Chinook FRAM Base Period Documentation: Sublegal Stock and Age Assignments

Galen Johnson (Northwest Indian Fisheries Commission), Angelika Hagen-Breaux (Washington Department of Fish and Wildlife [WDFW]), Pete McHugh (Eco Logical Research), Jon Carey (WDFW), Larrie LaVoy (National Oceanographic and Atmospheric Administration)
October 5, 2015

BACKGROUND

In the Chinook Fishery Regulation Assessment Model (FRAM), the number of encounters with fish below the size limit in a fishery (sublegals) is calculated as the number of encounters with fish at or above the size limit in a fishery (legals) times an average sublegals/legals ratio from that fishery. Because coded wire tags (CWTs) are not recovered from non-landed encounters, such as those with sublegals, methods are needed to infer stock and age composition of sublegal encounters in a fishery. Sublegal encounters are assigned only to stocks caught in the fishery (or a surrogate fishery) and may include sublegals from ages present in the legal catch as well as younger ages with few or no legals. In previous calibrations, total sublegal encounters in a fishery and time step were assigned to stocks and ages in two steps. First, total sublegal encounters were apportioned to stocks based on the stock composition of the landed catch in that fishery and time step (Unidentified Author, 2012). Next, sublegal encounters for a particular stock were assigned to ages based on the age composition of the sublegal population of that stock. Although this method offers a means to approximate stock impacts, it has some limitations. Most notably, perhaps, it has the potential to decouple sublegal encounter rates from legal exploitation rates, a scenario which has plagued recent FRAM applications that explored changes to minimum size limit regulations.

The Model Evaluation Workgroup (MEW) agreed on a revised method of assigning sublegal encounters to stocks and ages by applying the stock and age specific legal encounter rates to the sublegal population of a stock and scaling these estimated encounters to match the total number of sublegal encounters. In cases where an age class is not encountered, the encounter rate of the next highest age is applied. While this method can assign encounters to sublegals of ages not represented in the catch for a given stock, it cannot assign encounters to sublegals of a stock not represented in the catch. If genetic stock identification (GSI) data, CWT, or other information that can aid in stock/age assignments of sublegal encounters becomes available in the future, this method should be re-examined.

DATA DESCRIPTION

This analysis is predominantly based on sublegal/legal ratios collected during fishery sampling. Exploitation rates are derived from Regional Mark Information System (RMIS) CWT recoveries using calibration procedures in ChCal. The abundance of sublegal Chinook by stock and age is computed as a function that stock-age combination's average size, predicted by von Bertalanffy growth functions, distributional spread on length-at-age predictions, and a fishery's minimum size limit. Key data include:

- CWT recoveries for brood years 2005-2008 for all stocks (see stock profiles [currently available from MEW upon request]).
- Fishery-period of sublegal/legal ratios, presented in Appendix A.
- Size-at-age (and spread) predictions; for growth functions and coefficients of variation (CVs) by stock and age, see McHugh et al. companion submission for details ('Chinook FRAM Base Period Documentation: Growth Functions').
- Fishery minimum size limits.

ESTIMATING SUBLEGAL ENCOUNTERS BY STOCK AND AGE

The sublegal encounter rates used in FRAM are computed in three major steps during the calibration, as executed by the calibration program ChCal and described below. The proportion of the cohort that is legal or sublegal for each stock, age, fishery and time step was calculated using the equations given in FRAM Chinook Base Period Documentation (MEW, 2008a) and FRAM Technical Documentation for Chinook (MEW, 2008b) using the new growth functions and CVs (companion document) and the size limits for each fishery during the new base period years.

1. Compute the total number of sublegal encounters by fishery and time step:

$$TotSubEnc_{f,t} = LandedCatch_{f,t} * SubToLegRatio_{f,t}$$

where:

$TotSubEnc_{f,t}$ = Base period total sublegal encounters by fishery and time step,

$LandedCatch_{f,t}$ = Base period landed catch (legal sized fish) by fishery and time step based on expansions of CWT recoveries, and

$SubToLegRatio_{f,t}$ [formerly $TargetEncRate_{f,t}$] = base period target encounter rate adjustment, which is the ratio of sublegal encounters to legal encounters by fishery and time step.

