Correction to FRAM Algorithms for Modeling Size Limit Changes

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September 16, 2013

Pacific Fisheries Management Council
Salmon Methodology Review
October 1-3, 2013

Abstract

The Fishery Regulation Assessment Model (FRAM) for Chinook salmon was originally designed to allow for evaluation of changes in fishery catches and stock impacts resulting from changes in minimum size limit regulations. Changes in minimum size limits occur infrequently in many hook and line salmon fisheries. In recent years, changes in minimum size limits for Chinook salmon in Puget Sound sport fisheries have been discussed during pre-season management meetings. As part of these discussions, the FRAM methodology and supporting data was reviewed and determined to be flawed in its ability to accurately evaluate changes in size limits.

FRAM uses different rates to model encounters of legal and sublegal fish. These rates are computed during the calibration process and are based on landed catch and encounter information during the base period years (1976-1984). As such, they reflect the size limit conditions as they existed at the time.

When size limits are modeled in FRAM, each fish smaller than the size limit is treated as a sublegal fish. Sublegal encounter rates are used to compute releases and release mortalities. Conversely, each fish larger than the size limit is deemed legal and legal encounter rates are used to estimate catch as well as releases and release mortalities in mark selective fisheries. As the size limit is changed, a portion of the population (with sizes between the old and the new size limit) that previously received a sublegal encounter rate will receive a legal encounter rate or vice versa. This leads to the total number of computed encounters varying with size limits, an incorrect outcome, if effort remains constant.

At the 2012 Salmon Methodology Review, WDFW presented a method to fix this known FRAM problem. The corrected equations hold total encounters constant, regardless of the modeled size limit. In a first round of evaluations FRAM computes the encounters under base period size limits and then adjusts encounters computed under new size limit regulations to match the original encounters.

Several issues were raised by the Statistical and Scientific Review Committee (SSC) at last year's meeting. The main concern was the change in mortalities for all fisheries that had experienced size limit changes since the base period, causing significant increases in exploitation rates of key listed stocks. Additionally, there was a general discomfort with FRAM's sublegal encounter rates. It was decided that WDFW should investigate how to model size limit changes through an "external to FRAM approach" based on recent field data (i.e., length-frequency data for all Chinook encounters in recreational test fisheries) to estimate impacts to sublegal and legal sized Chinook. During the 2013 pre-season process, encounters of sublegal Chinook in Puget Sound sport fisheries were modeled using this "external approach" in conjunction with recent year field data.

For the October 2013 Salmon Methodology Review , the Model Evaluation Workgroup (MEW) has been tasked with incorporating recent information on sublegal encounters for all fisheries for which data exist. Along with this assignment, we revisited last year's size-limit methodology, because updating sublegal encounters remedies to some extent FRAM's internal sublegal encounter rates as well as the exploitation rate changes for key stocks. Because encounters would be calibrated to recent year observations under the proposed approach, those fisheries that experienced size limit changes since the base period would no longer need to be adjusted.

The size limit correction method described here would be an interim measure until a new Chinook FRAM calibration allows incorporation of new size limit algorithms. A comparison of sublegal and legal encounters (all stocks combined) for changing the Puget Sound sport fishery minimum size limit of 22 inches to 20 inches is shown as an example. During development of the new Chinook FRAM Base Period

data set and corresponding model calibration we would also revisit algorithms dealing with how FRAM distributes sublegal impacts over stocks and ages.

Introduction

During the 2013 North of Falcon/PFMC pre-season process several size limit proposals were discussed for Puget Sound sport fisheries. Ultimately, none of these were adopted, but new size limit proposals will likely be considered again for the 2014 season.

FRAM's algorithms for evaluating size limit changes are problematic, because two different rates are used to calculate the mortality of sublegal and legal Chinook. Sublegal fish are assigned a sublegal encounter rate and legal fish, a different, legal exploitation rate. The status of a fish as legal versus sublegal is a function of the size limit. If a fish is greater than the size limit it is considered legal and can be retained, unless there are additional restrictions as in mark selective fisheries. A fish that is smaller than the size limit is considered sublegal and must be released.
The mortality of encounters is computed as:

$$\text{Mortality}_{\text{Legal}} = \text{Abundance} * \text{Proportion Legal} * \text{FisheryScalar} * \text{LegalEncounterRate}$$
$$\text{Mortality}_{\text{Sublegal}} = \text{Abundance} * \text{ProportionSublegal} * \text{FisheryScalar} * \text{SublegalEncounterRate} * \text{ReleaseMortalityRate}$$

Legal encounter rates under base period size limits were calculated for each stock, age, fishery and time step using CWT recoveries. Sublegal encounter rates were developed for each fishery using the relationship between landed catch and sublegal release information from several data sources such as interview data, log books, observer programs etc. These rates are computed during the calibration process and are based on data collected from the base period years (1976-1984).

When the size limit is changed the proportion of the fish between the old and the new size limit will experience a different encounter rate (Figures 1-3). Hence the number of encounters changes with the size limit. All things being equal, this is an incorrect outcome, as the size limit is evaluated after a fish is encountered and should therefore not influence the number of encounters.

Figure 1. Encounters as a function of cohort size and size limit dependent encounter rates. BP SL is the base period size limit.

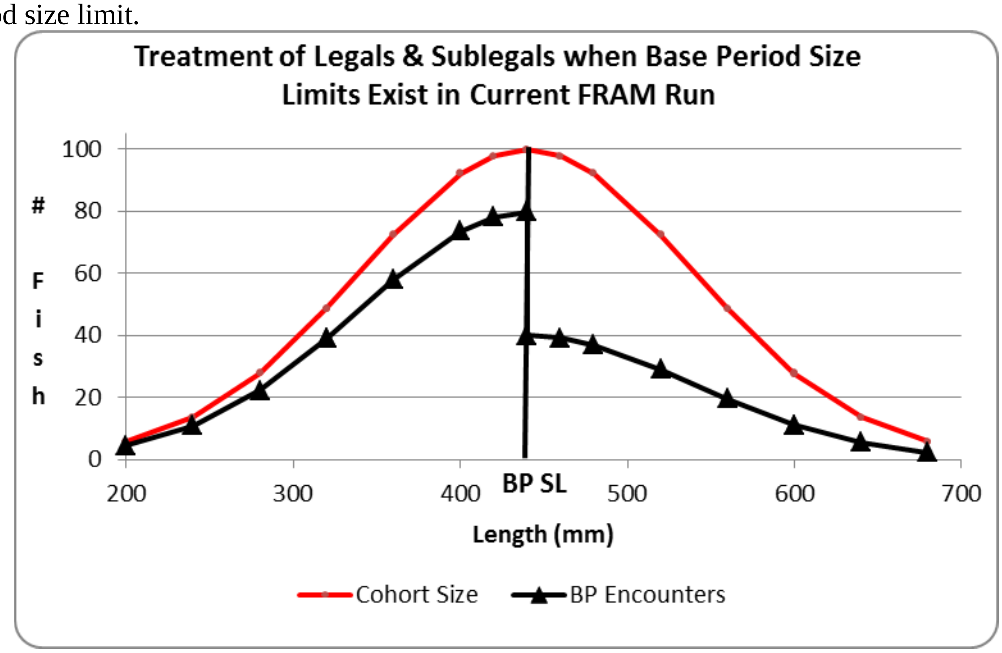


Figure 2. Treatment of Legals and Sublegals when the New Size Limit (FRAM SL) is smaller than the Base Period Size Limit. The blue striped area designates the catch that FRAM is underestimating when the size limit is lowered.

