Agenda Item H.1
Situation Summary
November 2009

2009 SALMON METHODOLOGY REVIEW

Each year, the Scientific and Statistical Committee (SSC) completes a methodology review to help assure new or significantly modified methodologies employed to estimate impacts of the Council's salmon management use the best available science. The Methodology Review is also used as a forum to review updated stock conservation objective proposals. This review is preparatory to the Council's adoption, at the November meeting, of all anticipated methodology and conservation objective changes to be implemented in the coming season, or in certain limited cases, of providing directions for handling any unresolved methodology problems prior to the formulation of salmon management options in March. Because there is insufficient time to review new or modified methods at the March meeting, the Council may reject their use if they have not been approved the preceding November.

This year the SSC is expected to report on an assessment of bias in the Fishery Regulation Assessment Model (FRAM) associated with multiple encounters during mark-selective fisheries (Agenda Item H.1.a, Attachment 1), an assessment of fall ocean salmon fisheries south of Cape Falcon (Agenda Item H.1.a, Attachment 2), an assessment of the September 1 maturity boundary for Klamath River fall Chinook (Agenda Item H.1.a, Attachment 3), and a proposal to update the conservation objectives for Puget Sound coho stocks (Agenda Item H.1.a, Attachment 4).

The Salmon Fishery Management Plan (FMP) allows conservation objectives to be updated without a formal FMP amendment, provided a comprehensive technical review of the best scientific information available provides conclusive evidence that, in the view of the Salmon Technical Team (STT), SSC, and the Council, justifies a modification. An exception is the 35,000 natural spawner floor for Klamath River fall Chinook which may only be changed by FMP amendment. Updating conservation objectives would potentially affect both the annual management process, by changing stock constraints, and the status determination process, by changing the evaluation criteria for triggering an overfishing concern or conservation alert. Table 3-1 in the FMP lists the conservation objectives and criteria for determining if an overfishing concern or conservation alert have been triggered (Agenda Item H.1.a, Attachment 5).

Council Action:

1. **Approve methodology changes as appropriate for implementation in the 2010 salmon season.**
2. **Approve updated conservation objectives and associated overfishing criteria for implementation in the 2010 salmon season.**
3. **Provide guidance, as needed, for any unresolved methodology issues.**

Reference Materials:

1. Agenda Item H.1.a, Attachment 1: Multiple Encounters in Salmon Mark Selective Fisheries: Bias Levels Introduced in FRAM Estimated Exploitation Rate of Unmarked Coho and Chinook Stocks.
2. Agenda Item H.1.a, Attachment 2: Assessment of fall ocean Chinook salmon fisheries south of Cape Falcon, Oregon.
3. Agenda Item H.1.a, Attachment 3: Is the September 1 river return date approximation appropriate for Klamath River fall Chinook?
4. Agenda Item H.1.a, Attachment 4: Proposed Updates for Puget Sound Coho Conservation Objectives.
5. Agenda Item H.1.a, Attachment 5: Salmon fishery Management Plan Table 3-1 Coho Excerpt.
6. Agenda Item H.1.b, STT Report.
7. Agenda Item H.1.b, MEW Report
8. Agenda Item H.1.b, NMFS Report
9. Agenda Item H.1.b, Supplemental SSC Report.
10. Agenda Item H.1.b, Supplemental SAS Report.

Agenda Order:

a. Agenda Item Overview — Chuck Tracy
b. Reports and Comments of Management Entities and Advisory Bodies
c. Public Comment
d. **Council Action**: Adopt Final Methodology Changes for 2010

PFMC
10/15/09

Multiple Encounters in salmon mark selective fisheries: bias levels introduced in FRAM estimated exploitation rate of unmarked coho and Chinook stocks.

MODEL EVALUATION WORKGROUP

September 21, 2009

Executive Summary

The Fisheries Regulation Assessment Model (FRAM) is the fishery simulation model currently used to assess impacts on Chinook and coho salmon in Council area fisheries including those designated as Mark Selective Fisheries (MSF). In MSF hatchery salmon without an adipose fin (fin clipped before release from the hatchery) can be retained while salmon with the fin are assumed to be wild and must be released. For small scale MSF the expectation is that multiple encounters would be minimal. However, an increasing array of MSF (from British Columbia through California marine and freshwater fisheries) raises concerns that multiple encounters should be a consideration in our fishery planning processes. Presently the FRAM algorithms maintain a linear relationship between marked and unmarked exploitation rates (of the same stock) within a single model time step. Multiple encounters of released unmarked salmon within a model time step would incur an additional fishing-related mortality causing a non-linear relationship, which presently is not accounted for in the FRAM .

To examine this issue the same MSF was run through two models. The FRAM and a Multiple Encounter Model (MEM) originally presented by Lawson and Sampson (1996). Results were compared between:

1. FRAM with the fishery in One Time Step.
2. FRAM with the fishery in two and three Time Steps.
3. MEM with disabled multiple encounter feature and disabled increasing release mortality rate (duplicating results from FRAM One Time Step).
4. MEM with the multiple encounter feature enabled.
5. MEM with the multiple encounter feature and increasing release mortality rate enabled.

We confirmed that when the MEM was run in mode without multiple encounters and without an increasing mortality rate that the MEM produced the same results as FRAM run as a one time step model. However, with these features enabled the MEM demonstrates how the exploitation rate on unmarked salmon increases faster than exploitation rate on marked salmon at increasing levels of MSF pressure. This bias will cause an underestimate of FRAM exploitation rates upon unmarked salmon. When the same fishery is modeled with FRAM over two or three Time Steps the bias was decreased as FRAM adjusts marked and unmarked abundance levels at the beginning of each model Time Step. At “low levels” of MSF there is negligible bias, but within a single Time Step the bias upon unmarked stock exploitation rate appears with a MSF impact of above 10% exploitation rate upon the marked stock component. With the fishery spread out over two or more Time Steps the bias upon an unmarked stock’s exploitation rate becomes apparent around the 30% MSF induced exploitation rate level on the marked stock component.

During the annual salmon fishery planning processes (Pacific Fishery Management Council and North of Falcon), fisheries are shaped to stay within allowable impacts upon wild stocks of coho and Chinook. These stocks are unmarked. The unmarked stock exploitation rates (or in some cases escapement) produced from FRAM modeling have been used as the metric of allowable impacts upon the wild stocks of concern. The results of this investigation suggest that past fishery impacts upon some wild coho stocks have been underestimated. We identified FRAM model modifications or other measures to account for the inaccuracy in unmarked exploitation rates potentially introduced by multiple encounters during mark selective fisheries.

Introduction

Every spring West coast salmon fisheries managers meet under the umbrella of the Pacific Fisheries Management Council (PFMC) to evaluate annual stock abundance forecasts and negotiate appropriate levels of coho and Chinook fisheries. The Fisheries Regulation Assessment Model (FRAM) is the planning tool used by the PFMC. A general description of this model is available as the 'Fishery Regulation Assessment Model (FRAM) – Overview for Chinook and Coho (MEW 2008a), produced by the PFMC's salmon Model Evaluation Workgroup (MEW). There are also companion documents available including 'Technical Documentation' (MEW 2008b) and descriptions of the construction of FRAM's coho Base Period (MEW 2007c) and the Chinook Base Period (MEW 2008d). These and other related reports of FRAM documentation are available from the PFMC website (http://www.pcouncil.org/salmon/salfram/salfram.html).

FRAM estimates stock-specific mortalities for any given set of fisheries, based upon a historic collection of Coded Wire Tag (CWT) recoveries from fisheries and escapements along the Pacific coast from California to Alaska (the "Base Period") (MEW 2007c and MEW 2008d). Hatchery stocks provide the great majority of recovered CWTs; FRAM functions with the assumption that wild stocks will distribute in time and space equal to representative tagged hatchery stocks from the same watershed. Thus wild fish were assumed to experience the same levels of fishery-related mortality as hatchery fish. With the advent of Mark-Selective Fisheries (MSF) this basic assumption was violated as unmarked hatchery and wild fish are released while the corresponding marked hatchery stocks are retained and removed from the population.

Coho MSF in the Washington and Oregon coastal fisheries have been implemented since 1998. At that time there were some modifications made to FRAM and to the coho Base Period to enable separate accounting of mortality for marked and unmarked fish. There have been corresponding changes to the Chinook Base Period to enable FRAM modeling of Chinook MSF; and has been used for Puget Sound marine MSF modeling. Chinook MSF have also been implemented in several river systems. There is the potential that Chinook MSF will be proposed for Council fisheries in the year 2010. The Council has not implemented larger scale ocean Chinook MSF due to the more complicated life history patterns of the various Chinook stocks, as compared to coho. Coho are susceptible to one season of MSF before returning to the rivers, while Chinook of the youngest age class could potentially be exposed to several successive years of MSF with increasing divergence between the hatchery-marked stocks and each corresponding unmarked wild stock. Management guidelines are based upon fishery impacts upon wild stocks.

At the November 2008, PFMC meeting the Council tentatively approved future "low impact' Chinook MSF in Council area ocean fisheries. This option was not exercised in 2009, but may be in subsequent years. At appropriate "low levels" MSF impacts upon marked and unmarked fish are similar, but diverge with increasing fishing pressure as demonstrated by a mark-selective fisheries model with the capability of estimating multiple encounters (Lawson and Sampson 1996). Based upon the Lawson paper, the PFMC's Scientific and Statistical Committee defined "low level" as less than a 30% Exploitation Rate (ER) in all MSF or 10% in a single MSF. The Lawson model uses instantaneous equations over essentially one fishery and one time step, while FRAM contains many fisheries and uses discrete catch equations for each of several model time steps during a fishing year (with natural mortality occurring at each time step). For these reasons it was unclear how "low level" MSF as suggested in the Lawson paper translate into a "low level" FRAM MSF.

Unmarked salmon released during a MSF have the possibility to be encountered multiple times within the same or subsequent MSF. If a fish sustained injury or stress from being caught and released, then there is also the possibly of increasing release-mortality rates for each subsequent encounter. Cumulative effects of anatomical and physiological trauma are possible. FRAM does not account for potential multiple encounters nor for increasing release-mortality rates. FRAM was originally created before the advent of MSF and has not been modified to reflect potential multiple encounters. This was a motivation for the Lawson and Sampson (1996) model which assigned random numbers to Marked and Unmarked fish in a closed population and subjected that population to varying rates of MSF with associated increases in release-mortality rates for multiple encounters. To better understand the application of results from Lawson's model to FRAM modeling, we recoded Lawson's model into Visual Basic (with Lawson's cooperation), duplicated Lawson's results, and made a few modifications to the code enabling the replication of many of FRAM's features. We will now refer to the modified Lawson model as the Multiple Encounter Model (MEM). The MEM can be run in a "FRAM mode" (however, only as a single Time Step), with multiple encounters turned on or off, and with increasing release-mortality rates on or off.

Methods

A Mark Selective sport fishery was run using a Multiple Encounter Model (MEM) in the following modes: multiple encounters turned OFF, multiple encounters ON, and multiple encounters ON with increasing release-mortality rates ON. FRAM model runs were made to confirm that the Multiple Encounter Model, with the multiple encounter feature OFF, duplicated FRAM's algorithms.

The algorithms for our Multiple Encounter Model are identical to Lawson and Sampson (1996) except we used a power function to calculate the increase in release-mortality rate with each successive encounter.

$$\boldsymbol{effective\ release\ mortality\ rate} = \boldsymbol{release\ mortality\ rate}^{\boldsymbol{b}^{\ \boldsymbol{number\ of\ times\ released}}}$$

Where *b* = multiple encounter mortality parameter (Figure 1). In the MEM simulations we used values of 0.0 or 0.843 for *b,* which are the equivalent of no increase and a 25% increase (Δ = 0.25 in Figure 4 of Lawson and Sampson 1996) in release-mortality rate with successive releases.

To allow direct comparisons between the MEM and FRAM model results, the parameter values in MEM were equated to those in the FRAM coho model (Table 1).

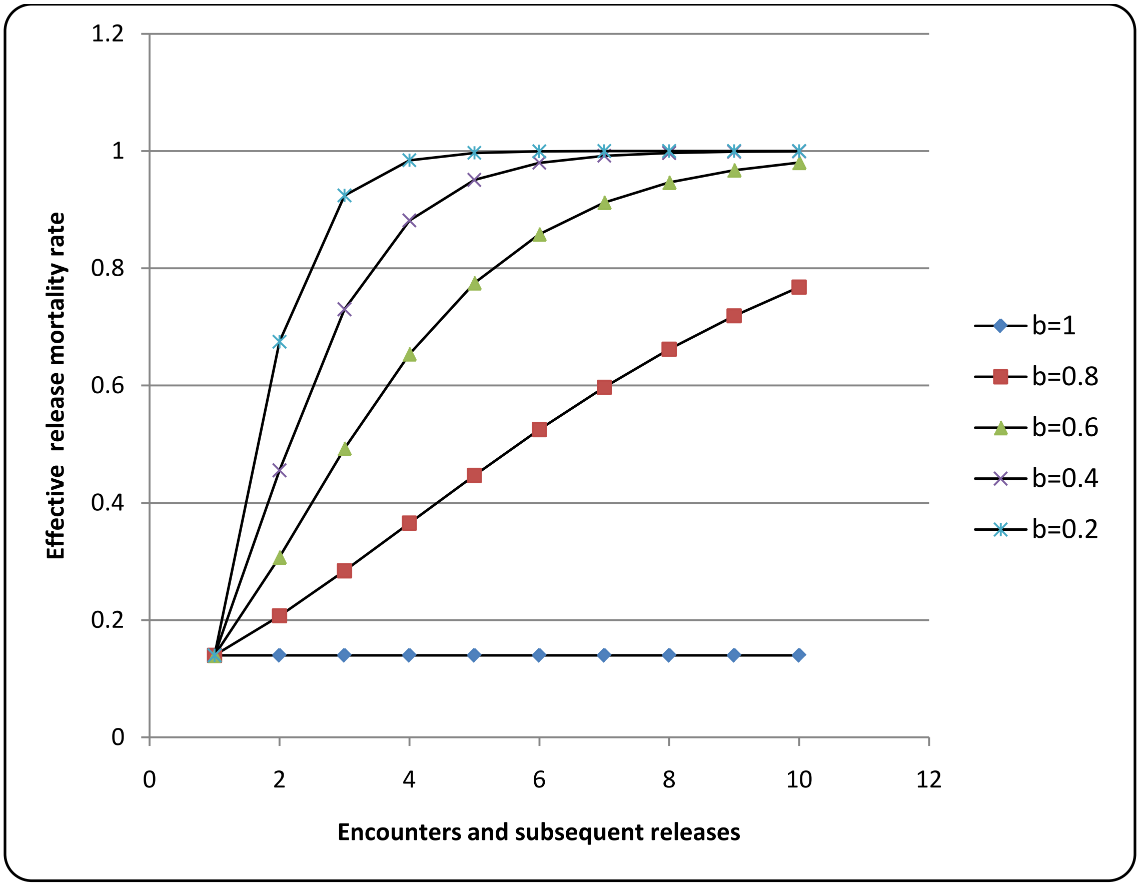

Figure 1. Increasing effective release-mortality rate as power function of successive releases (relationship for the initial WA ocean sport release mortality rate of 0.14).

Table 1. Parameter, variables, and values used in the selective fishery model.

parameter	**value**
b	Multiple encounter parameter that determined the increase in release-mortality rate with successive releases
Drop-off rate (α)	0.5
Drop-off mortality rate of (δ)	0.1 (α and δ together produce a drop-off mortality rate of 0.05 as in FRAM)
Effective release-mortality rate	Probability that a fish dies after one or more releases
Marked exploitation rate (marked ER)	marked fishing related mortalities/(marked fishing related mortalities + marked escapement)
Mark recognition rate (γ)	0.94
Natural Mortality Rate (between time steps)	0.020618 (as in coho FRAM)
Release-mortality rate (β)	0.14; Probability that a fish dies after its first release (as in FRAM)
Target marked harvest rate for defining the catch quota	Range of values of 0.1 through 0.6, 0.1 increments.
Unmarked exploitation rate (unmarked ER)	unmarked fishing related mortalities/(unmarked fishing related mortalities + unmarked escapement)
Unmarked recognition rate (ζ)	0.98

At the start of our selective fishery MEM model, there is a fish population with M marked and U unmarked fish. While the model is running, fish are selected at random and the ensuing chain of events depends on the following (see Table 2 for pseudo code). Does a fish encounter the gear? If so, did the fish "drop off" or escape the gear with a probability of α? If it escaped, did it succumb to gear-related injuries with a probability of δ? If it did not escape (probability = 1-α), did the fisher correctly recognize it as a marked or unmarked fish with a probability of γ and ζ respectively? If the fish was released either because the fisher recognized an unmarked fish or did not correctly recognize a marked fish, did the fish survive gear-related injuries with a probability of β? If the fish survived all of the above, it was returned to the population and the process was repeated until the marked target harvest rate was achieved. A running tally was maintained to record the numbers of releases per fish and type of mortalities at the 0.1, 0.2, … 0.6 marked harvest levels. Using outputs from the MEM model, unmarked and marked exploitation rates were calculated in the same manner as with FRAM output.

Total fishing-related mortality = drop-off mortality + release mortality + landed catch

Escapement = starting abundance – natural mortality – total fishing-related mortality

Coho FRAM has several monthly Time Steps during which significant ocean MSF may occur (July, August, and September). FRAM calculates total run by summing fishing-related mortalities and escapement. FRAM adjusts abundance for natural mortality at the start of each time step. The MEM runs as one continuous fishery which we arbitrarily assigned as occurring during the month of August (FRAM Time Step 3). To make exploitation rate calculations from the Multiple Encounter Model comparable to FRAM, the escapement was adjusted to account for natural mortality occurring in FRAM's Time Steps of Sept (Time Step 4) and Oct-Dec (Time Step 5):

$$\boldsymbol{Total\ run = Fishing\ related\ mortality + escapement \cdot (1 - natural\ mortality\ rate)^2}$$

$$\boldsymbol{ER = \frac{Total\ fishing\ related\ mortality}{Total\ run}}$$

To facilitate comparisons between FRAM and the MEM, we began the multiple-encounter modeling with stock specific abundances (marked and unmarked) taken from the PFMC Final coho pre-season 2009 FRAM model run. Entering the August Time Step there was a total of 385,560 Columbia River late stock coho salmon, with a 3.57 marked-to-unmarked ratio (population 78% marked) When a preliminary test with only two simulations took over 42 hours to complete, we searched for an optimal tradeoff between number of fish and number of simulations. Various combinations of total run sizes (2,000, 4,000, 4,570, 6,000, 7,000, 9,140, 11,430, 13,710, 14,000, 38,550, and 385,560) and number of simulations (10, 100, 1,000) were tested to find the smallest run size and least number of simulations that produced average observed release-mortality rates that were within 0.005 of those produced either by a maximum of 385,560 fish or a maximum of 1,000 simulations. Once we found the minimum number of fish and simulations to work with, we then modeled combinations of target marked harvest rates (0.1 through 0.6), marked proportions (0.5, 0.6, 0.67, 0.714, 0.75, and 0.78), and discrete release-mortality rates (0.14 and 0.26).

To further facilitate direct comparison to the MEM model results, FRAM modeling was reduced to only one mark-selective fishery (Area 1 sport) with the presence of only the Columbia River Late Coho stock. FRAM fish abundance levels were then proportionately reduced to be identical with the marked and unmarked coho abundances run through the different trials of the MEM model. The MEM catch input is in terms of target harvest rate (upon the marked abundance) producing a target quota. Note that some unmarked fish are also landed while some caught marked fish are released due to their respective mark recognition error rates (Table 1). FRAM catch input is usually a Total Quota, for either a MSF or a full retention fishery. For the purpose of these comparisons the FRAM catch quota inputs were the sum of landed fish, marked and unmarked, from the corresponding MEM runs.

Table 2. Model pseudo code for chain of events in mark selective fisheries and consequences.

1. Assign each fish in the population with a unique identification number and set its flag as either marked or unmarked according to the marked proportion.
2. Specify the release-mortality rate, e.g. 0.14 for ocean sport fisheries.
3. Specify the target marked harvest rates, e.g. 0.1, 0.2, …0.6
4. Initialize the number of encounters for each fish to zero.
5. Select a fish at random from combined pool of marked and unmarked fish (i.e. draw 1st random number – this simulates being caught by the gear)
6. If fish is alive then
    a. Draw 2nd random number from probability between 0 and 1. If probability <= drop-off rate (0.5) then
        i. Draw 3rd random number from probability between 0 and 1. If probability <= drop-off mortality rate (0.1) then
            a. Drop-off mortality (note in FRAM drop off rate and drop off mortality rate are combined in a single step, e.g. 0.05)
            b. Go to next fish
    b. Else not a drop-off and fish is unmarked then
        i. Draw 4th random number from probability between 0 and 1. If probability < unmarked recognition rate (0.98) then
            a. Unmarked fish is correctly identified and released
            b. Number of encounters(fish) + 1
            c. Effective release-mortality rate = β^ (b ^ number of encounters(fish))
            d. Draw 5th random number from probability between 0 and 1. If 5th random number < effective release-mortality rate then unmarked release mortality
            e. Go to next fish
        ii. Else unmarked fish incorrectly identified as marked
            a. unmarked fish landed by mistake
            b. Go to next fish
    c. Else not a drop-off and fish is marked then
        i. Draw 6th random number from probability between 0 and 1. If probability < mark recognition rate (0.94) then
            a. Marked fish correctly identified and landed
            b. Go to next fish
        ii. Else marked fish incorrectly identified as unmarked
            a. Marked fish released by mistake
            b. Number of encounters(fish) + 1
            c. Effective release-mortality rate = β^ (b ^ number of encounters(fish))
            d. Draw 7th random number from probability between 0 and 1. If probability < effective release-mortality rate then marked fish release mortality
            e. Go to next fish
7. Select another fish and continue until total landed fish = target marked harvest rate

Results

We first determined how to shorten the time needed to complete trial runs of the MEM without losing precision. When comparing the results against using 385,560 fish and 1,000 simulations, we found that we had to work with a minimum of 13,710 fish (maintaining initial 2009 preseason marked and unmarked ratios) and 100 simulations.

The MEM was used to run the same sets of mark-selective fisheries through the three available modeling modes:

1. without multiple encounters ("FRAM mode")
2. with multiple encounters, and
3. with both multiple encounters and increasing release-mortality rate with successive encounters.

The resulting relationships between marked ER and unmarked ER are presented in Figure 2. In the no multiple encounter mode ("FRAM –One Time Step") the relationship between unmarked and marked exploitation rates is linear. With multiple encounters, unmarked ER diverged rapidly from the linear FRAM –One Time Step relationship above the level of a 0.15 marked exploitation rate. The addition of a low level of increasing release mortality with successive encounters added additional bias when the marked exploitation rate was above 0.4.

Coho FRAM modeling of the intensive summer ocean MSF is broken into three monthly Time Steps (July, August, and September). We distributed the same MSF in FRAM runs of one, two and three time steps to evaluate the effect of FRAM's abundance adjustment between time steps. When FRAM resets abundance levels (as is done between time steps) the decreased number of marked fish (as compared to the unmarked fish) has the effect of increasing the encounters of unmarked fish and thus increases the fishing-related mortality on the unmarked cohort. This result is seen in Figure 2, designated as "FRAM Three Time Steps" trend line. The results of the FRAM "2 time step" and "3 time step" model runs were very similar because the great majority of the catch was modeled within the first 2 time steps. In this exercise, with our distribution over multiple time steps, the unmarked ER bias did not become apparent until the marked exploitation rate exceeded 0.35.

FRAM modeling did confirm that the same results were obtained from the Multiple Encounter Model when in the FRAM mode. In Table 3 we see that at the 0.10 marked harvest rate level both models produce essentially the same marked and unmarked exploitation rate even with multiple encounters activated. However, Table 3 also shows how with increasing levels of mark selective pressure the unmarked exploitation rate results from MEM increase as compared to FRAM results. Table 3 does not show the results of increasing release mortality rate with multiple releases; see Appendix Tables 1 and 2 for this perspective.

At the 0.60 marked harvest rate level, with multiple encounters ON (but with increasing release mortality rates OFF), the ER on marked fish is 0.642 and 0.198 on unmarked (Table 3). The same fisheries run with FRAM in a single time step produced approximately the same marked ER, but the unmarked ER was only 0.137. The bias of 0.061 is 31% of the Total unmarked ER. However, when the MSF impacts are spread over at least two FRAM time steps FRAM's unmarked ER increases to 0.161 while the marked ER remains the same. With the fishery spread over an additional time step FRAM is still underestimating the expected ER for unmarked fish by 19%.

Table 3. Summary of key Mark Selective Fishery modeling results that demonstrate the effect of potential multiple encounters upon the calculation of unmarked salmon exploitation rates. The relationship holds at a wide range of mark rates (78% marked and 50% marked shown in table) as long as the input Catch Quota is based upon the number of marked fish available. (See Appendix Table 1 and Table 2 for more detail.)

Mark-to-Unmarked Ratio	MSF Catch Quota based upon Marked Harvest Rate	MEM Marked Fish ER	**Unmarked Fish ER** MEM Multiple Encounters ON	 MEM, or FRAM One Time Step, Multiple Encounters OFF	 FRAM Two Time Steps (NO Multiple Encounters)
3.57:1	0.1	0.110	**0.024**	**0.023**	**.023**
3.57:1	0.2	0.218	0.052	0.046	
3.57:1	0.3	0.326	0.081	0.069	
3.57:1	0.4	0.432	0.114	0.092	
3.57:1	0.5	0.538	0.153	0.114	
3.57:1	0.6	0.642	**0.198**	**0.137**	**0.161**
1:1	0.1	0.108	**0.026**	**0.023**	**.023**
1:1	0.2	0.215	0.052	0.046	
1:1	0.3	0.320	0.079	0.069	
1:1	0.4	0.424	0.109	0.092	
1:1	0.5	0.527	0.146	0.114	
1:1	0.6	0.628	**0.188**	**0.137**	**0.161**

We initially modeled the actual mark rate that existed for this stock (Columbia River Late Coho) in the pre-season 2009 forecasts (78% marked, 3.57:1 ratio). We also ran the Multiple Encounter Model, and FRAM, at decreasing levels of mark rates to examine the effect of mark rate upon our results. However, as we adjusted the total catch quota based upon the number of marked fish available, the mark rate did not affect our exploitation rate results (Table 3). For additional perspective please refer to Appendix Tables 1 and 2. The first table details results from the 78% marked model runs while Appendix Table 2 has results from the 50% marked model runs. Note that in Appendix Table 1, at a 60% marked harvest rate Quota, the 78% mark rate has a resulting Catch is 6,464; while in Appendix Table 2 at a 50% mark rate the resulting Catch (and catch quota input to FRAM) is only 4,204. All model runs were done with the same starting total abundance of 13,710 fish.

The exploitation rate relationships seen at the 78% mark rate (Table 3) are essentially duplicated at the 50% mark rate, because the catch input is based upon the abundance of mark fish. The MEM used a target marked harvest rate to set the level of fishing pressure. FRAM was provided the total landed catch from the corresponding MEM run as the FRAM Catch Input Quota. These results demonstrate that within this range of mark levels, if the FRAM input MSF catch quota is adjusted according to the number of marked fish available then a consistent relationship between marked and unmarked exploitation rates is maintained. In other words, the appropriate MSF FRAM quota can be calculated to correspond to a Target, or Maximum, marked exploitation rate.

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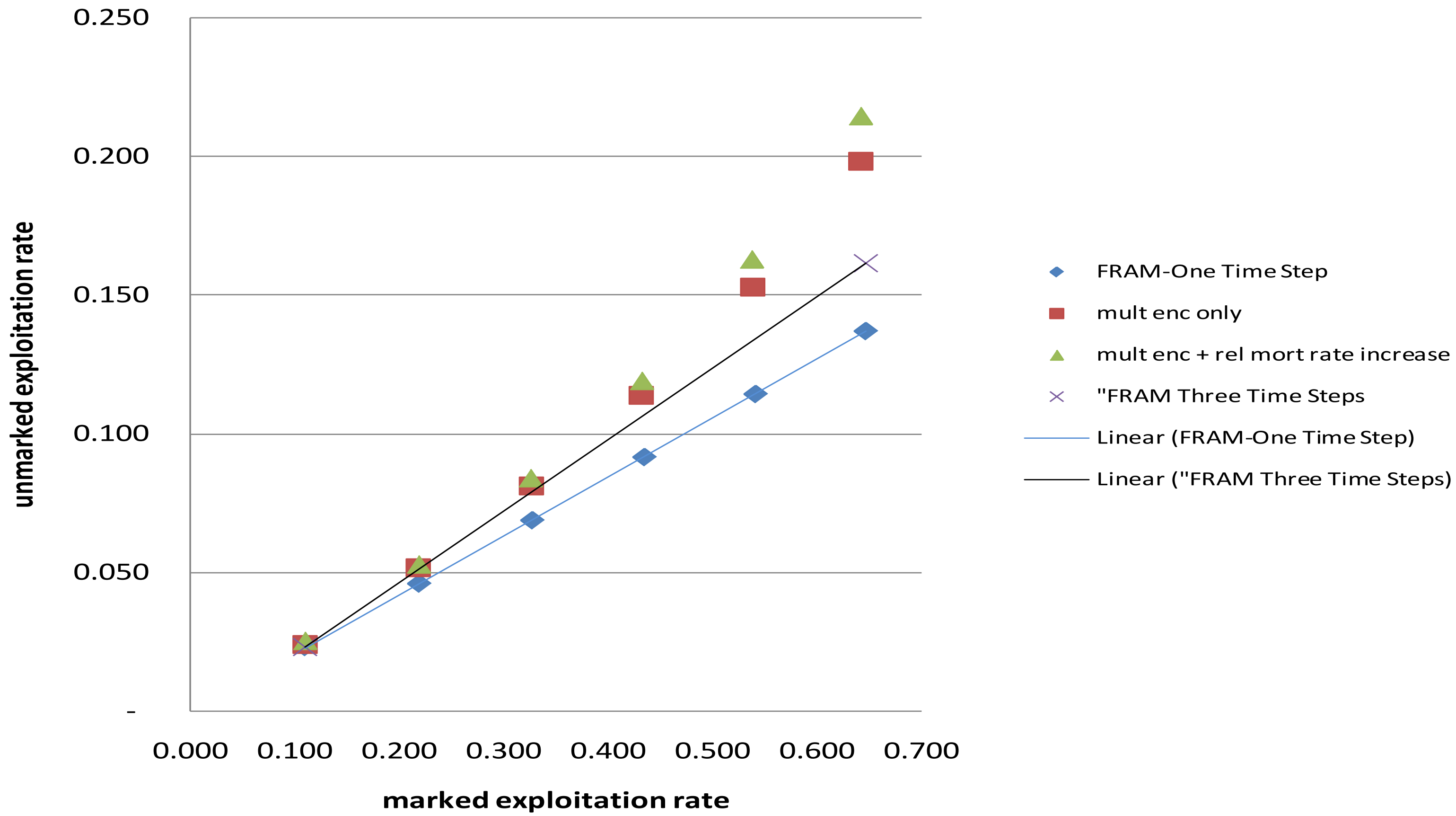

Figure 2. The relationship between Marked and Unmarked exploitation rates, with increasing Mark Selective Fishing pressure, is compared between the Lawson Multiple Encounter Mode (MEM)l and FRAM. The MEM was run in the "FRAM-One Time Step" mode, with multiple encounters turned ON, and then with multiple encounters and increasing release-mortality rate both turned ON. Also plotted are the results of additional FRAM runs done with the same level of MSF spread over three Time Steps.

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Discussion

With the advent of mark-selective fisheries the harvest impacts upon hatchery fish and wild fish diverge with increasing mark selective pressure. Various data users and modelers have built assumptions into their analyses to try to account for the differential fishery impacts upon marked and unmarked fish of the same stock. The Pacific Salmon Commissions' Selective Fishery Sub-Committee has adopted FRAM's assumed parameters for release-mortality rates and mark mis-identification rates (SFEC 2002). Multiple encounters of released fish has been raised as a concern primarily associated with developing Chinook MSF, perhaps motivated by the effects upon age classes that would be exposed to the MSF over more than one season. But the quantification of effects from potential multiple encounters, in the same fishing season, have not been part of FRAM modeling and to our knowledge have not been incorporated into salmon fishery management processes.

We have demonstrated that at low levels of MSF the bias introduced from multiple encounters may be negligible, but at increasing MSF fishing pressure the bias becomes a concern. In the past, fishery managers using FRAM have not fully considered the level of bias that MSF introduce to the calculations of wild stock ER. Table 4 presents the exploitation rate levels of Columbia River coho that the PFMC have approved for the prosecution of coho MSF in Council ocean waters over the past five years. The ER in hatchery marked coho stocks, in Southern U.S. Mark Selective Fisheries, has ranged from 19% (Columbia River Early marked stock, 2008 pre-season projection) to 63% (Columbia River Late marked stock, 2005 pre-season projection). Our results suggest that unmarked stock ER produced from FRAM modeling of coho MSF will be notably underestimated when the marked stock ER (in MSF) exceeds 35%.

Concerns with the implementation of Chinook MSF have been discussed in recent years. A major concern has been FRAM modeling being based upon a "fishing year" approach rather than a "brood year" approach and the potential to accumulate MSF impacts as the fish age. Since annual age-specific forecasts provided to FRAM each year could in theory account for differential survival of marked and unmarked cohorts of the same stock, this concern has decreased. However, we do not know of any abundance forecasting methodology that can, at this time, account for differential survival rate of marked and unmarked Chinook in the time frame needed for the development of annual forecasts. This may not be a major factor as long as the Chinook MSF remain at a "low level", as recommended by the SSC to the Council last November. We now are better able to define what that "low level" should be. For Chinook FRAM modeling, where the intensive MSF in Council waters would occur during the summer, there is only one FRAM Time Step (July-Sept). As illustrated in Figure 2 for FRAM-One Time Step, at levels increasing from 0.10 marked stock ER (summed over all MSF), the ER of the corresponding unmarked stock will be underestimated.

