Three Tests of a Potential Method for Development of a FRAM Sensitivity Analysis

Salmon Methodology Review

September 19, 2008

Prepared by:
Andy Rankis, Model Evaluation Workgroup (MEW)

Background

Sensitivity analysis (SA) of Chinook and Coho Fishery Regulation Assessment Models (FRAM) to major assumptions, including sensitivity to parameters related to mark-selective fisheries, has always been on the MEW "to do" list. At the April 2008 Pacific Fishery Management Council (Council) meeting this task was again discussed; however, it still wasn't clear what method would be most informative. In these discussions, the SSC emphasized a preference for a method utilizing a 'complete factorial design' approach. We left that meeting with the plan that the SSC would assist the MEW in designing these sensitivity analyses.

This is an exploratory report for one particular sensitivity analyses methodology. The level of parameter change is a topic for group discussion, as are all features of this exercise. The present purpose is to demonstrate this method and generate discussion.

Method

Bob Conrad (SSC) provided Chapter 8 of the 'Ecological Simulation Primer' (Swartzman and Kaluzny, 1987) as a good source of information and potential methods. This chapter is being mailed to all MEW members. The SA 'complete factorial design' method explored here is presented in pages 220-223. A model run is done for every varied parameter and all combinations of varied parameters. The number of model runs is m^n, with m being the number of levels examined and n being the number of parameters varied. The equations for calculating effects of parameter manipulation, as used here for model runs done with three parameters (n) at two levels (m) are presented in Table 1. These equations will change form according to the number of levels and parameters. Bob and I have discussed the limitations of this method but we believe it has merit because:

1) It captures the interaction of parameters being examined.
2) Flexibility in both parameters being examined and the model outputs chosen for evaluation.
3) A ranking of the effects is incorporated.
4) The output variables themselves can be evaluated for additional insight.
5) The number of model runs is not overwhelming.

Two of the limitations of this approach are that the choice of parameter levels is subjective, and while parameters can be ranked as to model sensitivity, that ranking is relative to the parameters (and the levels of adjustment) examined in the analysis.

Table 1. Equations used to calculate the "*effect statistic*" from model output results of varying parameters "a", "b", and "c", at two levels.

Perturbed Variable	**Form of Equation for Effect Statistic:** note that (1) designates the nominal condition
a	=(a+ab+ac+abc)/4 - ((1)+b+c+bc)/4
b	=(b+ab+bc+abc)/4 - ((1)+a+c+ac)/4
c	=(c+ac+bc+abc)/4 - ((1)+a+b+ab)/4
ab	=(abc+ab+c+(1))/4 - (ac+bc+a+b)/4
ac	=(abc+ac+b+(1))/4 - (ab+bc+a+c)/4
bc	=(abc+bc+a+(1))/4 - (ac+ab+b+c)/4
abc	=sum(a+b+c+ab+ac+bc)/6 – ((1)+abc)/2

Originally the FRAM was not set-up to model MSF. Thus, a FRAM sensitivity analysis should explore model functions without MSF as compared to model function when MSF are included. The model functions unique to only MSF add another component to the overall analysis. Thus, three sets of model runs are presented here:

1) General model function in standard non-MSF mode (Chinook series "1111").
2) General model function with significant level of fisheries converted to MSF (Chinook series "2222").
3) Specific model function of processes unique to MSF (coho series "2222").

Each series of eight model runs is presented with their own set of three tables.

For the Chinook exercises the three parameters manipulated were release mortality rates for: shaker release (**a**), legal size release (**b**), and drop-off and drop-out (**c**). These parameters were modeled at the nominal levels and at twice that level, for all FRAM fisheries. The standard Chinook legal size release mortality rate of 10% was doubled to 20%. The sub-legal release mortality rates and the drop-off/drop-out rates vary by fishery; the standard values and the doubled values can be seen in Appendix A. The two Chinook series were done with the same standardized set of recruit scalars and fishery effort scalars. Chinook series "2222" is simply a repeat of series "1111" but with all Puget Sound marine sport fisheries converted to Mark Selective Fisheries (MSF). An expanded set of Puget Sound marine sport fisheries was used to help demonstrate model functions; similarly the Puget Sound Chinook non-retention (CNR) fisheries were also expanded in area and time. The FRAM Chinook sensitivity analysis focused upon Puget Sound fisheries and stocks to take advantage of the experience gained with the MSFs already implemented in that region. .