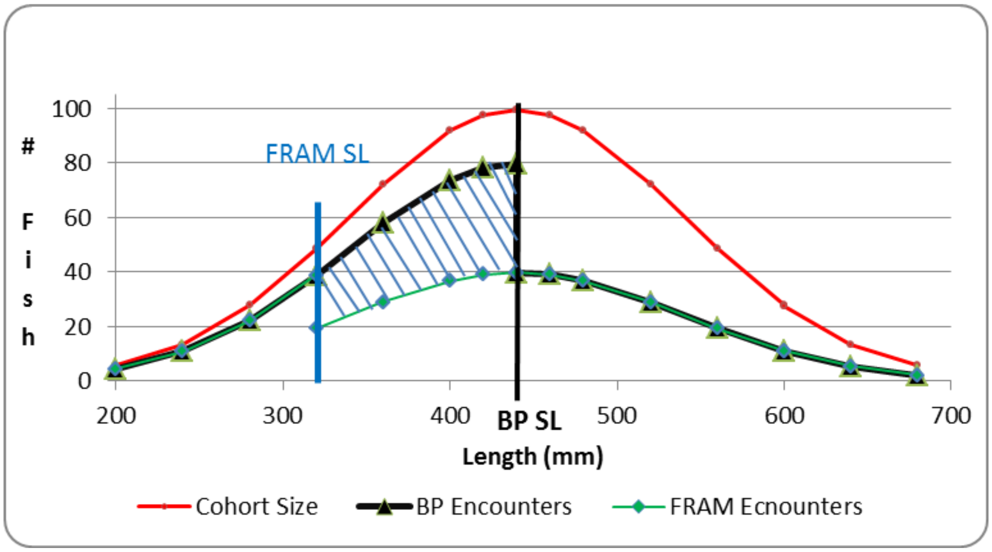
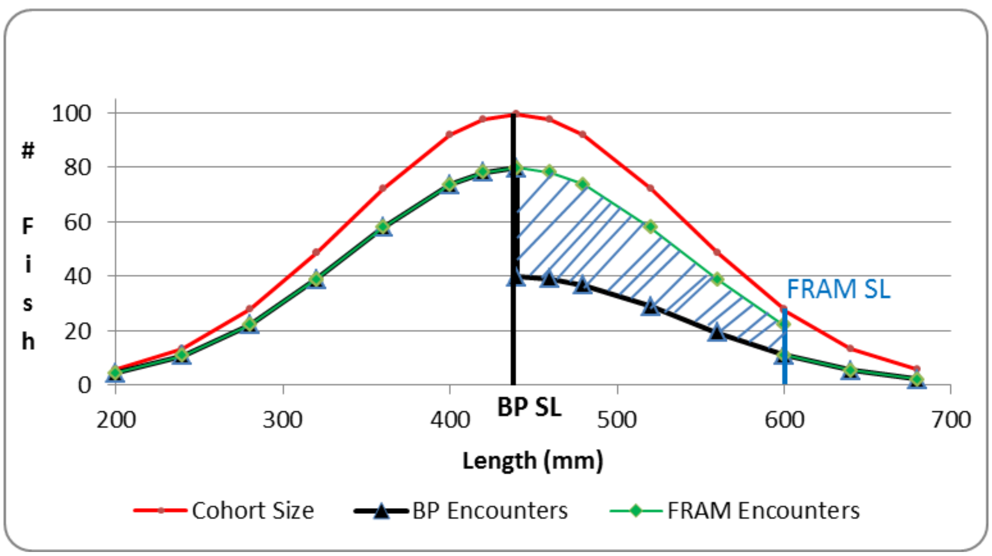


Figure 3. Treatment of Legals and Sublegals when the New Size Limit is larger than the Base Period Size Limit. The blue striped area designates the number of encounters that FRAM is overestimating when the size limit is increased.



The proposed size limit correction recalculates encounters in the area between the old size limit and the new size limit to match those under base period size limit regulations. For each fishery with size limit changes since the base period, the encounters computed with the size limit correction match encounters under base period size limits, regardless of what minimum size limit is specified, but are different from the encounters in the “uncorrected” FRAM.

Unfortunately, this change in encounters produces significant increases in exploitation rates on key natural stocks, such as mid-Hood Canal and Lower Columbia River natural Chinook, even if no size limits or other fishery inputs (i.e., scalars, quotas, etc.) are changed. This change was difficult to justify, because FRAM encounter estimates frequently do not match recent sampling observations, which WDFW and other agencies have been collecting for many years via angler interviews, on board observer programs, test fisheries, log books, and trip reports. Given the availability of these data, it was decided that it would be more prudent to update sublegal encounters before implementing the size limit correction. For 2013 pre-season modeling, WDFW used these data sources to produce recent relationships between legal and sublegal encounters in order to adjust FRAM computed sublegal encounters in Puget Sound sport fisheries. The MEW was tasked with expanding this approach to all fisheries for which data exist. In conjunction with the sublegal encounters modeling update (reviewed in McHugh et al. document), we propose that the size limit correction be reconsidered for use during 2014 preseason modeling, albeit on a reduced basis. Specifically, we propose that the algorithm only be applied to fisheries for which alternative minimum size limits are being considered given that fishery-level patterns of sublegal encounters will, in a sense, be 'recalibrated' to recent data in all fisheries with size limits differing from base period values. In the following sections, we (1) briefly review the basic algorithms and parameters associated with FRAM's consideration of size limits, (2) characterize the new (and improved) size limit correction, (3) consider the effects of implementing the correction on key modeling outputs, and (4) verify the realism of the correction by comparing model projections of changes in catch relative to what test fishery data suggest might occur.

Methods

FRAM Encounter Algorithms

FRAM models legal and sublegal Chinook encounters through the use of the von Bertalanffy growth equation for stocks that contribute to each fishery. The mean size of each stock at the midpoint of the time step is evaluated against the stock-specific growth equation to estimate the proportion vulnerable by stock, age, and time step. The algorithms from the PFMC (2008) (pgs. 18-19) FRAM documentation are as follows:

(27) $KTime_{s,a,t} = (Age_s - 1) \times 12 + \overbrace{MidTimeStep(Months)}$

(28) $MeanSize_{s,a,t} = \overbrace{L_s} \times (1 - (\exp(-\overbrace{K_s}) \times (\overbrace{KTime_{s,a}} - \overbrace{T0_s})))$

(29) $StdDev_{s,a,t} = \overbrace{CV_{s,a}} \times \overbrace{MeanSize_{s,a,t}}$

(30) $PV_{s,a,t} = 1 - NormalDistr(\underbrace{Minsize_{f,t}}, \overbrace{Meansize_{s,a,t}}, StdDev_{s,a})$

where:

$KTime_{s,a}$	=	Time for estimate of growth equation for stock ***s***, age ***a***,
$PV_{s,a,t}$	=	Percent Vulnerable for stock *s*, age *a*, at time step *t*,

L_s	=	Von Bertalanffy growth parameter for stock *s (Max Size)*,
K_s	=	Von Bertalanffy growth parameter for stock *s (Slope)* ,
$T0_s$	=	Von Bertalanffy growth parameter for stock *s (Time Zero)*,
$CV_{s,a}$	=	Coefficient of Variation of size distribution at $KTime_{s,a}$ for stock *s*, age *a*,
$MinSize_{f,t}$	=	Minimum Size Limit for fishery *f*, time step *t*, and
$MeanSize_{s,a,t}$	=	Mean total length of a fish of stock *s* at age *a* at time step *t*.

The distribution of Chinook sizes by age at a particular time is assumed to be normal with a variance that was calculated using lengths from CWT recovery data. Evaluation of the normal distribution is done using a calculation method developed for the original WDF/NBS Chinook model.

