of the general flow that the program follows:

1. Begin by reading in the above tables from the SRKW\_Inputs.xlsx file.
2. Query FRAM databases and pull all records from ‘Cohort’ and ‘Mortality’ tables.
3. Some pre-processing of the cohort and mortality data to:
   1. Exclude time step 4 from analysis.
   2. Calculate total mortality by stock, age, fishery, time-step.
   3. Convert from 78 stock to 39 stock format (combine marked and unmarked components of each stock).
   4. If ‘AbundFlag’ is set to 0, add natural mortality to ‘after pre-terminal fishing’ cohorts

Begin loop through each year (beginning with earliest)…

Begin loop through each run type (‘Fisheries on’ first, then ‘Fisheries Off’)…

1. Filter cohort and mortality data to correct Run ID (year and run type).

If mortality exists in PS terminal fisheries for run being processed…

1. Summarize mortalities due to Puget Sound terminal fisheries (b/c they have not yet been removed from the above cohort sizes)
   1. Filter mortality data (already filtered to specific RunID) to only fisheries with FishFlag=2 (terminal).
   2. For each record multiply total mortality by the weight value for that fishery from the ‘FishFlag’ table.
   3. Determine kCal/fish for each stock-age-time step combination (from ‘R\_In\_kCal-Age’) and use to convert above mortalities to kCals.
   4. Sum mortalities and kCals by age for time step 3 (over all stocks and fisheries). Append to a summary file that houses data from all years.

End If

1. Determine proportion coastal and proportion inland for each stock (from ‘R\_In\_Distribution’ table) and use to calculate the starting and ending abundances in each region for each stock-age-time step combination. Ending abundances used are dependent on how the ‘AbundType’ variable above was defined (when set to ‘0’ it will have pre-terminal fishing mortalities removed and natural mortality added back in).
   1. cohort$InlandAbundance <- cohort$MidCohort.sum \* cohort$ppnInland
   2. cohort$CoastalAbundance <- cohort$MidCohort.sum \* cohort$ppnCoastal
2. Determine kCal/fish for each stock-age-time step combination (from ‘R\_In\_kCal-Age’) and use to convert above abundances to available kCals.
   1. cohort$InlandkCal <- cohort$InlandAbundance \* cohort$kCal\_Selectivity
   2. cohort$CoastalkCal <- cohort$CoastalAbundance \* cohort$kCal\_Selectivity
3. Sum abundances and kCals by time step and age (over all stocks). Append to a summary file that houses data from all years and run types.
4. Subtract kCals from terminal fisheries from time step three to create an “after terminal fisheries” kCal estimate.
5. Sum age 3-5 kCals by time step for inland and coastal then divide by inland and coastal needs estimates to generate data for kCal-to-Needs table. Append to a summary file that houses data from all years and run types.

End run type loop

End year loop

1. Summarize and reformat data into necessary output tables.
2. Generate figures to accompany output tables.
3. Export tables and figures from (11) & (12) above into separate tabs of a single excel output file.

# References

McHugh P, Johnson G, Schaffler J. 2015. Chinook FRAM Base Period Documentation: Growth Functions.

O’Neill SM, Ylitalo GM, West JE. 2014. Energy Content of Pacific salmon as prey of northern and southern resident killer whales. Endang Species Res 25:265-281