The coho series used the 2007 pre-season final PFMC coho run (0714) to explore manipulation of three parameters input via FRAM's 'Selective Fishery Parameters' screen. The 'Mark Mis-ID', the 'UnMark Mis-ID', and the 'Drop-off' rates were modeled at nominal levels and at twice those values (Table 2). The manipulation of the coho MSF parameters was only applied to Council Area ocean fisheries.

Table 2 The standard Mark Selective Fishery input parameter values used in all Council area troll and sport fisheries, and the perturbed levels used for this coho MSF sensitivity analysis exercise.

Parameter Level	**Three MSF parameters manipulated in coho series "2222":**		
	Mark Mis-ID rate	**UnMarked Mis-ID rate**	**Drop-Off**
Standard values	0.06	0.02	0.05
Doubled values	0.12	0.04	0.10

In theory any model output variable could be evaluated for sensitivity to parameter manipulation. During the pre-season fishery planning process there is a focus on Exploitation Rates (ER) and natural stock escapement. The implementation of MSF will put more focus on hatchery stock escapements.

The Chinook sensitivity analysis "*effect statistic*" was calculated from model run outputs for natural stock preterminal ER (FRAM fisheries only) and escapement of hatchery and natural fish for two different Chinook stocks: Skagit summer/fall and Nisqually fall. These stocks were chosen because they have different patterns of pre-terminal fishery impacts, yet both would demonstrate effects from MSFs implemented in Puget Sound. Additional insight could be gained from looking at other model outputs. As a demonstration, three types of fishery mortality output (landed, shaker, and CNR) were used to calculate the effect statistic for a specific Chinook fishery (Area 9 sport).

The coho sensitivity analysis effect statistic was calculated from model run outputs of stock ER from NOF non-treaty troll fisheries, and from NOF plus Oregon area SOF sport fisheries. These fisheries were all MSF in the 2007 model. Four stocks were selected: Columbia River Marked and UnMarked, OCN UnMarked, and Thompson Wild. The three categories of fishery mortality were examined from the cumulative NOF non-treaty troll MSF (over all areas).

Results

Chinook Series "1111"

Table 3 (Skagit summer/fall Chinook) and Table 4 (Nisqually fall Chinook) present evaluated output and calculated effect statistics for pre-terminal ER, natural stock escapement, and hatchery stock escapement for these two Puget Sound Chinook stocks. Note that for change to a single parameter the effect statistic is the difference between the nominal run escapement output and perturbed parameter run escapement output. It is interesting to look at the change in output values resulting from these parameter manipulations and compare to the effect statistics to gage parameter inter-actions (or lack of).

Table 5 presents three types of fishery mortality output for the Area 9 sport fishery, by time step. Here it is interesting to observe the CNR mortality direct responsiveness to changes in the three mortality rate parameters. The 'effect statistic' for CNR mortality changes are perhaps easier to interpret than the effect statistic from other output variables. Referring to Table 5, Time Step Two Effects Statistic, the CNR Mortality for the nominal condition is 800 (600 shakers and 200 legal size mortalities). Doubling the shaker mortality rate adds 600 more mortalities, while doubling the legal size mortality rate adds 200 more. This is seen in both the Output and the Effect table columns. However, note that when both rates are doubled (command file "1ab1") although the Output CNR mortality increases by 800 total

mortalities the Effect Statistic is "0" because there is no inter-action between the mortality rates in CNR fisheries where the model input is a fixed number of encounters. Note the output makes it obvious that the model does not apply 'drop-off' mortality rate to CNR fisheries.

It is not as transparent to interpret the corresponding effect statistic for Landed and Shaker mortalities. Here, as presented in Table 5, there appears to be a slight interaction between the three mortality rate input parameters. This interaction effect increases as the model progresses through the time steps and is seen as a cumulative effect in Table 5's section for Time Step Two-Four (Time Step One output not presented here). This seems in conflict with the lack of inter-action for the examined parameters with the CNR fishery. The explanation is that, in this exercise, the input for retention fisheries are all in terms of 'fishery scalars' while the CNR inputs are fixed values. As the modeling progresses through time steps the stock abundances change in response to the release mortality rates, and 'fishery scalar' input produces fishery mortality that is responsive to changing abundance while fishery fixed value catch inputs are not responsive to abundance levels.

Chinook Series "2222"

The "2222" series is used to designate that MSF are included. Tables 6 and 7 correspond to Tables 3 and 4 presented for series "1111" above; and series "2222" Table 8 corresponds to Table 5.