(31) $Z = (\underbrace{MinSize_{f,t}} - \overbrace{Meansize_{s,a,t}}) \Big/ StdDev_{s,a}$

(32) $A1 = Z \times (0.000005383 \times Z + 0.0000488906) + 0.0000380036$

(33) $A2 = Z \times (A1 + 0.0032776263) + 0.0211410061$

(34) $A3 = 1/(1 + Z \times (Z \times A2 + 0.049867347))$

(35) $A4 = 1 - (0.5 \times A3^{16}) = PV_{s,a,t}$

For Chinook, the sublegal and legal size encounters are stock- and age- specific and are calculated using the von Bertalanffy growth curves described above. The calculations for sublegal sized Chinook are shown below:

(36) $SubLegProp_{s,a,t} = 1 - PV_{s,a,t}$

(37) $SubLegPop_{s,a,t} = Cohort_{s,a,t} \times SubLegProp_{s,a,t}$

(38) $SublegalMortality_{s,a,f,t} = \overbrace{SubER_{s,a,f,t}} \times SubLegPop_{s,a,t} \times \underbrace{FishScalar_{f,t}} \times \overbrace{RelRate_{f,t}}$

Where all components are defined previously and (1-$PV_{s,a,t}$) is the proportion of the cohort for stock *s*, age *a*, not vulnerable to the gear at time step *t* (for Chinook *PV* is function of von Bertalanffy growth curve).

Base Period Sublegal Encounter Rate Calculations

The Chinook FRAM base-period Sublegal Encounter Rate is calculated from the individual CWT-based stock catch estimates, externally estimated target sublegal encounter rates (i.e., sampling-based sublegal:legal encounter ratios), and stock/age sublegal population estimates. This methodology was used to match model estimates of sublegal encounters with observed base-period sublegal encounters and to estimate sublegal encounters for stock/age cohorts that did not have CWT recoveries in a fishery because of the minimum size limit restriction.

The sublegal encounter rates used in FRAM are computed in four major steps during the calibration (calibration program ChCal).

1. Compute Landed Catch by Fishery and Time Step

$$TimeCatch_{f,t} = \sum_{s,a} (BaseCWTRec_{s,a,f,t} * PEF_s)$$

2. Compute Sublegal Encounters by Fishery and Time Step

$$TotSubEnc_{f,t} = TimeCatch_{f,t} * TargetEncRate_{f,t}$$

3. Split Sublegal Encounters into Stocks and Ages[1]

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

$$PropSubPop_{s,a} = \frac{SubLegalPop_{s,a}}{SubLegalPop_s}$$

$$StockCatchProp_{s,f} = \frac{LandedCatch_{s,f}}{LandedCatch_f}$$

4. Compute Sublegal Encounter Rates

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

Where:

$TimeCatch_{f,t} = Base\ Period\ \ Catch\ by\ Fishery\ and\ Time\ Step$

$BaseCWTRec_{s,a,f,t} = Base\ Period\ CWT\ Recoveries\ by\ Stock, Age, Fishery, Time\ Step$

$PEF_s = Base\ Period\ Production\ Expansion\ Factor$

$TotSubEnc_{s,f} = Base\ Period\ Total\ SubLegal\ Encounters\ by\ Fishery\ and\ Time\ Step$

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[1] Methods for estimating the stock and age composition of sublegal encounters for a fishery and time step are under review for the new base period development. Because CWT returns could not be used to directly estimate the magnitude nor stock and age composition of the sublegals encountered, calculations of the sublegal encounter rate depend on fishery- and time step-specific Target Encounter Rates. This both decouples the legal and sublegal encounter rates for a stock/age combination and means the likelihood of a fish being encountered in FRAM depends on size limit regulations rather than ecology and fishing gear.

$TargetEncRate_{f,t}$ = *Base Period Target Encounter Rate Adjustment by Fishery, Time Step*

$PropSubPop_{s,a}$= *Proportion of the Sublegal Population of a Stock that is of a Given Age*

$SubLegalPop_{s,a}$= *Number of Sublegal fish of a Given Stock and Age*

StockCatchProp= Proportion of the Landed Catch of a Fishery that is of a Given Stock

$BaseShaker_{s,a,f,t}$ = *Base Period SubLegal Mortalities by Stock, Age, Fishery, Time Step*

$SubLegEnc_{s,a,f,t}$ = *Base Period SubLegal Encounters by Stock, Age, Fishery, Time Step*

$SubER_{s,a,f,t}$ = *Base Period SubLegal Encounter Rate by Stock, Age, Fishery, Time Step*

$SubLegalProp_{s,a,t}$=*Proportion of the Cohort that is Sublegal by Stock, Age, Time Step*

Proposed Evaluation of Minimum Size Limit Change

The method for calculating the Chinook FRAM base-period sublegal encounter rates does not allow for a simple algorithm to evaluate a change from the base-period minimum size limit. This is primarily due to the target sublegal encounter rate (TargetEncRate) and the stock/fishery catch proportion (StockCatchProp) variables used to calculate base-period encounters. The combination of these two variables results in an uneven distribution of legal and sublegal sized fish by stock and age for most fisheries and time steps. The simplest approach, and that which was presented during the 2012 model review, for evaluating a size limit change from the base period is to calculate the legal and sublegal encounters for both the base period and new minimum size limit and then adjust the differences so that total encounters remains constant. Encounter differences occur in the region between the base period size limit and the new minimum size limit (Figures 1-3).

When the new size limit is less than the base-period size limit, the difference in sublegal encounters between the base size-limit and the new size-limit becomes landed catch that is added to the calculated landed catch evaluated at the base-period size limit. Encounters are calculated by dividing the encounter estimates by the sublegal release mortality rate. The difference in encounters is used in this case because it incorporates the base-period sublegal encounter rates, which are always different than the base-period exploitation rates. It also allows for landed catch estimates for stock and age combinations that do not have base-period exploitation rates because of the base-period minimum size limit restriction. This adds an important element of realism because there are stock-age combinations that would not have appeared in landed catch under base period conditions, but may under the new limit. Importantly, this change also has the potential to produce modeling results that may otherwise seem counterintuitive (e.g., exploitation rate reductions for key stocks), as it allows for fishery quotas to be filled with stock-age combinations that were previously sublegal, thereby providing relief for others.

When the new size limit is greater than the base-period size limit, the difference in landed catch between the new size limit and the base-period size limit becomes sublegal encounters and is converted by multiplying sublegal encounters times the sublegal mortality rate. This encounter difference is added to the calculated sublegal encounters from the base-period size limit to get total sublegal encounter mortality. The difference in landed catch is used in this case because base-period CWT recoveries can be used to estimate an actual observed difference.

When New Size Limit is Less Than Base-Period Size Limit:

$$BaseSizeLimitSublegalEncounters_{s,a,f,t} = SubER_{s,a,f,t} * BaseSubLegalPop_{s,a,t} * RelRate_{f,t} * FishScaler_{f,t}$$

$$NewSizeLimitSublegalEncounters_{s,a,f,t} = SubER_{s,a,f,t} * NewSubLegalPop_{s,a,t} * RelRate_{f,t} * FishScaler_{f,t}$$

$$BaseSizeLimitEncounters_{s,a,f,t} = BaseSizeLimitSublegalEncounters_{s,a,f,t} / RelRate_{f,t}$$

$$NewSizeLimitEncounters_{s,a,f,t} = NewSizeLimitSublegalEncounters_{s,a,f,t} / RelRate_{f,t}$$

$$SublegalEncounterDiff_{s,a,f,t} = BaseSizeLimitEncounters_{s,a,f,t} - NewSizeLimitEncounter_{s,a,f,t}$$

$$BaseSizeLimitCatch_{s,a,f,t} = Cohort_{s,a,t} * BPER_{s,a,f,t} * FishScalar_{f,t} * BasePV_{s,a,t} * SHRS_{s,f,t}$$

$$\boxed{LandedCatch_{s,a,f,t} = BaseSizeLimitCatch_{s,a,f,t} + SublegalEncounterDiff_{s,a,f,t}}$$

Then if MSF apply MSF Calculations (PFMC-2007) by stock type (Marked and Un-Marked)

Where:

$BaseSizeLimitSublegalEncounters_{s,af,t} =$ $Sublegal\ encounters\ evaluated\ at\ Base\ Period\ Size\ Limit$

$NewSizeLimitSublegalEncounters_{s,af,t} = Sublegal\ encounters\ evaluated\ at\ New\ Size\ Limit$

$BaseSubLegalPop_{s,a,t} = SubLegal\ Population\ evalauted\ at\ Base\ Period\ Size\ Limit$

$BaseSizeLimitEncounters_{s,af,t} =$ $BaseSizeLimitSublegalEncounters\ divided\ by\ Release\ Mortality\ Rate$

$NewSizeLimitEncounters_{s,af,t} =$ $FRAM\ Sublegal\ Encounters\ divided\ by\ Release\ Mortality\ Rate$

$SublegalEncounterDiff_{s,a,f,t} = Difference\ between\ Base\ and\ New\ Size\ Limit\ Encounters$

$BaseSizeLimitCatch_{s,a,f,t} = FRAM\ Landed\ Catch\ at\ Base\ Period\ Size\ Limit$

$BasePV_{s,a,t} = Proportion\ Vulnerable\ evaluated\ at\ Base\ Period\ Size\ Limit\ by\ Stock, Age, Time$

$RelRate_{f,,t}$ = Release Mortality Rate

Remaining variables are described in PFMC, 2008.