2. Compute the number of sublegal encounters by stock and age by applying stock-age specific legal encounter rates to the sublegal population of each stock and age, then scaling to match the total number of sublegal encounters from step (1):

a) Compute legal catch rates by stock and age:

$$LegER_{s,a,f,t} = Catch_{s,a,f,t}/(Cohort_{s,a,t} * LegalProp_{s,a,f,t})$$

where:

$LegER_{s,a,f,t}$ = Base period catch rate of legal fish by stock, age, fishery and time step,

$Catch_{s,a,f,t}$ = Base period catch by stock, age, fishery and time step,

$Cohort_{s,a,t}$ = Base period cohort size by stock, age, and time step, and

$LegalProp_{s,a,f,t}$ = Proportion of the cohort that is of legal size (at or above the size limit) by stock, age, fishery and time step.

b) Compute the estimated number of sublegal encounters. The method is based on applying the legal catch rates by stock and age as encounter rates for the sublegal population. For a given stock, it is assumed that sublegals are only present in a fishery if legal fish are present. If a legal catch rate for an age doesn't exist, there are two options. If the legal proportion for that stock, age, fishery and time step is over 50% and no legals were caught, the sublegal encounter rate is assumed to be zero. If the legal proportion is less than 50%,the legal catch rate for fish one year older will be used (see Figure 1):

$$EstSubLegEnc_{s,a,f,t} = \left(Cohort_{s,a,t} * SubLegalProp_{s,a,f,t}\right) * LegER_{s,a,f,t}$$

where:

$EstSubLegEnc_{s,a,f,t}$ = Base period estimated sublegal encounters by stock, age, fishery and time step, and

$SubLegalProp_{s,a,f,t}$ = Proportion of the cohort that is sublegal (less than the size limit) for a stock, age, fishery and time step, and the appropriate $LegER_{s,a,f,t}$ value is determined as in Figure 1.