Discussions within the Model Evaluation Workgroup have produced several ways to potentially account for the inaccuracy in unmarked exploitation rates potentially introduced by multiple encounters during mark selective fisheries. Ideas identified to date include:

- Adding more FRAM time steps will reduce the level of error.
- Adding algorithms (specific for fishery release mortality rates) into each FRAM time step to account for multiple encounter bias.
- Setting maximum allowable marked stock exploitation rate (summed over all mark selective fisheries).
- Adding a buffer to the allowable exploitation rates for unmarked stocks.

Summary

The Multiple Encounter Model demonstrated how increasing levels of MSF produce a non-linear relationship between marked ER and unmarked ER. FRAM assumes a linear relationship. Comparisons were made between FRAM and between running the identical fisheries through three modeling modes of MEM. Actual FRAM runs were made to compare to the identical fisheries run through the MEM. In the non-multiple encounter mode the MEM produced results consistent with FRAM. In the multiple encounter mode the MEM demonstrated the increasing bias in FRAM estimates of unmarked ER, as compared to marked ER, at increasing MSF fish pressure. However, when FRAM extended the MSF over two or more Time Steps the bias was notably decreased, but still persists above a certain level of marked ER.

For Salmon fisheries management in the Pacific Northwest, “weak stock management” is the usual approach. The wild stocks identified as being at low abundance levels for a given year vary from year to year. The FRAM model is used to calculate the annual cumulative fishery effects upon the wild stocks defined as “drivers”. To avoid notable bias from MSF impacts upon a wild “driver” stock, the corresponding Mark Selective Fishery ER for marked hatchery stock should not exceed the 0.30 ER level over 2 times steps (generally coho), or the 0.10 ER level for one time step (generally Chinook).

Table 4. Pre-season (2005 – 2009) estimates of exploitation rates for Columbia River coho Early and Late stocks, and exploitation rate occurring in MSF.

Year and Model Run	FISHERY	Columbia Early			Columbia Late			Combined		
		Marked	Unmarked	Total	Marked	Unmarked	Total	Marked	Unmarked	Total
2009 Coho0921	Ocean Escapement (after B10)	238,573	115,387	353,960	152,761	67,759	220,520	391,334	183,146	574,480
	Marine Exploitation Rate	55.9%	17.3%	48.0%	47.9%	15.9%	41.0%	53.1%	16.8%	45.5%
	Exploitation in Southern U.S. marine Fisheries	55.5%	17.2%	47.6%	47.5%	15.8%	40.6%	52.7%	16.7%	45.2%
Coho0921	**ER in Southern U.S. MSF marine Fisheries**	**52.9%**	**14.1%**	**45.0%**	**44.0%**	**11.6%**	**37.0%**	**49.8%**	**13.2%**	**42.1%**
2008 Coho0824	Ocean Escapement (after B10)	60,964	31,428	92,392	49,094	18,962	68,056	110,058	50,390	160,448
	Marine Exploitation Rate	20.5%	6.0%	16.1%	25.3%	8.4%	21.3%	22.7%	6.9%	18.4%
	Exploitation in Southern U.S. marine Fisheries	20.0%	5.9%	15.7%	24.9%	8.3%	20.9%	22.3%	6.8%	18.0%
Coho0824	**ER in Southern U.S. MSF marine Fisheries**	**18.7%**	**4.6%**	**14.4%**	**22.6%**	**5.9%**	**18.6%**	**20.5%**	**5.1%**	**16.3%**
2007 Coho0714	Projected Ocean Escapement (after B10)	203,203	79,438	282,641	51,885	19,261	71,146	255,088	98,699	353,787
	Projected Marine Exploitation Rate	38.7%	12.8%	33.1%	55.4%	19.2%	49.2%	43.0%	14.2%	37.1%
	Exploitation in Southern U.S. marine Fisheries	38%	13%	33%	55.1%	19%	49%	43%	14.1%	37%
Coho0714	**ER in Southern U.S. MSF marine Fisheries**	**32.5%**	**8.1%**	**27.2%**	**45.4%**	**11.7%**	**39.6%**	**35.8%**	**8.8%**	**30.3%**
2006 Coho0619	Projected Ocean Escapement (after B10)	119,963	62,724	182,687	46,597	18,145	64,742	166,560	80,869	247,429
	Projected Marine Exploitation Rate	31.1%	9.7%	25.0%	49.5%	16.6%	43.2%	37.5%	11.3%	30.8%
	Exploitation in Southern U.S. marine Fisheries	31%	10%	25%	49%	16%	43%	37%	11.2%	30%
Coho0619	**ER in Southern U.S. MSF marine Fisheries**	**29%**	**8%**	**23%**	**45%**	**12%**	**39%**	**34%**	**9%**	**28%**
2005 Coho0519	Projected Ocean Escapement (after B10)	99,540	67,249	166,789	17,612	9,087	26,699			
	Projected Marine Exploitation Rate	51%	16%	41%	74%	26%	66%			
	Exploitation in Southern U.S. marine Fisheries	51%	16%	41%	73%	26%	66%			
Coho0519	**ER in Southern U.S. MSF marine Fisheries**	**45.7%**	**12.0%**	**36.2%**	**63.1%**	**18.1%**	**56.1%**			

Notes: These ER values were totaled from fisheries identified as MSF ER, but the below minor adjustments not completed:

1) Canadian impacts not included in ER although some of these are MSF.
2) Puget Sound sport impacts removed because of mixture of MSF and non-MSF.
3) May-June NT NOF Troll non-retention needs to be removed from ocean MSF totals.

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Appendix Table 1. Exploitation Rates from running the same Mark Selective Fisheries and modeling parameters through the Multiple Encounter Model and through FRAM with increasing number of FRAM Time Steps; using a high mark rate of 78%.

Modeling Scenario & Model Used	Fish available at "August" Fishery M	Fish available at "August" Fishery UnM	Mark Selective Fishery Modeling: Time Step	Catch Input	Landed Catch M	Landed Catch UnM	Total Mortality M	Total Mortality UnM	Resulting Exploitation Rate M	Resulting Exploitation Rate UnM
10% HR; 3.57:1 mark rate	**10,710**	**3,000**								
Multiple Encounter Model			single	10% M HR						
Run in "FRAM mode"					1,071	6	1,138	66	0.1102	0.0230
Run multiple encounter ON					1,064	7	1,130	70	0.1095	0.0243
Run with multiple encounters and increasing release-mortality rate ON					1,064	7	1,127	73	0.1092	0.0253
FRAM August only			August	1,077	1,071	6	1,138	66	0.1102	0.0229
FRAM July & August			July	539	536	3	570	33		
catch input 50% split between months			August	539	536	3	569	34		
			Total:	1,078	1,072	6	1,139	67	0.1102	0.0233
FRAM July, August, & Sept			July	254	253	1	268	15		
catch input split per 2009 monthly ratios			August	737	733	4	779	45		
			Sept	86	85	1	91	6		
			Total:	1,077	1,071	6	1,138	66	0.1102	0.0233
60% HR; 3.57:1 mark rate	**10,710**	**3,000**								
Multiple Encounter Model			single	60% M HR						
Run in "FRAM mode"					6,426	38	6,825	397	0.6469	**0.1371**
Run multiple encounter ON					6,371	55	6,775	576	0.6422	**0.1984**
Run with multiple encounters and increasing release-mortality rate ON					6,369	57	6,771	623	0.6418	**0.2146**
FRAM August only			**3**	6,464	6,426	38	6,825	395	0.6469	**0.1370**
FRAM July & August			2	3,232	3,213	19	3,413	198		
catch input 50% split between months			3	3,232	3,206	26	3,406	269		
			Total:	6,464	6,419	45	6,819	467	0.6421	**0.1612**
FRAM July, Augus, & Sept			2	1,524	1,515	9	1,610	93		
catch input split per 2009 monthly			3	4,423	4,393	30	4,666	307		
			4	518	512	6	544	65		
			Total:	6,465	6,420	45	6,820	465	0.6450	**0.1614**

Appendix Table 2. Exploitation Rates from running the same Mark Selective Fisheries and modeling parameters through the Multiple Encounter Model and through FRAM with increasing number of FRAM Time Steps; using a low mark rate of 50%.

Modeling Scenario & Model Used	Fish available at "August" Fishery		Time Step	Mark Selective Fishery Modeling					Resulting Exploitation Rate	
				Catch Input	Landed Catch		Total Mortality			
	M	UnM			M	UnM	M	UnM	M	UnM
10% HR; 1:1 mark rate	**6860**	**6860**								
Multiple Encounter Model			single	10% HR						
Run in "FRAM mode"					686	15	729	151	0.1102	0.0230
Run multiple encounter ON					669	18	712	168	0.1078	0.0255
Run with multiple encounters and increasing release-mortality rate ON					n.a.	n.a.	n.a.	n.a.	n.a.	**n.a**
FRAM August only			**3**	701	686	15	729	152	0.1105	0.0230
FRAM July & August			2	351	344	7	365	75		
catch input 50% split between months			3	351	343	8	364	79		
			Total:	702	687	15	729	154	0.1105	0.0236
FRAM July, Augus, & Sept			2	166	162	3	172	36		
catch input split per 2009 monthly			3	480	470	10	499	105		
			4	56	55	1	58	13		
			Total:	702	687	14	729	154	0.1104	0.0234
60% HR; 1:1 mark rate	**6860**	**6860**								
Multiple Encounter Model			single	60% HR						
Run in "FRAM mode"					4116	88	4,372	907	0.6469	**0.1371**
Run multiple encounter ON					3,990	126	4.241	1.246	0.6279	**0.1879**
Run with multiple encounters and increasing release-mortality rate ON					n.a.	n.a.	n.a.	n.a.	n.a.	**n.a**
FRAM August only			**3**	4,204	4116	88	4372	908	0.6479	**0.1373**
FRAM July & August			2	2,102	2058	44	2185	453		
catch input 50% split between months			3	2,102	2043	59	2170	613		
			Total:	4,204	4,101				0.6414	**0.1610**
FRAM July, August, & Sept			2	991	970	21	1,031	215		
catch input split per 2009 monthly			3	2,876	2808	68	2982	704		
			4	337	323	14	343	148		
			Total:	4,204	4,101	103	4,356	1,067	0.6443	**0.1610**

Agenda Item H.1.a
Attachment 2
November 2009

Assessment of fall ocean Chinook salmon fisheries south of Cape Falcon, Oregon

Michael R. O'Farrell

National Marine Fisheries Service

Southwest Fisheries Science Center

Fisheries Ecology Division

110 Shaffer Road, Santa Cruz, CA 95060

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1 Introduction

This report investigates the potential for, and limitations to, assessing fall ocean Chinook salmon fisheries for management areas south of Cape Falcon, Oregon. The current Pacific Fishery Management Council (PFMC) salmon fishery management context results in adoption of salmon management measures at the April (year t) PFMC meeting for the period between May 1 (t) to April 30 ($t+1$), even though there is no assessment of the expected, stock-specific Chinook impacts occurring south of Cape Falcon for the September 1 (t) to April 30 ($t+1$) portion of this period. In this report I present an evaluation of methods that might conceivably be used to assess the risk that fisheries pose to key Chinook stocks south of Cape Falcon during this September 1 (t) to April 30 ($t+1$) period, as well as on future fishing opportunity after April 30 ($t+1$). While the focus of the report is on fall fisheries, there is recognition that the same issues of adoption of fisheries without assessment occurs for Chinook fisheries conducted from January 1 ($t+1$) to April 30 ($t+1$).

Chinook salmon fisheries south of Cape Falcon primarily harvest fall-run Chinook. In the late summer and early fall, an age-dependent proportion of 2–5 year old fall-run Chinook mature, enter their respective river systems, and spawn shortly thereafter. Immature fish from these same broods remain in the ocean and sustain fall fisheries conducted over the remainder of the calendar year as well as winter/spring/summer ocean salmon fisheries in the following year. Ocean abundance forecasts for fall-run Chinook are made using a fitted linear model, with estimates of age-specific river returns or escapement estimates as the independent variable (PFMC 2009). Using river return or escapement estimates, the ocean abundance of immature fish from the same broods that did not return to spawn is forecast.

Since ocean abundance forecasts of fall Chinook require river return or escapement estimates, they are not able to be made until this quantity has been estimated. The PFMC Salmon Technical Team (STT) makes forecasts of September 1 ($t-1$) ocean abundance in February (t), which is when estimates of year ($t-1$) river returns and escapement first become available. The PFMC uses these abundance forecasts, published in the PFMC Preseason I report (e.g., PFMC 2009), during the March and April (t) meetings to craft and ultimately adopt salmon fishery management measures for the period May 1 (t) to April 30 ($t+1$). Because the abundance forecast for September 1 (t), will not be derived until February ($t+1$), fisheries for September 1 (t) to April 30 ($t+1$) are adopted without knowledge of the stock-specific ocean abundances. The impacts incurred from fall fisheries (t) are estimated after the fisheries take place. These postseason estimates of impacts are then deducted from the September 1 (t) abundance forecasts. Since this same set of abundances will support fisheries in the next year, fall fisheries in year (t) have an unknown impact on future fishing opportunity in year ($t+1$). Hence, fall fisheries have been termed "credit card fisheries", since fall (t) fishing opportunity must be paid for in terms of estimated impacts deducted from the ocean wide abundances affecting the year ($t+1$) opportunity.

The absence of timely abundance forecasts for September 1 (t), has different implications depending on the currency in which the conservation objective or consultation standard is expressed. Conservation objectives based on escapement goals or limits exist both for Sacramento River fall Chinook (SRFC) and Klamath River fall Chinook (KRFC), the stocks that most frequently constrain ocean fisheries south of Cape Falcon. The SRFC conservation objective is an escapement goal range of 122,000–180,000 hatchery and natural-area adult spawners. One part of the KRFC conservation objective is a minimum spawner escapement "floor" of 35,000 natural-area adult spawners. To conduct fishery impact assessment for stocks with an escapement-based conservation objective, forecasts of (1) impacts and (2) ocean abundance are necessary.

Other conservation objectives and consultation standards are based on harvest rates. For KRFC, in conjunction with the 35,000 natural-area adult escapement floor, the conservation objective also specifies that the spawner reduction rate (SRR) must be less than 67 percent. For threatened California Coastal Chinook, the NMFS ESA consultation standard is a forecast KRFC age-4 ocean harvest rate of 16 percent or less. To conduct fishery impact assessment for stocks with harvest rate-based constraints, a forecast of the harvest rate for planned fisheries is necessary. In some cases, it is possible to forecast the harvest rate absent an abundance forecast; in other cases this is not possible.

The remainder of this report evaluates the prospects for forecasting year (t) fall harvest, impacts, and harvest rates for SRFC and KRFC. For SRFC, the ability to assess the risk of year (t)

fall fisheries to that stock's ability to meet the lower end of the escapement goal range in year $(t+1)$ is discussed. For KRFC, the risk that fall (t) fisheries represent to that stock's ability to meet the escapement floor, the spawner reduction rate, and the age-4 ocean harvest rate constraints in year $(t+1)$ is investigated. In cases where a forecast using the standard models cannot be made, historical estimates are presented that may potentially be of use in establishing reasonable bounds on the expected impacts of future fall fisheries. The report concludes with recommendations regarding fall fishery risk assessment that may be useful for planning future fall ocean salmon fisheries.

2 Sacramento River fall Chinook

2.1 Current SRFC assessment context

The Sacramento Index (SI) and the Sacramento Harvest Model (SHM) are used to forecast harvest and escapement of SRFC. The SI is a September 1 $(t-1)$ ocean abundance index of adult (combined age 3-5) SRFC, and is forecast annually in February (t) based on jack escapement $(t-1)$ to the Sacramento River Basin (O'Farrell et al. 2008; PFMC 2009). Fall $(t-1)$ fishery harvest is estimated from coded-wire tag recoveries also in February (t) since these fisheries have already occurred (O'Farrell et al. 2008). Winter, spring, and summer (t) fishery harvests from completed, ongoing or upcoming fisheries through August 31 (t) are forecast at the March and April (t) PFMC meetings using the SHM (Mohr and O'Farrell 2008). Given the SI forecast for September 1 $(t-1)$, and the estimated and forecasted harvest from September 1 $(t-1)$ to August 31 (t), an escapement forecast is made with the SHM which can be compared to the SRFC conservation objective of 122,000–180,000 hatchery and natural-area adult spawners.

2.2 Fall (t) fishery assessment of SRFC

When considering the "risk" of fall (t) fisheries, it is with respect to the achievement the conservation objective of the stock in question in year $(t+1)$. The SRFC conservation objective is expressed in escapement. Direct evaluation of the implications of fall (t) fisheries on SRFC escapement ($t+1$) would require a forecast of the SI (t) to be available during the PFMC March and April (t) meetings, however this forecast in unavailable until February ($t+1$). Hence, an assessment of the risk of fall (t) fisheries on SRFC escapement ($t+1$) can not be made using current methods.

The method currently used for forecast SI (t) is based on SRFC jack escapement (t), but other methods have periodically been proposed for forecasting the ocean abundance of salmon stocks. To date, however, no other method has proven as stable or as reliable for SRFC as the current forecast model. Moreover, forecasting the SI as a simple average of historical values appears to have little promise. Figure II-1 in PFMC (2009) displays the SI time series from 1983–2008. during that time, the SI has been highly variable, and neither a long- nor short-term average of past estimates would provide a credible forecast of the SI for future years.

2.3 Historical SRFC estimates

While it is not possible to perform a fall fishery impact assessment for stocks with an escapement-based conservation objective absent an abundance forecast, managers may find inspection of past fall fishery data and estimates informative. In particular, if managers are interested in crafting fall fisheries that would be expected to have minimal impacts on SRFC, the historical incidence of SRFC in Chinook harvests from past fall fisheries is particularly relevant. The proportion of the total Chinook harvest that is comprised of SRFC varies by year, month, management area, and fishery. Figure 1 shows these proportions for harvests from the 1983–2008 period. Plots in the left column correspond to commercial fisheries, while the right column corresponds to recreational fisheries. Rows represent the seven management areas south of Cape Falcon, arranged from north to south. The management areas are northern Oregon (NO), central Oregon (CO), Klamath Management Zone (KMZ)-Oregon portion (KO), KMZ-California portion (KC), Fort Bragg (FB), San Francisco (SF), and Monterey (MO). Several generalizations can be drawn from these plots. First, SRFC make up an extremely high proportion of the fall Chinook harvest in the SF and MO management areas, regardless of month or fishery. Second, within the FB, KC, CO, and NO areas, the September values of the SRFC proportion varies widely, and in many cases the whiskers of

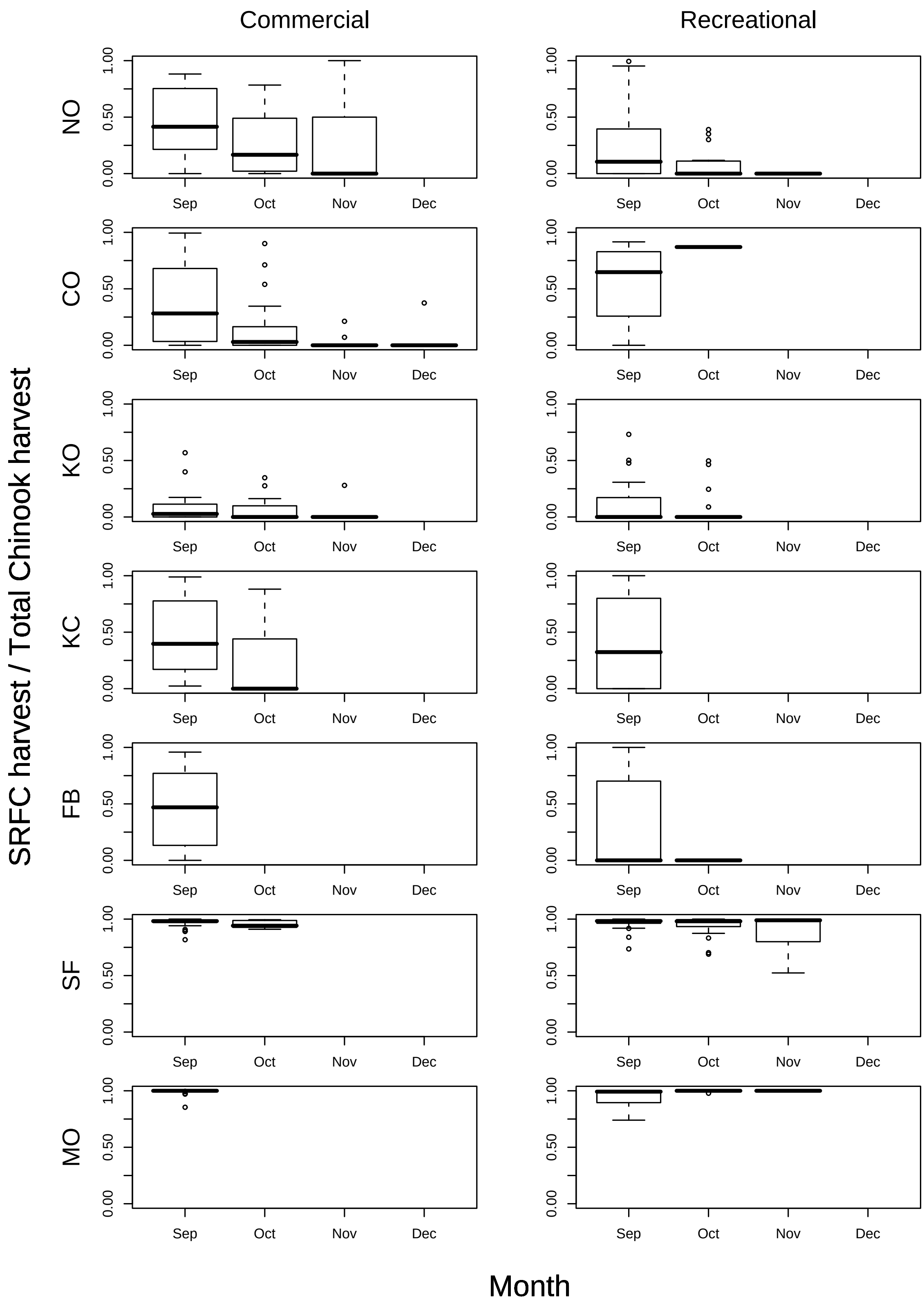

Figure 1. The proportion of total Chinook harvest estimated to be Sacramento River fall Chinook (SRFC). Boxplots are comprised of estimates extending from 1983 to 2008.

the boxplots span almost the entire range from zero to one. Third, the proportion SRFC in the KO management area is consistently lower than adjacent areas, although there are instances where the proportion exceeds 0.50. In summary, there are very few area, month, and fishery combinations where the harvest of SRFC could reliably be expected to be low.

3 Klamath River fall Chinook

3.1 Current KRFC assessment context

Age-specific abundance forecasts and the Klamath Ocean Harvest Model (KOHM) are used to forecast harvest, impacts, escapement, the spawner reduction rate, and age-specific harvest rates for KRFC. Forecasts of ocean abundance on September 1 ($t-1$) are made in February (t) using age-specific sibling regressions. For the sibling regressions, the river return ($t-1$) estimate of age $a-1$ KRFC is used to predict age a September 1 ($t-1$) ocean abundance (PFMC 2009). The assessment of KRFC uses a simplified accounting of the fall-run Chinook life history by assuming that mature KRFC leave the ocean for spawning in the Klamath Basin on August 31 (t). The fraction of the age 2–4 cohorts that do not mature and return to the river are assumed to remain in the ocean and advance one year in age on September 1 (t).

Age-specific fall ($t-1$) fishery impacts are estimated from coded-wire tag recoveries, also in February (t) since these fisheries have already occurred (Mohr 2006). Winter, spring, and summer (t) age-specific fishery impacts from completed, ongoing, or upcoming fisheries through August 31 (t) are forecast at the March and April (t) PFMC meetings using the KOHM (Mohr 2006). Given the age specific abundance forecasts ($t-1$), and the estimated and forecasted harvest impacts from September 1 ($t-1$) to August 31 (t), the KOHM is used to forecast the natural-area escapement, spawner reduction rate, and age-4 ocean harvest rate. These quantities can then be compared to the KRFC conservation objective and the California Coastal Chinook consultation standard. For a more detailed description of the KRFC abundance forecasting methods and the KOHM, see Mohr (2006).

3.2 Fall (t) fishery assessment of KRFC

Direct evaluation of the implications fall (t) fisheries on KRFC escapement ($t+1$) requires forecasts of age 3, 4, and 5 ocean abundance (t) be available during the PFMC March and April (t) meetings. Because the sibling-based forecasts are unavailable until February ($t+1$), current methods cannot be used to assess the risk of fall (t) fisheries on KRFC escapement ($t+1$). However, the KOHM could be used to forecast the age 4 and age 5 ocean abundance on September 1 (t) as follows.

$$N_{a+1,Sep1(t)} = N_{a,Aug31(t)} \times (1-\mu_a), \qquad a \in \{3,4\}, \tag{1}$$

where the age-specific ocean abundance of KRFC on August 31 ($N_{a,Aug31(t)}$) is forecast by the KOHM based on the $N_{a,Sep1(t-1)}$ sibling forecast, estimated fall fishery impacts ($t-1$), and forecast winter/spring/summer fishery (t) impacts through August 31 (t). The parameter μ_a is the maturation rate at age a. The $a+1$ subscript on the left hand side of equation (1) indicates that the cohort advances one year in age on September 1. Note however that it is not possible to forecast the September 1 (t) abundance of age-3 KRFC since no forecast of age-2, August 31 (t) abundance can be made. Age-2 KRFC are harvested in very low numbers in ocean fisheries because they are generally smaller than the minimum size limits. As such, that cohort is largely unseen until a portion of them returns to the Klamath Basin as jacks at age-2. As a result, we are unable to forecast an ocean abundance of the full complement of age 3, 4, and 5 KRFC abundance on September 1 (t), which is necessary for assessment of any Chinook stock with an escapement-based conservation objective. Furthermore, the abundance of age-3 KRFC has been highly variable (see table II-3 in PFMC 2009), which would preclude use of an average of historical age-3 abundance estimates to forecast the age-3 September (t) abundance.

The inability to forecast September 1 (t) KRFC abundance for the full complement of ages greater than two also precludes forecasting the SRR for fall (t) fisheries. The SRR is defined as

$$SRR = 1 - \frac{E}{E_0}, \tag{2}$$

where E is the forecast total number of age 3, 4, and 5 natural-area spawners and E_0 is the forecast total of age 3, 4, and 5 natural-area spawners in the absence of fishing. While the SRR portion of the KRFC conservation objective is a harvest-rate based constraint, an abundance estimate is needed to forecast this quantity. In particular, the relative contribution of the three cohorts that make up the age-specific escapement forecast must be known. For assessment of fall (t) fisheries, this is not currently possible.

Under certain circumstances it would be possible to forecast the KRFC age-4 ocean harvest rate for fall (t) fisheries, and this may have some utility for evaluating the risk of fall (t) fisheries. The KRFC age-4 ocean harvest rate for fall fisheries ($h^K_{4,fall}$) is defined as

$$h^K_{4,fall} = \frac{\sum\limits_{m,z,x} H^K_{4,m,z,x}}{N_{4,Sep1}}, \tag{3}$$

where $H^K_{4,m,z,x}$ is age-4 KRFC harvest in month $m \in \{\text{Sep, Oct, Nov, Dec}\}$, area $z \in \{\text{NO, CO, KO, KC, FB, SF, MO}\}$, and fishery $x \in \{\text{commercial, recreational}\}$. The quantity $H^K_{4,m,z,x}$ is a function of several other variables depending on whether a days-open or quota type fishery is operative.

For days-open fall fisheries (i.e., fisheries specified as the number of days open to fishing and not as a harvest quota), $H^K_{4,m,z,x}$ is forecast using predictors estimated from historical data and other parameters:

$$H^K_{4,m,z,x} = \left\{ \left[(\delta_{m,z,x} \times \beta^{f\delta}_{m,z,x}) \beta^{cf}_{m,z,x} \right] N_{4,m} \right\} p_{4,m,x}. \tag{4}$$

Here, $\delta_{m,z,x}$ is the number of days open to Chinook fishing, $\beta^{f\delta}_{m,z,x}$ is the fishing effort per day open, and the product of $\delta_{m,z,x}$ and $\beta^{f\delta}_{m,z,x}$ is fishing effort. $\beta^{cf}_{4,m,z,x}$ is the age-4 contact rate per unit effort, $N_{4,m}$ is the ocean-wide abundance of age-4 KRFC on the first day of month m, and $p_{4,m,x}$ is the proportion of age-4 KRFC that would be expected to be of legal size (and therefore legal to be retained as harvest). The abundance of age-4 KRFC on the first day of month m is a function of the September 1 age-4 abundance and all mortalities occurring after September 1:

$$N_{4,m} = N_{4,Sep1} \prod_{j=Sep}^{m-1} (1 - i_{4,j})(1 - v_4), \tag{5}$$

where $i_{4,j}$ is the age-4 fishery impact rate in month m, and v_4 is the monthly natural mortality rate. Each of the parameters identified in equation 4 and 5 can be forecast, and therefore the quantity $h^K_{4,fall}$ can be forecast for days-open fisheries using equation 3.

For quota fall fisheries $H^K_{4,m,z,x}$ is defined as

$$H^K_{4,m,z,x} = Q_{m,z,x} \times \rho^K_{4,m,z,x}, \tag{6}$$

where $Q_{m,z,x}$ is the month, area, fishery-specific quota and $\rho^K_{4,m,z,x}$ is the proportion of the quota that is expected to be age-4 KRFC. This proportion depends on the relative abundances of the constituent stocks caught the mixed stock ocean fisheries. As a result, September 1 (t) abundance forecasts for SRFC, the age 3, 4, and 5 cohorts of KRFC, Central Valley stocks other than SRFC, and Rogue River fall Chinook are necessary to forecast this quantity. Since forecast abundances and abundance indices are unavailable for September 1 (t) during the PFMC March and April (t) meetings, some less direct method would need to be considered for specifying $\rho^K_{4,m,z,x}$. One potential method could be to use a long-term average of postseason estimates of $\rho^K_{4,m,z,x}$. Or, for a more conservative approach, one could assume $\rho^K_{4,m,z,x}$ is equal to the largest value observed in a month, area, and fishery stratum, or even 1.0. A value of 1.0 for $\rho^K_{4,m,z,x}$ would imply that the entire quota harvest would be composed of age-4 KRFC. To convert these forecast KRFC age-4 harvests into an age-4 harvest rate (equation 3) also requires forecasting $N_{4,Sep1(t)}$, which as previously described could be done using the KOHM (equation 1).

In summary, a model-based forecast of the KRFC age-4 ocean harvest rate for fall (t) fisheries would be possible for combinations of days-open and quota fishery specifications. It would however require specific assumptions, rather than direct forecasts, of $\rho^K_{4,m,z,x}$ for fall quota fisheries.

3.3 Historical KRFC estimates

Absent a September 1 (t) abundance forecast of the age 3, 4, and 5 cohorts of KRFC, it is not possible to assess whether fall fisheries would contribute significantly to KRFC not meeting its escapement floor or SRR objectives. However, if managers are interested in configuring fall fisheries to avoid the KRFC stock, the proportions of past harvests that were KRFC may provide some guidance. Figure 2 illustrates the proportion of Chinook harvest for all areas south of Cape Falcon estimated to be KRFC, with all ages combined. These plots present a different spatial pattern than for SRFC. Fall fisheries in southern management areas (FB, SF, and MO), harvest proportionally few KRFC, with some very minor exceptions. A much higher and more variable proportion of KRFC are harvested in KO and KC, particularly in September. The NO and CO management areas appear to have a generally lower proportion of the Chinook harvest comprised of KRFC in the fall, though the estimates vary widely, particularly in September. Finally, there appears to be little difference in the proportions between the commercial and recreational fisheries.

While it has been identified that a forecast of the KRFC age-4 ocean harvest rate can be made from harvest model-type calculations, forecasting in this manner has some limitations. For one, a direct forecast of $\rho^{K}_{4,m,z,x}$ will not be available for fall (t) assessment of quota fisheries and therefore a value must be assumed. Without resorting to forecast models, retrospective analysis of age-4 ocean harvest rate estimates from fall fisheries can allow for inference regarding how fall fisheries have historically contributed to the overall KRFC age-4 ocean harvest rate, and may be used to develop a general expectation for future fall fisheries.

Figure 3 displays the KRFC age-4 ocean harvest rate from 1986–2008, and the subset of that rate that is attributed to fall fisheries. The total age-4 ocean harvest rate has ranged from a high of 55 percent to a low of 5.8 percent, with a marked decrease observed in the late 1980s and early 1990s. Since 1986, the age-4 ocean harvest rate attributed to fall fisheries has ranged from less than 0.01 percent to 10.3 percent, with a mean rate of 3.8 percent. There is no apparent temporal trend in the fall age-4 ocean harvest rate, unlike for the full, annual age-4 ocean harvest rate. Using this time series of fall age-4 ocean harvest rate estimates, one could reasonably expect that future fall fisheries would likely result in an age-4 ocean harvest rate of less than approximately 10 percent, provided that the scope of the planned fisheries is not unprecedented.