Coho Series "2222"

With these coho runs we are focused upon the sensitivity of modeled MSFs to parameters unique to only MSF, thus there is no comparison to be made with retention fisheries. The tables follow the Chinook pattern of first looking at sensitivity of stock specific output (ER values) and then looking at mortality categories within a fishery. However, we deviate from the Chinook approach by looking only at ER values produced in the Council area MSF non-treaty troll (Table 9) and MSF sport fisheries (Table 10). The presented MSF effect statistics should not be confounded by including results from non-MSFs.

In Table 11 the three categories of fishery mortality are presented, for coho series "2222", from the non-treaty NOF troll MSF fisheries (all areas combined). Here the effect statistics should not be confounded by changes in stock abundance over time (as seen above with Chinook fisheries modeled with effort scalars) as all the Council area coho fisheries are modeled with fixed catch inputs. Note however, Table 11 shows inter-action terms between all three manipulated parameters.

Discussion

There is plenty to sort out here. It is difficult to evaluate if the FRAM model is overly sensitive to any of the manipulated parameters; especially as the manipulation was a doubling of the standard values. But that has not been the purpose of this work. The evaluation of this particular type of sensitivity analysis methodology is the goal. Can this tool help the collective understanding of how the FRAM model operates and can it point to weakness in assumptions, areas of needed research, and even help find "model glitches"? Some of the hints from this evaluation are subtle, and should be explored beyond the scope of this presentation; some other issues are more clearly identified.

The presentation (in Tables 5, 8, and 11) of only three fishery mortality categories (landed, shaker, and CNR) is likely contributing to some confusion, as several types of mortalities are being combined to fit into those existing output report formats. In addition, there are differences in meaning between coho and Chinook "shaker" mortalities.

"Shaker" mortality is generally considered to be produced from the release of sub-legal fish, and this is the case in Chinook FRAM. However, in coho FRAM there are no sub-legal coho; coho "shakers" are release mortality from MSF. For both coho and Chinook, drop-off mortalities (legal sized Chinook only) are added to and reported as part of shaker mortality. Meanwhile, release mortalities from Chinook MSF (legal fish only) and coho MSF are summed into the CNR mortality category. Table 12 attempts to present how the various types of fishery related mortalities are categorized, and summed, for output reports.

'Landed' catch is straightforward and consistent between Chinook and coho FRAM.

Table 12. The assignment of various fishery mortality types to FRAM's output reporting categories.

Species	**The three fishery related mortality categories used in FRAM reports:**		
	Landed	**Shaker**	**Non-Retention (CNR)**
Coho	Landed or retained.	Drop-off mortality from both MSF and retention fisheries.	Release mortalities from non-retention (CNR).
			Release mortalities from MSF.
Chinook (legal size)	Landed or retained.	Drop-off mortality from both MSF and retention fisheries.	Release mortalities from non-retention (CNR).
			Release mortalities from MSF .
Chinook (sub-legal size)		Release mortalities from both MSF and retention fisheries.	Release mortalities from non-retention (CNR).
Notes:	1) For the same level of effort, the sub-legal release mortalities would be the same in a Chinook MSF as in a Chinook retention fishery.		
	2) FRAM does not calculate drop-off mortalities for either coho or Chinook CNR fisheries, but CNR input can be externally inflated to account for this.		
	3) FRAM does not apply a drop-off mortality rate to sub-legal Chinook encounters.		

Task Status

The MEW is exploring a potential tool for the FRAM sensitivity analysis task. The method presented here will be discussed and evaluated by a larger group at the October 15th Model Methodology Review Meeting. If this method is deemed worthwhile, then the MEW (preferably with input from the STT and SSC) can proceed to define a strategy to assess a larger set of parameters.

Parameters that potentially could be evaluated (under MSF and/or under retention fisheries) include: mortality rates, Chinook stock age structure, Chinook AEQ rates, and inter-actions between MSF specific parameters. Additional types of FRAM output should also be considered for evaluation. For example increasing the UnMarked Mis-Id rate (which would necessarily produce more dead Unmarked fish), in the presented coho MSF exercise, decreased the total MSF mortality; this result shifts the interest to the effect upon separated marked and unmarked mortality. In addition, FRAM output is apparently sensitive to whether catch input is provided as a 'fishery effort scalar' or as a 'quota'; this issue also warrants further investigation.

Literature Cited

Swartzman G. L. and S. P. Kaluzny: Chapter 8 Simulation Model Evaluation, in *Ecological Simulation Primer*, Macmillan Publishing Company, New York, 1987, pp. 220-223.