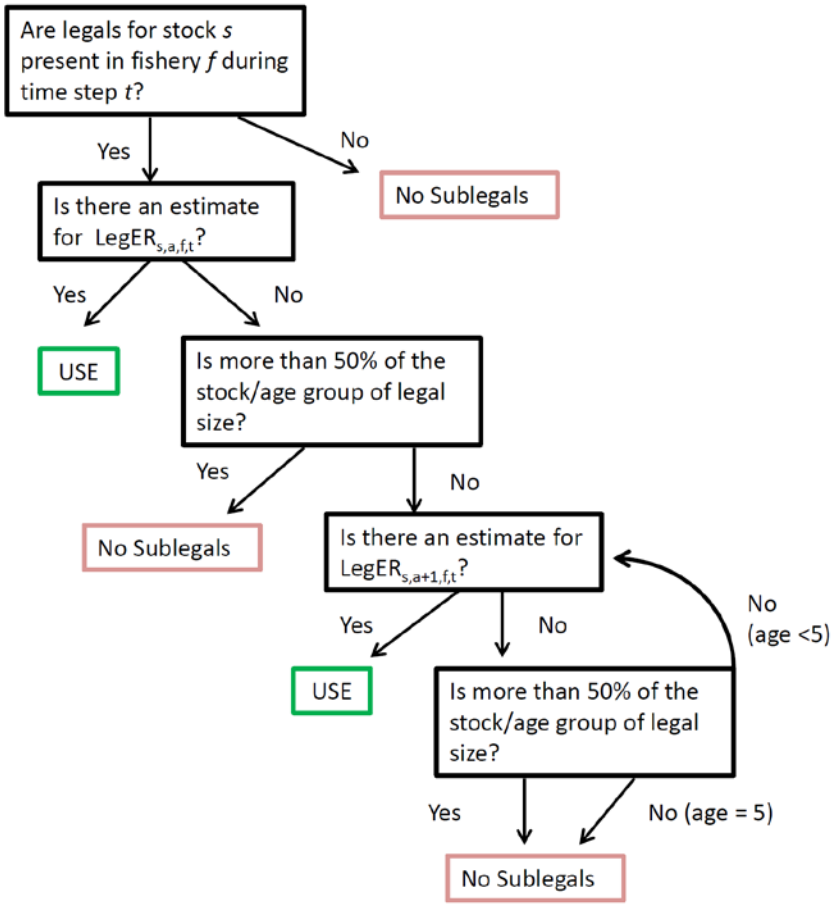

Figure 1. Decision tree for selecting a preliminary sublegal encounter rate (ER) for stock *s*, age *a* sublegals in fishery *f* during time step *t*.

c) Compute the proportion of sublegal encounters for a stock and age by fishery and time step:

$$SublegalStockAgeProp_{s,a,f,t} = \frac{EstSubLegEnc_{s,a,f,t}}{\sum_{s,a} EstSubLegEnc_{s,a,f,t}}$$

where:

SublegalStockAgeProp$_{s,a,f,t}$ = Proportion of sublegal encounters in a given fishery and time step of a given stock and age.

d) Apportion the total sublegal encounters in a fishery and time step by stock and age:

$$SubLegEnc_{s,a,f,t} = TotSubEnc_{f,t} * SublegalStockAgeProp_{s,a,f,t}$$

where

SubLegEnc$_{s,a,f,t}$ = Base period sublegal encounters by stock, age, fishery and time step.

3. Compute sublegal encounter rates by stock, age, fishery and time step:

$$SubER_{s,a,f,t} = SubLegEnc_{s,a,f,t}/(Cohort_{s,a,t} * SubLegalProp_{s,a,t})$$

Where:

SubER$_{s,a,f,t}$ = Base period sublegal encounter rate by stock, age, fishery and time step.

DISCUSSION

Because so little is known about the stock and age composition of sublegals encountered in any given fishery and time step, it is difficult to ground truth or test a method for assigning a stock and age to those sublegals. However, to account for discard (shaker) mortality appropriately in the FRAM model, it is necessary to make those stock and age assignments. Therefore, a method must be used that makes reasonable biological assumptions. This new method hopefully improves upon past methods by starting with the assumption that a legal fish and sublegal fish of the same stock and age have the same probability of being encountered, and that rate can be adjusted across all stocks and ages in the fishery if needed to obtain the correct number of sublegal encounters. Previously, the probability of a sublegal fish being encountered was only distantly related to the probability of a fish of the same stock and age being encountered. If there are no legal encounters for a given stock and age in a fishery and time step, and more than 50% of the stock and age is of legal size in that fishery (so that there was a reasonable chance of getting a CWT recovery for that stock/age combination if it occurred in the fishery), the stock/age combination is assumed not to occur in that fishery. However, if there are no legal encounters but less than 50% of the stock/age is of legal size, the legal encounter rate from the next age group (*a*+1) is used as a proxy. This method produces sublegal encounter rates with an explicit relationship to legal encounter rates of the same stock and, usually, age. The MEW workgroup favors

this method over previous methods because of this explicit relationship, and favors comparing model predictions of the stock composition of sublegal encounters with field data should it ever become available.

REFERENCES

Model Evaluation Workgroup (MEW). 2008a. *Chinook Fisheries Regulation Assessment Model (FRAM) Base Data Development v. 3.0 (Auxiliary Report to FRAM Technical Documentation for Coho and Chinook).* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Model Evaluation Workgroup (MEW). 2008b. *Fisheries Regulation Assessment Model (FRAM) Technical Documentation for Coho and Chinook v. 3.0.* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Unidentified author [Hagen-Breaux, A., McHugh, P., Packer, J.] (2012). FRAM Size Limit Modeling. Pacific Fishery Management Council Briefing Book, November 2012, Agenda Item C.3.a Attachment 5.