More inferences can be made by examining the fall age-4 ocean harvest rate segregated by management area. Figure 4 illustrates that there has not been a consistent spatial pattern to the age-4 KRFC harvest. While the observed spatial distribution of age-4 ocean harvest rates is partially

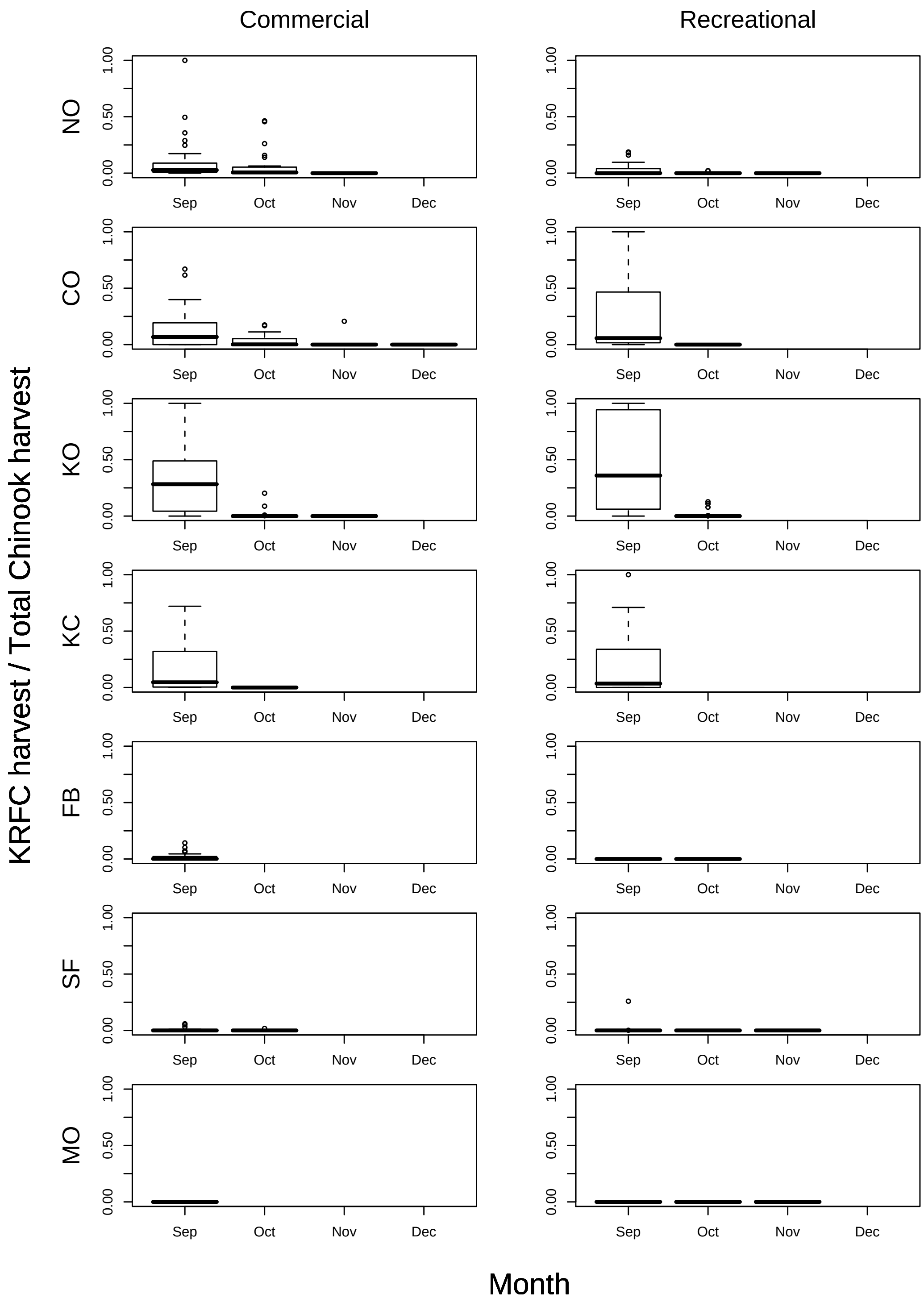

Figure 2. The proportion of total Chinook harvest estimated to be Klamath River fall Chinook (KRFC). Boxplots are comprised of estimates extending from 1983 to 2008.

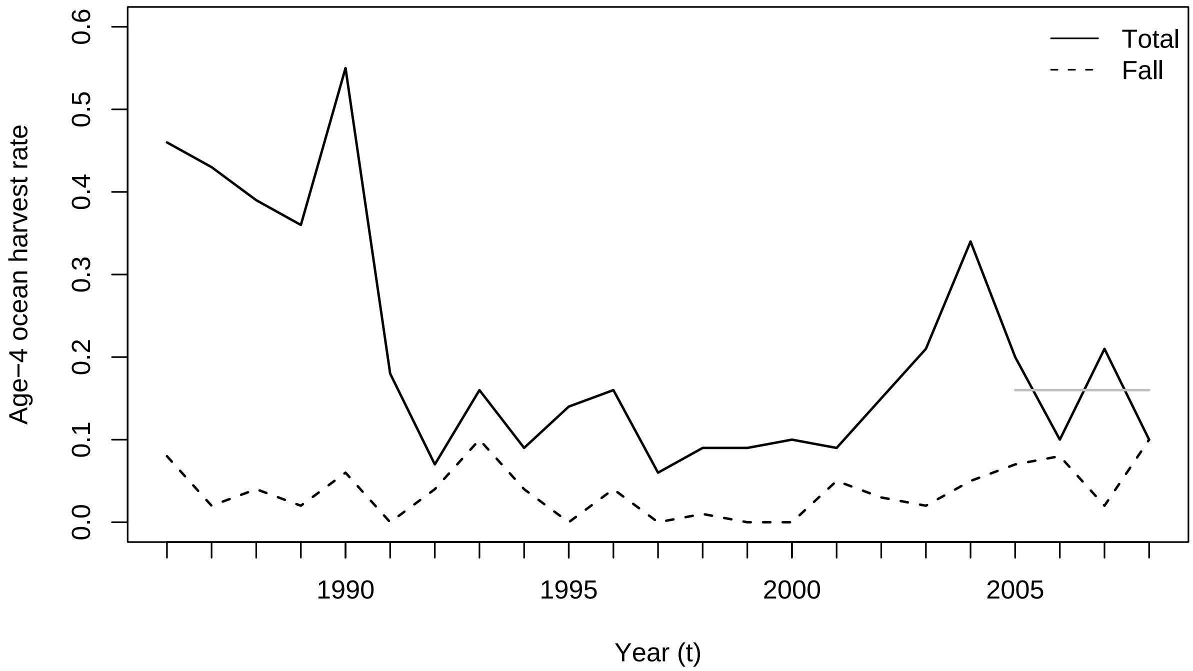

Figure 3. Klamath River fall Chinook (KRFC) age-4 ocean harvest rate estimates for the entire year (solid line; September 1 $(t-1)$ to August 31 (t)) and fall fisheries (dashed line; September 1 $(t-1)$ to December 31 $(t-1)$). The solid grey line denotes the California Coastal Chinook ESA consultation standard of a KRFC age-4 ocean harvest rate of 16 percent or less, in expectation.

determined by annual differences in fishing opportunity and effort among port areas, the observed variation in the location of age-4 harvest is not solely determined by fishing regulations. For example, a large proportion of the age-4 ocean harvest rate in 2008 (from fall 2007 fisheries) can be attributed to harvest in KC. The fall harvest of age-4 KRFC in the KC management area was primarily taken by the commercial fishery which had a 6,000 Chinook quota. The fishery was closed after three days (the season lasted from September 10–12, 2007) and the quota was exceeded. In comparison, for fishing year 2006, a year with a roughly similar fall age-4 ocean harvest rate as 2008, the age-4 ocean harvest rate taken in KC was a small proportion of the total rate from fall fisheries even though the commercial fishery was open for 13 days in September. Instead, age-4 KRFC harvest primarily came from Oregon areas, which had comparable levels of commercial opportunity in fall 2005 and fall 2007.

Fall harvest of age-4 KRFC appears to be relatively low in the more southern management

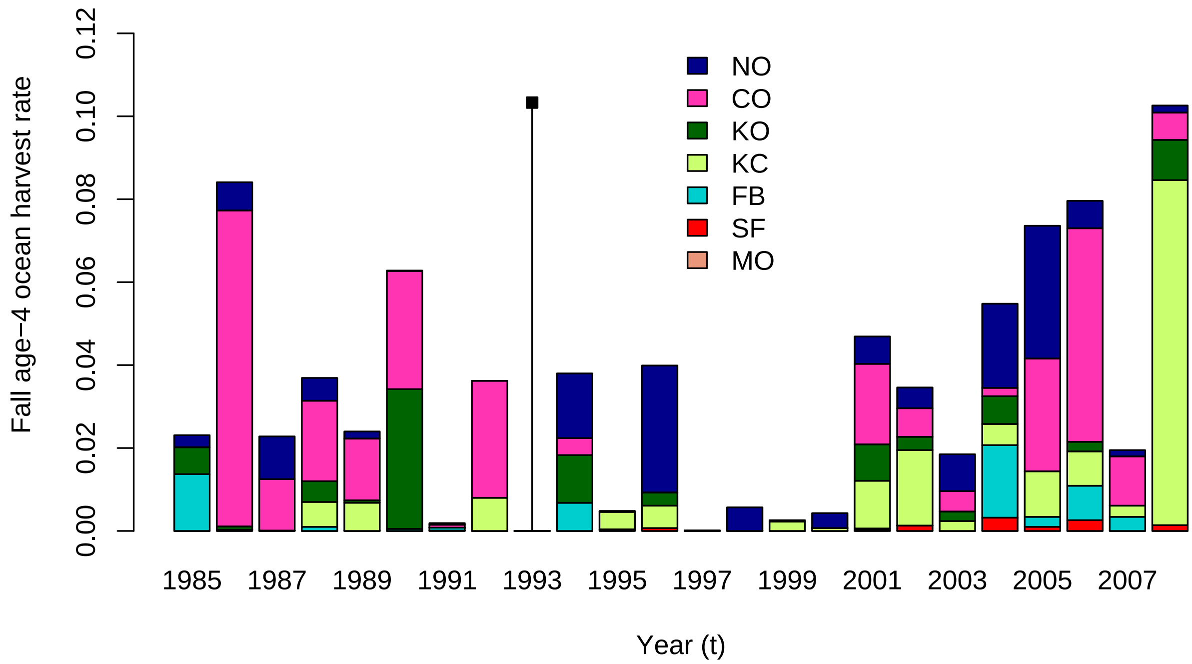

Figure 4. Klamath River fall Chinook (KRFC) age-4 ocean harvest rate estimates derived from harvest in the period from September 1 $(t-1)$ to December 31 $(t-1)$, for the seven management areas south of Cape Falcon, Oregon. For 1993, it was not possible to make a credible estimates of the geographic partitioning of the harvest rate owing to low numbers of coded-wire tag recoveries.

areas and the recreational fishery. Table 1 provides summary statistics of the age-4 ocean harvest rates by management area and fishery, as well as for the totals over all areas and fisheries south of Cape Falcon. Both commercial and recreational fisheries in the MO port area have not harvested age-4 KRFC in the fall and therefore do not contribute to the fall age-4 ocean harvest rate. Both commercial and recreational fisheries in the SF port area have contributed very little to the fall age-4 ocean harvest rate. Fall recreational fisheries in the FB management area also have not contributed historically to the KRFC age-4 ocean harvest rate.

In summary, fall age-4 ocean harvest rates of greater than 10.3 percent have never been observed. Thus, for future fall fisheries that are not expanded relative to past fall fisheries, we could reasonably expect the age-4 ocean harvest rate to be less than 10 percent in the fall period. In terms of the average rate that could be expected, the mean or median estimate over all years is currently 3.8 and 3.5 percent, respectively. The spatial distribution of past fall age-4 KRFC harvests would seem particularly relevant for managers in crafting future fall fisheries.

Table 1. Summary statistics for Klamath River fall Chinook age-4 ocean harvest rates from fall fisheries, $h^K_{4,fall}$, by management area and fishery. Estimates for 1993 are omitted since credible estimates by management area are not possible due to a low number of coded-wire tag recoveries.

	$h^K_{4,fall}$: *Commercial*						
Area	min	10%	25%	median	75%	90%	max
NO	0.00%	0.00%	0.03%	0.38%	0.73%	1.87%	3.10%
CO	0.00%	0.00%	0.00%	0.40%	1.93%	2.84%	7.62%
KO	0.00%	0.00%	0.00%	0.00%	0.07%	0.21%	2.73%
KC	0.00%	0.00%	0.00%	0.00%	0.53%	0.79%	7.38%
FB	0.00%	0.00%	0.00%	0.00%	0.13%	0.78%	1.75%
SF	0.00%	0.00%	0.00%	0.00%	0.05%	0.13%	0.32%
MO	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.00%	0.04%	0.48%	2.48%	3.78%	6.86%	8.39%
	$h^K_{4,fall}$: *Recreational*						
NO	0.00%	0.00%	0.00%	0.00%	0.03%	0.10%	0.25%
CO	0.00%	0.00%	0.00%	0.00%	0.02%	0.09%	1.19%
KO	0.00%	0.00%	0.00%	0.04%	0.52%	0.65%	1.15%
KC	0.00%	0.00%	0.00%	0.00%	0.28%	0.52%	0.94%
FB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SF	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
MO	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.00%	0.00%	0.02%	0.37%	0.71%	1.22%	1.90%
	$h^K_{4,fall}$: *Combined fisheries*						
NO	0.00%	0.00%	0.03%	0.43%	0.73%	1.89%	3.20%
CO	0.00%	0.00%	0.00%	0.57%	1.94%	2.84%	7.62%
KO	0.00%	0.00%	0.00%	0.07%	0.54%	0.94%	3.37%
KC	0.00%	0.00%	0.00%	0.26%	0.71%	1.13%	8.32%
FB	0.00%	0.00%	0.00%	0.00%	0.13%	0.78%	1.75%
SF	0.00%	0.00%	0.00%	0.00%	0.06%	0.14%	0.32%
MO	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.01%	0.30%	1.20%	3.47%	5.08%	7.84%	10.26%

Examination of the variability in the fall age-4 ocean harvest rate, and the variation in the contribution of the seven management areas suggests that model-based forecasts of the age-4 ocean harvest rate would be expected to perform poorly. The most robust forecast may simply be to use various percentiles of the historical age-4 ocean harvest rates to assess the risk of fishing opportunity reductions in year $(t+1)$ fisheries given the California Coastal Chinook consultation standard.

4 Conclusions

The inability to directly forecast September 1 (t) ocean abundance of SRFC and KRFC during the PFMC March and April (t) meetings is the core limitation to assessing the risk of fall fisheries to both salmon populations and future fishing opportunity. Given this limitation, a host of other methods have been explored which offer some potential to assess the risks associated with fall fisheries. The key findings of this analysis are:

1. Forecasts of fall (t) harvest or impacts for SRFC and all cohorts of KRFC cannot be made without an accompanying forecast of the respective fall (t) ocean abundance. As a result, assessment of the impact fall (t) fisheries have on year $(t+1)$ SRFC escapement, KRFC escapement, and the KRFC spawner reduction rate cannot currently be made.

2. There are very few area, month, and fishery combinations for fall fisheries where the harvest of SRFC could reliably be expected to be low.

3. Fall fisheries harvest proportionally few KRFC in the FB, SF, and MO management areas. More northern areas harvest a higher and more variable proportion of KRFC in the fall.

4. A model-based forecast of the KRFC age-4 ocean harvest rate could be made for planned fall fisheries.

5. Analysis of historical KRFC age-4 ocean harvest rates attributed to fall fisheries can provide a means of risk assessment for future fall fisheries, provided that new fall fisheries are not augmented in space or time beyond those occurring in the past.

6. In general, fall fisheries (both commercial and recreational) in the SF and MO management areas have contributed little to the KRFC age-4 ocean harvest rate. Fall recreational fisheries in FB have also had a negligible contribution to the KRFC age-4 ocean harvest rate.

7. The contribution of the five northernmost management areas to the KRFC age-4 ocean harvest rate has been highly variable over time. This result strongly suggests that model-based forecasts of the age-4 ocean harvest rate using month, area, and fishery-specific contact rate predictors may perform poorly.

5 Recommendations

Given the conclusions, the following recommendations are provided for future risk assessment of planned fall fisheries.

1. When planning fall fisheries, it should be acknowledged that such fisheries pose an unknown level of risk to the SRFC and KRFC stock's ability to meet their conservation objectives in the following year. This results in an unknown level of risk to future fishing opportunity.

2. Model-based forecasts of the KRFC age-4 ocean harvest rate should not be made for fall fisheries. The observed variability in the age-4 ocean harvest rate attributable to fall fisheries will likely result in low quality forecasts. Additionally, the proportion of age-4 KRFC expected in quota fisheries must be assumed rather than directly forecast.

3. The risk that fall fisheries pose to future fishing opportunity, if constrained by the California Coastal Chinook consultation standard, should be assessed by examination of historical estimates of the KRFC age-4 ocean harvest rate from fall fisheries.

4. Future fall fishing opportunity should not be increased above levels that have occurred historically. Doing so will result in the historical estimates of the KRFC age-4 ocean harvest rate being less useful for determining credible bounds for future fall fisheries.

6 Acknowledgements

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Agenda Item H.1.a
Attachment 3
November 2009

Is the September 1 river return date approximation appropriate for Klamath River fall Chinook?

Michael R. O'Farrell[1]

Melodie L. Palmer-Zwahlen[2]

Jennifer Simon[2]

[1]National Marine Fisheries Service

Southwest Fisheries Science Center

Fisheries Ecology Division

110 Shaffer Road, Santa Cruz, CA 95060

[2]California Department of Fish and Game

Marine Region

Ocean Salmon Project

475 Aviation Boulevard, Suite 130

Santa Rosa, CA 95403

September 22, 2009

1 Introduction

The Klamath River fall Chinook (KRFC) cohort analysis and Klamath Ocean Harvest Model (KOHM) both make the simplifying approximation that immediately prior to September 1, mature KRFC leave the ocean for the Klamath Basin and immature KRFC remaining in the ocean after September 1 advance one year in age. The river return date approximation was chosen to be a date when the ocean abundance of KRFC transitions from being a mixture of immature and maturing fish to one of primarily immature fish that will contribute to future fisheries and escapement. The return date approximation is a simplification of the true maturation process in which mature fall Chinook leave the ocean for the Klamath Basin during a reliable, yet more protracted period of time than the models assume.

Age-specific preseason forecasts of KRFC ocean abundance, annually published in the Preseason I report (e.g., PFMC 2009a), are effective on the September 1 return date approximation. The KOHM projects these age-specific September 1 year $(t-1)$ preseason forecasts of ocean abundance through completed, ongoing, and proposed fisheries during the September 1 $(t-1)$ through August 31 (t) period, accounting for both harvest impacts and natural mortality on a monthly basis. After August (t) ocean mortality is deducted from the August (t) ocean abundance, the remaining ocean abundance (age-specific) is multiplied by age-dependent, long-term average maturation rates to forecast the river run size (t), and ultimately escapement (t), of KRFC. The KRFC cohort analysis is based on the same structural relationships as the KOHM, except that individual cohorts are reconstructed from the end of their lifetimes as age-5 spawners backward in time, accounting for both harvest impacts, natural mortality, and maturation (Mohr 2006; Goldwasser et al. 2001). The cohort analysis provides the maturation, harvest, contact, and impact rate estimates that are vital to the overall KRFC assessment process. Choice of an appropriate river return date approximation for the KOHM and cohort analysis has implications for both harvest allocation and estimation of, at the very least, fishery contact, harvest, and impact rates.

With regard to harvest allocation, the September 1 river return date approximation results in impacts for the September 1 $(t-1)$ to August 31 (t) period being applied to the year (t) harvest allocation accounting and conservation objectives. A model river return date set too early relative to the KRFC overall return schedule can result in mature fish destined to spawn in year $(t-1)$ being caught in the ocean after the designated return date. The harvest and impacts of these mature fish caught after the designated river return date will be counted toward year (t) allocation accounting and conservation objectives. Conversely, if the model river return date is set too late relative to the overall return schedule, a large number of immature fish, which would largely contribute to year (t) fisheries and escapement, would instead be counted toward year $(t-1)$ allocation accounting and conservation objectives. Hence, the choice of a model river return date which simultaneously minimizes both of these allocation misclassifications is appropriate.

With regard to estimation of contact, harvest, and impact rates, a disparity between the timing of the actual river return period and the model river return date can create biases in the reconstructed cohort abundances, that in turn could result in biased estimates of these key rates. If the model river return date is assumed to be a date that is set before or at the beginning of the actual river return period, the reconstructed ocean abundance between the model date and the actual period will be biased low. Viewed from a forward projection perspective, the model assumes that the ocean abundance of a cohort is decreased just prior to the model return date, owing to maturation, when in fact the true cohort abundance will not be reduced until the actual return period commences at a later time. The result of this bias in the cohort's ocean abundance is that contact, harvest, and impact rates could be biased high for the period between the model return date and the actual return period since the cohort abundance, the denominator of these rate calculations, is biased low. Conversely, if the model river return date is set later than the actual river return period, the reconstructed abundance between the actual period and the model date will be biased high. Again, from a forward projection perspective, the model population is reduced by maturation at the time immediately preceding the model river return date. However, the true cohort abundance in the ocean is being reduced by maturation well before the model return date. This high cohort abundance bias would result in the contact, harvest, and impact rates being biased low. All biases described above would be of greater magnitude for cohorts with higher overall maturation rates (e.g., age-4 KRFC relative to age-3 KRFC). To minimize bias in cohort abundance reconstruction, as well as contact, harvest, and impact rates, the model river return date should be chosen to minimize the total, temporal distance between the model return date and the center of the actual river return period.

For KRFC, there is a unique opportunity to evaluate the appropriateness of the September 1 model river return date. Every year, the Yurok Tribe conducts a gillnet fishery in the mainstem Klamath River between the mouth and the confluence with the Trinity River. A substantial portion of the Yurok gillnet fishery occurs in the Klamath River estuary, harvesting Chinook salmon shortly after they exit the ocean. In many years, the fishery operates nearly continuously from early spring, when Klamath River spring Chinook (KRSC) begin entering the river, through the fall when lower river abundance of KRFC tapers off. The fishery is monitored by the Yurok Tribe and coded-wire tags (CWTs) are collected, which allows for the evaluation of river entry timing for each run, by hatchery (Iron Gate vs. Trinity) and release type (fingerling vs. yearling). These data can be used to evaluate run timing for the KRFC stock, acknowledging that there is some unknown, but likely short, time lag between when mature KRFC are unavailable to ocean fisheries and their subsequent capture in the Yurok estuary fishery.

Using Yurok catch and CWT recovery data from the Klamath River estuary, we investigate KRFC river return timing and evaluate the appropriateness of the current September 1 return date approximation made in the cohort analysis and KOHM. Section 2 describes the treatment of the Yurok catch and CWT recovery data while section 3 describes the temporal distribution of river return timing inferred from the Yurok data and examines estimated fall ocean fishery impact rates relative to KRFC river return timing. Section 4 evaluates the appropriateness of the September 1 model river return date, given the data and the KRFC assessment structure. Section 5 synthesizes the results and conclusions into recommendations for future KRFC assessment.

2 Data and methods

The Yurok and Hoopa Valley tribes are allotted 50 percent of the total allowable KRFC annual harvest, with the Yurok Tribe generally receiving 80 percent of this tribal allocation. The Yurok gillnet fishery generally begins in late April or early May, depending on when KRSC begin returning to the Klamath Basin. Fishing, and sampling of the catch, typically continues through the summer and fall until the KRFC run is complete in late October or early November. The harvest of KRFC in this fishery is regulated by harvest quotas, and in some years the fishery is closed well before the terminus of the fall run owing to the KRFC quota having being met.

Sampling of the fishery is stratified into three management areas: estuary (mainstem Klamath River from the ocean mouth to the highway 101 bridge), middle Klamath (mainstem Klamath River from the highway 101 bridge to Surpur Creek), and upper Klamath (mainstem Klamath River from Surpur Creek to the Trinity River mouth). Sampling is stratified by management area and week (Sunday through Saturday), with between 20 and 40 percent of the catch sampled per stratum. Samplers attempt to collect the heads from all adipose fin clipped (i.e., ad-clipped) salmon observed during monitoring. A clipped adipose fin indicates the salmon head contains a CWT, which provides brood year, hatchery or river of origin, run, release size, and release location information for that fish. Fishery monitoring data provided by the Yurok Tribe contained information on the number of salmon sampled, the number of ad-clipped salmon observed, the number of heads collected from ad-clipped salmon, as well as the estimated catch by week and river management area stratum. These data were used in conjunction with the CWT recovery data and any discrepancies (e.g., more heads collected than ad-clipped fish observed, more salmon sampled than the total estimated catch, more CWT recoveries than heads collected) were resolved with the Yurok Tribe prior to these analyses.

Occurrence of KRSC and KRFC in the Yurok gillnet fisheries tends to overlap for several weeks in August as the KRSC run wanes and the KRFC run builds. Segregation of the two runs in the catch was accomplished using the proportions of expanded KRSC and KRFC CWTs recovered per week and river management area strata. The total net harvest of KRFC by management area and year was then compared to the total Yurok Tribe KRFC catch reported in Table B-5 of PFMC (2009b) to ensure that the estimates used for this report were consistent with those published in PFMC reports.

This report considers catch from the estuary management area only as this represents the first instance of in-river harvest of mature KRFC and is most appropriate for the river return timing analyses. Data from the middle and upper Klamath management areas would be less informative than the estuary since salmon are known to stage in the river as they migrate upstream, which would further complicate the analysis of river return. The estuary, encompassing the lowermost 2.8 river miles, also receives the highest amount of fishing effort of the three management areas.

Yurok catch estimates were available for the period between 1994 and 2008. However, several years (1994, 1995, 2000, and 2006) were omitted from this analysis because quotas closed the estuary fishery prior to the completion of the KRFC run. In addition, data from 2002 was excluded because low river flows and high temperatures resulted in an atypical migratory pattern up the Klamath River. The well publicized "fish kill" in the lower Klamath River occurred in 2002 and this year was characterized by low flows and high temperatures that impeded upstream migration.

2.1 River return timing: composite stock

The estimate of total KRFC catch in the Yurok gillnet fishery by week and management area stratum was provided by the Yurok Tribe for this analysis. These catch estimates are for the composite stock, comprised of natural origin KRFC from both the Klamath and Trinity river basins, as well as hatchery origin fish from the two hatcheries. To evaluate run timing for the composite stock, we examined weekly catch estimates in the Yurok gillnet fishery in the Klamath River estuary.

2.2 River return timing: hatchery stocks

Estimates of hatchery-origin KRFC catch in Yurok gillnet fisheries was determined by coupling CWT information with catch sample data. Successfully decoded CWTs were expanded to an estimate of the catch associated with each tag recovery by accounting for the weekly sampling fraction (f) in the fishery and the hatchery tagging fraction (p) for the particular tag code. The sampling fraction is defined as

$$f = f_c \times f_a \times f_d, \tag{1}$$

where f_c is the fraction of the catch sampled, f_a is the fraction of heads from ad-clipped salmon collected and processed, and f_d is the fraction of observed CWTs that were successfully decoded. The tagging fraction is the fraction of the total salmon released (both ad-clipped and non ad-clipped) that contained a particular CWT code. Therefore, the estimated catch per CWT recovery for that particular tag code is equal to $1/(f \times p)$. For this analysis, CWT recoveries were further classified into release types based on hatchery or river of origin, run, release location, or size of fish at release. The four primary KRFC release types include Iron Gate Hatchery fingerlings (IGHF), Iron Gate Hatchery yearlings (IGHY), Trinity River Hatchery fingerlings (TRHF), and Trinity River Hatchery yearlings (TRHY). Both hatcheries also produced small groups of experimental KRFC fingerlings and yearlings and several thousand wild Chinook were captured and tagged each year. The experimental production and wild fish tagging stopped in 1997. For this report, we examine the temporal occurrence of the four primary KRFC release types in the Yurok estuary gillnet fishery, and do not consider experimental or wild tag groups further.

2.3 River return timing and estimated ocean fishery impact rates

Concerns have been raised regarding the relationship between the September 1 model river return date and fall (primarily September) ocean fishery impact rates. In particular, if mature fish caught after September 1 ($t-1$) contribute heavily to September ($t-1$) impact rates, fishing opportunity in spring/summer (t) fisheries could be reduced. To evaluate the potential role the September 1 model return date has had on fall fishery impact rates, we plot the cohort analysis-estimated age-3 and age-4 ocean fishery impact rates for all months to determine how fall fishery impact rates compare to winter/spring/summer fishery impact rates. We then examine the correlation between the September age-4 impact rates for IGHF, IGHY, TRHF, and TRHY hatchery release types and the observed "lateness" of the run for those tag groups. The "lateness" metric used for this analysis is defined as the proportion of Yurok estuary catch occurring after September 1. To the extent that a delay in run timing contributes to higher fall fishery nominal impact rates, these two variables should be positively correlated.

3 Results

3.1 River return timing: composite stock

For years when the Yurok estuary fishery was not closed early due to attainment of its quota, we used the weekly estimated catch to infer river return timing of the composite KRFC stock. Figure 1 displays the proportion of the overall KRFC catch from the Yurok estuary fishery by Julian day. This catch includes KRFC of natural and hatchery origin. In general, KRFC harvest in the estuary begins close to August 1, and tapers off toward the end of September. In five of the ten years evaluated, the median date of capture was before September 1. The interannual differences in run timing are relatively small, on the order of days rather than weeks. In general, these data suggest that September 1 is an appropriate midpoint of composite KRFC stock river return timing.

3.2 River return timing: hatchery stocks

Figure 2 displays the estimated cumulative harvest by day of age-3 and age-4 IGHF, IGHY, TRHF, and TRHY, as well as these four release types combined. Age-3 Iron Gate Hatchery origin KRFC tend to have a slightly earlier river return timing distribution relative to age-3 Trinity River Hatchery origin KRFC. TRHY age-3 have the most variable and latest river return timing of the four release types. The median date of capture for the total age-3 hatchery KRFC ranges from August 30 to September 14, with a mean date of September 5. For age-4, Iron Gate Hatchery origin fish have a median river return date clustered around September 1. Timing of age-4 TRHF is quite variable, but also exhibits a median date of capture with a central tendency of September 1. Age-4 TRHY have median dates of capture slightly later than the other release types, ranging from August 26 to September 17. For the total age-4 hatchery catch, median river return timing is clustered fairly tightly, with a mean date of August 31. In general, total hatchery origin age-3 river return timing appears to be slightly later relative to hatchery origin age-4 river return timing.

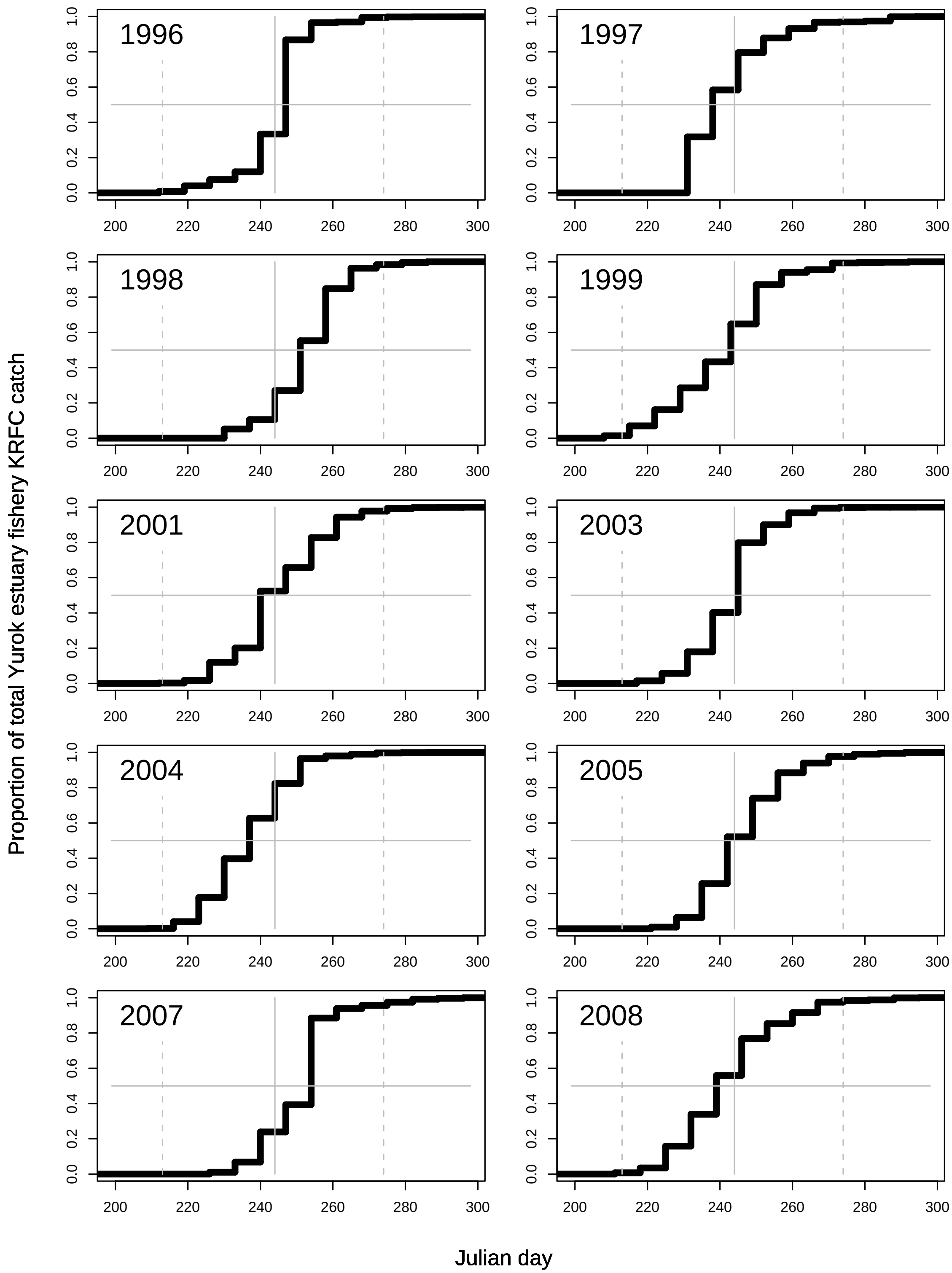

Figure 1. Yurok estuary catch of KRFC by sampling week. The heavy black line is the cumulative catch distribution, plotted at the midpoint of the sampling week. Dashed vertical grey lines represent August 1 and October 1, while the solid vertical grey line represents September 1 (Julian day 244). The horizontal grey line identifies a proportion of 0.50.