Table 3. Results with three parameters at two levels, utilizing a complete factorial design focused on model output for Skagit Summer/Falls.

Model Run		Evaluated Output:			Effect Statistic:		
.cmd	parameter perturbed	PreTerm Nat ER	Nat Esc	Hat Esc	PreTerm Nat ER	Nat Esc	Hat Esc
1**1**11	Standardized abundance & standardized fisheries (retention and CNR), standard release Mortality Rates	**0.4564**	**10978**	**427**			
1**a**11	1111 w/ doubled marine **shaker release Mortality Rate**	0.4769	10930	426	0.0202	-48	-2
1**b**11	1111 w/ doubled marine **legal-sized release Mortality Rate**	0.4594	10940	427	0.0030	-38	-1
1**c**11	1111 w/ doubled **drop-off Mortality Rate**	0.4682	10800	421	0.0116	-177	-7
1**ab**1	1111 w/ doubled shaker & legal-sized release Mortality Rates	0.4799	10892	425	0.0000	-1	0
1**ac**1	1111 w/ doubled shaker & drop-off release Mortality Rates	0.4882	10754	419	-0.0003	0	0
1**bc**1	1111 w/ doubled legal-sized & drop-off Mortality Rates	0.4713	10764	421	0.0000	0	0
1**abc**	1111 w/ doubled all three release Mortality Rates	0.4912	10715	418	0.0002	0	0

Table 4. Results with three parameters at two levels, utilizing a complete factorial design focused on model output for Nisqually Falls.

Model Run		Evaluated Output:			Effect Statistic:		
.cmd	parameter perturbed	PreTerm Nat ER	Nat Esc	Hat Esc	PreTerm Nat ER	Nat Esc	Hat Esc
1111	Standardized abundance & standardized fisheries (retention and CNR), standard release Mortality Rates	**0.4993**	**872**	**4558**			
1a11	1111 w/ doubled marine **shaker release Mortality Rate**	0.5274	863	4499	0.0274	-9	-60
1b11	1111 w/ doubled marine **legal-sized release Mortality Rate**	0.5096	857	4446	0.0100	-15	-112
1c11	1111 w/ doubled **drop-off Mortality Rate**	0.5140	846	4373	0.0141	-26	-185
1ab1	1111 w/ doubled shaker & legal-sized release Mortality Rates	0.5373	848	4385	-0.0002	0	-1
1ac1	1111 w/ doubled shaker & drop-off release Mortality Rates	0.5411	838	4314	-0.0005	0	0
1bc1	1111 w/ doubled legal-sized & drop-off Mortality Rates	0.5241	831	4262	-0.0001	0	0
1abc	1111 w/ doubled all three release Mortality Rates	0.5508	822	4201	0.0005	0	0

Table 5. Results of a FRAM Sensitivity Analysis looking at three parameters at two levels, utilizing a complete factorial design focused on Chinook fishery mortality output from Area 9 sport fishery.

Model Run		TIME STEP TWO (MAY-JUNE)						TIME STEP THREE (JULY-SEPT)					
.cmd	parameter perturbed	Mortality Output			Effect Statistic			Mortality Output			Effect Statistic		
		Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR
1111	Standardized abundance & standardized fisheries (retention and CNR), standard release Mortality Rates	**565**	**159**	**800**				**4875**	**1458**	**700**			
1a11	1111 w/ doubled marine **shaker release Mortality Rate**	563	287	1400	-2	128	**600**	4830	2630	1100	-46	1171	400
1b11	1111 w/ doubled marine **legal-sized release Mortality Rate**	564	159	1000	-1	0	**200**	4857	1456	1000	-19	-2	300
1c11	1111 w/ doubled **drop-off Mortality Rate**	563	187	800	-2	28	**0**	4856	1699	700	-19	240	0
1ab1	1111 w/ doubled shaker & legal-sized release Mortality Rates	562	287	1600	0	0	0	4810	2629	1400	-1	0	0
1ac1	1111 w/ doubled shaker & drop-off release Mortality Rates	561	315	1400	0	0	0	4811	2869	1100	0	-1	0
1bc1	1111 w/ doubled legal-sized & drop-off Mortality Rates	563	187	1000	0	0	0	4838	1697	1000	0	0	0
1abc	1111 w/ doubled all three release Mortality Rates	560	315	1600	0	0	0	4792	2867	1400	0	1	0

