UPPER SKAGIT INDIAN TRIBE

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WRITTEN TESTIMONY AND STATEMENT OF THE UPPER SKAGIT INDIAN TRIBE

Delivered by

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Delivered April 13, 2016

Skagit River Coho Escapement Needs – 2016

Dear Members of The Pacific Fisheries Management Council, The Comprehensive Coho Management Plan (Comp Coho) was developed with the goal: *Develop and implement improved coho management approaches that support the maintenance and restoration of wild stocks in a manner that reflects the region's fisheries objectives (resource protection, allocation, and harvest stabilization), production constraints, and production opportunities.*

One of the tools for stock management is the identification of normal, low, and critical "Abundance Breakpoints". Of concern in 2016 is the CRITICAL breakpoint, defined in Comp Coho as ***the escapement level below which an unacceptable risk exists (resulting from population instability, unpredictability, or productivity) and that the abundance will be less than the low/normal breakpoint in one to three cycles.***

The critical breakpoint for wild Skagit coho has been defined as 16,000 spawners. The State of Washington and treaty tribes have agreed that the 2016 preseason forecast of Skagit wild coho ocean abundance is 8,900 (with a projected escapement to spawning of less due to various pre-terminal mortalities), which places it under ***critical management status***. Although Comp Coho suggests that "up to 10%" exploitation rate for southern US fisheries (and an additional 10% for Canadian fisheries) should be the limit, it also provides that the managers may establish conservation requirements below this level.

The Upper Skagit Indian Tribe continues to assert that the Skagit wild coho in 2016 (and any other year) requires a minimum spawning escapement of 16,000 to ensure population stability and persistence. Some co-managers have indicated that they are willing to accept that the 2016 minimum required spawning abundance should be an amount considerably below this level. Upper Skagit categorically opposes this management approach, believes it is contrary to both scientific and policy requirements and that nothing less than 16,000 should be acceptable to

PFMC participant parties as a required spawning escapement for Skagit wild coho. To do otherwise would be to jeopardize the future of Skagit Coho.

Upper Skagit acknowledges, based on the ageed-to 2016 pre-season forecast, that with only an estimated run of 8,900 wild Coho, we cannot expect to achieve this critical escapement abundance this year. Therefore, it is clear that there are no Skagit River wild coho salmon available for harvest this year. Any planning for fisheries which take Skagit River wild coho must be shaped to take this into consideration.

The Upper Skagit Tribe submits that ***the projected return of wild coho salmon to the Skagit River is far below "the escapement level below which an unacceptable risk exists" and "that the abundance will be less than the low/normal breakpoint in one to three cycles"***.

Based on the established best management practices, biological considerations, and the forecast abundance of fewer than 9,000 wild adults, the Upper Skagit Indian Tribe contends that the minimum required escapement of natural spawners to the Skagit River is 16,000 adults and that all fisheries should be managed to achieve the maximum possible escapement to spawning.

Supplemental information included below.

Supplemental information on coho production.

The criteria in Comprehensive Coho for Skagit wild coho were initially developed under the following biological / environmental conditions:

- Coho stocks were relatively healthy throughout the Canadian and SUS management area
- Coho spawning abundance on the Skagit averaged 70,000 (1993-2000)
- Ocean survival conditions varied, but were generally good (relatively productive for salmon)
    - Skagit coho survival had been 9%
    - Hayman's reassessment presented to the Coho Technical Committee (2009) used Skagit coho at 6% survival for recent years

Hayman (2009) proposal to the CTC for adjustment of the coho management breakpoints suggested that the low/critical breakpoint should be about 16,000 expected spawning escapements. We only saw this level in 2006 with a wild escapement of 7,702; the survival of that escapement (to adult) was approximately 4% under very good ocean conditions encountered in the 2008 outmigration (as opposed to the poor ocean conditions encountered by the 2003 brood when they migrated out in 2005 and returned in 2006), as presented in Table 1.