When New Size Limit is Greater Than Base-Period Size Limit:

$$BaseSizeLimitCatch_{s,a,f,t} = Cohort_{s,a,t} * BPER_{s,a,f,t} * FishScalar_{f,t} * BasePV_{s,a,t} * SHRS_{s,f,t}$$

$$NewSizeLimitCatch_{s,a,f,t} = Cohort_{s,a,t} * BPER_{s,a,f,t} * FishScalar_{f,t} * PV_{s,a,t} * SHRS_{s,f,t}$$

$$BaseSizeLimitSublegalEncounters_{s,a,f,t} = SubER_{s,a,f,t} * BaseSubLegalPop_{s,a,t} * {}^{RelRate_{f,t}} * FishScaler_{f,t}$$

$$SublegalEncoutners_{s,a,f,t} = BaseSizeLimitSublegalEncounters_{s,a,f,t} + (BaseSizeLimitCatch_{s,a,f,t} - NewSizeLimitCatch_{s,a,f,t}) * RelRate_{f,t}$$

The size limit modeling approach proposed for use during preseason 2014 modeling follows the methods outlined above, with one important difference. The algorithm's implementation will no longer hinge upon whether a given fishery's size limit differs from what was in effect during the base period, a departure in methodology facilitated by the recalibration of sublegal encounter rates to those observed under recent minimum size limits (PFMC 2013). Thus, the computations required to maintain constant encounters when size limits are increased or decreased will reference the size limit(s) in effect during the years used to update the sublegal encounter rates.

Results

FRAM validation runs for 2003 to 2010 fishing years were adjusted to produce updated sublegal/legal ratios. All fisheries in these model runs were converted to scalar fisheries (rate based fisheries) in order to prevent fixed (quota) fishery inputs from interfering with the evaluation of new size limit regulations. Results of these model runs were reported in "Incorporating Recent Empirical Information on Sublegal Encounters into FRAM Modeling" (PFMC, 2013). These runs were then used to model size limit changes with the new size limit methodology described here. Size limits for Puget Sound marine sport fisheries (mark-selective and nonselective) were altered from 22 in. (55 cm) total length (52 cm fork length, the modeled FRAM value) to 20 in. (51 cm) total length (48 cm fork length, the modeled FRAM value). When the new size limit is smaller than the reference size limit, the size limit correction adjusts the landed catch by the difference in sublegal encounters between a run at reference size limits and a run at new size limit.

The size limit correction produces encounters at 20 in. that closely match the number of encounters at 22 in. The sum of the sublegal and legal Chinook should be identical. Small differences are due to time step effects and rounding issues in FRAM (Tables 1-2).

Table 1. Comparison of Chinook Encounters at 22 in. and 20 in. Size Limits in the Summer (Time 3)

Average Encounters (2003-2010) Time 3

	22"			20"		
Area	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
7	1188	1980	0.600	1019	2147	0.475
5	3816	4034	0.946	3395	4449	0.763
8.1/8.2	0	0		0	0	
9	3816	4034	0.946	3395	4449	0.763
6	75	2212	0.034	66	2220	0.030
10	2218	1813	1.223	1967	2062	0.954
11	4898	7652	0.640	4421	8118	0.545
12	2058	1213	1.696	1783	1484	1.202
13	2407	1633	1.474	2230	1807	1.234

Figure 4. FRAM Chinook Encounters of Sublegals and Legals in Puget Sound Marine Sport Fisheries at 22 inch and 20 inch Size Limits in the Summer (Time 3)

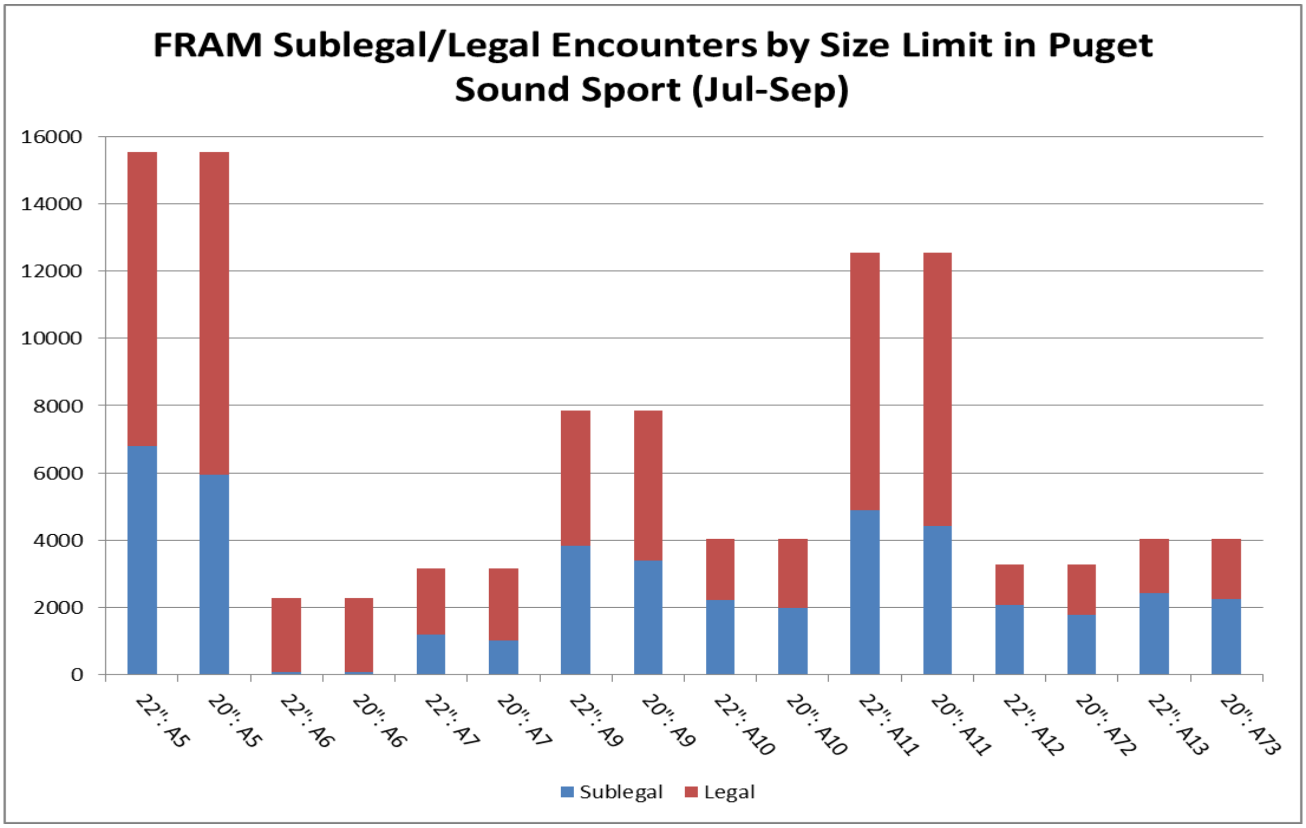


Table 2. Comparison of Chinook Encounters at 22 in. and 20 in. Size Limits in the Winter (Time 4)