Model Run		TIME STEP FOUR (OCT-APRIL)						TIME STEP TWO-FOUR sub-total					
.cmd	parameter perturbed	Mortality Output			Effect Statistic			Mortality Output			Effect Statistic		
		Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR
1111	Standardized abundance & standardized fisheries (retention and CNR), standard release Mortality Rates	**4838**	**3226**	**500**				**10278**	**4843**	**2000**			
1a11	1111 w/ doubled marine **shaker release Mortality Rate**	4730	6145	900	-108	2916	400	10122	9063	3400	-156	4215	1400
1b11	1111 w/ doubled marine **legal-sized release Mortality Rate**	4826	3226	600	-12	-1	100	10248	4841	2600	-31	-3	600
1c11	1111 w/ doubled **drop-off Mortality Rate**	4818	3466	500	-20	237	0	10237	5352	2000	-41	504	0
1ab1	1111 w/ doubled shaker & legal-sized release Mortality Rates	4719	6144	1000	1	0	0	10091	9060	4000	-1	-1	0
1ac1	1111 w/ doubled shaker & drop-off release Mortality Rates	4710	6379	900	0	-3	0	10082	9563	3400	1	-5	0
1bc1	1111 w/ doubled legal-sized & drop-off Mortality Rates	4806	3465	600	0	0	0	10207	5349	2600	0	-1	0
1abc	1111 w/ doubled all three release Mortality Rates	4699	6378	1000	0	2	0	10051	9559	4000	0	4	0

Table 6. Results with a **MSF background** utilizing three parameters at two levels, focused on model output for Skagit Summer/Falls.

Model Run		Evaluated Output			Effect Statistic		
.cmd	parameter perturbed	PreTerm Nat ER	Nat Esc	Hatch Esc	PreTerm Nat ER	Nat Esc	Hatch Esc
2222	Chinook series "1111" with Puget Sound marine sport fisheries converted to **Mark Selective Fishery**	**0.4078**	**11663**	**431**			
2**a**22	2222 w/ doubled marine **shaker release Mortality Rate,** MSF	0.4308	11614	428	0.0222	-46	-2
2**b**22	2222 w/ doubled marine **legal-sized release Mortality Rate,** MSF	0.4180	11536	430	0.0096	-124	-1
2**c**22	2222 w/ doubled **drop-off Mortality Rate,** MSF	0.4207	11478	424	0.0129	-187	-7
2**ab**2	2222 w/ doubled shaker & legal-sized release Mortality Rates, MSF	0.4395	11498	428	-0.0005	2	0
2**ac**2	2222 w/ doubled shaker & drop-off release Mortality Rates, MSF	0.4432	11431	422	0.0000	-3	0
2**bc**2	2222 w/ doubled legal-sized & drop-off Mortality Rates, MSF	0.4308	11353	423	0.0002	-3	0
2**abc**	2222 w/ doubled all three release Mortality Rates, MSF	0.4528	11303	421	0.0002	2	0

Table 7. Results with a **MSF background** utilizing three parameters at two levels, focused on model output for Nisqually Falls.

Model Run		Evaluated Output			Effect Statistic		
.cmd	parameter perturbed	PreTerm Nat ER	Nat Esc	Hatch Esc	PreTerm Nat ER	Nat Esc	Hatch Esc
2222	Chinook series "1111" with Puget Sound marine sport fisheries converted to **Mark Selective Fishery**	**0.3648**	**1053**	**4747**			
2a22	2222 w/ doubled marine **shaker release Mortality Rate,** MSF	0.4035	1045	4688	0.0335	-3	-56
2b22	2222 w/ doubled marine **legal-sized release Mortality Rate,** MSF	0.4076	995	4599	0.0377	-53	-145
2c22	2222 w/ doubled **drop-off Mortality Rate,** MSF	0.3829	1025	4561	0.0205	-34	-189
2ab2	2222 w/ doubled shaker & legal-sized release Mortality Rates, MSF	0.4305	1008	4553	-0.0048	5	3
2ac2	2222 w/ doubled shaker & drop-off release Mortality Rates, MSF	0.4208	1016	4502	0.0027	-6	-4
2bc2	2222 w/ doubled legal-sized & drop-off Mortality Rates, MSF	0.4251	967	4414	0.0028	-5	-3
2abc	2222 w/ doubled all three release Mortality Rates, MSF	0.4596	958	4354	-0.0005	4	3

Table 8. Results with a **MSF background** of a FRAM Sensitivity Analysis looking at three parameters at two levels, utilizing a complete factorial design focused on Chinook fishery mortality output from the Area 9 MSF sport fishery.