Ocean conditions in late 2013 to present (early 2016) have been poor for salmon survival. This contributed to the extremely low coho and pink salmon returns in 2015, throughout the Puget Sound region. Coho survival for the 2012 brood (2015 return) was approximately 1.3%. We expect that survival of the 2013 brood (2016 return) to be similar and have no reason to believe that the 2014 brood (2017 return) will be much better, though ocean conditions have improved somewhat. Ocean indicators support this assumption (see Table 1; 2014 coho outmigrant conditions for 2015 returns, and 2015 outmigrant conditions for 2016 returns).

Table 1. Scores were assigned based on their effect on juvenile salmonids. We show variables that are correlated with returns of coho salmon after 1 year and of Chinook salmon after 2 years. For example, positive PDO values (and red colors) indicate poor ocean conditions in coastal waters off the northern California Current. Similarly, higher sea surface temperatures in summer are a negative indicator for salmon, but particularly so for resident coho salmon. [From NOAA presentation].

	Year																	
Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
PDO (Sum Dec-March)	16	6	3	12	7	17	11	15	13	9	5	1	14	4	2	8	10	18
PDO (Sum May-Sept)	10	4	6	5	11	15	14	16	12	13	2	9	7	3	1	8	17	18
ONI (Average Jan-June)	18	1	1	6	12	14	13	15	8	11	3	10	16	4	5	7	9	17
46050 SST (°C; May-Sept)	15	8	3	4	1	7	18	14	5	16	2	9	6	10	11	12	13	17
Upper 20 m T (°C; Nov-Mar)	17	11	8	10	6	14	15	12	13	5	1	9	16	4	3	7	2	18
Upper 20 m T (°C; May-Sept)	14	11	13	4	1	3	18	16	7	8	2	5	12	10	6	15	17	9
Deep temperature (°C; May-Sept)	18	6	8	4	1	9	12	14	10	5	2	7	13	11	3	17	16	15
Deep salinity (May-Sept)	18	3	7	4	5	14	15	8	6	1	2	11	16	10	9	13	17	12
Copepod richness anom. (no. species; May-Sept)	17	3	1	7	6	13	12	16	14	11	8	10	15	4	5	2	9	18
N. copepod biomass anom. (mg C m^{-3}; May-Sept)	17	13	9	10	3	15	12	18	14	11	6	8	7	1	2	4	5	16
S. copepod biomass anom. (mg C m^{-3}; May-Sept)	18	2	5	4	3	13	14	17	12	10	1	7	15	9	8	6	11	16
Biological transition (day of year)	17	11	6	7	8	12	10	16	15	3	1	2	14	4	9	5	13	18
Ichthyoplankton biomass (mg C 1000 m^{-3}; Jan-Mar)	18	9	2	5	7	16	15	11	14	13	1	10	3	12	8	6	17	4
Chinook salmon juvenile catches (no. km^{-1}; June)	17	4	5	15	10	12	16	18	11	8	1	6	7	14	3	2	9	13
Coho salmon juvenile catches (no. km^{-1}; June)	17	7	12	5	6	2	14	18	15	3	4	9	10	13	16	1	11	8
Mean of ranks	16.5	6.6	5.9	6.8	5.8	11.7	13.9	14.9	11.3	8.5	2.7	7.5	11.4	7.5	6.1	7.5	11.7	14.5
Rank of the mean rank	18	5	3	6	2	13	15	17	11	10	1	7	12	7	4	7	13	16
Ecosystem Indicators not included in the mean of ranks or statistical analyses																		
Physical Spring Trans UI based (day of year)	3	6	17	14	4	11	13	18	11	1	5	2	7	10	15	8	16	9
Physical Spring Trans Hydrographic (day of year)	17	3	13	8	5	12	14	18	6	9	1	9	16	3	11	2	15	7
Upwelling Anomaly (April-May)	8	2	15	4	7	12	11	18	8	3	5	6	13	15	13	10	17	1
Length of Upwelling Season UI based (days)	6	2	16	10	1	11	8	18	5	3	7	3	13	15	13	12	17	9
SST NH-5 (°C; May-Sept)	8	6	5	4	1	3	18	15	9	16	2	17	10	7	13	12	14	11
Copepod Community Index (MDS axis 1 scores)	18	5	4	8	1	13	14	16	15	10	2	6	12	9	7	3	11	17
Coho Juv Catches (no. fish km^{-1}; Sept)	11	2	1	4	3	6	12	14	8	9	7	15	13	5	10	NA	NA	NA