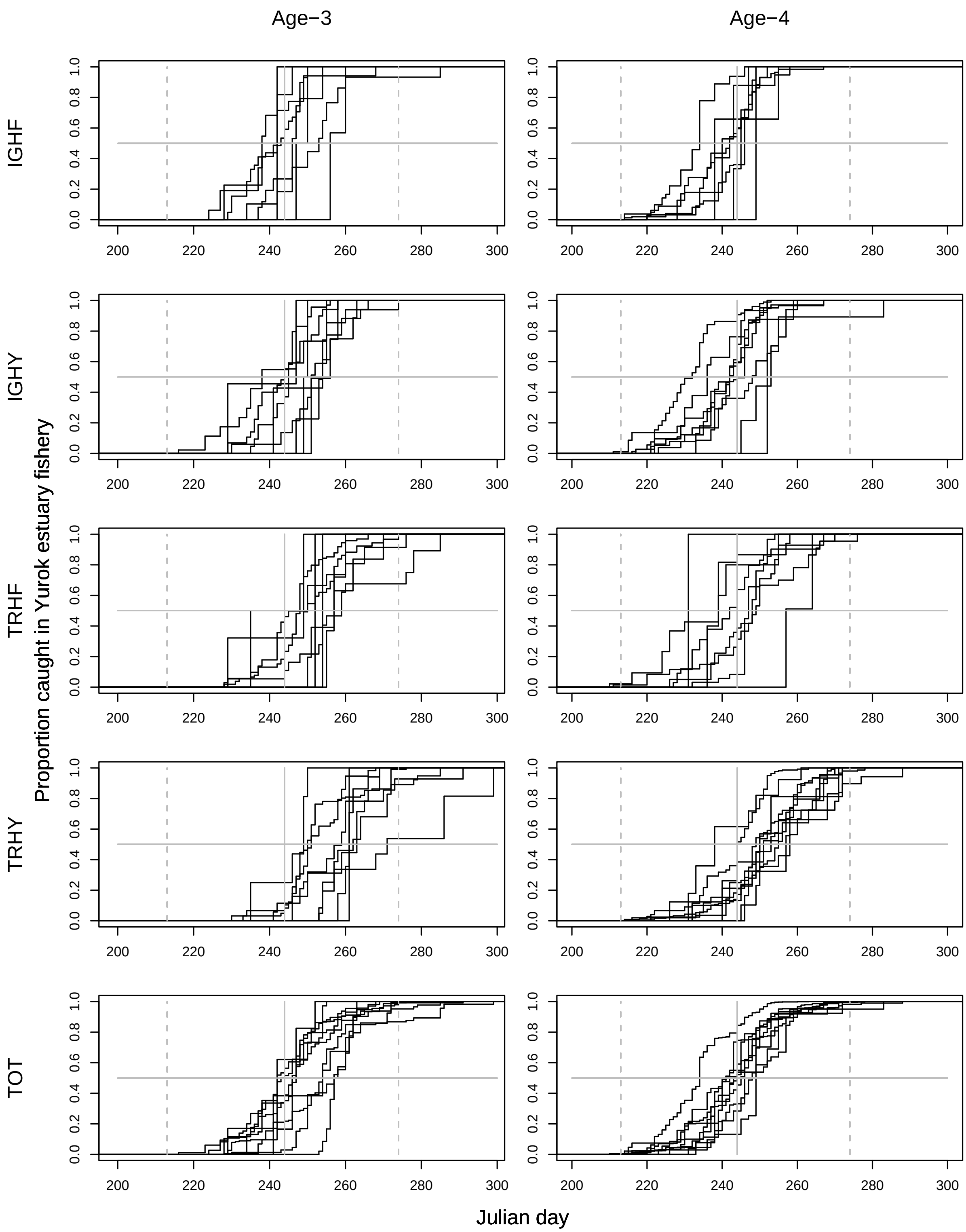

Figure 2. Estimates of cumulative catch of hatchery KRFC by Julian day. IGHF and IGHY are Iron Gate Hatchery fingerlings and yearlings, respectively. TRHF and TRHY are Trinity River Hatchery yearlings and fingerlings. TOT is the total catch of the four hatchery release types combined. Each black line represents an individual year. Grey lines are defined as in Figure 1.

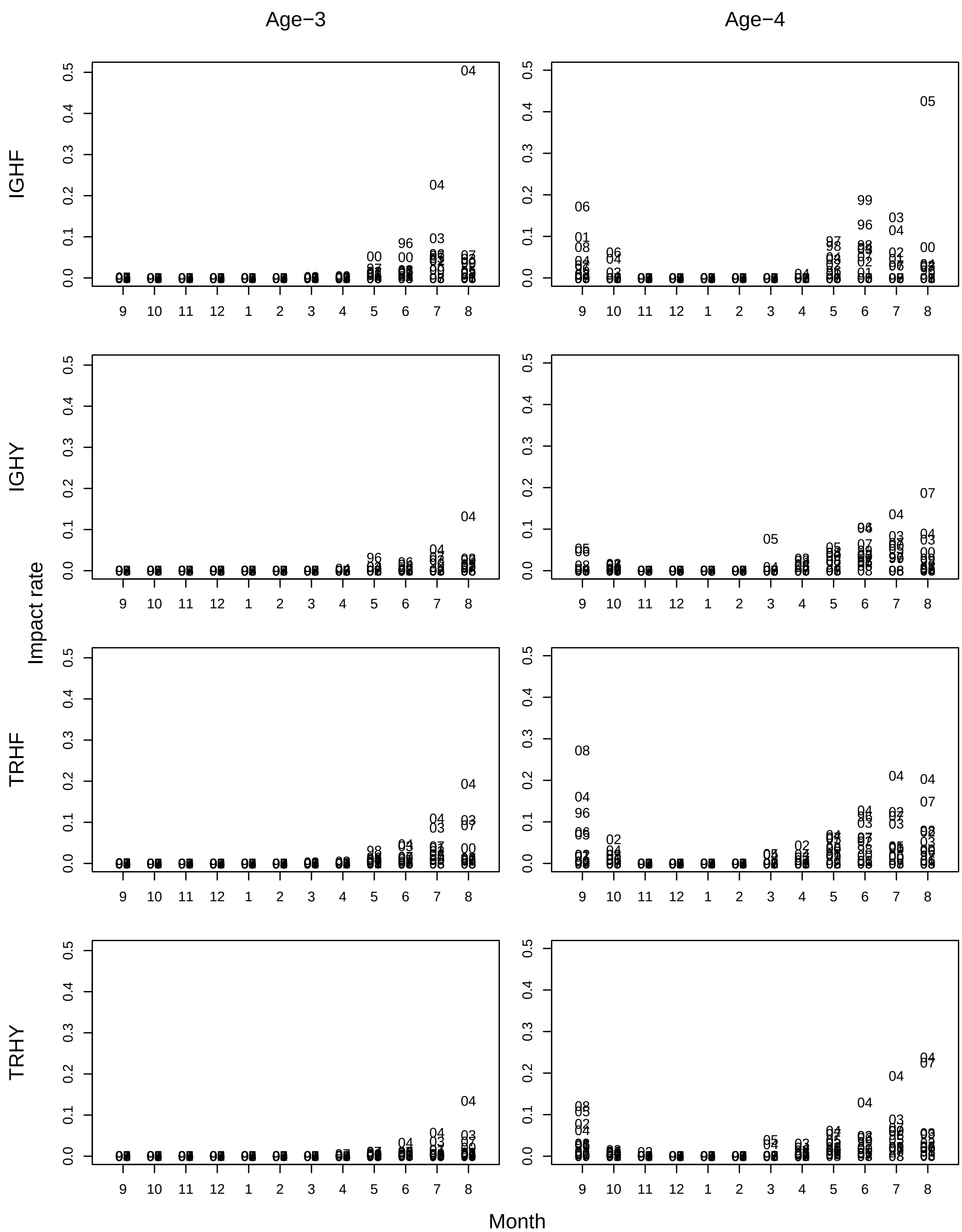

Figure 3. Ocean fishery impact rates for the four major KRFC release types plotted by month. Numbers in the plot denote the year in which the impact rates are applied in forecasting escapement. For example, September–December 2003 and January–August 2004 impact rates are labeled as "04".

3.3 River return timing and estimated ocean fishery impact rates

Figure 3 displays the temporal distribution, and interannual variation in cohort analysis-estimated age-3 and age-4 ocean fishery impact rates for the four major hatchery release types. The years depicted in Figure 3 correspond with the years in Figure 1. For age-3 hatchery KRFC, there are very low levels of fall impacts as only a small proportion of age-3 are vulnerable to harvest because most are smaller than minimum size limits. Age-3 impact rates increase during winter/spring/summer fisheries. Age-4 hatchery KRFC can experience relatively high impact rates from fall fisheries, particularly in September, though they are not appreciably different than August age-3 impact rates. High (greater than 10 percent) impact rates in September have been observed for age-4 IGHF, TRHF, and TRHY.

It can reasonably be assumed that September age-4 ocean impacts are comprised of some mature and some immature KRFC, and the relative proportions of this mixture would have a dependence on river return timing. Table 1 displays the correlation coefficients between the September age-4 ocean impact rates and the "lateness" of the age-3 river return for each of the four hatchery release groups of the same brood. A significantly positive correlation coefficient would indicate a positive association exists between delayed age-3 river return and the age-4 ocean impact rate. The correlation coefficients in Table 1 do not support the hypothesis that age-3 river return timing and September age-4 ocean harvest rates are correlated. Three of the four correlations are negative, while one is positive. None of the correlations are significantly different than zero. It should be noted that the long term average age-3 maturation rate of KRFC is 39 percent. Therefore, even if all maturing age-3 KRFC in a given year had an unrealistically late river return timing (e.g., all KRFC in the cohort returned to the river after September 30) 39 percent of the September age-4 impacts would be expected to be mature fish. In reality, a much smaller, yet variable, proportion of September impacts would be expected to be mature, given the river return timing inferred from Figures 1 and 2 and the particular timing of ocean fisheries in September. Also note that the data and estimates presented here do not allow for direct estimation of the proportion of September impacts that were mature KRFC. It is possible that even the highest September impact rates could be largely the result of immature fish mortalities.

Table 1. Pearson correlation coefficients for the September age-4 ocean impact rate and the "lateness" of the age-3 river return timing. Numbers in parentheses are p-values.

	Fingerling	Yearling
IGH	-0.419 (0.350)	-0.074 (0.862)
TRH	-0.328 (0.428)	0.228 (0.587)

4 Conclusions

The timing of the composite KRFC catch in the Yurok estuary fishery suggests that September 1 is an appropriate river return date approximation for KRFC models. While some hatchery components exhibit slightly later river return timing (e.g., age-3 TRHF and TRHY), this does not have a strong bearing on the river return timing of the composite KRFC stock. As with any salmon stock, various tributaries and hatchery releases might be expected to vary in their timing of river entry. However, as was pointed out in the Introduction, an appropriate model return date that minimizes allocation and estimation errors should approximate the midpoint of the composite stock river return timing. This balances errors that are inherent in setting the model return date too late for early returning substocks and too early for late returning substocks.

September age-4 ocean fishery impact rates are not dramatically higher than summer impact rates, which also suggests that the September 1 model return date is appropriate. Hankin and Logan (2009) constructed a cohort analysis for KRFC using coded-wire tag recoveries from each of the four major release types in the Klamath Basin and observed implausibly high fall impact rates for Trinity River hatchery Chinook when they assumed a September 1 return date. Because of this observation, they explored alternative, later model return dates, though the result of these modifications to their cohort analysis was not noted in their report. We do not observe these same implausibly high rates with the KRFC cohort analysis used for KRFC assessment. Rather, age-4 September impact rates are of the same general magnitude as impact rates for July and August.

While it is impossible to know, given current data, what proportion of ocean catch in a particular month is comprised of mature fish, one could reasonably assume that high age-4 impact rates in

September could arise if age-3 river return timing was much later than the September 1 model return date. However, this correlation is not observed for any of the four KRFC hatchery release types. Rather, high (or low) impact rates can occur for cohorts exhibiting either late or early run timing.

High September $(t-1)$ age-4 ocean harvest rates may affect fishing opportunity in spring/summer (t) fisheries owing to the California Coastal Chinook Endangered Species Act consultation standard of a maximum KRFC age-4 ocean harvest rate forecast of 16 percent. The degree to which mature age-3 KRFC contribute to September $(t-1)$ age-4 ocean harvest has periodically been a concern. Examination of age-3 maturation rates and inferred run timing from the Yurok fishery allows for some evaluation of the expected mature fish contribution to age-4 September ocean harvest. The long-term mean maturation rate of age-3 KRFC is 39 percent. Given the age-3 hatchery catch data from the Yurok estuary fishery, one would expect that substantially less than 39 percent of the catch occurring on September 1 would be comprised of mature fish. By September 15, the expected proportion of mature age-4 in the ocean catch would drop to a very low level because most mature fish have exited the ocean to spawn as 3 year old KRFC (see Figure 2). If a goal was to minimize the risk of having mature KRFC impacts in September ocean fisheries, one tactic could be to limit fisheries between September 1 and September 15. Combining this observation based on river return timing with the fall age-4 ocean harvest rate estimates presented by ocean management area in O'Farrell (2009) allows for a more refined approach to decreasing this risk. Limiting fall commercial fisheries during the period between September 1 and September 15 in the California Klamath Management Zone (KC) and the Central Oregon (CO) management areas, and to a lesser degree, Northern Oregon (NO), the Oregon Klamath Management Zone (KO), and Fort Bragg (FB), could greatly reduce the risk of harvesting mature KRFC. Commercial fisheries in Monterey (MO) and (SF) have a very small contribution to the fall age-4 ocean harvest rate, and recreational fisheries in general contribute relatively little to this rate. This tactic may be less effective if substantial effort transfer results from limitation of fisheries in certain ocean management areas. For example, if limitations on commercial fisheries in the CO or KC management area results in a large effort shift to the KO management area, the reduction in mature fish contribution to the age-4 ocean harvest may be lower than expected.

The KRFC conservation objective, specified in the salmon Fishery Management Plan, applies to the composite stock of fish originating in the Klamath and Trinity rivers, including all hatcheries and tributaries. A previous attempt to perform cohort reconstructions and ocean abundance estimates separately for each stock component (e.g., IGHF, TRHY) performed poorly relative to current methods (KRTAT 1994). Given these results, the choice of an appropriate river return date for models used on the composite stock should reflect the return timing observed for the entire KRFC stock. Based on analysis of harvest in the Yurok estuary fishery, September 1 continues to be a valid approximation for the KRFC river return date used in KRFC fishery assessment models.

5 Recommendations

Given these conclusions, the following recommendations are provided for future KRFC assessment.

1. The current September 1 river return date approximation should be retained in KRFC fishery assessment models. The September 1 date is clearly an appropriate average midpoint date of capture for the composite KRFC stock in the Yurok Tribe estuary fishery, a close proxy for the timing of escapement from ocean fisheries.

2. Limiting commercial fisheries in the KC and CO ocean management areas between September 1 and September 15 could reduce the risk of harvesting mature KRFC that have not yet returned to the river. If there is a desire to decrease the risk of having year $(t-1)$ impacts of mature KRFC apply to year (t) conservation objectives and consultation standards, and thus constraining year (t) fisheries, limiting commercial fisheries during these times and areas would likely be effective in achieving this goal.

6 Acknowledgements

We wish to thank the Yurok Tribe, particularly Desma Williams, for providing historical data and estimates from their Klamath River gillnet fishery. The analysis could not have been completed without this information. We also thank Michael Mohr for his comments on this report.

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State of Washington
DEPARTMENT OF FISH AND WILDLIFE
Mailing Address: 600 Capitol Way North
Olympia, Washington 98501-1091
Main Phone (360) 902-2200 TDD (360) 902-2207
Main Office Location: Natural Resources Building 1111
Washington Street Southeast, Olympia Washington

NORTHWEST INDIAN FISHERIES COMMISSION
6730 Martin Way East
Olympia, Washington 98516-5540
Phone (360) 438-1180
Fax (360) 753-8659
www.nwifc.org

September 30, 2009

Mr. Chuck Tracy,
Staff Officer for Salmon and Pacific Halibut
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384

Dear Chuck,

The Puget Sound Indian tribes and the Washington Department of Fish and Wildlife (WDFW) are submitting a proposal to the Council for changes to the Salmon Fishery Management Plan conservation objectives for Puget Sound coho salmon. Our understanding is that this proposal will be considered within the Council's 2009 Salmon Methodology Review process, and that members of the Scientific and Statistical Committee (SSC) and the Salmon Technical Team (STT) will review our proposal at a meeting to be conducted on October 5, 2009.

To aid the Council's review process, we have attached the specific proposal for changes to the Puget Sound coho management objectives (Table 1.), and also have attached existing documentation of the rationale supporting these changes.

For background, the current/proposed management objectives were developed to support the maintenance and restoration of wild stocks within Puget Sound. A key objective of the abundance based or stepped exploitation rate approach was to provide a management framework that is consistent with our technical capabilities. Estimates of the MSH exploitation rate obtained from a stock-recruit function are likely to have less bias than estimates of the MSH escapement. Additionally, the stepped exploitation rate approach is expected to provide greater long-term catches than a fixed escapement goal approach while minimizing inter-annual variability in fishing seasons.

The stepped exploitation rate approach defines three abundance or status categories for each key wild management unit (individual population or group): critical, low and normal. The abundance that defines a change in status between critical and low, termed the critical/low breakpoint, identifies escapement numbers that have an unacceptable risk of future population instability, unpredictability, or productivity. The low/normal breakpoint identifies abundance levels with low risk to future production and achievement of MSH.

The approach establishes three ceiling or maximum exploitation rates for each of the key wild management units; one for each abundance category (normal, low and critical). The normal category exploitation rate is defined to provide for MSH under assuming average environmental and survival conditions. The low category exploitation rate is defined to provide for MSH assuming low survival conditions. The exploitation rate ceiling associated with the critical status category is defined to prevent the escapement from falling below the critical low breakpoint and present fishery managers with very difficult policy choices. The three status defined exploitation rate levels for the Puget Sound coho stocks of concern to the Pacific Fishery Management Council are presented in Table 1. The technical basis for these objectives is provided within the attached documents.

This approach has served the Puget Sound wild coho management units well since it was implemented in the mid-1990's. The combination of good ocean survival, habitat restoration efforts and management of fisheries using this stepped exploitation rate approach has kept the stock abundances up in the upper quadrants (spawning escapements for Skagit, Stillaguamish, Snohomish, Hood Canal, eastern Strait of Juan de Fuca coho have been above the critical level).

The Southern Coho Management Plan of the recently revised Pacific Salmon Treaty has adopted the same abundance based, stepped exploitation rate approach to managing coho salmon fisheries in Canada and the United States.

The Puget Sound Indian tribes and WDFW look forward to the opportunity to provide an overview of the proposal and the supporting rationale to the Salmon Subcommittee of the SSC and STT, and to engage in a discussion of the management objectives in the interest of gaining support for the proposal.

Please contact either of us if you have questions prior to our engagement.

Sincerely,

Craig Bowhay
Northwest Indian Fisheries Commission

Pat Pattillo
Washington Department of Fish and Wildlife

Table 1. Management Objectives for Puget Sound Natural Coho management units, expressed as exploitation rate ceilings for Critical, Low and Normal abundance based status categories, with runsize breakpoints (abundances expressed as Ocean Age 3).

	Management Unit				
	Strait of Juan de Fuca	Hood Canal	Skagit	Stillaguamish	Snohomish
Critical/Low runsize breakpoint	11,679	19,545	22,857	9,385	51,667
Critical exploitation rate	0.20	0.20	0.20	0.20	0.20
Low/normal runsize breakpoint	27,445	41,000	62,500	20,000	125,000
Low exploitation rate	0.40	0.45	0.35	0.35	0.40
Normal exploitation rate	0.60	0.65	0.60	0.50	0.60

MEMORANDUM

TO:	Jeff Haymes
FROM:	Bob Hayman
DATE:	October 14, 2009
SUBJECT:	Recalculation of Skagit Coho Breakpoints & Exploitation Rate Ceilings

After re-doing the analysis, I am proposing the following breakpoints and exploitation rate ceilings for Skagit coho:

Normal Exploitation Rate:	60%
Low Exploitation Rate:	30%
Low/Normal Breakpoint:	25,000
Critical/Low Breakpoint:	Still Developing; looks like about 16,000

In the May 5, 1998 Second Interim Report, the corresponding values were:

Normal Exploitation Rate:	64%
Low Exploitation Rate:	47%
Low/Normal Breakpoint:	18,900
Critical/Low Breakpoint:	9,000

There were two major changes in the new calculations:

1) It was assumed that mean marine survival for the next 6 or so years (until the next scheduled long-term review) would be closer to recent survival rates (mean of 9.0%) than to long-term survival (adjusted mean was 12.6%; unadjusted was 16%); and

2) Environmental variation and management error were included in the calculations.

The methods and calculations were as follows:

METHODS

<u>Low/Normal Breakpoint:</u>

The low/normal breakpoint is defined in the Second Interim Report as “the estimated MSH escapement under low survival conditions, where low survival is the survival rate expected to be exceeded 90% of the time.” This value would then be calculated by setting survival at the “low” level, and determining the escapement goal that gives maximum long-term harvest under those conditions. The steps are:

1) Write a program that uses input spawner-recruit and management error parameters to calculate the mean catch and escapement that results from long-term application of different fixed-point spawning escapement goals.

2) For the spawner-recruit function, use recent marine survival values (and their variance) to calculate the Marine/FW Survival rate (and its associated variance) that would be exceeded 90% of the time.

3) Select a low/normal breakpoint (fixed-point escapement goal);

4) For each year, generate a recruitment (using random variability in the survival rate) from a Beverton-Holt function, and a forecasted recruitment (using a randomly-chosen forecast error factor). For these runs, the smolt capacity (Beverton-Holt a) was set at 1.2 million, and the productivity (a/b) was set at 70 smolts/spawner;

5) Calculate the exploitation rate needed to hit the escapement goal under that forecast, and generate an actual exploitation rate by applying a randomly-chosen exploitation rate error factor;

6) Multiply that actual exploitation rate by the true recruitment to get the catch and escapement;

7) Model that escapement goal over 25 years.

8) Calculate the mean harvest and escapement over the years.

9) Repeat that simulation for that escapement goal 1000 times (with different random seeds);

10) Calculate the mean harvest for each simulation;

11) Calculate the overall mean harvest for all the simulations done with that escapement goal;

12) Repeat this process for a different escapement goal.

The escapement goal that provides the highest mean catch is then, by definition, the low/normal breakpoint.

<u>Low Exploitation Rate Ceiling:</u>

The low exploitation rate is defined in the Second Interim Report as "the exploitation rate that provides the MSH under low survival conditions, where low survival is the survival rate expected to be exceeded 90% of the time." This value would then be calculated by setting survival at the "low" level, and determining the exploitation rate that gives maximum long-term harvest under those conditions. The steps are:

1) Modify the program developed above so that it uses an exploitation rate target, rather than a fixed escapement goal, to determine the catch.

2) For the spawner-recruit function, use the same low freshwater-adjusted marine survival values used above.

3) Select an exploitation rate target.

4) For each year, generate a recruitment (using random variability in the survival rate), and a forecasted recruitment (using a randomly-chosen forecast error factor). The forecast is used only to determine whether to apply the target rate, or, if the forecast is below a selected threshold, a minimum rate.

5) Generate an actual exploitation rate by applying a randomly-chosen exploitation rate error factor to the target rate;

6) Multiply that actual exploitation rate by the true recruitment to get the catch and escapement;

7) Model that target rate over 25 years.

8) Calculate the mean harvest and escapement over the years.

9) Repeat that simulation for that target exploitation rate 1000 times (with different random seeds);

10) Calculate the mean harvest for each simulation;

11) Calculate the overall mean harvest for all the simulations done with that exploitation rate target;

12) Repeat this process for a different exploitation rate target.

The exploitation rate target that provides the highest mean catch is then, by definition, the low exploitation rate ceiling.

<u>Normal Exploitation Rate Ceiling:</u>

The normal exploitation rate ceiling is defined in the Second Interim Report as "the exploitation rate that provides the MSH under average environmental conditions." This value would then be calculated by setting survival at an average level, with average variation, and determining the normal exploitation rate target that gives maximum long-term harvest under those conditions. When forecasts are for escapements below the low/normal breakpoint, either the low exploitation rate target or a minimum rate would be used. The steps for calculating this rate are the same as those above, with these differences:

1) For the spawner-recruit function, use the mean freshwater-adjusted marine survival, with its variance.

2) Before each run of 25 years, choose a different set of Beverton-Holt a and b parameters, in order to simulate uncertainty in the spawner-recruit values (this was not done for the low rate or breakpoint because those values were defined for specific survival assumptions).

3) If the forecast was for an escapement below the low/normal breakpoint, but above a selected threshold, then the low target exploitation rate was used. If the forecast was for an escapement below the threshold, then a minimum exploitation rate was used.

As with the low exploitation rate ceiling, the normal exploitation rate target that provides the highest mean catch is then, by definition, the normal exploitation rate ceiling.

Critical/Low Breakpoint:

This breakpoint is not defined mathematically. The Second Interim Report defines it as "the escapement level below which an unacceptable risk exists (resulting from population instability, unpredictability, or productivity) that the abundance will be less than the low/normal breakpoint in one to three cycles." It can be thought of as a point below which the population destabilizes. I used two methods to calculate this level:

Method 1:

1) Modify the above model so that the minimum exploitation rate is applied below a selected breakpoint, and the point of destabilization varies each run as a function of the chosen Beverton-Holt a parameter (5% of the capacity that results from using that a parameter).

2) Input the low/normal breakpoint, and the low and normal exploitation rate ceilings calculated above, and then select a critical breakpoint.

3) Run the model for 25 years 1000 times for each selected critical breakpoint.

4) Count the number of times, and the number of runs, in which escapement fell below the point of destabilization.

5) Graph the number of simulations (out of 1000) in which the escapement fell below the point of instability (or in which the run size dropped to 0), for each critical breakpoint, or, alternatively, the percentage of years (out of all the years run for each breakpoint), in which escapement fell below the point of instability.

6) Pick some breakpoint that looks good. E.g., look for an inflection point in the graph, or the critical breakpoint at which the frequency of below-stability escapements dropped to an acceptable level.

Because this breakpoint is not mathematically defined, its selection is kind of subjective ("looks good"?!). An alternative is to calculate the breakpoint the same way I did the Skagit spring chinook critical levels (which doesn't use a QuickBasic model). The theory behind this method is described in my 1/19/2000 memo on spring chinook exploitation targets and floors (get a copy from Pat):

Method 2:

1) Assume that the point of instability is 5% of the normal capacity (per Peterman – this assumption is also used for Method 1)

2 Using the variability parameters for the Beverton-Holt a parameter and the freshwater-adjusted marine survival, generate 1000 random smolt capacity values and 1000 random survival rates.

3) Multiply these numbers together (to get 1000 adult capacities), and multiply their products by 5%, to get the point of instability for each of the 1000 pairs of values.

4) Calculate the mean and standard deviation for the 1000 point of instability values. Do this about 20 times, and get a mean of the means. This mean of means is the estimated point of instability and its standard deviation.

5) Scale the management error values so that a scalar of 1.0 means no error; a scalar of 0.5 means an error of –50%; and a scalar of 1.5 means an error of +50%. (I.e., add 1 to the percent error values).

6) Calculate the mean of the management error scalars, and their standard deviation.

7) For a range of escapement values, calculate the probability that that value is less than the point of instability (i.e., the area to the right of that escapement on the point of instability frequency distribution curve), and the Y-value of the curve (the frequency level) at that escapement.

8) Select an expected escapement.

9) For the same range of escapement values used in Step 7, calculate the probability that, given that expected escapement, the post-season escapement will be less than each of the escapement values in that range (i.e., for that given expected escapement, calculate the area under the management error distribution that is to the left of each escapement value in the range), and calculate the Y-value of the management error distribution for each escapement value in the range.

10) Identify the escapement value for which the Y-value of the management error distribution equals the Y-value of the point of instability frequency distribution.

11) For that escapement value, sum the area to the right of that point on the point of instability frequency distribution, and the area to the left of that point on the management error distribution.

12) Go back to Step 8. Continue until the sum (Step 11) is equal to, or just less than, 5%.

13) The expected escapement that gave that answer is the critical/low escapement breakpoint.

RESULTS

Low/Normal Escapement Breakpoint:

Marine Survival: The only marine survival rate estimates in recent years for Skagit wild coho are from the Baker wild coho CWT releases. Since BY 1989, their survival has averaged 9.0%, with a standard deviation of 3.0% (Table 1).

Freshwater Survival: I didn't have the individual freshwater scalars for Deschutes, Big Beef, Sunset Falls, and Snow Creek, but I did have a 2/25/97 data table from Jim Scott that said that their mean scalar was 1.0, and the 10th percentile was 0.63. With a normal distribution, this would mean that the standard deviation is 0.29.

Freshwater-Adjusted Marine Survival: From these distributions, I calculated 10,000 marine survival rates and 10,000 freshwater survival scalars, multiplied them together, and calculated a mean freshwater-adjusted marine survival of 9.0%, a standard deviation of 4.0%, and a 10th percentile survival value of 4.2% (Table 1).

Preseason Forecast Error: The difference between preseason and postseason estimated Skagit recruitment (calculated as [preseason/postseason] – 1) ranged from –49.8% (1994) to 150.6% (1993). The forecasts were biased high, with a mean error of 26.5% (Table 1).

Exploitation Rate Forecast Error: The difference between preseason and postseason estimated Skagit exploitation rates (calculated as [postseason/preseason] – 1) ranged from –33.0% (1993) to 5.4% (1996). The forecasts were biased high, with a mean error of –9.0% (Table 1).

Survival Rate Distribution: There was some confusion about whether "under low survival conditions" means at exactly the 10th percentile of survival, or with a mean survival at the 10th percentile. So I evaluated the breakpoint under 5 survival rate variation assumptions:

1) Survival fixed at the 10th percentile (4.2%);
2) Survival varies randomly around 4.2% (but can't drop below a positive minimum);

3) Survival varies symmetrically around 4.2%, with a minimum of 0.1% and a maximum of 8.3%;
4) Same as above, except the maximum survival is set at the highest observed recently 13.8%;
5) Survival varies cyclically about 4.2%, over a 24-yr cycle with an amplitude of ± 50%.

Calculated MSH Escapement: In order to distinguish between escapement targets, I examined increments of 5,000. Under all survival rate variation assumptions, the maximum mean harvest was achieved at an escapement goal of **25,000** (Table 2; Fig. 1).

It might be noted that, without management error or survival variation, the calculated MSH escapement under low survival is about 12,200. Thus, modeling error and variation has the effect of doubling the MSH escapement level.

Sensitivity Analyses: Because some of the model inputs are somewhat arbitrary, I examined the sensitivity of the MSH escapement to the following inputs: number of years run; number of runs; initial escapement; Beverton-Holt a (smolt capacity); Beverton-Holt a/b; minimum survival rate; and point of instability. The MSH escapement was sensitive only to the smolt capacity and the point of instability.

At a smolt capacity of 2.0 million, MSH escapement was 30,000; at 3.0 million, it was 35,000. Data from Seiler's smolt trap, which has estimated smolt outmigration under a wide range of spawning escapements, indicates a very low probability that current smolt capacity could average 2 million or higher (it could get that high in an exceptional year, but that would not be an average expectation).

The modeled point of instability was 7,574 (5% of capacity, calculated by Jim Scott). At 9,000 (the formerly-proposed critical breakpoint), MSH escapement was still 25,000. At a point of instability of 2500, MSH escapement was 15,000; at a point of instability of 5000, MSH escapement was 20,000; at a point of instability of 15,000, MSH escapements of 30,000 to 40,000 gave approximately the same long-term catch. The lowest observed escapement with a return above replacement was about 16,000 (in 1991).

I also initiated the runs with 3 different random seed numbers, for each survival assumption, to make sure the results weren't sensitive to the random seed used. The runs labeled "Rndm 1" used a starting seed of –100; runs labeled "Rndm 2" used a starting seed of –1007; and "Rndm 3" used a starting seed of –2001. The starting seed had very little effect on the results (Fig. 1).

Low Exploitation Rate Ceiling:

I examined the low exploitation rate target under the same survival rate variation assumptions used above, except I dropped the run with the 13.8% maximum, because no runs generated a survival rate that high.

For this analysis, the survival rate variation assumption had an effect. For the fixed survival at 4.2%, MSH occurred with a target exploitation rate of 50%; for the runs with survival varying randomly about 4.2%, exploitation rates of 30% to 50% gave approximately the same long-term catch; for cyclical variation in survival, MSH occurred at 50% to 60% (Table 3; Fig. 2).