APPENDIX A. SUBLEGAL : LEGAL RATIOS

Appendix Table A1. Sublegal:legal (S:L) ratios proposed for Chinook FRAM base period calibration. Data type corresponds to OB = onboard observations, Int = interviews, Log = log book (volunteer or charter/lodge), TF = test fishery, Oth = Other (e.g., ADFG's model-based estimate for SEAK troll). "-99" corresponds to a time-area that either lacks or doesn't require (i.e., is closed) a S:L ratio.

Fishery	Fish. No.	Value for Time Step				data type	Years	Source	Comments
		1 Oct-Apr	2 May-Jun	3 Jul-Sep	4 Oct-Apr				
SE Alaska Troll	1	0.314	0.314	0.314	0.314	OB, Oth	2008-2013	ADFG	
SE Alaska Sport	3	0.560	0.560	0.560	0.560	Int	2008-2013	ADFG	
BC Outside Sport	8	0.001	0.001	0.001	0.001	Int, Log	2008-2013	CDFO	No sublegal encounters
BC No/Cent Troll	9	0.114	0.114	0.114	0.114	Log	2008-2013	CDFO	
BC WCVI Troll	10	0.099	0.099	0.099	0.099	Log	2008-2013	CDFO	
BC WCVI Sport	11	0.180	0.180	0.180	0.180	Int, Log	2008-2013	CDFO	
BC Georgia Strait Troll	12	NA	NA	NA	NA	NA	NA	NA	N/A (fishery essentially closed during BP years)
BC N Georgia Strait Sport	13	0.553	0.553	0.553	0.553	Int	2008-2013	CDFO	
BC S Georgia Strait Sport	14	1.258	1.258	1.258	1.258	Int	2008-2013	CDFO	
BC JDF Sport	15	0.468	0.468	0.468	0.468	Int	2008-2013	CDFO	
NT Area 3:4:4B Troll	16	-99	0.937	0.482	-99	OB	2003-2006	WDFW	
Tr Area 3:4:4B Troll	17	0.937	0.937	0.482	0.937	OB	2003-2007	WDFW	Based on NT Troll observations
NT Area 3:4 Sport	18	-99	1.014	1.014	-99	OB	2006-2013	WDFW	
NT Area 2 Troll	20	-99	1.147	1.200	-99	OB	2003-2007	WDFW	
Tr Area 2 Troll	21	-99	1.147	1.200	-99	OB	2003-2007	WDFW	Based on NT Troll observations
NT Area 2 Sport	22	-99	0.645	0.645	-99	OB	2006-2013	WDFW	
Area 1 Troll	26	-99	4.475	4.682	-99	Oth	NA	NA	Est'd from A1 sport obs. and A2 Troll:Sport ratio.
Area 1 Sport	27	-99	2.34	2.34	-99	OB	2006-2013	WDFW	
Central OR Troll	30	0.474	1.086	1.086	0.474	Int	2005, 2011	ODFW	KMZ values
Central OR Sport	31	0.920	0.583	0.689	0.920	Int	2005,2011-12	ODFW	KMZ values; no T1 SL enc's in current base period