Average Encounters (2003-2010) Time 4

Area	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
7	494	2041	0.242	442	2089	0.211
5	4185	1663	2.517	3745	2099	1.784
8.1/8.2	6103	1673	3.648	5459	2316	2.357
9	4185	1663	2.517	3745	2099	1.784
6	787	744	1.058	705	824	0.856
10	7006	1148	6.104	6258	1895	3.303
11	1397	712	1.963	1251	858	1.458
12	2255	681	3.313	2010	924	2.176
13	1002	119	8.393	898	224	4.011

Figure 5. FRAM Chinook Encounters of Sublegals and Legals in Puget Sound Marine Sport Fisheries at 22 inch and 20 inch Size Limits in the Winter (Time 4)

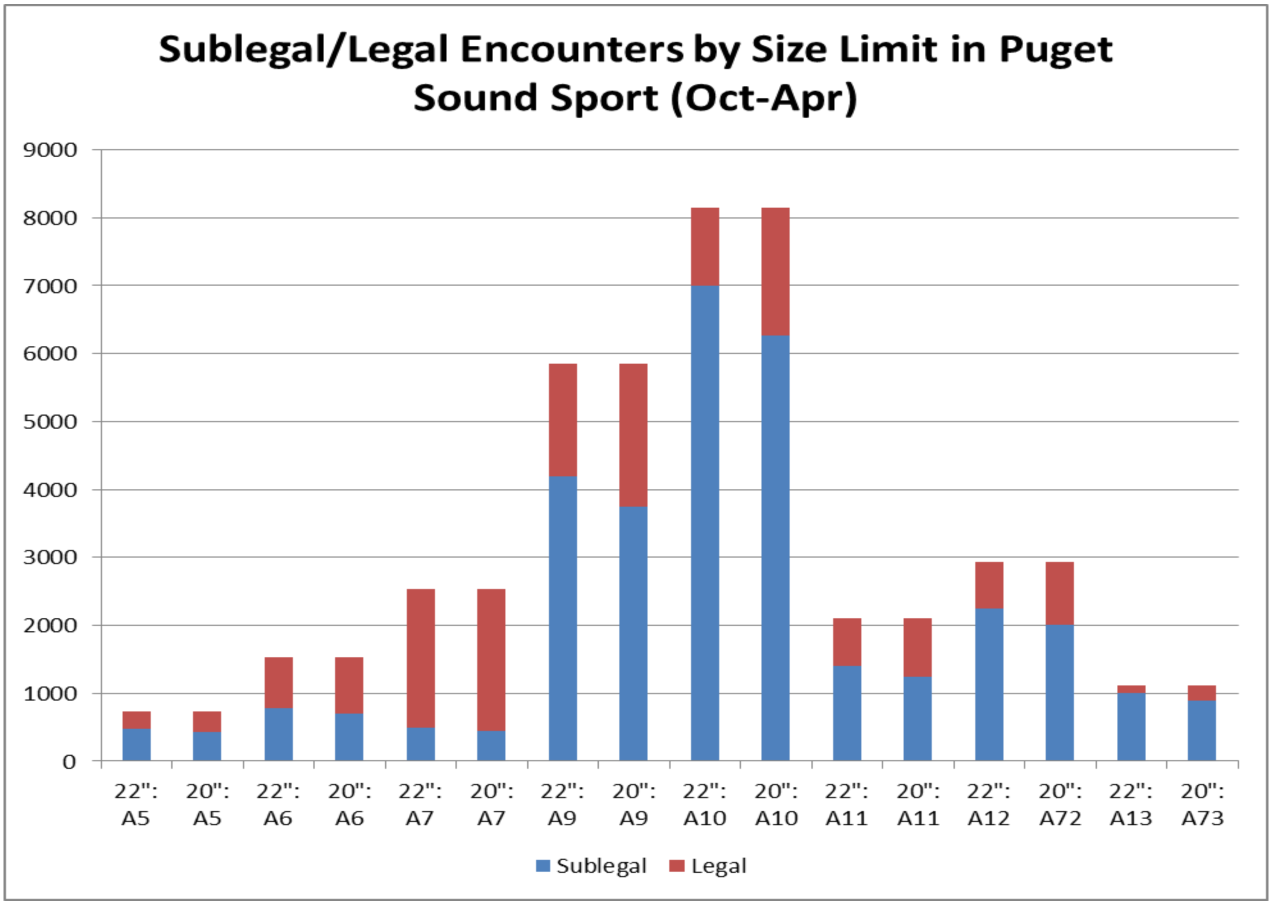
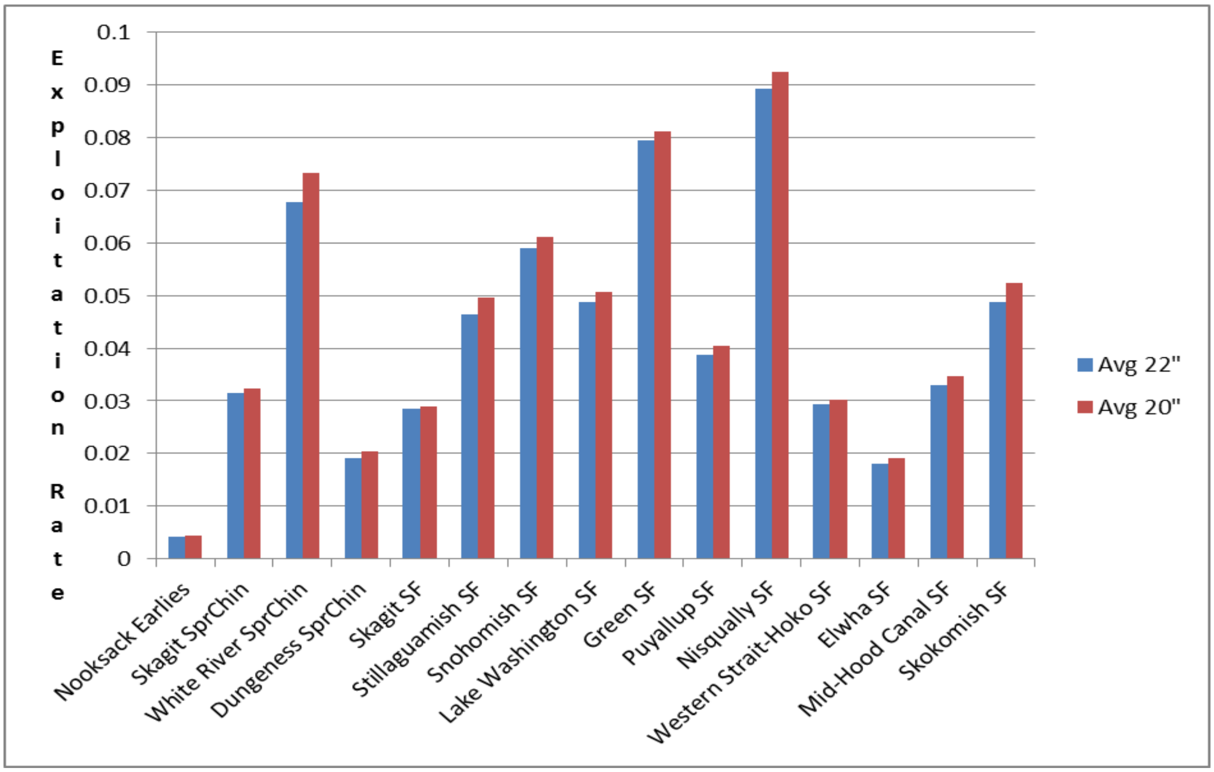