From this analysis, it appears that there could be justification for using any target rate **between about 30% and 50%** as the low exploitation rate ceiling. I am tentatively proposing to use **30%** as the low ceiling rate, because escapements should be higher with this ceiling, which should make the stock more robust to perturbations, which may be important at low status. **But a higher rate, up to 50%, could also be justified**.

Sensitivity analysis indicated that, besides the survival rate assumptions, the MSH exploitation rate wasn't really sensitive to anything else. At a low assumed point of instability (2500), the MSH occurred at a rate of about 40% (with randomly varying survival), but nothing else noticeably changed the MSH rate.

<u>Normal Exploitation Rate:</u>

Because the low exploitation rate target was not definitive, I examined potential normal exploitation rate targets under 3 different low exploitation targets: 30%, 40%, and 50%. Also, because there was a suggestion to apply the low rate to a range of escapements around the low/normal breakpoint (and not just to escapements below that breakpoint), I did runs with the low/normal breakpoint set at 40,000 and the low exploitation rate set at 30%.

For this examination, there were only 2 survival rate assumptions that needed to be examined: random variation about the mean (9.0%), or cyclical variation. This meant that I examined 8 different low exploitation target/breakpoint/survival assumption scenarios.

> <u>MSH Exploitation Rate:</u> MSH exploitation rates varied somewhat according to the scenario, but they all ranged between about 55% and 75% (Table 4, Figs. 3 and 4). At a low target of 30%, and random survival variation, long-term catches were essentially the same for target rates between 55% and 75%; with cyclic variation in survival, MSH rates ranged from 60% to 75%. The MSH rates were somewhat higher for the higher low target exploitation rates. Because a rate of 60% appears to be in the range of MSH exploitation rates under all scenarios, I am proposing **60%** as the normal exploitation rate ceiling.
>
> <u>Low/Normal Breakpoint = 40,000:</u> With the low/normal breakpoint set at 40,000, expected harvests were noticeably lower than under a breakpoint of 25,000 (Fig. 4).
>
> <u>Sensitivity Analysis:</u> As noted above, the range of MSH exploitation rates was somewhat sensitive to the low exploitation rate and the survival assumption. The range of MSH rates was also somewhat lower when higher low/normal breakpoints were used (at a breakpoint of 50,000, the range of MSH exploitation rates was about 50% to 60%). The MSH exploitation rate was not sensitive to any other inputs.

Critical/Low Breakpoint:

In doing the critical/low breakpoint analysis, I examined only breakpoints between 0 and 25,000 (the low/critical breakpoint), because the critical/low breakpoint should not be higher than the low/critical breakpoint.

Method 1:

The number of runs with at least one escapement below the point of destabilization was highly dependent on the minimum allowed survival rate, the number of years in the run, the survival rate variation assumption (i.e., whether survival rates varied randomly or cyclically), and the assumed point of destabilization. For example, for a 40-year run, with a 1% minimum survival rate, a variable point of destabilization (5% of a randomly-chosen Beverton-Holt capacity), and random survival variation, the number of runs that got escapements below the point of destabilization ranged from 50% to 70%. For the same runs, with minimum survival set at 3.4%, the range was more like 7% to 30%.

Since these inputs are somewhat arbitrary (or at least don't have real good data indicating one is better than another), I examined several different combinations of years/run, minimum survival, points of destabilization, and survival rate variation assumptions, to determine whether these different inputs affected the location of an inflection point in the relation between the critical/low breakpoint and the number of runs that fell below the point of destabilization. The inputs I examined were:

Years/Run: 40 years
25 years
10 years

Minimum Survival: 1% (arbitrary low number)
3.4% (minimum observed marine survival, multiplied by lower 10 percentile freshwater survival rate – see Table 1)
5.4% (minimum observed marine survival in last 8 years)

Point of Destabilization: 3000 (OCN minimum spawner density)
8000 (approximately 5% of calculated capacity)
Variable (5% of randomly-chosen capacity. This turned out to have a mean of about 8100 with a standard deviation of about 1800 – see Method 2 below)

Survival Rate Variation: Random (mean 9%, standard deviation 4.2%)
Cyclical (24-yr cycle about 9%, with amplitude = $\pm$ 50%)

The results, like the criteria, were not definitive (Tables 5 to 9; Figs 5 and 6). For most combinations, the slope of the relation appeared to level off after the point of destabilization, which, because that point is a user-set input, is not really a usable result. The cyclic survival curves were most sensitive to changes in critical breakpoints, and, by squinting hard at these curves, one might tease out points of leveling off (which might be proposed as critical/low breakpoints) between about 10,000 and 16,000. The random survival curves declined very gradually and evenly for breakpoints past the point of destabilization, and showed no distinct change in benefits for any particular breakpoint.

If I had to pick a most likely seat-of-the-pants combination, I'd probably pick a cyclic survival with variable point of destabilization, and use 25 years as adequate for the analysis. In that case, the frequency of runs below the point of destabilization drops below 5% at a breakpoint of 12,000; drops to a plateau below 3% at a breakpoint of 13,000; and drops to a plateau below 2% at a breakpoint of 18,000 (Table 7; Fig. 6). Any one of which could be proposed as a critical breakpoint.

Alternatively, we could declare that the results were not definitive, and change the criteria for selecting the critical/low breakpoint. For example, the criterion could be the breakpoint that maximizes long-term catch. However, long-term catch did not vary much between breakpoints, and the breakpoint with maximum catch was not consistent between combinations. The 10-year runs were probably too short to establish a stable maximum; the 25-year runs with variable points of destabilization had maximum catches at breakpoints of 17,000 (1% minimum survival), 11,000 (3.4% minimum), 7,000 (5.4% minimum), and 14,000 (cyclical survival). The 40-year runs had maxima at breakpoints of 16,000 (1% and 3.4%), 5,000 (5.4%), and 22,000 (cyclical).

All of which leaves the choice of critical/low breakpoint, calculated from Method 1, kind of up in the air, with something between about 13,000 and 18,000 probably the most defensible.

Method 2:

The Method 2 analysis, in contrast, did yield a calculated result (not surprising, since its criteria were more specific).

Point of Destabilization Distribution: Using a Beverton-Holt a parameter (smolt capacity) that varied between 1.2 million and 2.1 million, with the probability exponent (10) set such that there was a 10% probability that smolt capacity would be above 1.5 million, and a 1% probability it would be above 2 million, and a Beverton-Holt a/b parameter that was constrained between 28 and 113 with a mean of 70 and standard deviation of 8.85, the mean point of destabilization was 8075, with a standard deviation of 1777 (Table 10).

Management Error Distribution: After rescaling the exploitation rate error scalars shown in Table 1, as described in the Methods section, the mean exploitation rate error scalar (expressed as preseason forecast/postseason estimate) was 1.119, with a standard deviation of 0.172 (Table 10).

Preseason Forecast Escapement with 5% Probability of Resulting Escapement < Point of Destabilization: At a preseason forecast escapement of 15,000 the management error distribution and the point of instability distributions intersect at escapement = 11,800.

The area of their overlap is 4.5% (Table 10). Thus, at a preseason forecast escapement of 15,000, the probability of getting a resulting escapement below the point of destabilization, given these error distributions, is less than 5%. Under Method 2, therefore, the critical/low breakpoint would be about 15,000.

Conclusion:

The Method 2 analysis yielded a result (15,000) that is within the range indicated by the Method 1 analysis (13,000 to 18,000). This is also close to the lowest previously observed escapement from which there were more than 1.0 observed recruits/spawner (escapement of 16,000 in 1991 resulted in over 100,000 recruits in 1994). Given the somewhat ambiguous results of this analysis, the least controversial way of selecting a critical/low breakpoint might be simply to disregard all the analyses of critical/low breakpoint presented in this memo, and just use the lowest previously-observed escapement, 16,000, as the critical/low breakpoint.

cc: Comprehensive Coho Steering Committee

Table 1. SKAGIT COHO SURVIVAL RATE AND MANAGEMENT ERROR VARIABLES FOR CCMP MODELING

Generation of Low Freshwater/Marine Survival Rates with Updated Skagit Coho Marine Survivals

Baker Wild Tagged Coho Marine Survival Rates

Brood Yr	Marine S
1989	13.8%
1990	6.0%
1991	11.1%
1992	8.3%
1993	10.6%
1994	6.3%
1995	10.6%
1996	5.4%
Mean	9.0%
Stddev	3.0%
10 %ile	5.8%
P=90%	5.2%

Freshwater Survival Scalars for Deschutes, Big Beef, Sunset, & Snow Creek

Mean	1
Stddev	0.29
P=90%	0.63

Mean	9.0%	100.3%	9.0%
Stddev	3.0%	29.3%	4.0%
10 %ile	5.2%	62.9%	4.2%
Minimum	0.1%	1.0%	0.0%
Maximum	20.5%	211.6%	30.5%

RandNormal Marine Survivals	RandNormal Freshwater Scalars	Marine * Freshwater
5.3%	93.0%	5.0%
8.4%	104.6%	8.8%
7.1%	66.4%	4.7%
11.9%	143.8%	17.1%
13.4%	89.2%	11.9%
6.2%	96.1%	5.9%
7.4%	100.5%	7.5%
12.6%	112.2%	14.2%
6.9%	116.7%	8.1%
7.3%	114.3%	8.3%
13.6%	87.8%	11.9%
10.4%	69.0%	7.2%
9.0%	94.1%	8.5%
6.1%	137.3%	8.4%
11.4%	102.6%	11.7%
11.3%	90.8%	10.3%

Skagit Escapement PSF Error

Year	PSF Esc	Post-Season Esc Est	% Error post/pre-1
1980	30000	25000	-16.7%
1981	16300	15000	-8.0%
1982	30000	9000	-70.0%
1983	21700	24000	10.6%
1984	30000	33000	10.0%
1985	18000	18000	0.0%
1986	27000	45000	66.7%
1987	18300	33000	80.3%
1988	24000	19000	-20.8%
1989	19200	17000	-11.5%
1990	23400	15000	-35.9%
1991	26800	7800	-70.9%
1992	28150	7500	-73.4%
1993	20538	13400	-34.8%
1994	15538	29300	88.6%
1995	20067	13400	-33.2%
1996	22872	8300	-63.7%
1997	61945	32612	-47.4%
1998	95349	69800	-26.8%
1999	89263	35000	-60.8%
		Mean	-15.9%
		Median	-23.8%
		Stddev	48.4%
	Std Error of Mean		10.8%

Variation in Beverton-Holt a/b

Site	B-H a/b (slope @ origin)
Deschutes	31.4
Big Beef	73.4
Skykomish	90.8
Snow Creek	84.9
Mean	70.1
Std Dev all sites	26.8
w/o Deschutes	8.8

Skagit Run Size PSF Error

Year	PSF RS	Post-Season RS Est	% Error pre/post-1
1988	113088	127562	-11.3%
1989	104434	166214	-37.2%
1990	132291	143709	-7.9%
1991	127529	99852	27.7%
1992	107336	59869	79.3%
1993	95114	37960	150.6%
1994	52877	105241	-49.8%
1995	86888	59664	45.6%
1996	60730	43014	41.2%
		Mean	26.5%
		Median	27.7%
		Stddev	62.5%
	Std Error of Mean		20.8%

Skagit Exploitation Rate PSF Error

Year	PSF Expl Rate	Post-Season Expl Rate	% Error post/pre-1
1987	75.3%	53.6%	-28.8%
1988	71.8%	69.1%	-3.8%
1989	75.4%	74.2%	-1.6%
1990	76.4%	72.0%	-5.7%
1991	72.3%	66.2%	-8.4%
1992	65.8%	64.7%	-1.7%
1993	71.7%	48.1%	-33.0%
1994	60.2%	52.6%	-12.5%
1995	70.0%	70.0%	0.0%
1996	50.3%	53.0%	5.4%
1997	45.2%	41.4%	-8.4%
		Mean	-9.0%
		Median	-5.7%
		Stddev	11.9%
	Std Error of Mean		3.6%

Table 2. Mean Coho Catches by Escapement Target Under Different Low Survival Rate Variation Assumptions

Survival Fixed @ 4.2%

Etarget	Rndm 1	Rndm 2	Rndm 3
0	1416	1414	1418
5000	1567	1529	1543
10000	2225	2215	2230
15000	4461	4570	4556
20000	6735	6628	6614
25000	6907	6955	6954
30000	6241	6226	6246
35000	5392	5416	5438
40000	4765	4801	4788
45000	4392	4390	4396
50000	4092	4115	4108
55000	3900	3886	3901
60000	3751	3733	3725
65000	3620	3613	3615
70000	3515	3515	3515
75000	3463	3464	3459
80000	3433	3432	3433

Mean = 4.2% w/ Random Variation

Etarget	Rndm 1	Rndm 2	Rndm 3
0	1404	1386	1373
5000	1542	1560	1567
10000	2390	2297	2329
15000	3816	3832	3845
20000	4610	4439	4584
25000	4785	4866	4925
30000	4675	4571	4525
35000	4276	4246	4130
40000	3786	3677	3718
45000	3544	3623	3596
50000	3432	3348	3288
55000	3154	3152	3061
60000	2876	2791	2819
65000	2806	2843	2809
70000	2791	2717	2685
75000	2633	2647	2578
80000	2506	2426	2451

Survival Range Symmetrical (.1% to 8.3%)

Etarget	Rndm 1	Rndm 2	Rndm 3
0	1402	1383	1371
5000	1536	1554	1561
10000	2375	2280	2308
15000	3790	3794	3811
20000	4575	4396	4556
25000	4749	4832	4888
30000	4626	4540	4486
35000	4241	4204	4090
40000	3753	3644	3685
45000	3508	3589	3562
50000	3395	3319	3252
55000	3125	3119	3030
60000	2853	2765	2791
65000	2778	2815	2785
70000	2761	2693	2655
75000	2611	2621	2553
80000	2488	2405	2431

Max Survival = Max Recent Obs (13.8%)

Etarget	Rndm 1	Rndm 2	Rndm 3
0	1404	1386	1373
5000	1542	1560	1567
10000	2390	2297	2329
15000	3816	3832	3845
20000	4610	4439	4584
25000	4785	4866	4925
30000	4675	4571	4525
35000	4276	4246	4130
40000	3786	3677	3718
45000	3544	3623	3596
50000	3432	3348	3288
55000	3154	3152	3061
60000	2876	2791	2819
65000	2806	2843	2809
70000	2791	2717	2685
75000	2633	2647	2578
80000	2506	2426	2451

Cyclical Variation in Survival

Etarget	Rndm 1	Rndm 2	Rndm 3
0	1488	1442	1474
5000	1820	1733	1766
10000	3184	3349	3343
15000	4650	4739	4971
20000	5467	5305	5300
25000	5595	5536	5506
30000	5291	5305	5259
35000	4982	4869	4807
40000	4570	4492	4705
45000	4329	4224	4265
50000	3880	3999	4003
55000	3621	3623	3772
60000	3494	3405	3366
65000	3227	3289	3309
70000	3012	3102	3165
75000	2935	2970	2941

80000	2911	2887	2908

Table 3. Mean Coho Catches by Exploitation Rate Target Under Different Low Survival Rate Variation Assumptions

Survival Fixed @ 4.2%

UTarget	Rndm 1	Rndm 2	Rndm 3
0%	3	2	2
5%	1484	1482	1484
10%	2885	2884	2888
15%	4196	4200	4196
20%	5396	5406	5408
25%	6474	6477	6483
30%	7393	7393	7395
35%	8095	8108	8096
40%	8562	8572	8555
45%	8771	8777	8782
50%	8839	8846	8842
55%	7453	7375	7413
60%	4372	4524	4440
65%	3353	3279	3381
70%	2857	3039	2979
75%	2761	2683	2653
80%	2224	2230	2265

Mean = 4.2% w/ Random Variation

UTarget	Rndm 1	Rndm 2	Rndm 3
0%	68	72	68
5%	1146	1137	1146
10%	2065	2032	2019
15%	2739	2757	2707
20%	3200	3091	3157
25%	3607	3702	3742
30%	4033	3962	3881
35%	4049	4108	4044
40%	4069	3920	3932
45%	4043	4122	4201
50%	4025	4069	4116
55%	3838	3911	3789
60%	3545	3486	3538
65%	3480	3449	3458
70%	3439	3346	3394
75%	3242	3236	3164
80%	3132	3075	2950

Survival Range Symmetrical (1% to 7.4%)

UTarget	Rndm 1	Rndm 2	Rndm 3
0%	68	72	69
5%	1133	1124	1132
10%	2036	2005	1988
15%	2700	2713	2658
20%	3145	3030	3105
25%	3534	3641	3674
30%	3939	3897	3802
35%	3961	3992	3962
40%	3989	3825	3837
45%	3958	4051	4115
50%	3945	3979	4011
55%	3734	3819	3707
60%	3461	3406	3455
65%	3393	3377	3355
70%	3351	3254	3312
75%	3149	3142	3075
80%	3018	2986	2883

Cyclical Variation in Survival (± 50%)

UTarget	Rndm 1	Rndm 2	Rndm 3
0%	56	52	55
5%	1508	1504	1507
10%	2711	2732	2752
15%	2678	2666	2808
20%	3222	3142	3121
25%	3736	3640	3615
30%	4097	4020	4086
35%	4289	4424	4141
40%	4742	4692	4826
45%	4841	4721	4647
50%	5035	4915	4953
55%	4938	4983	4933
60%	4852	4973	4914
65%	4508	4787	4697
70%	4432	4610	4548
75%	4479	4492	4607
80%	4595	4439	4452

Table 4. Mean Coho Catches by Normal Exploitation Rate Target Under Different Low Utargets, Survival Rate Variation Assumptions, & Low/Normal BP's

Low Target U = 30%; Low/Normal Breakpoint = 25,000

Survival Varies Randomly about 9%				Survival Varies Cyclically between 4.5% & 13.5%			
Normal Target U	Rndm 1	Rndm 2	Rndm 3	Normal Target U	Rndm 1	Rndm 2	Rndm 3
30%	16918	16745	16021	30%	19012	19496	19367
35%	18810	19535	18202	35%	21865	21264	22054
40%	20890	20591	20735	40%	23784	23764	23682
45%	21711	22042	22601	45%	26169	25923	25514
50%	24406	22877	23774	50%	27370	26982	27520
55%	25486	25070	24306	55%	28489	28982	28552
60%	25803	25422	25357	60%	30442	29066	29895
65%	25695	26501	26044	65%	30191	29911	30018
70%	25808	26093	26420	70%	29839	30213	29968
75%	25386	25412	26182	75%	30126	28962	29234
80%	23790	23164	23739	80%	27549	27707	27721
85%	23058	22256	21568	85%	26064	25596	25124
90%	19111	19669	19146	90%	21654	21258	21989

Low Target U = 30%; Low/Normal Breakpoint = 40,000

Survival Varies Randomly about 9%				Survival Varies Cyclically between 4.5% & 13.5%			
Normal Target U	Rndm 1	Rndm 2	Rndm 3	Normal Target U	Rndm 1	Rndm 2	Rndm 3
30%	16918	16745	16021	30%	19012	19496	19367
35%	18581	19301	18005	35%	21608	20981	21850
40%	20429	20162	20286	40%	23355	23185	23163
45%	20949	21339	21954	45%	25266	25006	24678
50%	23487	21854	22834	50%	26080	25689	26231
55%	24049	23710	22933	55%	26678	27152	26788
60%	23930	23737	23836	60%	28098	26921	27721
65%	23484	24234	23788	65%	27507	27244	27323
70%	22991	23341	23646	70%	26435	26672	26518
75%	22299	22258	23136	75%	26253	25245	25265
80%	20291	19921	20269	80%	23261	23325	23360
85%	19686	19002	18309	85%	22105	21475	21190
90%	17184	17804	17168	90%	19503	19162	19698

Low Target U = 40%; Low/Normal Breakpoint = 25,000

Survival Varies Randomly about 9%				Survival Varies Cyclically between 4.5% & 13.5%			
Normal Target U	Rndm 1	Rndm 2	Rndm 3	Normal Target U	Rndm 1	Rndm 2	Rndm 3
40%	20378	20117	20285	40%	22909	23656	23478
45%	21323	21652	21912	45%	25470	24789	25761
50%	24106	22238	23213	50%	26921	26829	26416
55%	25134	24402	23566	55%	28960	28605	28065
60%	25335	25368	24642	60%	29258	28846	29652
65%	25621	26197	25694	65%	29774	30346	29859
70%	25834	25808	26696	70%	30880	29684	30559
75%	25636	25664	26273	75%	30032	29895	29991
80%	24538	23879	24429	80%	28687	29162	28926
85%	24487	23653	22892	85%	28094	26937	26993
90%	21479	22651	21540	90%	24556	24794	24873

Low Target U = 50%; Low/Normal Breakpoint = 25,000

Survival Varies Randomly about 9%				Survival Varies Cyclically between 4.5% & 13.5%			
Normal Target U	Rndm 1	Rndm 2	Rndm 3	Normal Target U	Rndm 1	Rndm 2	Rndm 3
50%	23036	22672	21425	50%	26598	27467	27147
55%	23979	24768	23601	55%	28870	28030	28975
60%	25184	25140	25560	60%	29453	29502	29124
65%	25199	25634	26125	65%	31132	30645	30098
70%	27106	25020	26081	70%	30634	30243	31115
75%	27100	26141	25602	75%	30631	31269	30720
80%	26455	26339	25331	80%	30852	29740	30702
85%	24752	25774	25043	85%	29359	29121	29297
90%	23882	23825	24420	90%	27815	28102	27925

Table 5. Relation between coho critical breakpoint and catch, escapement, and number of runs out of 1000 with an escapement below a point of destabilization (EscDepense or Ecrit), for 10 years/run. All runs use a low/normal breakpoint of 25,000, and exploitation rate constrained to 12% to 91% with a low ceiling of 30% and normal ceiling of 60%. Point of destabilization varies with each run (between 3000 and 16000) according to randomly-selected spawner-recruit parameters.

10 YEAR RUNS

1% Min Surv, Variable Ecrit, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	27121	31122	312
2000	27947	31917	298
3000	26703	31453	295
4000	28375	32589	276
5000	28622	33010	243
6000	27993	32857	227
7000	27883	32539	244
8000	29858	34607	212
9000	28955	33857	224
10000	27716	33305	221
11000	29110	34452	220
12000	28242	34538	214
13000	27915	34006	224
14000	27867	34450	213
15000	28284	33949	246
16000	28075	35132	194
17000	28383	35316	212
18000	27326	35287	221
19000	28029	35742	205
20000	27966	36326	194
21000	27909	36425	195
22000	27664	36479	212
23000	27912	36955	207
24000	26999	36617	186
25000	27330	37126	200

3.4% Min Surv, Variable Ecrit, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	30226	34877	97
2000	30673	35410	96
3000	29406	34815	88
4000	30995	35786	69
5000	31218	36021	61
6000	30275	35615	66
7000	29914	35178	55
8000	31849	37071	33
9000	31068	36703	37
10000	29788	36091	33
11000	31247	37199	25
12000	30174	37132	24
13000	30081	37055	25
14000	30016	37511	20
15000	30411	37298	33
16000	29849	37819	22
17000	30230	38140	25
18000	29472	38446	14
19000	30114	38771	21
20000	29666	38975	23
21000	29781	39318	21
22000	29495	39542	22
23000	29855	40245	15
24000	29033	39807	18
25000	29403	40509	18

CYCLIC SURVIVAL

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	32452	36027	159
2000	31683	35264	163
3000	32818	36454	143
4000	31650	35498	129
5000	32350	36296	106
6000	30678	35646	91
7000	32017	36161	47
8000	31586	36315	46
9000	32197	36812	36
10000	31539	37133	18
11000	31699	37037	24
12000	31927	37423	10
13000	31947	37470	15
14000	31094	37515	10
15000	32014	38401	5
16000	30929	38105	7
17000	31753	38969	9
18000	30956	38444	4
19000	31969	39887	6
20000	30646	38909	4
21000	31167	39896	9
22000	29253	39313	6
23000	30635	39692	4
24000	29937	39936	3
25000	30574	40573	1

Table 6. Relation between coho critical breakpoint and catch, escapement, and number of runs out of 1000 with an escapement below a point of destabilization (EscDepense or Ecrit), for 40 years/run. All runs use a low/normal breakpoint of 25,000, and exploitation rate constrained to 12% to 91% with a low ceiling of 30% and normal ceiling of 60%. Point of destabilization varies with each run (between 3000 and 16000) according to randomly-selected spawner-recruit parameters.

40 YEAR RUNS

1% Min Surv, Variable Ecrit, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	20256	22686	674
2000	20420	22987	687
3000	21736	24206	646
4000	21975	24691	625
5000	23219	25913	612
6000	22510	25656	616
7000	24296	27325	561
8000	24341	27568	537
9000	23871	27611	555
10000	24578	28338	539
11000	24364	28253	556
12000	24345	28521	546
13000	24880	29235	513
14000	23973	28463	542
15000	24692	29386	512
16000	25115	29819	518
17000	24689	30104	515
18000	25054	30766	480
19000	24842	30505	510
20000	24294	30324	542
21000	24098	30615	506
22000	23788	30509	522
23000	24833	31709	512
24000	23670	30702	509
25000	24334	31759	496

3.4% Min Surv, Variable Ecrit, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	28170	32143	270
2000	28286	32285	285
3000	29199	33034	238
4000	29061	33225	221
5000	29999	34147	199
6000	29074	33756	197
7000	29833	34485	172
8000	29874	34927	140
9000	29231	34805	129
10000	29658	35469	107
11000	29725	35661	102
12000	29504	35983	117
13000	29750	36429	92
14000	29363	36221	103
15000	29685	36739	103
16000	30427	37791	91
17000	29640	37657	78
18000	29898	38027	83
19000	29677	38083	83
20000	29503	38384	88
21000	29200	38459	71
22000	28868	38663	84
23000	29658	39543	74
24000	28697	39162	71
25000	29209	39740	74

5.4% Min Surv, Variable Ecrit, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	32336	36842	30
2000	31684	36434	27
3000	32051	36741	23
4000	31906	36856	15
5000	32659	37301	17
6000	32626	37323	21
7000	32520	37502	19
8000	32725	37808	14
9000	31565	37051	14
10000	31862	37814	5
11000	32232	38119	16
12000	32106	38345	6
13000	32215	38683	8
14000	31422	38376	11
15000	32362	39274	12
16000	31361	39168	10
17000	32107	39844	9
18000	32471	40233	3
19000	32146	40573	4
20000	31240	40333	5
21000	31113	40657	10
22000	31089	41035	11
23000	31172	41585	13
24000	30897	41378	12
25000	30236	41467	4

CYCLIC SURVIVAL

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	27159	29004	460
2000	26187	28351	460
3000	27562	29984	419
4000	27560	30184	414
5000	28780	31695	334
6000	30289	33492	265
7000	29460	33178	230
8000	29872	34162	155
9000	30941	35254	125
10000	30711	35632	92
11000	31760	36692	83
12000	30760	36363	61
13000	30550	36339	55
14000	31013	37171	37
15000	31242	37614	32
16000	31062	37851	33
17000	31327	38321	28
18000	30056	37636	28
19000	30804	38643	27
20000	30385	38504	26
21000	30931	39301	16
22000	31343	39919	26
23000	30164	39493	20
24000	29627	39298	19
25000	30273	39951	23

Table 7. Relation between coho critical breakpoint and catch, escapement, and number of runs out of 1000 with an escapement below a point of destabilization (EscDepense or Ecrit), for 25 years/run. All runs use a low/normal breakpoint of 25,000, and exploitation rate constrained to 12% to 91% with a low ceiling of 30% and normal ceiling of 60%. Point of destabilization varies with each run (between 3000 and 16000) according to randomly-selected spawner-recruit parameters.

25 YEAR RUNS

POINT OF DESTABILIZATION VARIES

1% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	23033	25809	563
2000	23370	26320	551
3000	24551	27735	528
4000	25049	28582	493
5000	24662	28166	493
6000	25001	28796	470
7000	26370	30205	424
8000	25682	29789	445
9000	25639	29777	448
10000	25550	30317	419
11000	26111	30592	419
12000	25763	30817	400
13000	25596	30721	428
14000	26261	31451	408
15000	25815	31521	417
16000	26028	31843	407
17000	26647	32628	393
18000	25963	32456	401
19000	25948	32600	397
20000	26167	33135	385
21000	25826	33170	390
22000	25762	33416	401
23000	26621	34351	381
24000	26499	34621	363
25000	25443	33985	380

3.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	29487	33464	198
2000	29481	33592	198
3000	29782	34018	199
4000	30405	34873	164
5000	29715	34290	160
6000	29368	34498	123
7000	30418	35433	92
8000	29846	35172	101
9000	29908	35539	93
10000	29289	35471	82
11000	30317	36390	80
12000	29808	36357	70
13000	29666	36450	80
14000	30261	37115	52
15000	29485	36952	59
16000	29904	37611	58
17000	30283	38089	57
18000	29526	38009	52
19000	29627	38437	44
20000	29837	38841	46
21000	29381	38859	50
22000	29359	39310	46
23000	29715	39739	46
24000	29768	40025	42
25000	28863	39725	55

5.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	32533	37080	13
2000	32469	37125	17
3000	32528	37191	22
4000	33045	37734	13
5000	32363	37192	12
6000	31765	37001	9
7000	32685	37634	9
8000	32135	37463	7
9000	32070	37554	10
10000	31417	37464	4
11000	32393	38217	6
12000	31808	38120	9
13000	31796	38482	10
14000	32191	38839	4
15000	31390	38537	9
16000	31889	39414	4
17000	32233	39923	7
18000	31443	39822	7
19000	31560	40224	5
20000	31763	40649	5
21000	31305	40808	5
22000	31201	41179	5
23000	31597	41608	2
24000	31631	41905	8
25000	30767	41724	6

CYCLIC SURVIVAL

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	28524	31133	455
2000	29083	31692	427
3000	28759	31675	391
4000	28904	32280	338
5000	29687	33074	291
6000	30761	34625	210
7000	30377	34399	188
8000	30469	34971	146
9000	30879	35544	110
10000	31568	36344	74
11000	31060	36223	68
12000	30884	36588	42
13000	31198	36950	28
14000	31722	37948	25
15000	31234	37737	20
16000	30848	37841	25
17000	30945	38262	24
18000	31342	38692	16
19000	30735	38592	14
20000	30409	38742	12
21000	30523	38967	9
22000	30886	39892	14
23000	30397	39601	13
24000	30130	39911	12
25000	30027	40109	17

Table 8. Relation between coho critical breakpoint and catch, escapement, and number of runs out of 1000 with an escapement below a point of destabilization (EscDepense or Ecrit), for 25 years/run, with the point of destabilization fixed at 3000.

25 YEAR RUNS

POINT OF DESTABILIZATION FIXED AT 3000

1% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	28676	32628	159
2000	28879	33035	134
3000	29296	33645	114
4000	29728	34275	102
5000	29048	33699	104
6000	28474	33543	90
7000	29450	34273	85
8000	28968	34199	78
9000	28804	34100	83
10000	28165	34076	100
11000	29190	34967	84
12000	28694	34912	77
13000	28580	35044	75
14000	29038	35440	79
15000	28281	35360	65
16000	28815	36063	71
17000	29201	36555	77
18000	28409	36340	71
19000	28452	36714	71
20000	28725	37237	63
21000	28260	37172	70
22000	28228	37462	75
23000	28566	37897	80
24000	28652	38377	67
25000	27738	37868	79

3.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	30619	35319	7
2000	30682	35503	0
3000	30786	35607	5
4000	31260	36182	0
5000	30519	35583	0
6000	29945	35432	0
7000	30886	36130	0
8000	30362	36039	0
9000	30288	36161	0
10000	29652	36057	0
11000	30610	36873	0
12000	30068	36778	0
13000	30003	37044	0
14000	30432	37420	0
15000	29626	37208	0
16000	30124	37984	0
17000	30512	38547	0
18000	29702	38327	0
19000	29779	38745	0
20000	30018	39158	0
21000	29606	39301	0
22000	29544	39669	0
23000	29872	40067	0
24000	29952	40399	0
25000	29078	40175	0

5.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	32606	37203	0
2000	32539	37222	0
3000	32683	37404	0
4000	33141	37861	0
5000	32407	37250	0
6000	31814	37065	0
7000	32724	37694	0
8000	32187	37535	0
9000	32110	37611	0
10000	31432	37492	0
11000	32433	38274	0
12000	31874	38224	0
13000	31844	38554	0
14000	32216	38880	0
15000	31437	38617	0
16000	31918	39460	0
17000	32272	39984	0
18000	31457	39835	0
19000	31584	40254	0
20000	31791	40693	0
21000	31353	40866	0
22000	31227	41212	0
23000	31617	41641	0
24000	31673	41971	0
25000	30786	41754	0

CYCLIC SURVIVAL

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	31681	35480	0
2000	32196	35885	0
3000	31625	35493	0
4000	31455	35641	0
5000	31697	35731	0
6000	32220	36613	0
7000	31842	36312	0
8000	31611	36448	0
9000	31729	36721	0
10000	32174	37185	0
11000	31534	36882	0
12000	31273	37096	0
13000	31412	37228	0
14000	31840	38121	0
15000	31397	37953	0
16000	31089	38150	0
17000	31137	38511	0
18000	31512	38945	0
19000	30836	38724	0
20000	30545	38918	0
21000	30612	39080	0
22000	30957	40032	0
23000	30531	39783	0
24000	30188	39999	0
25000	30204	40363	0

Table 9. Relation between coho critical breakpoint and catch, escapement, and number of runs out of 1000 with an escapement below a point of destabilization (EscDepense or Ecrit), for 25 years/run, with the point of destabilization fixed at 8000.