Fishery	Fish. No.	Value for Time Step				data type	Years	Source	Comments
		1 Oct-Apr	2 May-Jun	3 Jul-Sep	4 Oct-Apr				
KMZ Troll	32	0.474	1.086	1.086	0.474	Int	2005, 2011	ODFW	
KMZ Sport	33	0.920	0.583	0.689	0.920	Int	2005,2011-12	ODFW	
So Calif. Troll	34	0.474	0.368	0.600	0.474	Int	2005, 2011	CDFW	no T1 SL enc's in current base period
So Calif. Sport	35	0.920	0.610	0.495	0.920	Int	2005,2011-12	CDFW	
NT Area 7 Sport	36	0.396	-99	0.600	0.396	TF, Log, Int	2004-12 (T2-3), 2008-14 (T1/4)	WDFW	
Tr JDF Troll	41	-99	-99	-99	-99	NA	NA	NA	No recent est's available
NT Area 5 Sport	42	1.920	-99	0.824	1.920	TF, Log, Int	2004-14 (T2-3), 2004-13 (T1/4)	WDFW	
NT Area 8-1 Sport	45	3.602	-99	-99	3.602	TF, Log	2006-13	WDFW	
NT Area 9 Sport	53	2.488	-99	0.860	2.488	TF, Log	2008-14 (T2-3), 2008-13 (T1/4)	WDFW	
NT Area 6 Sport	54	0.289	-99	0.064	0.289	TF, Log, Int	2004-11 (T2-3), 2012-13 (T1/4)	WDFW	
NT Area 10 Sport	56	6.579	-99	1.102	6.579	TF, Log	2008-14 (T2-3), 2008-14 (T1/4)	WDFW	
NT Area 11 Sport	57	1.838	0.589	0.589	1.838	TF, Log	2008-14 (T2-3), 2010-13 (T1/4)	WDFW	
NT Area 12 Sport	64	1.708	-99	1.87	1.708	Int, Log	2003-11 (T2-3), 2010-13 (T1/4)	WDFW	
NT Area 13 Sport	67	9.37	1.47	1.47	9.37	Int	2003-6 (T2-3), 2003-11 (T1/4)	WDFW	