Table 3. 2003-2010 Average Exploitation Rates in Puget Sound Marine Sport at 22 in. and 20 in. Size Limits

Puget Sound Chinook Stocks	2003-2010			
	Avg 22"	Avg 20"	Avg Relative Increase	Avg Absolute Increase
Spring/Early:				
Nooksack (n)	0.424%	0.438%	3.4%	0.014%
Skagit (n)	3.139%	3.230%	2.9%	0.091%
White	6.772%	7.316%	8.0%	0.543%
Dungeness	1.918%	2.034%	6.0%	0.115%
Summer/Fall:				
Skagit	2.860%	2.892%	1.1%	0.032%
Stillaguamish (n)	4.648%	4.962%	6.7%	0.314%
Snohomish (n)	5.900%	6.102%	3.4%	0.202%

Lake Wa. (Cedar R.)	4.878%	5.054%	3.6%	0.175%
Green	7.942%	8.113%	2.2%	0.171%
Puyallup	3.875%	4.051%	4.5%	0.176%
Nisqually	8.921%	9.244%	3.6%	0.323%
Western Strait-Hoko	2.938%	3.013%	2.6%	0.075%
Elwha	1.808%	1.914%	5.8%	0.105%
Mid-Hood Canal tribs. (n)	3.293%	3.465%	5.2%	0.172%
Skokomish	4.883%	5.236%	7.2%	0.353%

Figure 4. 2003 to 2010 Average Exploitation Rates in Puget Sound Marine Sport at 22 in. and 20 in. Size Limits

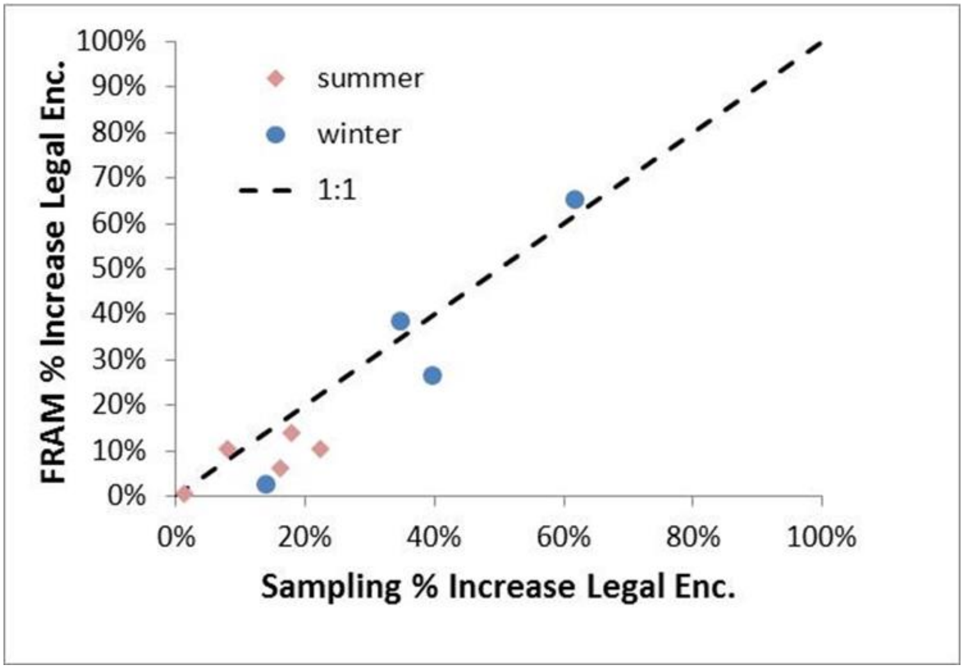


Reductions in size limits, particularly in non-selective fisheries, result in increases in exploitation rates (more fish are landed). Exploitation rate increases are typically quite small. The average exploitation rate increase for a change in size limit from 22 in. to 20 in. was 0.19% and ranged from 0.014% to 0.54% (Table 3, Figure 4).

In addition to verifying that the size limit correction held encounters constant and quantifying its effect on total ERs, we evaluated the accuracy of model-projected increases in total legal encounters at the fishery level. Length-frequency data from marine sport test fisheries were used to quantify the number of legal and sublegal Chinook encountered relative to 22 in. and 20 in. limits, and the corresponding relative increase in legal encounters that might be expected with the size limit reduction. The sampling data-projected increase in legal encounters with a size limit decrease, corresponds well with FRAM estimates (Figure 5). The average increase in legal encounters for the summer period is 8% using FRAM and 13%

using sampling data. The average increase in the winter period is 33% using FRAM and 38% using sampling data.

Figure 5. FRAM and Sampling Data Estimates of the Increase in Legal Encounters when Size Limit Changes from 22” to 20”



Discussion

Considerations and Issues Related to Size Limit Changes

FRAM has several modeling constants that are unique to sublegal and legal encounters. Since sublegal/legal status is determined by the size limit, a change in the size limit will cause a change in the designation for Chinook between the old and the new size limit and consequently a change in the rates that are unique to either sublegal or legal size fish. Thus, a modeling correction was needed in order to hold encounters constant across alternative minimum size limit scenarios, but it also affects other modeling parameters.

Drop-Off

Drop-off results when a fish is hooked, but lost before it is brought onboard or onshore. Drop-off mortality is computed as 5% of the legal encounters. When the size limit is decreased, legal encounters increase, resulting in an increase of drop-off mortality. The size limit correction does not address this issue. However, the increase in mortality is considered negligible and in the case of legal unmarked fish released in mark selective fisheries, other forms of mortality help to compensate for a potential under-estimate in mortality (see next paragraph).

Release Mortality

The release mortality in Puget Sound marine sport fisheries is 10% for legal Chinook and 20% for sublegal Chinook. In FRAM, each legal fish encountered is landed in a non-selective fishery. Differing release mortality rates can become an issue in mark-selective fisheries, where all unmarked fish are required to be released (legal and sublegal). Because the legal release mortality is smaller than the sublegal release mortality, fish between 22” and 20” will experience a lower release mortality rate when the size limit is reduced even though their fate is exactly the same (release in MSF). The size limit correction does not address this issue, because a correction would be complex and result in a minor change in the mortality estimate. Size limits have changed numerous times for many fisheries since the base period and have never resulted in adjustments to mortality rates such as these. The size limit change most likely to be considered for 2014 is relatively small (2" reduction) and for Puget Sound sport fisheries only, where a 20" size limit has existed previously. The studies used to develop the release mortality rates did not focus on size definitions of salmon ("A Review of Recent Studies of Hooking Mortality…"). Release mortality estimates are commonly considered to be rough estimates and do not lend themselves to differentiation of small changes in size limit.

Additionally, when unmarked fish between 20" and 22" inches get reassigned to "legal" status they also experience a 5% drop-off mortality and a variable unmarked retained rate. A portion of legal unmarked fish encountered are mistakenly retained in mark-selective fisheries. In the most recent FRAM model these rates varied between 1% and 8% depending on fishery and time step. At an unmarked retained rate of 5.56% effective legal and sublegal mortality rates are equal, resulting in constant mortality estimates for runs with different size limits. Thus, while reclassifying a fish from sublegal to legal introduces a lower release mortality rate, which may be of concern in ESA-related evaluations, there are compensating mechanisms that help to keep the realized mortality rate for that fish approximately constant (Table 4).

Table 4. Example of Sublegal and Legal Release Mortality Rates as a Function of % Unmarked Retained

UM Retained	0%	3%	6%	9%	12%
Drop-Off	5%	5%	5%	5%	5%
Legal RelMort	10%	10%	10%	10%	10%
Sublegal RelMort	20%	20%	20%	20%	20%
Effective Rate Legal	15%	17.7%	20.4%	23.1%	25.8%
Effective Rate Sublegal	20%	20%	20%	20%	20%

Mark Release Rate

A portion of the legal marked fish encountered in a mark-selective fishery are voluntarily released by anglers. Currently FRAM assigns a 13% release rate to legal marked fish encountered. It could be argued that this rate might increase if the size limit were to decrease, because a greater number of smaller and potentially less desirable fish would be legal. Again, the size limit correction does not address this issue, but data collected from mark-selective fisheries at new size limits would be analyzed post-season. If the data reveal an increase in the mark-release rate, or some underlying relationship between mark release rate and fish size, this modeling parameter would be adjusted in subsequent model runs.