25 YEAR RUNS

POINT OF DESTABILIZATION FIXED AT 8000

1% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	22794	25476	594
2000	22950	25846	596
3000	24519	27630	545
4000	25331	28697	505
5000	25139	28646	492
6000	25442	29222	465
7000	26661	30403	423
8000	26470	30565	421
9000	26229	30307	445
10000	25763	30497	425
11000	26549	31018	402
12000	26288	31331	387
13000	26238	31376	394
14000	26864	32051	390
15000	26188	31858	394
16000	26609	32324	398
17000	27320	33312	359
18000	26415	32858	381
19000	26180	32814	379
20000	26389	33287	372
21000	26415	33760	373
22000	26222	33838	373
23000	26849	34451	364
24000	26824	34878	354
25000	25884	34343	372

3.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	29559	33514	208
2000	29669	33845	195
3000	29877	34119	185
4000	30628	35149	148
5000	29870	34461	160
6000	29520	34702	109
7000	30619	35683	79
8000	29997	35398	85
9000	30079	35798	68
10000	29454	35733	61
11000	30434	36573	55
12000	29952	36580	36
13000	29853	36779	49
14000	30251	37085	46
15000	29542	37044	40
16000	29983	37730	45
17000	30372	38241	43
18000	29580	38076	35
19000	29659	38496	35
20000	29938	38995	28
21000	29514	39092	30
22000	29426	39392	38
23000	29770	39827	34
24000	29852	40186	31
25000	28983	39940	36

5.4% Min Surv, Random surv

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	32595	37179	2
2000	32538	37220	2
3000	32675	37385	3
4000	33134	37847	2
5000	32407	37250	0
6000	31811	37060	1
7000	32724	37694	0
8000	32187	37535	0
9000	32106	37606	2
10000	31432	37492	0
11000	32433	38274	0
12000	31872	38219	1
13000	31844	38553	1
14000	32216	38880	0
15000	31437	38617	0
16000	31918	39460	0
17000	32272	39984	0
18000	31457	39835	0
19000	31584	40254	0
20000	31791	40693	0
21000	31352	40866	1
22000	31227	41209	1
23000	31617	41641	0
24000	31673	41971	0
25000	30786	41754	0

CYCLIC SURVIVAL

Crit BP	Avg Catch	Avg Esc	# Runs < EscDepense
1000	28495	31093	471
2000	28991	31526	451
3000	28528	31296	443
4000	28808	32088	381
5000	29582	32863	337
6000	30899	34791	221
7000	31059	35197	149
8000	31065	35715	93
9000	31336	36153	49
10000	31954	36867	33
11000	31361	36640	24
12000	31232	37043	6
13000	31406	37219	2
14000	31840	38121	0
15000	31372	37925	2
16000	31083	38144	1
17000	31117	38477	4
18000	31498	38924	1
19000	30830	38713	1
20000	30545	38918	0
21000	30612	39080	0
22000	30936	39984	3
23000	30506	39753	2
24000	30177	39981	2
25000	30185	40327	5

Table 10. Calculation of Probability that PSF will Result in Escapement Below Pt of Instability

Skagit Coho Data

Ecrit=	8075	
stddev =	1777	
		Scaled to PSF
Mean Err	1.119	16780
Stddev Err	0.172	2585
PSF	15000	
Min smolt K	1200000	
BH expnt	10	
Max smolt K	2100000	
LT mean Surv	0.126	
Std LT mean	0.021	

	Mgmt Err	Err Scalar
	0.404	1.404
	0.040	1.040
	0.016	1.016
	0.060	1.060
	0.092	1.092
	0.017	1.017
	0.493	1.493
	0.143	1.143
	0.000	1.000
	-0.051	0.949
	0.092	1.092
Mean	0.119	1.119
Std Dev	0.172	0.172

U rate error post/pre-1	+1	inverse	pre/post-1
-0.288	0.712	1.404	0.404
-0.038	0.962	1.040	0.040
-0.016	0.984	1.016	0.016
-0.057	0.943	1.060	0.060
-0.084	0.916	1.092	0.092
-0.017	0.983	1.017	0.017
-0.330	0.670	1.493	0.493
-0.125	0.875	1.143	0.143
0.000	1.000	1.000	0.000
0.054	1.054	0.949	-0.051
-0.084	0.916	1.092	0.092

Mean	7678
Std Dev	800.7045
Min	6363
Max	8413

Random Values

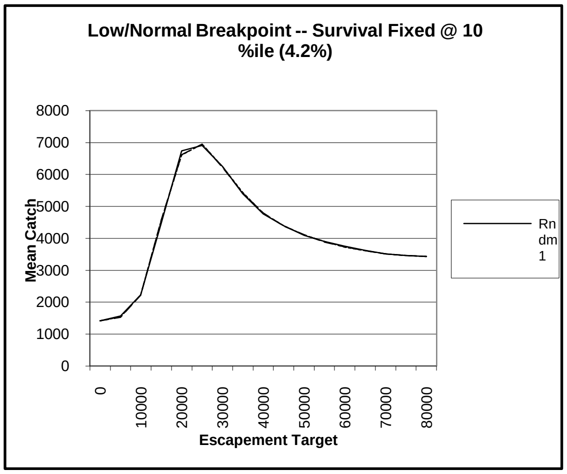
Smolt K	Survival	Ecrit
1200299	10.6%	6363
1200000	14.0%	8413
1236900	12.7%	7876
1439564	11.4%	8172
1200005	12.6%	7565
|		
|		
|		
V		
1000 Rows		

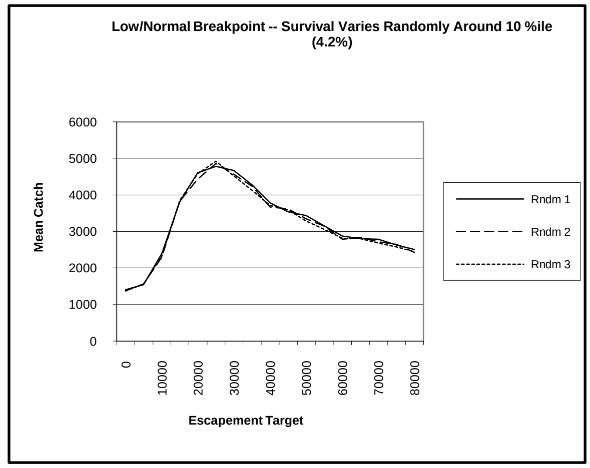
Results of Runs

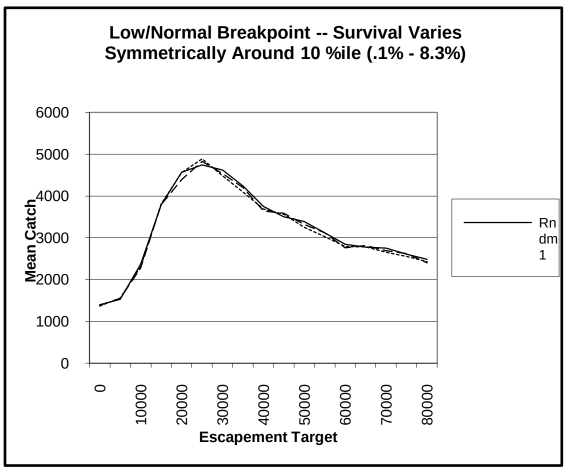
	Mean	Std Dev
	8033	1815
	8183	1820
	8128	1819
	8072	1737
	8009	1791
	8066	1711
	8076	1681
	8055	1767
	8070	1665
	8019	1744
	8077	1826
	8084	1806
	8230	1917
	8003	1704
	8137	1876
	8057	1723
	8040	1762
	8072	1791
	8081	1750
	8059	1810
	8100	1831
	8005	1755
Mean	8075	1777
Std Dev	56	62

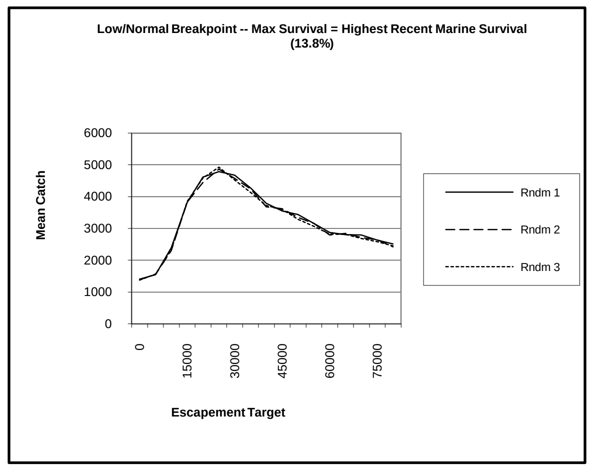
	Escpmt X	P(Obsd E<X)	P(X<Ecrit	Joint P	Sum P	Value of Normal Curve P(E<X)	P(X<Ecrit)
	7000	0.008%	72.741%	0.006%	72.749%	0.000%	0.019%
	7200	0.010%	68.881%	0.007%	68.891%	0.000%	0.020%
	7400	0.014%	64.800%	0.009%	64.814%	0.000%	0.021%
	7600	0.019%	60.542%	0.012%	60.561%	0.000%	0.022%
	7800	0.026%	56.154%	0.014%	56.179%	0.000%	0.022%
	8000	0.034%	51.688%	0.018%	51.723%	0.000%	0.022%
	8200	0.045%	47.202%	0.021%	47.247%	0.000%	0.022%
	8400	0.059%	42.751%	0.025%	42.810%	0.000%	0.022%
	8600	0.078%	38.390%	0.030%	38.467%	0.000%	0.021%
	8800	0.101%	34.171%	0.034%	34.272%	0.000%	0.021%
	9000	0.130%	30.142%	0.039%	30.272%	0.000%	0.020%
	9200	0.168%	26.341%	0.044%	26.509%	0.000%	0.018%
	9400	0.215%	22.802%	0.049%	23.017%	0.000%	0.017%
	9600	0.273%	19.547%	0.053%	19.820%	0.000%	0.016%
	9800	0.346%	16.591%	0.057%	16.937%	0.000%	0.014%
	10000	0.435%	13.941%	0.061%	14.376%	0.000%	0.012%
	10200	0.545%	11.594%	0.063%	12.139%	0.001%	0.011%
	10400	0.678%	9.543%	0.065%	10.221%	0.001%	0.010%
	10600	0.840%	7.772%	0.065%	8.611%	0.001%	0.008%
	10800	1.034%	6.262%	0.065%	7.296%	0.001%	0.007%
	11000	1.266%	4.992%	0.063%	6.258%	0.001%	0.006%
	11200	1.542%	3.936%	0.061%	5.478%	0.002%	0.005%
	11400	1.868%	3.069%	0.057%	4.938%	0.002%	0.004%
	11600	2.252%	2.367%	0.053%	4.619%	0.002%	0.003%
→	11800	2.699%	1.805%	0.049%	4.504%	0.002%	0.002%
	12000	3.219%	1.361%	0.044%	4.580%	0.003%	0.002%
	12200	3.818%	1.015%	0.039%	4.833%	0.003%	0.002%
	12400	4.506%	0.748%	0.034%	5.254%	0.004%	0.001%
	12600	5.289%	0.545%	0.029%	5.834%	0.004%	0.001%

Figure 1. Mean coho catches by Escapement Target under different low survival rate variation assumptions.









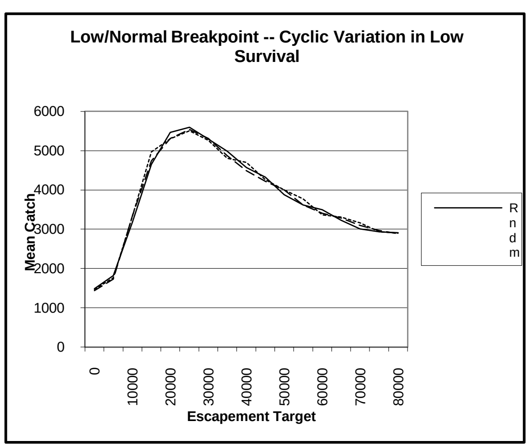


Figure 2. Mean coho catches by Exploitation Rate Target under different low survival rate variation assumptions.

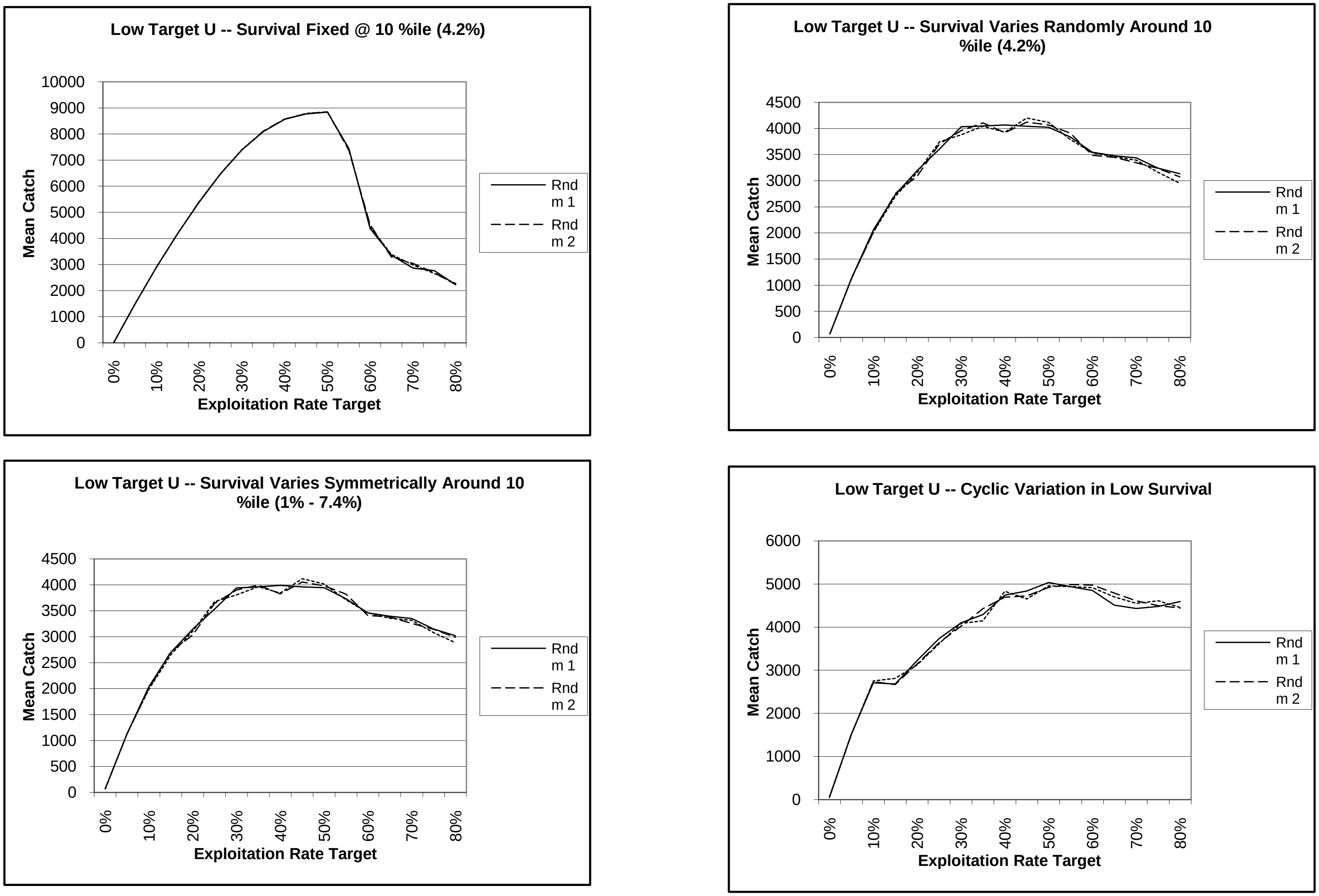
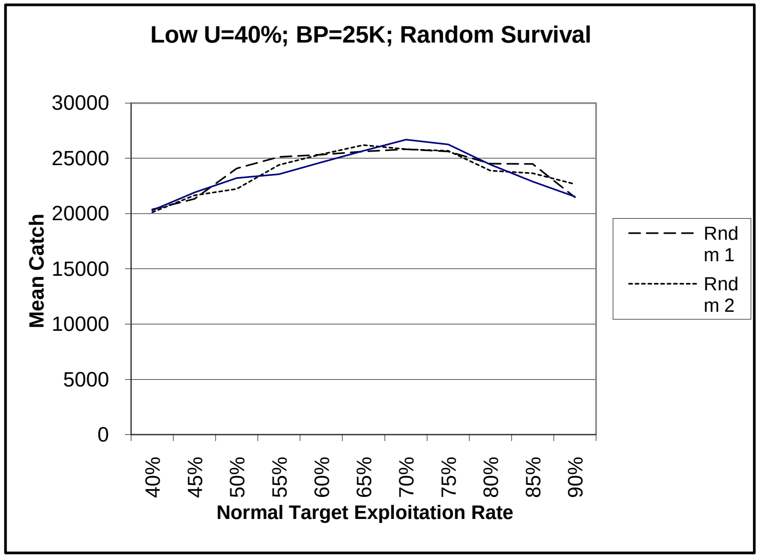
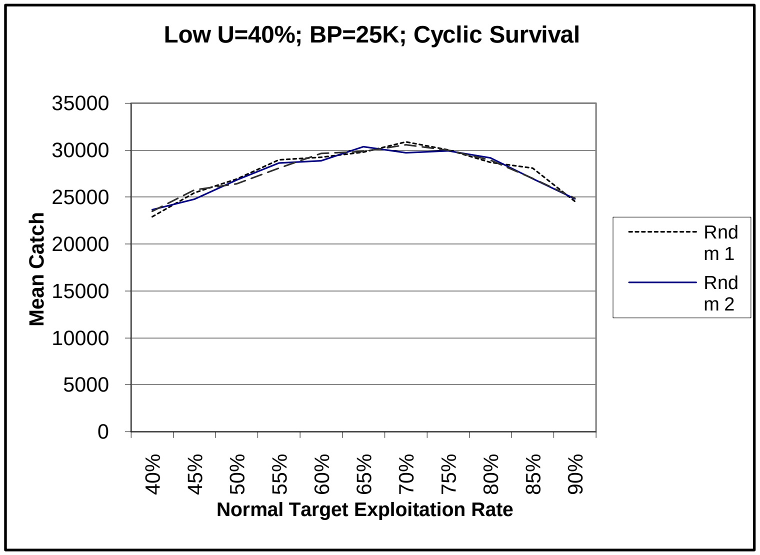
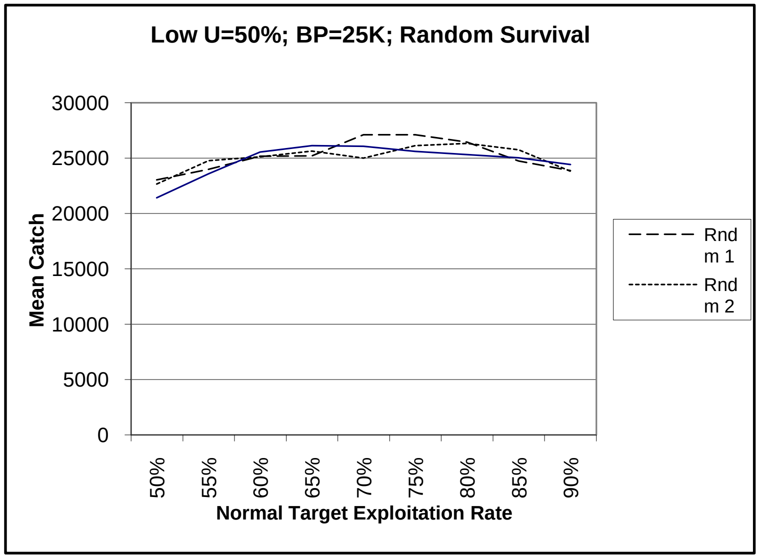


Figure 3. Mean coho catches by normal exploitation rate target, under low Utargets of 40% and 50%, and random or cyclic survival.







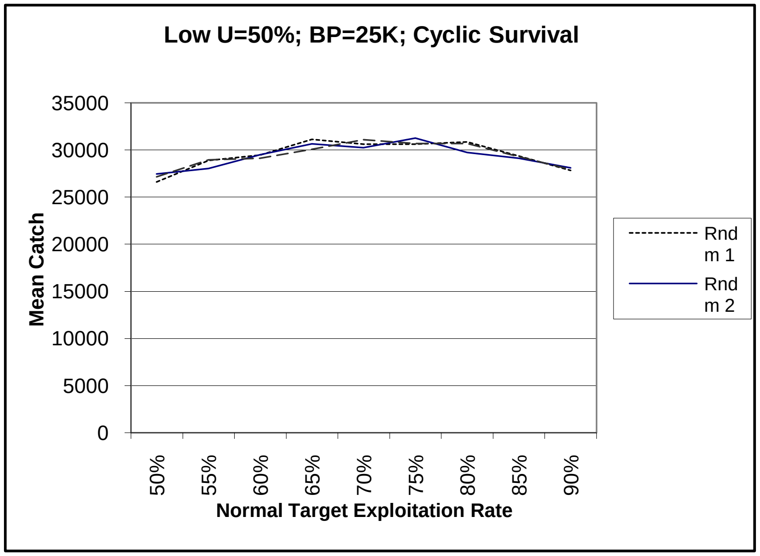
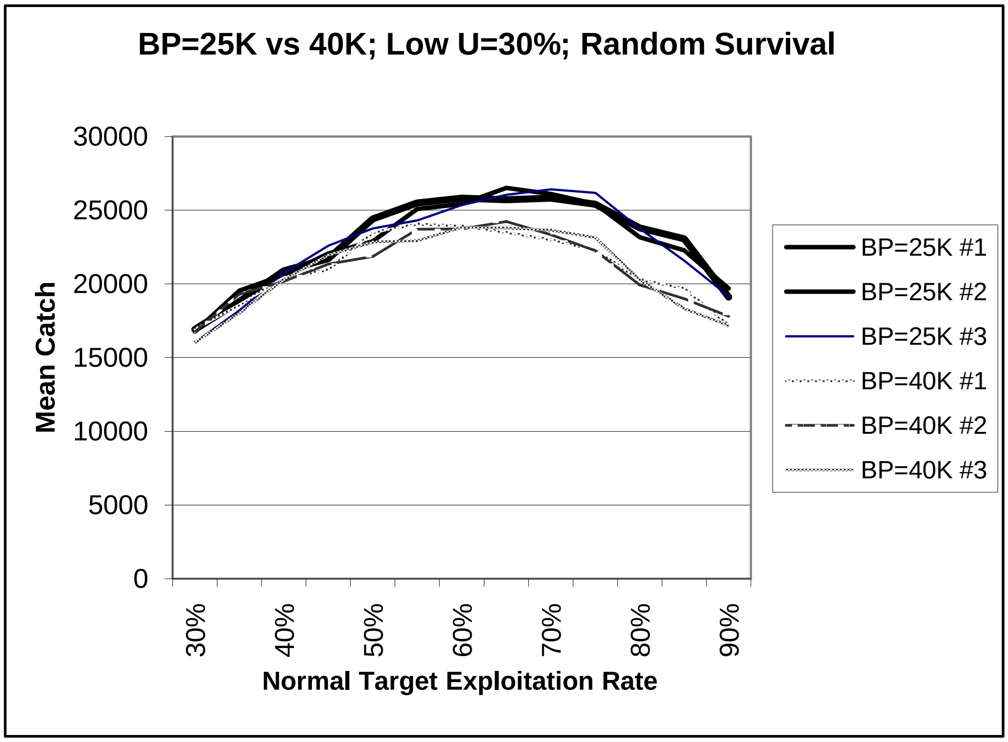


Figure 4. Mean catches by normal exploitation rate target under different low/normal breakpoints and survival rate variation assumptions.



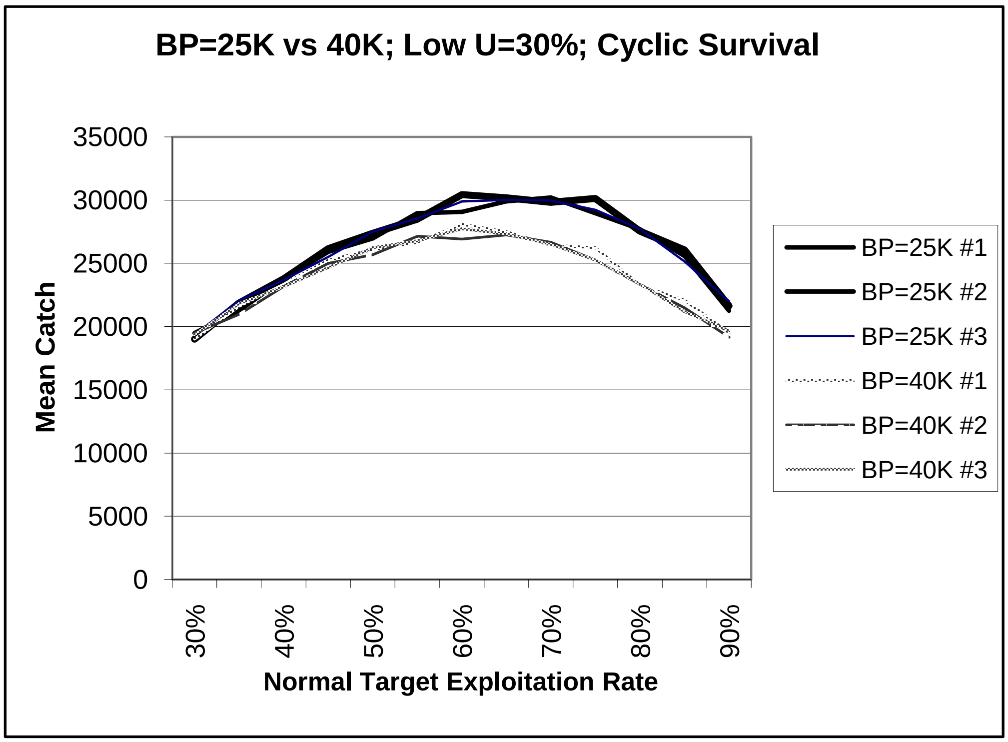
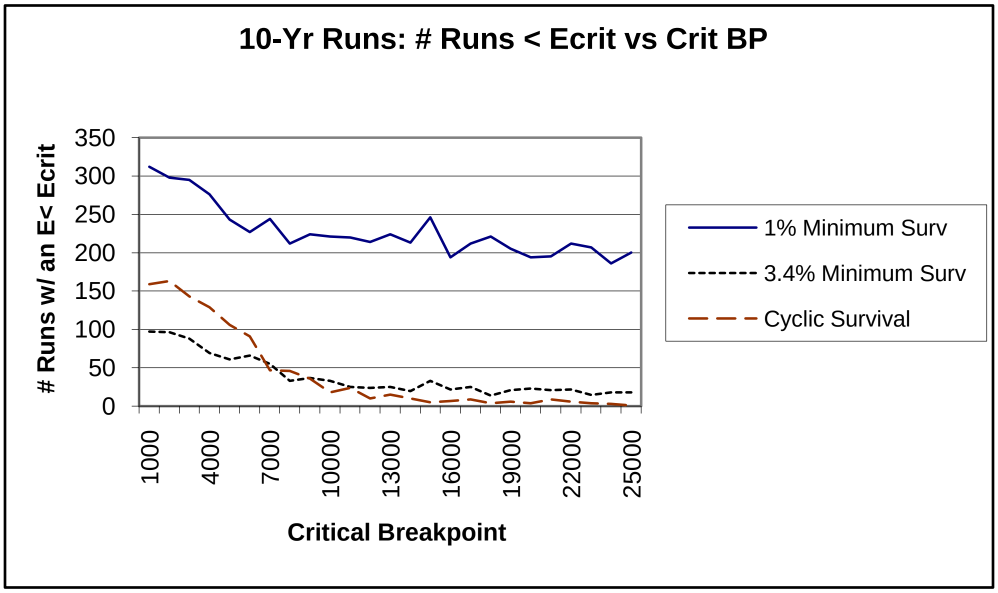


Figure 5. Number of times out of 1000 runs that at least 1 escapement falls below the point of instability (Ecrit), under different critical breakpoints, years/run, and survival assumptions.



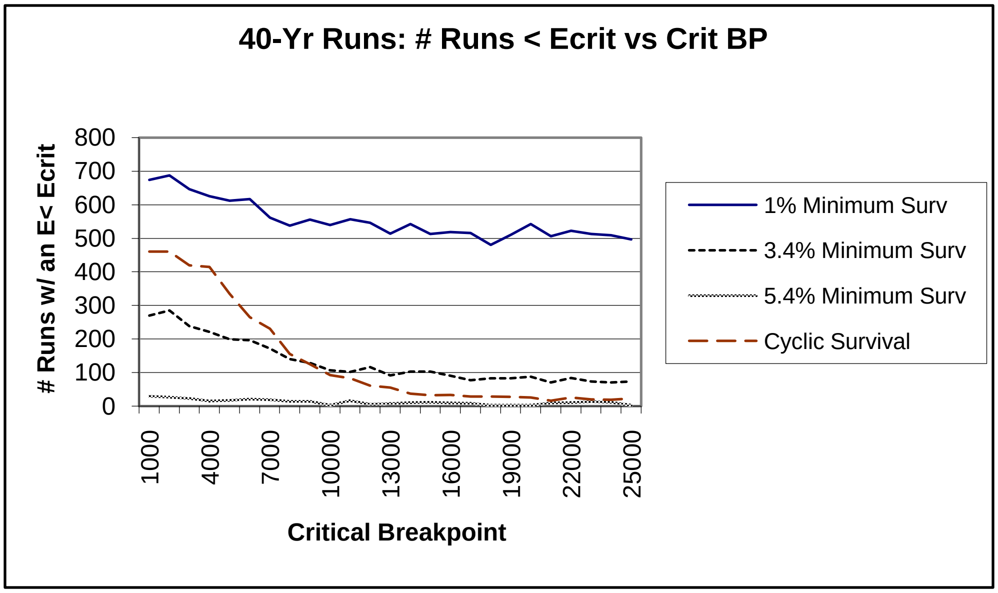
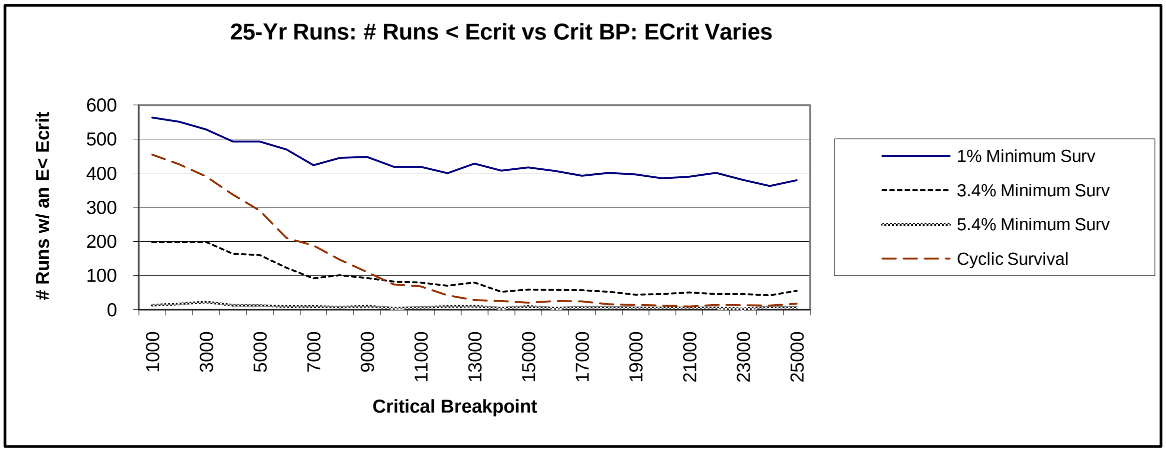
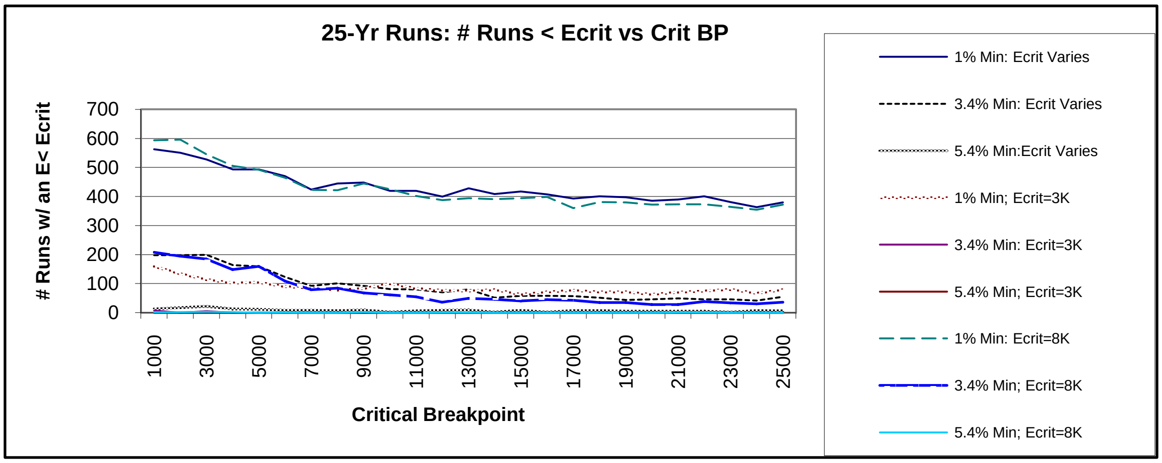
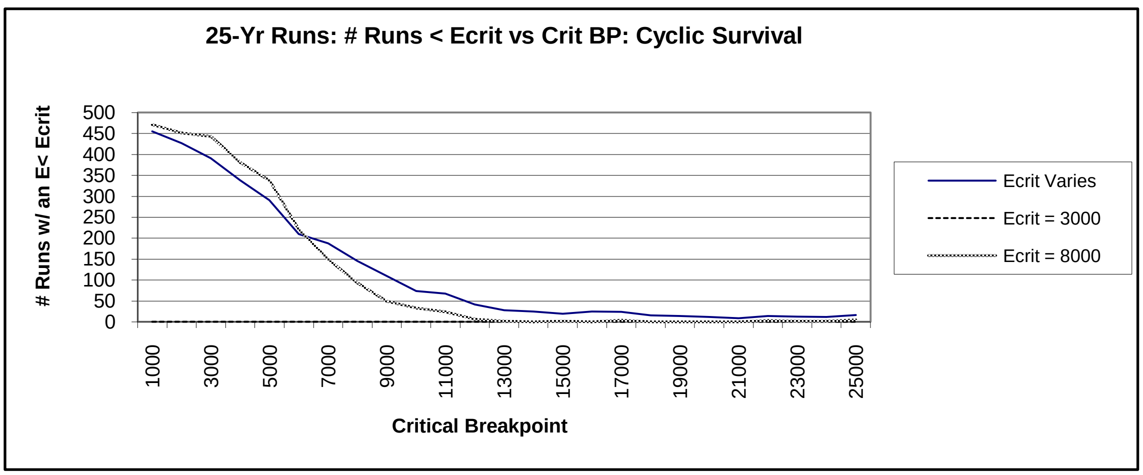


Figure 5. Number of times out of 1000 runs that at least 1 escapement falls below the point of destabilization (Ecrit), under 25-year runs with different critical breakpoints, survival assumptions, and assumptions about critical escapement.