APPENDIX B. VISUAL BASIC CODE FOR COMPUTING SUBLEGAL ENCOUNTERS

```
'CODE EXCERPT FROM CHCAL CALIBRATION PROGRAM, SHAKER SUBROUTINE
'COMPUTE SHAKER MORTALITY IF CATCH OCCURRED IN FISHERY
        FishSublegalPop = 0
        If TotCatch(Fish, TStep) > 0 Then


            'COMPUTE TOTAL NUMBER OF ENCOUNTERS
                 'in OOB run, this sets sublegal encounters to the catch of a ‘stock in a fishery and time step
                 unless TargetEncRate is set
            If TargEncRate(Fish, TStep) <> -1.0! Then
                TotEnc = TimeCatch(Fish, TStep) * TargEncRate(Fish, TStep)
            Else
                TotEnc = 0
            End If

            'COMPUTE SUBLEGAL POPULATION FOR STOCK
            ' FOR FISHERIES WITH SUBLEGAL ENCOUNTERS
            ' USE ONLY STOCKS WITH CATCH IN THIS FISHERY

            If TotEnc > 0 Then
                For STk = MinStk To MaxStk



                    If StockCatchProp(STk, Fish) > 0 Then ' catch of this stock in this fishery = 1 for OOB
                        TotSubLegalPop = 0
                            FishYear = BaseYear
                            For Age = 2 To MaxAge
                                CompLegProp()

PropSubPop(STk, Age) = CohortAll(STk, Age, TermStat, TStep) * SubLegalProp
TotSubLegalPop = TotSubLegalPop + PropSubPop(STk, Age)

                                FishSublegalPop = FishSublegalPop + TotSubLegalPop 'total sublegalpop summed
over stocks in a fishery tstep
         'StkinFishTS(STk) = CWTAll(STk, Age, Fish, TStep) + StkinFishTS(STk)
                                LegProp(STk, Age) = LegalProp
                            Next Age

                            If TotSubLegalPop > 0 Then
                                For Age = 2 To MaxAge
                        AgeProp(STk, Age) = PropSubPop(STk, Age) / TotSubLegalPop
                                Next
                            End If

                    End If ' stockCatchProp > 0
                Next STk 'end result for GalenMethod = 1 is # sublegals by stock and age as well as total
sublegal for fishery

                ' deal with stocks without sublegal population in a fishery, need to redistribute impacts over
remaining stocks




                    For STk = 1 To NumStk
                        For Age = 2 To MaxAge ' sum sublegals for a stock over ages
                            CompLegProp()
                            StkSubLegalPop(STk) = StkSubLegalPop(STk) + CohortAll(STk, Age, PTerm, TStep) *
SubLegalProp
                        Next Age
                    Next STk

                    For STk = 1 To NumStk
                        If StkSubLegalPop(STk) > 0 Then 'only add stock with sublegal pop > 0

                            NewTotSublegalPop = NewTotSublegalPop + StockCatchProp(STk, Fish)

                        End If
                    Next STk

                    For STk = 1 To NumStk
                        If StkSubLegalPop(STk) > 0 Then
```

```
                            For Age = 2 To MaxAge
                                NewStockCatchProp(STk) = StockCatchProp(STk, Fish) / NewTotSublegalPop
                            Next Age
                        End If
                    Next


                    SumSublegalStock = 0
                    For STk = 1 To NumStk

                        'If StkinFishTS(STk) > 0 Then

                        If StockCatchProp(STk, Fish) > 0 Then
'JON VERSION ########################################
                            For Age = 2 To MaxAge

                                If CohortAll(STk, Age, 0, TStep) * LegProp(STk, Age) <> 0 Then
                                    LegalRate(Age) = CWTAll(STk, Age, Fish, TStep) * EscExpFact(STk) /
(CohortAll(STk, Age, 0, TStep) * LegProp(STk, Age))

                                Else
                                    LegalRate(Age) = 0
                                End If
                            Next
                            For Age = 2 To MaxAge
'if legal expl.rate is > 0 for age, set it as sublegal exploitation rate
                                If LegalRate(Age) > 0 Then

                                    SubLegalRate(Age) = LegalRate(Age)
                                Else
                                    'if LegalRate(Age) is 0:
                                    '   set SubLegalRate(Age) to 0 if LegalProp(Age) is > 0.5
                                    '   otherwise move to Age+1
                                    '       if LegalRate(Age+1) > 0 then SubLegalRate(Age) = LegalRate(Age+1)
                                    '       if LegalRate(Age+1) = 0 then SubLegalRate(Age) = 0 if
LegalProp(Age+1) is > 0.5
                                    '   otherwise move to Age+2, etc...
                                    For newage = Age To MaxAge
                                        If LegalRate(newage) <> 0 Then

                                            SubLegalRate(Age) = LegalRate(newage)
                                            newage = 5
                                        Else
                                            SaveAge = Age
                                            Age = newage

                                            If LegProp(STk, Age) > 0.5 Then
                                                SubLegalRate(SaveAge) = 0
                                                newage = 5
                                            End If
                                            Age = SaveAge

                                        End If
                                    Next
                                End If

                                SublegalStock(STk, Age) = 0

                                If 1 - LegProp(STk, Age) <> 0 Then
                                    SublegalStock(STk, Age) = PropSubPop(STk, Age) * SubLegalRate(Age)
                                    SumSublegalStock = SumSublegalStock + SublegalStock(STk, Age)
                                End If
                            Next 'age

                        End If
                        'End If 'stock in fish
                    Next 'stock

                    For STk = 1 To NumStk
                        For Age = 2 To MaxAge
                            If SumSublegalStock > 0 Then
                                SublegalPPN(STk, Age) = SublegalStock(STk, Age) / SumSublegalStock
                                ShakerAll(STk, Age, Fish, TStep) = TotEnc * SublegalPPN(STk, Age) *
ShakMortRate(Fish, TStep)
                                'ShakerAll(STk, Age, Fish, TStep) = TotEnc * SublegalPPN(STk, Age) 'Encounters

                            Else
' when size limit is small this method will not produce any sublegals
                                ShakerAll(STk, Age, Fish, TStep) = TotEnc * AgeProp(STk, Age) *
ShakMortRate(Fish, TStep) * NewStockCatchProp(STk)
'ShakerAll(STk, Age, Fish, TStep) = TotEnc * AgeProp(STk, Age) * NewStockCatchProp(STk) 'Encounters
```

```
                    End If
                Next
            Next
        End If 'Tot Enc > 0
    End If ' Tot Catch > 0
End Sub
```