Next Steps

The MEW is in the process of devising a new FRAM base period. For this base period, recent data will be analyzed with regard to the relationship between legal and sublegal encounters in order to update FRAM's sublegal encounter rates. Once these rates are updated and calibrated to recent size limits, adjustments (PFMC 2013) to sublegal encounters will no longer be necessary. In conjunction with updated sublegal/legal ratios also known as target encounter rates, modelers will also evaluate current procedures for assigning stock and age composition to sublegal encounters. Ideally a new calibration should go along with major changes in size limits.

The corrected size limit algorithms presented here should be applied whenever new size limits are adopted. Size limit proposals have only been put forward for Puget Sound fisheries and are currently not under consideration for ocean fisheries. The data collected from these new fisheries can then be used to make adjustments to sublegal/legal ratios for future modeling.

Pros and Cons of the Size Limit Correction

The biggest improvement of the new method is the consistency in total encounters for each of the size limits modeled. It allows the model to function as initially intended and provides an easy to apply framework for modeling size limit changes during the hectic preseason management period. The new method, when applied to updated sublegal encounters (PFMC 2013) produces acceptable and logical changes in exploitation rates and landed mortalities that agree fairly well with field data. On average landed mortalities are lower using FRAM than using estimates from field data. While the differences are generally small, it may be desirable for key Puget Sound sport fisheries to “pad” FRAM’s estimates of sublegal encounters to meet or exceed field estimates.

References

Pacific Fishery Management Council (PFMC). October 2008. Fishery Regulation Assessment Model (FRAM) – Technical Documentation for Coho and Chinook. Pacific Fishery Management Council, Salmon Document Library.

Pacific Fishery Management Council (PFMC). October 2008. Fishery Regulation Assessment Model (FRAM) – Base Data Development. Pacific Fishery Management Council, Salmon Document Library.

Pacific Fishery Management Council (PFMC). November 2012 C3a Attachment 5. Review of Modifications to Chinook FRAM Size Limit Algorithms Implemented to Allow Evaluation of Size Limit Changes. Pacific Fishery Management Council, Briefing Book.

Pacific Fishery Management Council (PFMC). November 13. Incorporating Recent Empirical Information on Sublegal Encounters into FRAM Modeling. Pacific Fishery Management Council, Briefing Book.

NWIFC, Puget Sound Treaty Tribes, and WDFW. August, 1993. “A Review of Recent Studies of Hooking Mortality for Chinook and Coho Salmon with Recommendations for Fishery Management and Future Research.”

Appendix

Appendix Table 1. Base Period and Current Size Limits by Fishery (converted to fork length in millimeters).

Fishery	Base Period				Current FRAM			
Fishery	Time 1	Time 2	Time 3	Time 4	Time 1	Time 2	Time 3	Time 4
SEAK Troll	670	670	670	670	670	670	670	670
SEAK Net	100	100	100	100	****	100	100	****
SEAK Sport	670	670	670	670	670	670	670	670
N/C BC Net	100	100	100	100	****	100	100	****
WCVI Net	100	100	100	100	100	100	100	100
GS Net	100	100	100	100	100	100	100	100
Canada JDF Net	100	100	100	100	100	****	100	100
Outside BC Sport	300	300	300	300	300	300	300	300
N/C BC Troll	620	620	620	620	670	670	670	670
WCVI Troll	620	620	620	620	550	550	550	550
WCVI Sport	620	620	620	620	600	600	600	600
GS Troll	480	480	480	480	620	620	620	620
No GS Sport	430	430	430	430	620	620	620	620
So GS Sport	430	430	430	430	620	620	620	620
BC JDF Sport	430	430	430	430	620	620	620	620
NT Area 3:4:4B Troll	670	670	670	670	****	670	670	****
T Area 3:4:4B Troll	570	570	570	570	570	570	570	570
NT Area 3:4 Sport	570	570	570	570	****	570	570	****
N Wash. Coastal Net	100	100	100	100	****	100	100	****
NT Area 2 Troll	670	670	670	670	****	670	670	****
T Area 2 Troll	670	670	670	670	****	570	570	****
NT Area 2 Sport	570	570	570	570	****	570	570	****
NT G. Harbor Net	100	100	100	100	****	****	100	****
T G. Harbor Net	100	100	100	100	****	****	100	****
Willapa Bay Net	100	100	100	100	****	****	100	****
Area 1 Troll	670	670	670	670	****	670	670	****
Area 1 Sport	570	570	570	570	****	570	570	****
Columbia River Net	100	100	100	100	100	****	100	100
Buoy 10 Sport	570	570	570	570	****	****	570	****
Central OR Troll	620	620	620	620	640	670	670	640
Central OR Sport	520	520	520	520	570	570	570	570

KMZ Troll	620	620	620	620	640	670	670	670
KMZ Sport	520	520	520	520	570	570	570	570
S. Calif. Troll	620	620	620	620	620	670	670	620
S. Calif.Sport	520	520	520	520	480	570	570	480
NT Area 7 Sport	480	480	480	480	520	520	520	520
NT Area 6A:7:7A Net	100	100	100	100	100	****	100	100
T Area 6A:7:7A Net	100	100	100	100	100	****	100	100
NT Area 7B-7D Net	100	100	100	100	100	****	100	100
T Area 7B-7D Net	100	100	100	100	100	****	100	100
T JDF Troll	520	520	520	520	520	520	520	520
NT Area 5 Sport	480	480	480	480	520	520	520	520
NT JDF Net	100	100	100	100	100	****	100	100
T JDF Net	100	100	100	100	100	100	100	100
NT Area 8-1 Sport	480	480	480	480	520	520	520	520
NT Skagit Net	100	100	100	100	100	****	100	100
T Skagit Net	100	100	100	100	100	100	100	100
NT Area 8D Sport	480	480	480	480	****	****	520	****
NT St/Snohomish Net	100	100	100	100	100	****	100	100
T St/Snohomish Net	100	100	100	100	100	100	100	100
NT Tulalip Bay Net	100	100	100	100	100	****	100	100
T Tulalip Bay Net	100	100	100	100	100	****	100	100
NT Area 9 Sport	480	480	480	480	520	520	520	520
NT Area 6 Sport	100	100	100	100	520	520	520	520
T Area 6B:9 Net	100	100	100	100	520	****	520	520
NT Area 10 Sport	480	480	480	480	520	520	520	520
NT Area 11 Sport	480	480	480	480	520	520	520	520
NT Area 10:11 Net	100	100	100	100	100	****	100	100
T Area 10:11 Net	100	100	100	100	100	****	100	100
NT Area 10A Sport	480	480	480	480	520	****	520	520
T Area 10A Net	100	100	100	100	520	****	520	520
NT Area 10E Sport	100	100	100	100	520	****	520	520
T Area 10E Net	100	100	100	100	520	****	520	520
NT Area 12 Sport	480	480	480	480	520	520	520	520
NT Hood Canal Net	100	100	100	100	100	****	100	100
T Hood Canal Net	100	100	100	100	100	****	100	100
NT Area 13 Sport	480	480	480	480	520	520	520	520
NT SPS Net	100	100	100	100	100	****	100	100
T SPS Net	100	100	100	100	100	****	100	100
NT Area 13A Net	100	100	100	100	100	****	100	100
T Area 13A Net	100	100	100	100	100	****	100	100
Freshwater Sport	100	100	100	100	100	****	100	100