Derivation of Comprehensive Coho management goals for wild Stillaguamish and Snohomish coho

Marla Maxwell, Tulalip Fisheries
January 25, 2001

Introduction

In order to establish stock-specific management goals for Skagit coho, Bob Hayman (Skagit Systems Cooperative) has developed a computer model that identifies MSY escapement and exploitation rates, given variability in environmental conditions, inaccuracies in forecasting run sizes pre-season, and lack of precision in harvesting the allowable catch. The model simulates coho stock-recruitment dynamics and harvest management, and predicts the average catch and escapement produced by a range of escapement and exploitation goals, under different marine survival conditions. Because the model is based on stock-specific parameters, it can be used to evaluate target exploitation rates and escapements for any stock. The model has already been used to develop draft management goals for Hood Canal wild coho (see Jeff Haymes' 10/20/00 memorandum), and the approach was recently used, as described herein, to identify management goals for the Stillaguamish and Snohomish wild coho runs.

This report outlines the sources of data used as input parameters to model the Stillaguamish and Snohomish systems, and provides the preliminary results of this modeling exercise. A detailed description of the model structure is not provided in this paper, as Bob Hayman has previously disseminated this information in a series of memos and presentations. Furthermore, the model used in this application was virtually identical to that used in previous analyses, with only minor modifications to the original computer code that did not affect the model's overall nature.

Results from the "Hayman" simulation model were used to identify the "low/normal escapement breakpoint", as well as target exploitation rates under both "low" and "normal" marine survival conditions for the Stillaguamish and Snohomish wild coho stocks. However, the model was not used to identify the "critical/low escapement breakpoint" for either stock, as simulation results did not clearly indicate where such a breakpoint should occur. Preliminary values for the critical/low escapement breakpoints were instead identified by examining historical escapement records.

Input Parameters

The model simulates wild coho stock recruitment dynamics by separating coho life history into freshwater and marine components. Essentially, the model predicts the number of smolts entering the ocean in a given year (the freshwater phase) and estimates the proportion of those smolts that return to Puget Sound as age-3 adults (the marine phase). These adults become available for harvest in the fishery, which is modeled as a single event, and those fish that are not harvested then return to spawn and produce the next generation of smolts. The model thus requires a relationship that predicts the number of smolts generated by a certain number of spawners, as well as a relationship that estimates of the number of age-3 adults resulting from a given number of smolts. In addition, in order to simulate the errors inherent in harvesting the returning adults, the model requires an estimate of the error in forecasting run-size pre-season, as well an estimate of the error involved in harvesting the expected number of available recruits (i.e. the degree to which the stock is over- or under-harvested). Parameter values that were used as inputs to the model are listed in Table 1, and details of the generation of these inputs are provided below.

Table 1. Summary of Stillaguamish and Snohomish CompCoho model parameters

	Stillaguamish	Snohomish
BevHolt smolt capacity	360,000	1,900,000
BevHolt initial slope	80	80
Initial escapement	15,000	80,000
Depensatory escapement	3,240	17,100
‘Normal’ marine survival	9.0%	9.0%
‘Normal’ marine survival SD	4.0%	4.0%
‘Poor’ marine survival	4.2%	4.2%
‘Poor’ marine survival SD	1.9%	1.9%
Minimum marine survival	1.0%	1.0%
Minimum exploitation rate	0.10	0.10
Maximum exploitation rate	0.80	0.80
Number of years	25	25
Number of runs	1000	1000

Spawner-smolt relationship

Based on guidance from WDFW and tribal biologists regarding which stock-recruitment model is most appropriate for simulating coho dynamics in freshwater (see Jeff Haymes’ 10/20/00 memorandum and Greg Volkhardt’s 03/14/94 memorandum), I used a Beverton-Holt model to represent the relationship between spawner abundance and the resulting production of smolts. Historical spawner records for Stillaguamish and Snohomish wild coho were provided by Curt Kraemer (WDFW, Mill Creek). However, there is no record of smolt outmigrants for either the Stillaguamish or Snohomish River. Therefore, estimates of historical smolt numbers were “back-calculated” from available data for terminal adult recruits from each river (Table 2). For brood years 1981 to 1994, the number of terminal adults (provided by Jeff Haymes, WDFW) was expanded to total age-3 adult recruits using an estimate of the pre-terminal harvest rate that would have applied to a given brood year. The time-series of pre-terminal harvest rates was calculated from CWT recovery data for Wallace Creek hatchery coho. Estimates of total adult recruits were then expanded to smolts using the marine survival rate that applied to that brood year. The brood year marine survival rate used was the average of the brood year marine survival rates for Big Beef and Deschutes wild coho. These rates were chosen because they represented the longest available time series of marine survivals for wild coho in Puget Sound.

Table 2a. Back-calculation of Stillaguamish smolts from terminal adult recruits

Brood Year	Stillaguamish Terminal Adult Recruits	CRAS Wallace River Pre-Terminal Harvest Rate	Stillaguamish Total Adult Recruits	Marine Surv Mean of BB and Deschutes	Stillaguamish Smolts	Spawners
1981	26,067	0.53	54,878	0.20	267,762	9,000
1982	32,119	0.54	70,282	0.21	339,200	9,000
1983	47,671	0.49	92,655	0.30	313,766	15,000
1984	44,930	0.50	89,265	0.29	307,598	20,700
1985	34,603	0.52	72,543	0.20	368,894	14,300
1986	12,663	0.58	29,936	0.14	212,013	25,100
1987	32,790	0.65	92,366	0.20	467,440	14,900
1988	10,632	0.61	27,053	0.08	329,719	14,500
1989	18,145	0.60	44,913	0.11	399,053	7,000
1990	9,150	0.67	27,727	0.06	459,061	18,000
1991	25,600	0.48	48,762	0.21	234,320	6,100
1992	20,134	0.45	36,875	0.09	421,434	13,200
1993	10,050	0.43	17,570	0.09	194,143	10,400
1994	11,132	0.17	13,364	0.13	106,867	26,100

Table 2b. Back-calculation of Snohomish smolts from terminal adult recruits

Brood Year	Snohomish Terminal Adult Recruits	CRAS Wallace River Pre-Terminal Harvest Rate	Snohomish Total Adult Recruits	Marine Surv Mean of BB and Deschutes	Snohomish Smolts	Spawners
1981	94,467	0.53	198,878	0.20	970,373	37,000
1982	122,749	0.54	268,597	0.21	1,296,319	56,000
1983	194,735	0.49	378,494	0.30	1,281,726	145,000
1984	179,509	0.50	356,640	0.29	1,228,947	108,700
1985	131,789	0.52	276,287	0.20	1,404,969	70,600
1986	143,822	0.58	340,005	0.14	2,407,965	117,400
1987	163,925	0.65	461,761	0.20	2,336,845	93,300
1988	85,032	0.61	216,366	0.08	2,637,007	75,800
1989	117,317	0.60	290,389	0.11	2,580,085	94,500
1990	54,293	0.67	164,524	0.06	2,723,911	90,800
1991	160,917	0.48	306,509	0.21	1,472,891	43,800
1992	94,254	0.45	172,626	0.09	1,972,873	74,300
1993	56,309	0.43	98,442	0.09	1,087,760	51,300
1994	59214	0.17	71,085	0.13	568,454	142,800

The reconstructed smolt time-series were then used in conjunction with spawner data for the same brood years to fit Beverton-Holt relationships using non-linear regression. Regressions were fit for spawner-smolt data both with and without data from the 1994 brood year, because this brood produced an uncharacteristically low number of smolts due to a large winter flood event in 1995. Results of the regressions that included the 1994 data point provided a biologically reasonable Beverton-Holt curve for the Snohomish coho stock, but not for the Stillaguamish stock (Table 3). In contrast, regressions where the 1994 brood was removed produced more reasonable results for the Stillaguamish stock, but generated values for smolt capacity that were much too large for the Snohomish system. Accordingly, it was decided that the Snohomish stock would be modeled including data from the 1994 brood year, while that same brood would be excluded from the Stillaguamish data set.

Table 3. Best-fit Beverton-Holt parameters for Stillaguamish and Snohomish wild coho

	Stillaguamish	Snohomish	Stillaguamish No 1994	Snohomish No 1994
Smolt capacity (a parameter)	270,000	1,900,000	360,000	3,000,000
Initial slope (a/b)	-250	120	250	50
Spawners at ½ smolt capacity (b parameter)	-1,080	15,833	1,440	60,000

In addition to estimating best-fit Beverton-Holt parameters using non-linear regression, I also calculated the probability that a particular Beverton-Holt curve (as defined by a particular set of Beverton-Holt parameters) described the data, for a range of curves. This enabled me to evaluate how well the best-fit parameters described the spawner-smolt relationship, relative to other possible parameter values. In other words, I could assess whether the available data indicated that the best-fit relationship was the only appropriate curve to describe the spawner-smolt relationship, or if there were a number of other Beverton-Holt curves that described the data nearly as well. Results (Appendix A) indicated that the data was very informative concerning the ‘a’ parameter (maximum smolt capacity) of the Beverton-Holt function for both rivers. However, for a given smolt capacity, there was a wide range of Beverton-Holt slope values (‘a/b’) that described the spawner-smolt relationship equally well. This occurs because there is little data available at low spawner abundances for these rivers, and therefore the initial slope of the function cannot be clearly defined. I thus deferred to the regional managers and biologists to define this parameter, and they collectively agreed that 80 smolts/spawner was an appropriate slope to use when modeling these systems. The resulting Beverton-Holt parameters used as inputs to the simulation model are listed in Table 1, and the spawner-smolt relationships described by these parameters are displayed in Figure 1.

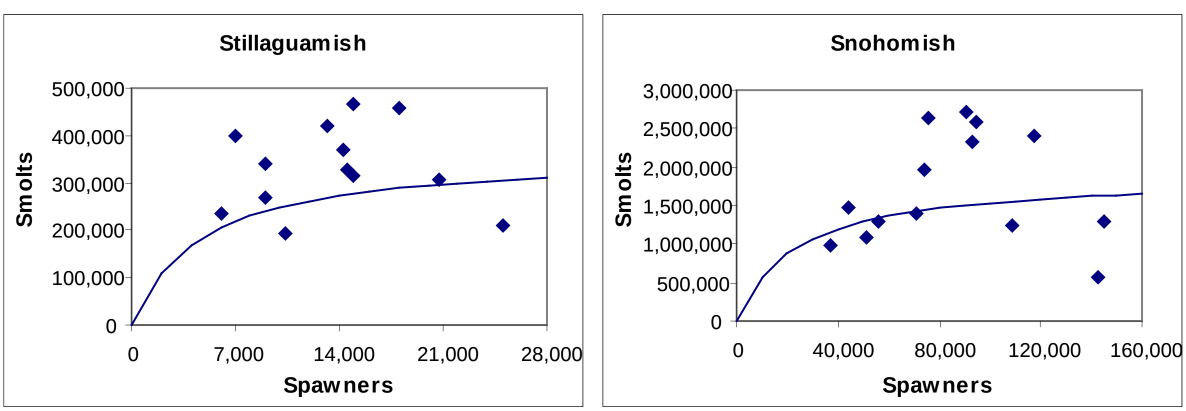


Figure 1. Beverton-Holt spawner-smolt relationships

Depensatory escapement level

The Beverton-Holt function models compensatory density dependence with increasing spawner density, producing a relationship where the number of smolts produced per spawner decreases as spawner abundance increases. The flipside of this statement is that as the number of spawners decreases, the model indicates that the number of smolts produced per spawner will increase, such that the maximum number of smolts per spawner occurs at very low spawner numbers. However, biological theory suggests that below some minimum spawner density, the number of smolts produced per spawner should actually decrease, due biological mechanisms such as to the inability to find mates at low population density, or to non-linear feeding responses of coho predators. In order to capture this effect in the model, I have incorporated depensatory density dependence at low spawner abundances. The result of this depensatory effect is that below a "depensatory escapement level" the model will generate only one adult recruit per spawner, rather than the approximately seven adult recruits per spawner expected given normal marine survival rates. The depensatory escapement level was modeled as 10% of the largest expected unfished run-size for each of the Stillaguamish and Snohomish wild coho stocks (Table 1). The unfished run-size was estimated by multiplying the maximum smolt capacity for each system by 9.0%, which represents the wild coho marine survival expected under "normal" ocean conditions. The effect of this depensatory escapement level on age-3 adult recruits is shown in Figure 2. Adult values used in this figure were expanded from the spawner-smolt relationships, assuming a 9.0% marine survival rate.

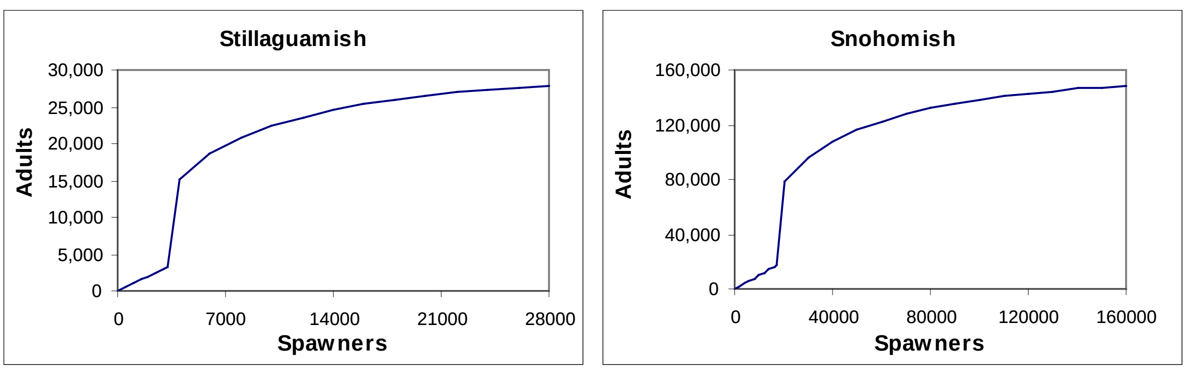


Figure 2. Beverton-Holt spawner-adult relationships incorporating a depensatory effect at low spawner abundance

Marine survival (smolt-to-age 3) rate

Wild coho marine survival rates used in this model were identical to those used in the Skagit analysis (Table 1). The values were based on marine survival rates estimated from tagged wild coho from Baker Creek, weighted by freshwater survival scalars (see Hayman documentation for further details). Marine survival in a given year was simulated as a random variable, drawn from a normal distribution with a mean of 9.0% and a standard deviation 4.0% to represent "normal" ocean conditions, and a mean of 4.2% and a standard deviation of 1.9% to represent "poor" ocean conditions.

Pre-season run-size forecasting error

For each of the Stillaguamish and Snohomish wild coho runs, the pre-season run-size forecasting error was evaluated by calculating the relative difference between the pre-season and post-season estimates of terminal run-size for each year from 1985 to 1998. Histograms were plotted of the resulting errors, and any "holes" in the distributions were filled in to create the more complete distributions that would be expected given additional years of data. The "filled-in" distributions (Figure 3) were then adjusted so that they had similar means and standard deviations to the raw data.

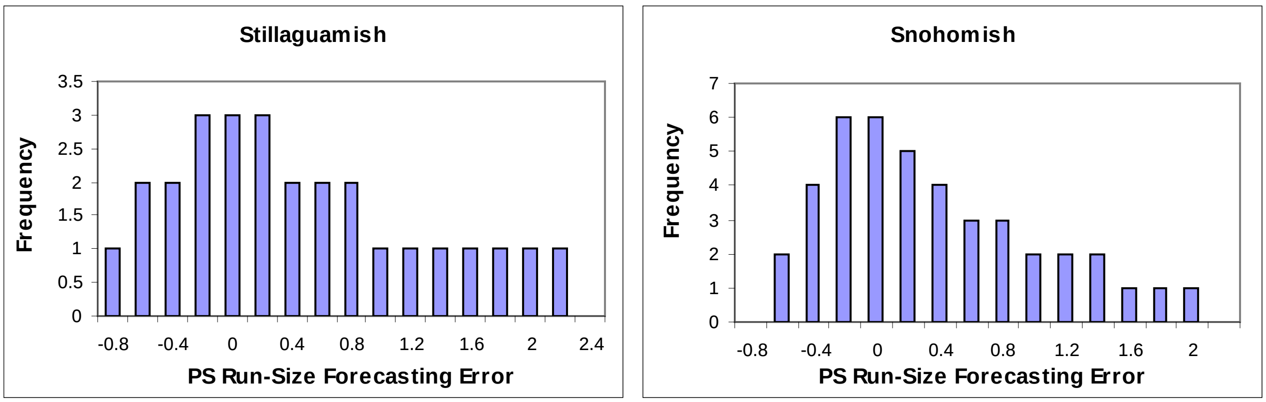


Figure 3. Pre-season run-size forecasting error for Stillaguamish and Snohomish wild coho

Exploitation rate error

The exploitation rate error used in this analysis was based on the Skagit exploitation rate error data for 1987 – 1997 from Hayman's analysis. However, in this application, the original exploitation rate error distribution was also "filled in" as described in the previous section, while ensuring that the mean and standard deviation of the new distribution were similar to those of the unmodified data (Figure 4).

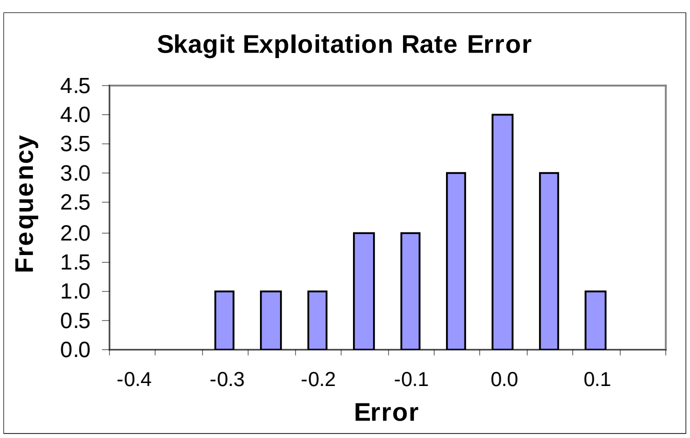


Figure 4. Exploitation rate error based on Skagit data

Results

Results from model outputs and ensuing discussion among co-managers have produced the following management goals for Stillaguamish and Snohomish wild coho (Table 4). Details of how these results were arrived at are provided in the following sections. Note that, for all simulations, the term "yield" (as in Maximum Sustainable Yield) is defined as the average catch produced over 25 generations.

Table 4. Stillaguamish and Snohomish Wild Coho Management Goals

	Critical/Low Escapement Breakpoint	Low Exploitation Rate Ceiling	Low/Normal Escapement Breakpoint	Normal Exploitation Rate Ceiling
Stillaguamish	6,100	0.35	10,000	0.50
Snohomish	31,000	0.40	50,000	0.60

Low/normal escapement breakpoint

The low/normal escapement breakpoint is defined as the "estimated MSY escapement under low survival conditions". Accordingly, the escapement targets that produced the MSY under "poor" marine survival rates, according to the model, were 10,000 for the Stillaguamish, and 50,000 for the Snohomish. Figure 5 shows the relationship between average catch, average escapement, and the escapement target for each river. Note that the "MaxCatch" line indicated the MSY target according to the model output.

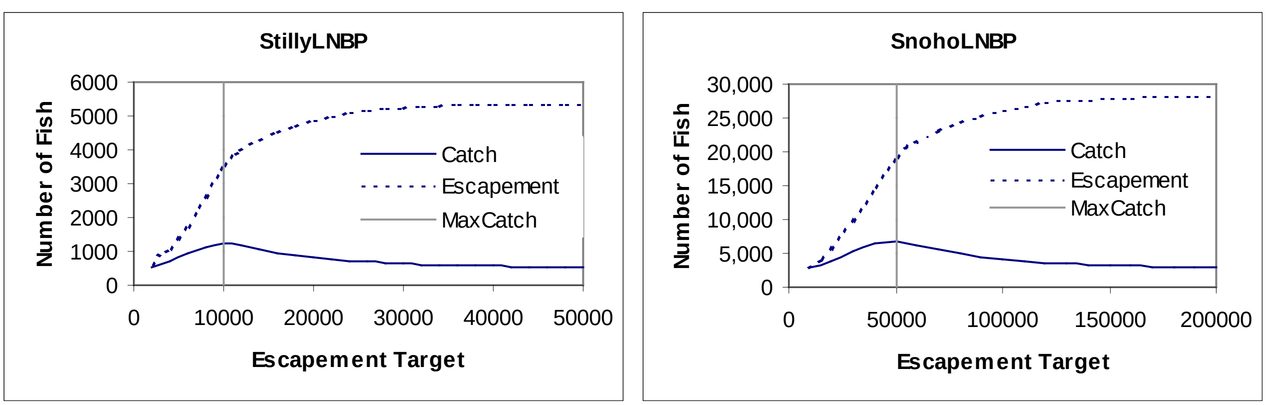


Figure 5. Low/Normal Escapement Breakpoint model outputs

Low exploitation rate ceiling

The low exploitation rate ceiling is defined as “the exploitation rate that provides the MSY under low survival conditions”. Output from the simulation model indicates that the MSY occurs at a 45% exploitation rate for both the Stillaguamish and Snohomish rivers (Figure 6).

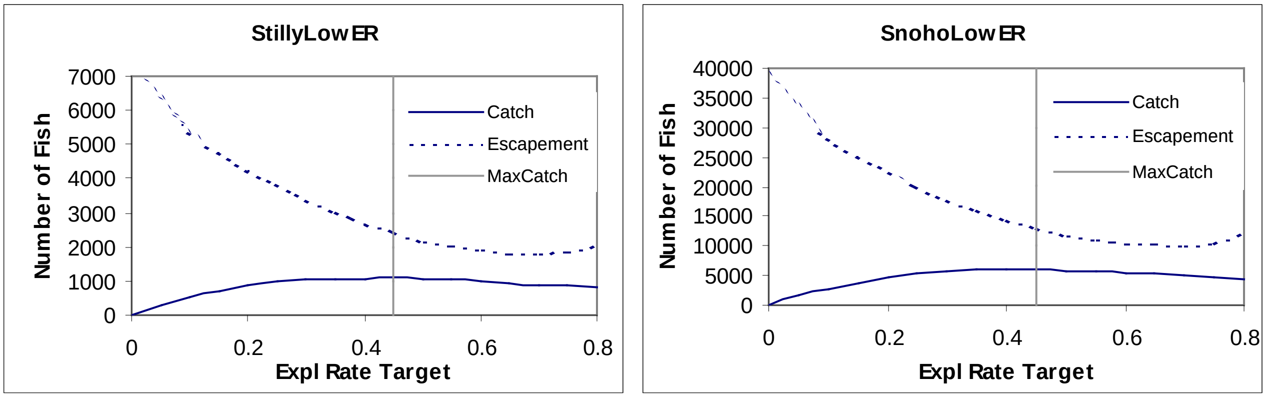


Figure 6. Low Exploitation Rate model outputs

However, further inspection of the model output shows that the average catch changes very little over a large range of exploitation rate targets (as indicated by the flatness of the catch curves in Figure 6). On the other hand, the average escapement varies approximately two-fold over that same range of escapement targets. Because of this observation, the relationship between the change in catch and the change in escapement was examined for a range of exploitation rate targets. Specifically, for a given exploitation rate, the increase in escapement from MSY escapement was divided by the decrease in catch from the MSY escapement. For the Stillaguamish River, this ratio reached a peak of 54.1 at an exploitation rate of 35% (Table 5). This means that decreasing the low exploitation rate target from 45% to 35% yields an average increase in escapement of 54 fish for every loss of one fish from the average catch. Based on this observation, regional managers decided that 35% was the most appropriate low exploitation rate target for Stillaguamish coho. The same analysis was also done for Snohomish coho, which indicated that the optimal low exploitation rate should be 40%, rather than 45% as indicated by the model output.

Table 5. Comparison of MSY low exploitation rates from model output with exploitation rates adjusted to maximize escapement per catch

	Model Output	Max. $\frac{\lvert \Delta esc \rvert}{\lvert \Delta catch \rvert}$	Low ER at Max. $\frac{\lvert \Delta esc \rvert}{\lvert \Delta catch \rvert}$
Stillaguamish	0.45	54.1	0.35
Snohomish	0.45	52.5	0.40

Normal exploitation rate ceiling

The normal exploitation rate ceiling is defined as “the exploitation rate that provides the MSY under average environmental conditions”. Output from the simulation model (Figure 7) indicates that the MSY occurs at a 65% exploitation rate for both the Stillaguamish and Snohomish rivers when using the low/normal breakpoints and low exploitation rate ceilings defined above.

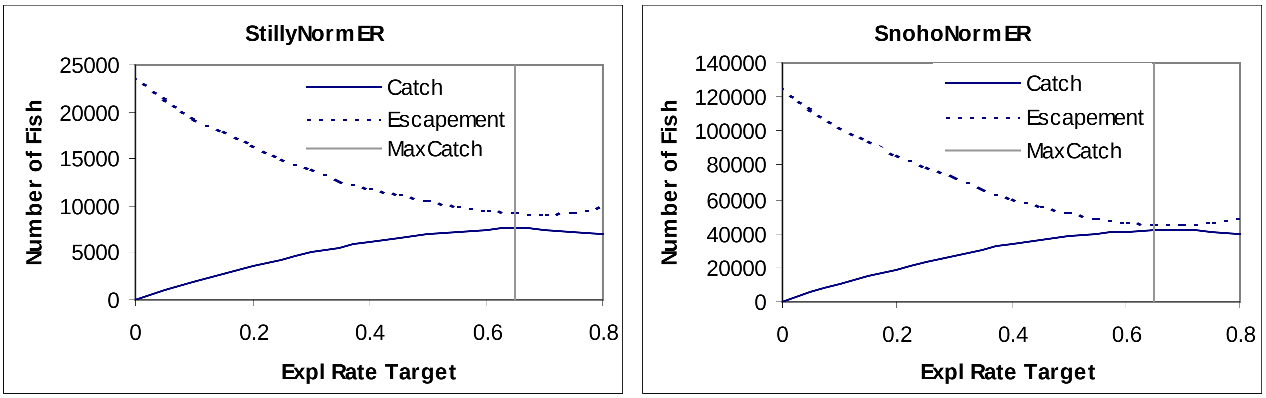


Figure 7. Normal Exploitation Rate model outputs

However, as was the case for the low exploitation rate analysis, there is a range of exploitation rate targets where the loss of escapement is greater than the gain in catch for the same increase in exploitation rate. Accordingly, the same analysis was performed for the normal exploitation rate ceiling as was done for the low exploitation rate ceiling. Results (Table 6) show that the ratio of the change in escapement to change in catch peaks at a 50% exploitation rate for the Stillaguamish River, and a 60% exploitation rate for the Snohomish River. The magnitude of the escapement to catch ratios was substantially smaller than for the low exploitation rate analysis, but the proposed reduction in exploitation rates from the MSY exploitation rates would nonetheless result in an increase in spawners that is at least twice as large as the accompanying loss in catch.

Table 6. Comparison of MSY normal exploitation rates from model output with exploitation rates adjusted to maximize escapement per catch

	Model Output	Max. $\frac{\lvert \Delta esc \rvert}{\lvert \Delta catch \rvert}$	Low ER at Max. $\frac{\lvert \Delta esc \rvert}{\lvert \Delta catch \rvert}$
Stillaguamish	0.65	2.3	0.50
Snohomish	0.65	4.0	0.60

Critical/low escapement breakpoint

In addition to calculating the average catch and escapement produced by a particular harvest or escapement target, output from the simulation model also indicated the percentage of runs where the escapement fell below the depensatory escapement breakpoint. This output was examined to see if there was a target escapement below which the percentage of low escapements substantially increased. Unfortunately, no such escapement level could be identified. Therefore, rather than attempting to identify a critical/low escapement breakpoint from the model output, regional co-managers decided to set this breakpoint based on historical escapement levels. For both rivers, the critical/low breakpoint was identified as the lowest escapement level recorded since 1965. For the Stillaguamish, this escapement was 6,100, and for the Snohomish, the escapement was 31,000 (Table 4).

Conclusions

Draft management goals for Stillaguamish and Snohomish wild coho, as identified in Table 4, represent the product of a population dynamics and harvest management model that takes into account variable environmental conditions and potential management errors. The outputs of the model were examined by regional co-managers who adjusted model outputs, where deemed necessary, to achieve the maximum harvest possible, given the need to maintain reasonable escapement levels. We believe the management goals described herein represent the most appropriate levels for Stillaguamish and Snohomish wild coho, given the management objectives outlined in the Comprehensive Coho Management Plan.

Further details of this analysis are available upon request. Please direct your inquiries to Marla Maxwell, Tulalip Fisheries.

Appendix A

POINT NO POINT TREATY COUNCIL

Port Gamble S'Klallam * Lower Elwha Klallam * Jamestown S'Klallam * Skokomish

Fishery Services

October 29, 2001

TO: Hood Canal JTC Workgroup

FR: Nick Lampsakis, PNPTC

SUBJ: Summary Description of Stepped Exploitation Rate Management Basis for Hood Canal Coho

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The general description of the approach used to apply exploitation rate based management for Hood Canal coho salmon has been outlined previously for the Hood Canal JTC. The origins of the present form of this management approach date back to the work of the JTC in 1991 and 1992, which culminated in the development of the currently used MSH escapement estimates and escapement goals. However, it has become apparent that the current members of the JTC may be unfamiliar with the rationale and basis for this approach, particularly when attempting to compare/contrast it with approaches that may have been discussed for other basins and areas. So, while using some of the previously presented materials, the intent of this summary is to focus on the basis and intent of the Hood Canal approach.

Basis and Intent

The initial basis of the Hood Canal approach can be found in the "Results" and the Recommendations" sections of the JTC report entitled *Hood Canal Natural Coho MSH Escapement Estimate and Escapement Goals* (PNPTC; USFWS; WDFW; 1994). The work detailed in that report was completed in 1993.

In short, the JTC found that the value of MSH escapement, for Hood Canal naturally reared coho salmon, can vary between 16,010 and 30,305 spawners (between 14,350 and 27,150 for *primary* management units). See: pp. 6-8 of the above report. This range has been termed the <u>MSH Escapement Range</u>. MSH was estimated as applicable to <u>all</u> intercepting fisheries (*JTC Recommendation #4*). In practice, the lower and upper bounds of the range were estimated using the 10% and 90% exceedance levels of BBC summer low flow in the production function shown in Appendix 2 of the above report.

The basis of further development of management approaches has been to focus on the approaches that would result in most years' escapements occurring in the MSH Escapement Range. Fishery stability has been a secondary consideration.

Application

Escapement Breakpoints
In order to construct a stepped exploitation rate approach, the MSH Escapement Range was used to establish a "Normal" population abundance status, with each end of the range being considered as an escapement breakpoint. The "average MSH escapement" which had been used as a fixed escapement goal, was used to establish the "critical" breakpoint, by halving the average MSH goal value. The rationale for this stems from the use of the ½ MSH value, under the National Standards established by the *Magnuson-Stevens Act*, to indicate "overfishing".

In this manner, three escapement breakpoints were established and are named by the intervening escapement ranges: Critical/Poor; Poor/Normal; Normal/Abundant.

Stepped Exploitation Rates

The four escapement ranges (Critical, Poor, Normal, Abundant) can be associated with four ranges of population abundance and four recruit abundance breakpoints. The recruit abundance breakpoints are estimated by dividing each escapement breakpoint by the lowest escapement rate (1- maximum exploit. rate) that can be applied and still achieve the escapement breakpoint.

In practice, only two exploitation rates need be determined. The "Normal" and the "Critical". The "Normal" exploitation rate should be chosen to be applicable to most years in the recent record. It should not be too low, to avoid having most years being "abundant" instead of "normal". It should not be too high, in order to avoid having "normal", or "abundant" conditions occurring only on rare occasions. For Hood Canal, the value of 70% was chosen as appropriate maximum exploitation rate.