This presentation illustrates that ocean conditions encountered by juvenile coho salmon migrating into the North Pacific Ocean in 2014 and 2015 encountered conditions (red-colored cells) which were suspected of being not favorable to their growth and survival.

Table 2

2016 Puget Sound Primary Natural Coho Management Unit Exploitation Rate Ceilings

Management Unit	Preseason Forecast Of Abundance[1] (Ocean Age Three)	Management Status[2]	Total Exploitation Rate Ceiling
Strait of Juan de Fuca	4,400	critical	20%
Hood Canal	35,300	low	45%
Skagit	8,900	critical	20%
Stillaguamish	2,800	critical	20%
Snohomish	20,600	critical	20%

1 Concern for low returns extend to both natural and hatchery stocks throughout Puget Sound and the Washington Coast. The enacted annual fishery regulation will need to provide for adequate spawning escapement for natural stocks and hatchery rack returns for hatchery stocks.

2 All the critical stocks are well below their critical low abundance threshold that denotes stock instability. Spawning escapement targets below this threshold must be agreed by the co-managers. These discussions are on-going between the co-managers.

NOTE: (Table 2 WDFW provided material at co-manager meeting for North of Falcon) As stated in the footnote of Table 2, "All the critical stocks are well below their critical low abundance threshold and that denotes stock instability."

Supplemental Information on coho management and "Treaty between the Government of Canada and the Government of the United States of American concerning Pacific Salmon".

Part of the responsibility of salmon management is management for the resource, not just management of the harvest of the resource. In this instance, the critical part of the Pacific Salmon Treaty can be found in Annex IV: Chapter 5: Coho Salmon; under the Southern Coho Management Plan (p. 110).

> 11. Each Party may:
> (a) shape fisheries to achieve a lower exploitation rate than the limits allowed under Paragraph 9(b)-(d) to address domestic management objectives;
> (b) request additional reductions in exploitation rates determined under Paragraph 9(b)-(d) to meet critical conservation concerns not adequately addressed by the Plan. The requesting Party shall describe the measures taken in its own fisheries to respond to the conservation concern and make its request in a timely manner relative to pertinent management planning processes. The Southern Panel will

discuss and explore ways in which agreement might be reached to accommodate the request;

One might infer from this, that an option for management in a year where coho stocks are CRITICAL (unstable) that managers might pursue a path of FISH protection, rather than FISHERY protection; unfortunately this is not the case in 2016. Some tribes and the state of Washington are still managing fisheries with significant impacts (> 6% ER) on Skagit coho.

Breakpoint recalculation by Hayman as presented to the PFMC Coho Technical Committee (2009).

MEMORANDUM

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

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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

Low/Normal Breakpoint:

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.

Normal Exploitation Rate Ceiling:

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):

<u>Method 2:</u>

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 10^{th} 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 10^{th} percentile of survival, or with a mean survival at the 10^{th} percentile. So I evaluated the breakpoint under 5 survival rate variation assumptions:

1) Survival fixed at the 10^{th} 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.

Normal Exploitation Rate:

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.

MSH Exploitation Rate: 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.

Low/Normal Breakpoint = 40,000: With the low/normal breakpoint set at 40,000, expected harvests were noticeably lower than under a breakpoint of 25,000 (Fig. 4).

Sensitivity Analysis: 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 = ± 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

[Analytical results not included here, but available ftp://ftp.pcouncil.org/pub/Salmon/Skagit%20Coho%20Mgt%20Obj%20Derivation.doc]