Freshwater Net	100	100	100	100	****	100	100	****

Appendix Tables 2-18. Sublegal and Legal Encounters at 22 in. and 20 in. Size Limits by Area, Time Step, and Year

Area 7 Sport Time 3

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	1252	2087	0.600	1055	2282	0.462
2004	811	1351	0.600	694	1467	0.473
2005	946	1577	0.600	832	1690	0.492
2006	1231	2052	0.600	1063	2219	0.479
2007	1732	2886	0.600	1525	3091	0.493
2008	1087	1811	0.600	907	1987	0.457
2009	1456	2426	0.600	1257	2622	0.479
2010	988	1646	0.600	817	1814	0.450

Area 7 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	227	938	0.242	203	960	0.212
2004	140	577	0.242	125	591	0.211
2005	270	1115	0.242	242	1142	0.211
2006	520	2147	0.242	464	2200	0.211
2007	576	2381	0.242	515	2435	0.212
2008	691	2857	0.242	618	2925	0.211
2009	635	2624	0.242	570	2684	0.212
2010	893	3689	0.242	796	3779	0.211

Area 5 Sport Time 3

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	7009	9055	0.774	5857	10203	0.574
2004	9215	11906	0.774	8032	13083	0.614
2005	3791	4898	0.774	3446	5241	0.657
2006	6006	7760	0.774	5477	8286	0.661
2007	4955	6402	0.774	4339	7017	0.618
2008	4659	6019	0.774	4068	6605	0.616
2009	9626	12438	0.774	8605	13453	0.640
2010	8996	11622	0.774	7811	12802	0.610

Area 5 Sport Time 4

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	612	319	1.920	549	382	1.438
2004	244	127	1.920	217	151	1.434
2005	344	179	1.920	308	214	1.440
2006	509	265	1.920	457	318	1.436
2007	346	180	1.920	310	217	1.431
2008	605	315	1.920	540	376	1.436
2009	758	395	1.920	681	472	1.444
2010	449	234	1.920	400	279	1.434

Area 8.1/8.2 Sport Time 4

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	5811	1593	3.648	5180	2221	2.333
2004	4720	1294	3.648	4214	1799	2.343
2005	7902	2166	3.648	7066	3001	2.354
2006	7122	1952	3.648	6378	2695	2.367
2007	10325	2830	3.648	9235	3917	2.358
2008	5117	1403	3.648	4582	1937	2.366
2009	6489	1779	3.648	5821	2446	2.380
2010	1338	367	3.648	1194	510	2.339

Area 9 Sport Time 3

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	0	0		0	0	
2004	0	0		0	0	
2005	0	0		0	0	
2006	0	0		0	0	
2007	9270	9799	0.946	8194	10860	0.755
2008	7932	8385	0.946	7031	9265	0.759
2009	4994	5279	0.946	4535	5730	0.791
2010	8335	8812	0.946	7399	9735	0.760

Area 9 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	2784	1106	2.517	2488	1397	1.780
2004	3131	1244	2.517	2802	1573	1.781
2005	1744	693	2.517	1563	873	1.790
2006	7440	2956	2.517	6663	3729	1.787
2007	7315	2906	2.517	6534	3680	1.776
2008	3560	1414	2.517	3186	1787	1.783
2009	5865	2330	2.517	5258	2932	1.793
2010	1638	651	2.517	1465	823	1.781

Area 6 Sport Time 3

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	117	3435	0.034	98	3453	0.028
2004	93	2727	0.034	81	2737	0.030
2005	42	1233	0.034	38	1237	0.031
2006	28	819	0.034	25	820	0.031
2007	47	1378	0.034	41	1383	0.030
2008	39	1135	0.034	34	1141	0.030
2009	142	4163	0.034	127	4176	0.030
2010	95	2803	0.034	83	2815	0.029

Area 6 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	584	552	1.058	523	611	0.857
2004	328	310	1.058	293	343	0.855
2005	486	459	1.058	436	509	0.857
2006	1013	957	1.058	908	1062	0.855
2007	904	854	1.058	808	947	0.853
2008	751	710	1.058	674	788	0.856
2009	1363	1288	1.058	1223	1424	0.859
2010	868	820	1.058	776	908	0.854

Area 10 Sport Time 3

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	0	0		0	0	
2004	0	0		0	0	
2005	0	0		0	0	
2006	0	0		0	0	
2007	2855	2335	1.223	2492	2694	0.925
2008	2691	2200	1.223	2382	2504	0.951
2009	2755	2253	1.223	2495	2509	0.994
2010	9439	7718	1.223	8364	8788	0.952

Area 10 Sport Time 4

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	7075	1159	6.104	6323	1909	3.312
2004	4615	756	6.104	4129	1242	3.324
2005	3504	574	6.104	3144	934	3.366
2006	4334	710	6.104	3883	1162	3.343
2007	24321	3984	6.104	21667	6634	3.266
2008	6731	1103	6.104	6020	1812	3.322
2009	3764	617	6.104	3371	1006	3.351
2010	1705	279	6.104	1525	459	3.320

Area 11 Sport Time 3

	22"			20"		
Year	Sub Enc	Leg Enc	S/L Ratio	Sub Enc	Leg Enc	S/L Ratio
2003	5031	7861	0.640	4402	8474	0.519
2004	4155	6492	0.640	3759	6879	0.546
2005	3937	6150	0.640	3643	6439	0.566
2006	5149	8045	0.640	4785	8403	0.569
2007	9614	15023	0.640	8508	16107	0.528
2008	5922	9253	0.640	5363	9793	0.548
2009	2316	3619	0.640	2134	3798	0.562
2010	3057	4777	0.640	2777	5053	0.550

Area 11 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	1256	640	1.963	1123	772	1.454
2004	919	468	1.963	824	564	1.460
2005	1186	604	1.963	1063	726	1.466
2006	1991	1014	1.963	1787	1219	1.466
2007	2913	1484	1.963	2598	1798	1.445
2008	1033	526	1.963	925	633	1.463
2009	1389	708	1.963	1246	849	1.467
2010	489	249	1.963	438	299	1.461

Area 12 Sport Time 3

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	1582	933	1.696	1429	1082	1.321
2004	2647	1561	1.696	2346	1858	1.263
2005	3511	2070	1.696	2820	2755	1.023
2006	2439	1438	1.696	2017	1857	1.086
2007	3516	2073	1.696	3265	2319	1.408
2008	1206	711	1.696	1021	893	1.144
2009	960	566	1.696	859	665	1.292
2010	600	354	1.696	508	445	1.142

Area 12 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	1401	423	3.313	1254	570	2.199
2004	1266	382	3.313	1130	517	2.186
2005	1633	493	3.313	1442	684	2.109
2006	2448	739	3.313	2163	1022	2.117
2007	2296	693	3.313	2060	927	2.223
2008	2515	759	3.313	2239	1033	2.168
2009	4960	1497	3.313	4441	2013	2.207
2010	1517	458	3.313	1350	624	2.164

Area 13 Sport Time 3

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	2019	1370	1.474	1818	1566	1.161
2004	1599	1085	1.474	1477	1206	1.225
2005	2420	1642	1.474	2276	1784	1.275
2006	2862	1942	1.474	2713	2089	1.299
2007	5035	3416	1.474	4566	3876	1.178
2008	2299	1560	1.474	2143	1710	1.253
2009	1990	1350	1.474	1880	1459	1.288
2010	1032	700	1.474	969	763	1.270

Area 13 Sport Time 4

Year	22" Sub Enc	22" Leg Enc	22" S/L Ratio	20" Sub Enc	20" Leg Enc	20" S/L Ratio
2003	571	68	8.393	513	129	3.970
2004	604	72	8.393	542	135	4.015
2005	1074	128	8.393	963	237	4.054
2006	2342	279	8.393	2094	515	4.068
2007	1956	233	8.393	1748	448	3.904
2008	1251	149	8.393	1124	278	4.049
2009	218	26	8.393	202	50	4.064
2010	0	0		0	0	