The "Critical" exploitation rate indicates a situation where no harvest is desirable because the resulting escapement would have no chance of approaching the MSH escapement range. In this case, for Hood Canal, the rate of 10% exploitation by US fisheries was selected . This value was selected because recent experience has shown that US fisheries can be constrained to this, or a lower, level. Foreign interceptions would have to be added, to determine the actual rate.

The other two exploitation rate ceilings (Poor, Abundant) can be estimated last. The "Poor" status is merely a transition zone between "Normal" and "Critical", therefore the applicable exploitation can be transitional as well. For Hood Canal, since a rate of 10% Canadian interception was assumed under "Critical", for a total of 20%, the "Poor" status ceiling exploitation was proposed at 45% (intermediate between 20% and 70%).

In the "Abundant" status, by definition, escapements would exceed the upper end of the MSH escapement range. Under this premise, the biomass exceeding the Normal/Abundant recruit threshold is "harvestable". Therefore, a 90% marginal exploitation rate ceiling has been proposed to apply to recruit numbers in excess of those necessary to provide 110% of the upper MSH escapement threshold, after application of the "Normal" ER ceiling.

Recent Years' Results

Using the above selections, as outlined in the table below, during the period of 1986 through 1999, the results would have been: 5 years of Abundant; 6 years of Normal; 2 years of Poor; and 1 year of Critical. If the Normal exploitation rate ceiling were changed to 60% (the Poor status exploitation ceiling still being intermediate, at 40%), then the result for the same period would have been: 8 years of Abundant; 4 years of Normal; 1 year of Poor; and 1 year of Critical. The following table provides three sample sets of exploitation rates and recruit breakpoints for comparison. The PNPTC preferred Option is C. The option used during the year 2001 preseason planning, is Option B.

	Critical		Low		Normal		Abundant
Escapement BP		10750		14350		27150	
ER	10% SUS		40%		60%		60%+Marg.90%
DA2 BP, Opt. A		23900		47800		90500	
ER	10% SUS		45%		65%		65%+Marg.90%
DA2 BP, Opt. B		26100		54700		103400	
ER	10% SUS		45%		70%		70%+Marg.90%
DA2 BP, Opt. C		26100		63800		120700	

Items for further consideration

Exploitation Rate Ceilings

Using no additional data, or analyses, as the table above indicates, different exploitation rate ceiling values can be applied in order to achieve a desired result, or match particular fishery regimes. However, no stable regimes can be evaluated without the aid of simulation modeling (FEM model). This is because any candidate for optimum fishery regime that takes into account all stocks present, in all areas, would have to be evaluated against a mix of particular fisheries, throughout the stocks' ranges.

Escapement Breakpoints

The escapement breakpoints, determined through use of the MSH Escapement Range, should be reviewed and adjusted, as additional years of escapement, recruitment and climatic conditions become available (*JTC Recommendation #5*). When a review and re-evaluation is done, it is expected that the MSH Escapement, the MSH Escapement Goals and MSH Escapement Ranges, will change. At that time, an updated MSH escapement range can be used to establish new breakpoints and appropriate exploitation rate ceilings.

TABLE 3-1. Conservation objectives and management information for natural and hatchery salmon stocks and stock complexes of significance to ocean salmon fisheries. Abundance information is generally based on the period 1994-1998.[a/] (Page 1 of 3)

Stock	Conservation Objective[b/] (to be met annually, unless noted otherwise)	Subject to Council Actions to Prevent Overfishing	Other Management Information[c/]
		- - - COHO - - -	
WASHINGTON COASTAL (continued)			
Western Strait of Juan de Fuca (Sekiu, Hoko, Clallam, Pysht, East and West, and Lyre rivers and miscellaneous streams west of the Elwha River)	MSP objective of 11,900 natural adult spawners (Clark 1983 modified by habitat apportionment of WDFW/Tribal Technical Committee in 1998) or annual target agreed to through fixed procedures established in U.S. District Court.	Yes. Conservation alert or overfishing concern based on fewer than 11,900 natural spawners.	Small population. Low to depressed abundance. Little information on ocean distribution. A new annual objective of stepped exploitation rates is under consideration by WDFW and the tribes.

PUGET SOUND - All pertinent natural and hatchery stocks originating from U.S. tributaries to Puget Sound and the eastern Strait of Juan de Fuca (east of Salt Creek). The Puget Sound Salmon Management Plan defines management objectives and long-term goals for these stocks as developed by representatives from federal, state, and tribal agencies. Conservation objectives for specific stocks are currently based on either MSP principles for stocks managed primarily for natural production or upon hatchery escapement needs for stocks managed for artificial production. However, a transition to exploitation rate management is currently under consideration by the involved managers. Annual escapement targets for these coho stocks are developed through procedures established in U.S. District Court. Puget Sound management procedures are outlined in a Memorandum Adopting Salmon Management Plan (U.S. v. Washington, 626 F. Supp. 1405 [1985]). The original conservation objectives were developed by a State/Tribal Management Plan Development Team following the Boldt Decision with the goal for natural spawning stocks defined as Athe adult spawning population that will, on the average, maximize biomass of juvenile outmigrants subsequent to incubation and freshwater rearing under average environmental conditions.@ The methodology used to develop the objectives was based on assessment of the quantity and quality of rearing habitat and the number of adult spawners required to fully seed the habitat (Zillges 1977). Some objectives have subsequently been modified in 1983 by the U.S. District Court Fisheries Advisory Board (Clark 1983 and PSSSRG 1997) and later determinations of the

Eastern Strait of Juan de Fuca (Streams east of Salt Creek through Chimacum Creek)	MSP objective of 950 natural adult spawners (Clark 1983 modified by habitat apportionment of WDFW/Tribal Technical Committee in 1998) or annual target agreed to in fixed procedures set by U.S. District Court. The Elwha and Dungeness rivers are not included in this objective, but are managed on a harvest rate basis.	Yes. Conservation alert or overfishing concern based on fewer than 950 natural spawners.	Small population. Low to depressed abundance. Little information on ocean distribution. A new annual objective of stepped exploitation rates is under consideration by WDFW and the tribes.

TABLE 3-1. Conservation objectives and management information for natural and hatchery salmon stocks and stock complexes of significance to ocean salmon fisheries. Abundance information is generally based on the period 1994-1998.[a/] (Page 2 of 3)

Stock	Conservation Objective[b/] (to be met annually, unless noted otherwise)	Subject to Council Actions to Prevent Overfishing	Other Management Information[c/]
		- - - COHO - - -	
PUGET SOUND (continued)			
Hood Canal	MSP objective of 21,500 natural adult spawners (Clark 1983 modified since 1994 by WDFW/Tribal Technical Committee) or annual target agreed to in fixed procedures set by U.S. District Court.	Yes. Conservation alert or overfishing concern based on fewer than 21,500 natural spawners.	Low to medium abundance. Contributor to U.S. ocean fisheries north of Cape Falcon; significant contributor to ocean fisheries off British Columbia, in Puget Sound, and inside tribal fisheries. A new objective utilizing stepped exploitation rates is under consideration by WDFW and the tribes which may utilize harvest rate management rather than a fixed spawner
Skagit	MSP objective of 30,000 natural adult spawners (Zillges 1977 and Clark 1983) or annual target agreed to in fixed procedures set by U.S. District Court. (The spawner assessment methodology is currently being revised and may result in an objective significantly different from 30,000.)	Yes. Conservation alert or overfishing concern based on fewer than 30,000 natural spawners.	Low to depressed abundance. Contributor to U.S. ocean fisheries north of Cape Falcon; significant contributor to ocean fisheries off British Columbia, in Puget Sound, and inside tribal fisheries. A new objective is under consideration by WDFW and the tribes which may utilize harvest rate management rather than a fixed spawner goal.
Stillaguamish	MSP objective of 17,000 natural adult spawners (Zillges 1977) or annual target agreed to in fixed procedures set by U.S. District Court.	Yes. Conservation alert or overfishing concern based on fewer than 17,000 natural spawners.	Medium to low abundance. Contributor to U.S. ocean fisheries north of Cape Falcon; significant contributor to ocean fisheries off British Columbia, in Puget Sound, and inside tribal fisheries. A new objective is under consideration by WDFW and the tribes which may utilize harvest rate management rather than a fixed spawner goal.

TABLE 3-1. Conservation objectives and management information for natural and hatchery salmon stocks and stock complexes of significance to ocean salmon fisheries. Abundance information is generally based on the period 1994-1998.[a/] (Page 3 of 3)

Stock	Conservation Objective[b/] (to be met annually, unless noted otherwise)	Subject to Council Actions to Prevent Overfishing	Other Management Information[c/]
		- - - COHO - - -	
PUGET SOUND (continued)			
Snohomish	MSP objective of 70,000 natural adult spawners (Zillges 1977 as modified by WDFW/Tribal Technical Committee) or annual target agreed to in fixed procedures set by U.S. District Court.	Yes. Conservation alert or overfishing concern based on fewer than 70,000 natural spawners.	High to medium abundance. Contributor to U.S. ocean fisheries north of Cape Falcon; significant contributor to ocean fisheries off British Columbia, in Puget Sound, and inside tribal fisheries. A new annual objective is under consideration by WDFW and the tribes which may utilize harvest rate management rather than a fixed spawner goal.
South Puget Sound (Hatchery)	Hatchery rack return goal of 52,000 adults. Natural production goals under development.	No (hatchery exception).	High abundance. Contributor to U.S. ocean fisheries north of Cape Falcon; significant contributor off British Columbia, in Puget Sound, and inside tribal fisheries.

MODEL EVALUATION WORKGROUP REPORT ON SALMON METHODOLOGY REVIEW

At the Salmon Methodology Review meeting, in October, the Model Evaluation Workgroup (MEW) presented progress to the Salmon Subcommittee of the Scientific and Statistical Committee (SSC) and the Salmon Technical Team (STT) on two tasks:

1) Evaluation of bias, introduced by Mark Selective Fisheries (MSF), in Fisheries Regulation Assessment Model (FRAM) calculations of exploitation rates for unmarked stocks.
2) Development of alternative methods for estimation of pre-season abundance of Columbia River Chinook stocks.

Since the advent of MSF, there has been concern that fish released in MSF may potentially be encountered more than once, but the FRAM model does not currently have the ability to model multiple encounters within a model time step. Ideally, each time a fish is landed and released it should be subjected to a modeled release mortality rate. The MEW quantified the MSF bias introduced to FRAM calculations of unmarked stock exploitation rate by modeling the same simplified coho fishery with FRAM and with another model developed with multiple encounter capability. The MEW report to the SSC/STT, *'Multiple Encounters in salmon mark selective fisheries: bias levels introduced in FRAM estimated exploitation rate of unmarked coho and Chinook stocks'* is available as Agenda Item H.1.a, Attachment 1

We found that FRAM produced unmarked exploitation rates that are biased low when MSF are implemented. At low levels of MSF this bias may not be a concern, but it still exists. Various ways to address this bias were discussed at the October meeting. The MEW agrees that the preferred solution would be to modify FRAM to enable accounting for multiple encounters. This is complicated by drop-off mortality and mark recognition error rates of both marked and unmarked salmon. However, the great majority of bias is introduced by the release mortality of multiple encountered unmarked fish in MSF. Equations to adjust unmarked exploitation rates were discussed, and are being evaluated by the MEW at this time. The equation confirmed within the group as appropriate could be added to the FRAM code and results from the revised FRAM compared to the results from the multiple encounter model. If this work proceeds on schedule, in January the MEW will be prepared to present results to the SSC/STT to evaluate the potential use of the revised FRAM for 2010 pre-season modeling.

This proposed FRAM modification will be for coho only; similar work for Chinook is more complicated and will proceed over the next year. Chinook MSF have not yet been implemented in Council fisheries, and thus MSF bias is not as big of a concern. Solutions for MSF exploitation rate bias for unmarked Chinook stocks could be on the agenda for the 2010 October Model Review meeting.

For the second task of deriving pre-season abundance forecasts for Columbia River Chinook stocks, progress reports on two methods were presented at the October meeting. This topic is not ready for a full evaluation at this point, but work will continue.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

OCT 14 2009

F/SWR2:JLI

Mr. David Ortmann, Chairman
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384

Dear Chairman Ortmann:

I am writing to provide you with an update on the progress by the NMFS Southwest Region (SWR) towards reinitiating Section 7 consultation under the Endangered Species Act (ESA) for the ocean salmon fishery's impacts on the endangered Sacramento River Winter Chinook (Winter Run). The current biological opinion for the Winter Run expires at the end of the 2009 fishing year, thus a new opinion must be in place by May 1, 2010. The SWR also may reinitiate consultation on Central Valley Spring Chinook (Spring Run) if new information reveals reinitiation is necessary. If so, we would probably issue a joint opinion covering both of these ESA-listed Evolutionarily Significant Units (ESUs).

ESA Section 7 and its implementing regulations (50 CFR 402.16) require reinitiation of consultation if new information reveals the action may be affecting the listed species in a manner not considered in an earlier opinion. In the past, NMFS and the Council have relied heavily upon data produced from the recoveries of coded wire tags (CWTs) from ocean fisheries to inform and guide management decisions relative to these ESA-listed ESUs in California. At this time, the SWR believes that CWTs continue to represent the best scientific information available concerning ocean harvest impacts on these ESUs. There is new CWT data available since the last opinion was developed for Winter Run (in 2004) and Spring Run (in 2000) that has not previously been analyzed or considered. Biologists from the Southwest Fisheries Science Center, Santa Cruz Lab (Michael Mohr, Mike O'Farrell, and Allen Grover) are collecting the new CWT data and analyzing it for use in the consultation. Specifically, they have collected and are analyzing CWT data from 2000 to 2007 to determine spatial and temporal ocean distribution of the two ESUs, and the age-specific and total brood ocean impact rates.

The results of this information will allow us to consider the performance of the fishery conservation and management measures in place per the 2004 Biological Opinion for Winter Run and the 2000 Opinion for Spring Run, and to what degree this new information may influence, confirm, or change the understanding about how ocean fisheries interact with these

ESUs. The results will also inform the Council and SWR Sustainable Fisheries Division in describing the proposed action that will be the subject of the section 7 consultation with SWR Protected Resources Division.

The Center is nearing completion of the cohort reconstructions and estimates of ocean harvest impact rates for Winter Run and Spring Run. The new opinion for Winter Run must be available, at least in draft form, for the pre-season planning process starting in March, and finalized by May 1, 2010. If it appears that Section 7 consultation for Spring Run needs to be reinitiated, and the May deadline will not be met for an opinion covering both ESUs, then the SWR will first finalize a Winter Run Opinion to meet the deadline, and will finish a separate Spring Run consultation later in 2010.

NMFS expects to have the cohort analyses complete in November shortly after the Council meeting. However, preliminary results will be available to allow us to start discussions with Council staff in early November. Additionally, the draft opinion will undergo a peer review by the Center for Independent Experts. We will provide an overview of the draft opinion for the Salmon Technical Team, the Scientific and Statistical Committee, and the Salmon Advisory Subcommittee at or prior to the March meeting.

If you have any questions, please contact Mark Helvey, Assistant Regional Administrator for Sustainable Fisheries in the SWR (Mark.Helvey@noaa.gov or 562-980-4040).

Sincerely,

Anthony C. Morton

for Rodney R. McInnis
Regional Administrator

SALMON TECHNICAL TEAM REPORT ON SALMON METHODOLOGY REVIEW

The Salmon Technical Team (STT) met on October 5-6, 2009 with the Scientific and Statistical Committee's (SSC) Salmon Subcommittee and the Model Evaluation Workgroup to review:

- Multiple Encounters in Salmon Mark Selective Fisheries: Bias Levels Introduced in FRAM Estimated Exploitation Rate of Unmarked Coho and Chinook Stocks
- Assessment of fall ocean Chinook salmon fisheries south of Cape Falcon
- Appropriateness of the September 1 river return date approximation for Klamath River fall Chinook
- Proposed Modification of Puget Sound Coho Conservation Objectives
- Progress report on Columbia River Fall Chinook Ocean Abundance forecasts

The STT agrees with the finding that bias in estimating mark selective impacts on unmarked fish increases as marked selective fishing harvest rates increase. This results in an underestimation of exploitation rates (ER) on unmarked stocks which affects preseason projections as well as post season reconstructions and assessment of compliance with management objectives. The multiple encounter simulations support the earlier SSC recommendation that bias in unmarked stock ER estimates could be quite high in intense mark selective fisheries (i.e., a marked ER greater than 0.10 in an individual mark selective fishery or 0.30 in all mark selective fisheries). The STT agrees that the preferred option to address this bias is to add a bias correction factor within FRAM to account for the multiple encounter bias in mark selective fisheries.

The STT found no justification for changing the September 1 river return approximation used for Klamath River fall Chinook. The analysis examined KRFC river return timing, inferred from the Yurok Tribe estuary gillnet fishery, by age and hatchery release group, as well as for the composite stock. While some groups, such as age-3 Trinity River Hatchery fingerlings and yearlings, exhibited slightly later river return timing than other groups, this variation does not have a strong bearing on the river return timing of the composite stock, comprised of hatchery and natural-origin fish. The composite stock river return timing was consistently centered about September 1.

The analysis of potential assessment methods for fall ocean Chinook salmon fisheries south of Cape Falcon demonstrated that there are few reliable means of forecasting the impact these fisheries have on key stocks. In the absence of timely September abundance forecasts, it is not possible to assess the impact fall fisheries will have on future escapement of Sacramento and Klamath River fall Chinook (SRFC, KRFC). Examination of historical KRFC age-4 ocean harvest rate estimates from the fall months suggested that commercial and recreational fisheries in San Francisco and Monterey, and recreational fisheries in Fort Bragg, have contributed little to this rate. The STT agrees with the conclusion that fall fisheries pose an unknown level of risk to the SRFC and KRFC stock's ability to meet their conservation objectives in the following year.

The STT recommends that the Puget Sound coho management objectives currently used by the Pacific Salmon Commission be adopted as the conservation objectives in the FMP. However, we note that adoption of these management objectives would combine Eastern and Western Strait of Juan de Fuca coho stocks. These were split apart in the current FMP, in part, because they were placed in different Evolutionarily Significant Units by the National Marine Fisheries Service, and the Western Strait of Juan de Fuca stock is currently under an overfishing concern. The STT is also concerned that these Puget Sound coho conservation objectives do not specify clear Status Determination Criteria. The STT recommends that the critical/low breakpoint be adopted as a minimum stock size threshold for determining stock status (Overfishing Concern and Conservation Alert in the current FMP), and the allowable exploitation rate per the exploitation rate-abundance matrix be adopted as a maximum fishing mortality threshold.

Agenda Item H.1.b
Supplemental SAS Report
November 2009

SALMON ADVISORY SUBPANEL REPORT ON SALMON METHODOLOGY REVIEW

The Salmon Advisory Subpanel (SAS) met by conference call on October 22, 2009 to discuss salmon methodology review issues, including the topics discussed at the October 5-6 meeting of the Salmon Technical Team (STT) and the Salmon Subcommittee of the Scientific and Statistical Committee (SSC):

- Multiple Encounters in Salmon Mark Selective Fisheries: Bias Levels Introduced in FRAM Estimated Exploitation Rate of Unmarked Coho and Chinook Stocks

The SAS recognizes the need to address bias in the FRAM due to multiple encounters in mark selective fisheries, and recommends the Model Evaluation Workgroup (MEW) continue to evaluate methods to address this bias. However, given the current low levels of mark-selective fishery exploitation rates, adjustments to both Chinook and Coho FRAM should not be made until a thorough assessment has been completed and properly reviewed.

- Assessment of fall ocean Chinook salmon fisheries south of Cape Falcon

The SAS notes that the report does not recommend against fall fishing, but only points out that there are certain risks. The SAS fully recognizes that fall fisheries pose a risk to fishing opportunity in the following spring and summer; however, the SAS feels that their role is to make recommendations to the Council on when some risk is worth taking. The report illustrates that there are times and areas that can provide opportunities for fall fisheries while minimizing potential impacts to constraining stocks, and the SAS will take these into consideration when making recommendations to the Council. The SAS also recommends the STT include the justification for omitting data in their analysis, such as the KRFC CWT estimates in 1993.

- Appropriateness of the September 1 river return date approximation for Klamath River fall Chinook

The SAS appreciates the cooperation of the Yurok Tribe in facilitating the analysis of the KRFC maturity boundary and requests that similar catch data be made available to the STT for the preseason planning process. The SAS is concerned that it appears yearling releases have a later river entry timing that other hatchery releases, and may disproportionately contribute to the age-4 ocean harvest rate in fall fisheries. The SAS would like the STT to attempt to estimate the median date of entry for age-3 KRFC on an annual basis and use that date to calculate fall age-4 ocean impacts in the preseason process the following spring. The SAS also requests that the catch data used to produce Figures 1 and 2 in the report be made available, and if possible presented, to the SAS.

- Proposed Modification of Puget Sound Coho Conservation Objectives

The SAS recommends the proposed Puget Sound coho conservation objectives be adopted. These objectives reflect the need to comply with Pacific Salmon Treaty (PST), and could provide justification for an international exception to the Annual Catch Limit (ACL) requirements, should that be considered. The proposed objectives are also based on MSY, which is an important reference point used in setting ACLs. The SAS recommends the issues associated with Strait of Juan de Fuca coho stock division be deferred to the state-tribal co-managers for resolution. This stock is important to inland fisheries but contributes little to Council area fisheries.

The SAS also reviewed the NMFS report on the Biological Opinion process for Sacramento winter Chinook. If the new BO is based on an exploitation rate and not the current time/area restrictions, the SAS requests NMFS consider allowing very limited or experimental fisheries to explore impacts on Sacramento winter Chinook and Klamath River fall Chinook in time/area strata that were closed under the current Biological Opinion.

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON 2009 METHODOLOGY REVIEW

The Salmon Subcommittee of the Scientific and Statistical Committee (SSC), the Salmon Technical Team (STT), and the Model Evaluation Workgroup (MEW) met at the Pacific Fishery Management Council (Council) office in Portland, Oregon on October 5 and 6, 2009, to review the four salmon methodology issues identified by the Council at the September meeting:

- Characterization of bias in Chinook and Coho Fishery Regulation Assessment Models (FRAM) associated with multiple encounters in mark-selective fisheries.
- Forecasting impact rates in fall fisheries for Klamath River fall Chinook and Sacramento River fall Chinook.
- Assessment of the September 1 maturity boundary assumption for Klamath River fall Chinook.
- Conservation objective updates for Puget Sound coho.

A summary of each of the items discussed was given to the full SSC at the November meeting. The reviews this year covered substantive issues that have been of interest to the Council for several years. In most cases materials were well documented, submitted on schedule, and had relevant management focus. The SSC commends the authors.

The SSC recommendations on each item are summarized below.

Characterization of Bias in the Chinook and Coho Fishery Regulation Assessment Models

In 2008, the SSC requested an analysis to estimate the level of bias in Fishery Regulation Assessment Model (FRAM)-estimated exploitation rates for unmarked fish in mark-selective fisheries. This bias was expected to occur primarily because FRAM cannot currently account for mortalities from multiple encounters of individual unmarked fish with the fishing gear. The result is that FRAM underestimates total mortalities of unmarked fish in mark-selective fisheries. In 2008 the SSC recommended interim measures to account for this bias, pending an analysis by the MEW. Mr. Andy Rankis of the MEW described the work that has been done over the past year to address this concern.

The MEW developed a Multiple Encounter Model (MEM) which provided results identical to those of FRAM given no multiple encounters. Two multiple encounter scenarios were then considered, with and without an increasing release-mortality rate with multiple releases. FRAM models summer fisheries with either a single time step (Chinook: July to September) or three time steps (coho: July, August, September). The MEM estimates higher unmarked mortality rates than FRAM in either case, with the difference between the two increasing exponentially as the marked exploitation rate increases. With multiple time steps the bias is reduced but not eliminated. The SSC agrees that the MEM better reflects the expected dynamics of mark-selective fisheries and provides a standard which can be compared to appropriate FRAM model output to estimate the bias in FRAM. However it would be impractical to incorporate the MEM computational framework into FRAM. A partial analytical solution was proposed for implementation in 2010, with further review and development anticipated for 2011. In particular, an option will be added within coho FRAM to include an analytical equation which accounts for multiple encounters within a time-step and area in mark-selective fisheries. This option should be completed and its performance evaluated by the MEW in time for use in the February 2010 coho FRAM runs. The SSC endorses the implementation of this adjustment in the coho FRAM. If this model change is to be used to model 2010 fisheries it will require one more stage of review prior to March 2010. Review material should include documentation of changes made to the coho FRAM and a demonstration that the revised model performance achieves the expected bias reduction. In order to allow time for review, material needs to be submitted to the Council office by 8 January 2010.

In the Chinook FRAM bias correction will be more difficult to implement because of the multiple age classes that are subject to harvest. The SSC recommends maintaining the guidelines proposed in 2008, limiting exploitation rates in each modeled selective fishery to 10 percent, with a maximum 30 percent overall exploitation rate. The SSC recommends developing bias correction methods for the Chinook FRAM for review in the fall of 2010.

Forecasting Impact Rates in Fall Fisheries for Klamath River Fall Chinook and Sacramento River Fall Chinook

Dr. Mike O'Farrell summarized his investigations into the problem of forecasting impacts of fall fisheries for Chinook salmon on Sacramento River Fall Chinook (SRFC) and Klamath River Fall Chinook (KFRC). The basic problem is that fall fisheries conducted south of Cape Falcon, Oregon occur after the model-assumed end of river entry (i.e., after the end of the model year *t*), but before the estimate of the year *t*+1 abundance is available. These fisheries are termed "credit card" fisheries because they borrow from the as yet unassessed stock abundance. Hence, any harvest is deducted from the next year's allocation.

An estimate of September 1 abundance in year *t* is not currently available until February of year *t*+1 (i.e., after the fishery has occurred). Dr. O'Farrell examined whether existing modeling methods or historical data could provide the needed estimates of September 1 abundance in year *t* for the year *t* management planning cycle. He concluded that these forecasts would be of low quality and would not be useful for management purposes.

When planning fall fisheries, the degree to which these fisheries will constrain ocean fisheries in the following year is unknown. In the worst case these fisheries can affect the Council's ability to meet conservation objectives for SRFC and KRFC. Dr. O'Farrell recommended that future fall fishing opportunities not be increased above historical levels because the risk of fall fishing cannot be accurately estimated. He also recommended that the risk that fall fisheries pose to future fishing opportunity, if constrained by the California Coastal Chinook consultation standard, should be assessed by examination of historical estimates of the KRFC age-4 ocean harvest rate from fall fisheries.

The SSC endorses the conclusions and recommendations of this report. Specifically,

- Currently, there are no methods available which can reliably forecast the September 1 abundances of Sacramento River Fall Run Chinook and Klamath River Fall Run Chinook in the fall of year *t* at the time of PFMC fishery management planning process in the spring of that year.

- There are very few area, month, and fishery combinations for fall fisheries where the harvest of SRFC could reliably be expected to be low so time-area management to reduce the impacts of fall fisheries to the SRFC stock is currently not feasible.
- Fall fisheries harvest proportionally few KRFC in some ocean management areas. More northern areas usually harvest a higher and more variable proportion of KRFC in the fall. Time-area management to reduce the impacts of fall fisheries to the KRFC stock may be feasible
- The risk that fall fisheries pose to future fishing opportunity, if constrained by the California Coastal Chinook consultation standard, should be assessed by examination of historical estimates of the KRFC age-4 ocean harvest rate from fall fisheries.

<u>Assessment of the September 1 Maturity Boundary Assumption for Klamath River Fall Chinook</u>

Dr. Mike O'Farrell and Ms. Melodie Palmer-Zwahlen presented their assessment and recommendations regarding the appropriateness of the September 1 river return date for Klamath River Fall Chinook (KRFC).

Choice of an appropriate river return date has implications for harvest allocation and estimation of fishery contact, harvest, and impact rates. KRFC ocean harvest after September 1 is credited against the following year's fisheries, prior to the Council's annual preseason forecasts. This has management implications for meeting Council conservation objectives and the NMFS ESA consultation standard for California Coastal Chinook.

The KRFC cohort analysis and Klamath Ocean Harvest Model (KOHM) both make a simplifying approximation that immediately prior to September 1, mature KRFC leave the ocean for the Klamath Basin and immature KRFC remaining in the ocean advance one year in age. If the proxy date is set too early the estimated ocean abundance would be negatively biased in the cohort reconstructions, and if the proxy date is set too late the estimated ocean abundance would be biased high. Any bias in estimated cohort ocean abundance propagates to bias in contact, harvest, and impact rates. To minimize bias in cohort abundance reconstruction, the proxy date should be the midpoint for the timing of escapement from ocean fisheries.

For KRFC there was a unique opportunity to evaluate the appropriateness of the September 1 proxy from catch timing data in the Yurok Tribal gillnet fishery in and near the Klamath River estuary. The assessment concluded that September 1 was an appropriate proxy for the mid-point river return date. In addition, most of the mature KRFC were estimated to have entered the Klamath River by September 15.

The SSC endorses the report recommendation that the current September 1 river return date approximation should be retained in KRFC fishery assessment models. The SSC agrees that the September 1 date is an appropriate average midpoint date for the timing of escapement from ocean fisheries. The SSC notes that, in the future, more accurately partitioning the harvest of mature and immature KRFC in August and September may be possible with the collection of additional biological data from ocean fishery sampling to identify KRFC catch proportions, age, and maturity.

The SSC notes that both of the previous discussion items have implications to the risk posed to the KRFC stock by fall ocean fisheries. The Council may want to consider an option to reduce the risk of harvesting mature KRFC in the September fisheries, the impacts of which apply toward the conservation objectives and consultation standards in the following year. The SSC concurs with the recommendation that the risk of harvesting mature KRFC that have not yet returned to the river could be reduced by limiting ocean fisheries between September 1 and September 15, particularly the commercial fisheries in the California Klamath (KC) and Central Oregon (CO) ocean management areas, while preventing compensatory expansion of fisheries in the Oregon Klamath (KO) management area.

Conservation Objective Updates for Puget Sound Coho

Mr. Pat Pattillo presented the conservation objectives for Puget Sound coho that are currently used in the U.S. v Washington annual management process to the SSC salmon subcommittee, the STT, and the MEW. These conservation objectives are exploitation rate (ER) targets based on forecast abundances with three categories (Normal, Low, Critical) separated by abundance forecast "breakpoints." Exploitation rates and associated breakpoints were established through simulation modeling for three of five management units (MUs). For the other two MUs these values were based on views of maximum sustainable harvest (MSH) for the systems. Mr. Pattillo explained that the objectives were designed with ER objectives for MSH rather than escapement goals because, with the use of hatchery indicator stocks and CWT data, ERs could be measured more precisely than escapements. This system is also consistent with, and coordinated with, abundance-based management of Canadian stocks as negotiated through the Pacific Salmon Treaty.

Conceptually, target ERs and breakpoints are based on MSH under two survival conditions (low and high). Simulations were run by setting fixed escapement goals and searching for ERs that provided MSH given expected levels of survival variability and management error. The resulting values are chosen to be somewhat precautionary. The SSC was concerned with the knife-edged nature of the control rule, so that in principle a change in forecast abundance of one fish could lead to a 15-25 percent change in exploitation rate. Other systems either have smaller steps (e.g., Oregon Coastal Natural coho) or tie ERs to escapement level so that escapements are maintained by increasing ERs gradually with increasing abundance (e.g., Klamath River Fall Chinook).

The methods provided in the report were not sufficient for a thorough SSC review. Documentation was insufficient to evaluate the justification for the resulting ERs and breakpoints. The SSC supports the use of a Management Strategy Evaluation approach for analysis of alternative breakpoints, but was not provided with standard outputs on strategy performance to interpret the results and conclusions. These would include presentation of the variability in model outputs and model runs to show the likely performance of a range of control rule parameters. Performance should be evaluated in terms of likelihood of meeting specific targets under a variety of environmental conditions (marine survival), and resulting expected stock abundance, catch, and escapement. This management system has been in place since 2000. An analysis of the historical performance of abundance-based management in Puget Sound would provide an empirical basis for comparing management outcomes with model expectations.

It was unclear to the SSC how the U.S. v Washington conservation objectives for Puget Sound work within the Council FMP. Because of the negotiated agreements with Canada these stocks would likely merit an international exemption. It was, again, unclear whether the exemption would apply to Status Determination Criteria as well as Annual Catch Limits and Accountability Measures. Overfishing criteria should be related to the Critical threshold only, and not to MUs crossing between Normal and Low categories.

PFMC
11/01/09

Salmon Methodology Review

The Tribes are still very concerned about mark-selective fisheries for Chinook and the ability of the Chinook FRAM to project the impacts of any mark-selective fisheries. Work on suitable methodologies needs to continue so that the bias in the estimates of exploitation rates for unmarked fish and sensitivity of the estimates to key model parameters can be examined. The Council must be confident that this tool is adequate for assessing fishery impacts from the suite of fisheries that we ultimately recommend for adoption.

Washington Department of Fish and Wildlife has stated that it is their intent to put more mark-selective fisheries on the water. The Tribes agree with the SSC and STT statements to use “bias-corrected” exploitation rate estimates for unmarked stocks in the coho FRAM for the 2010 fishery evaluations. For Chinook, we agree to maintain the guidelines proposed in 2008.

The Tribes encourage the MEW, STT and SSC to continue working on the Chinook FRAM bias correction equation and provide the Council with their recommendations on what metric should be utilized to monitor the impact or intensity levels of Chinook mark-selective fisheries. The Tribes are committed to participating in the technical process required to develop and evaluate the tools needed for these analyses.

Completion of this work is essential, if the Council is to continue to fulfill its obligation to constrain fishery impacts to sustainable levels on stocks of concern.