Model Run		TIME STEP TWO (MAY-JUNE)						TIME STEP THREE (JULY-SEPT)					
.cmd	parameter perturbed	Mortality Output			Effects:			Mortality Output			Effects:		
		Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR
2222	Chinook series "1111" with Puget Sound marine sport fisheries converted to **Mark Selective Fishery**	**366**	**160**	**821**				**3009**	**1463**	**894**			
2a22	2222 w/ doubled marine **shaker release Mortality Rate,** MSF	365	288	1421	-1	128	600	2980	2637	1292	-29	1173	398
2b22	2222 w/ doubled marine **legal-sized release Mortality Rate,** MSF	366	159	1041	-1	-1	220	2996	1461	1384	-13	-4	490
2c22	2222 w/ doubled **drop-off Mortality Rate,** MSF	365	188	821	-1	29	0	2998	1708	893	-11	243	-1
2ab2	2222 w/ doubled shaker & legal-sized release Mortality Rates, MSF	364	287	1641	0	0	0	2967	2634	1782	0	-1	-1
2ac2	2222 w/ doubled shaker & drop-off release Mortality Rates, MSF	364	316	1421	0	0	0	2969	2880	1292	0	-1	0
2bc2	2222 w/ doubled legal-sized & drop-off Mortality Rates, MSF	364	188	1041	0	1	0	2985	1704	1383	0	-1	-1
2abc	2222 w/ doubled all three release Mortality Rates, MSF	363	316	1641	0	0	0	2955	2875	1780	1	2	1

Model Run		TIME STEP FOUR (OCT-APRIL)						TIME STEP TWO-FOUR sub-total (MAY-APRIL)					
.cmd	parameter perturbed	Mortality Output			Effects:			Mortality Output			Effects:		
		Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR	Land	Shaker	CNR
2222	Chinook series "1111" with Puget Sound marine sport fisheries converted to **Mark Selective Fishery**	**3048**	**3229**	**684**				**6423**	**4852**	**2398**			
2a22	2222 w/ doubled marine **shaker release Mortality Rate,** MSF	2979	6149	1080	-69	2917	394	6324	9073	3793	-99	4217	1392
2b22	2222 w/ doubled marine **legal-sized release Mortality Rate,** MSF	3039	3228	965	-9	-2	279	6401	4848	3391	-22	-5	989
2c22	2222 w/ doubled **drop-off Mortality Rate,** MSF	3034	3471	683	-14	239	-1	6397	5367	2397	-26	510	-2
2ab2	2222 w/ doubled shaker & legal-sized release Mortality Rates, MSF	2970	6148	1358	0	0	-2	6302	9069	4780	0	0	-3
2ac2	2222 w/ doubled shaker & drop-off release Mortality Rates, MSF	2966	6385	1079	1	-3	0	6298	9581	3791	0	-4	0
2bc2	2222 w/ doubled legal-sized & drop-off Mortality Rates, MSF	3025	3469	964	0	-1	0	6375	5361	3388	0	-1	-1
2abc	2222 w/ doubled all three release Mortality Rates, MSF	2957	6383	1356	0	2	2	6275	9574	4777	1	4	3

Table 9. Results of a coho FRAM Sensitivity Analysis looking at three Mark Selective Fishery (MSF) parameters at two levels, utilizing a complete factorial design focused on Exploitation Rate (ER) in Ocean non-treaty NOF troll MSF for four coho stocks (86-92 Base Period as used in 2008).

MSF Model Run		Evaluated Output ER in NOF NT Troll MSF for:				Effect Statistic			
		Columbia River		OCN	Thompson	Columbia River		OCN	Thompson
.cmd	parameter perturbed	Marked	UnMark	UnMark	Wild	Marked	UnMark	UnMark	Wild
C222	Pre-season 2007 abundance & 2007 fisheries (MSF and CNR), standard Mark Id Rates and Drop-off Rate	**0.0129**	**0.0051**	**0.0082**	**0.0041**				
C**a**22	C222 w/ doubled **Mark Mis-ID Rate**	0.0131	0.0054	0.0087	0.0044	0.0002	0.0003	0.0005	0.0002
C**2b**2	C222 w/ doubled **Unmark Mis-ID Rate**	0.0127	0.0052	0.0084	0.0044	-0.0002	0.0001	0.0001	0.0001
C22**c**	C222 w/ doubled **Drop-off Mortality Rate**	0.0134	0.0058	0.0093	0.0048	0.0006	0.0007	0.0012	0.0005
C**ab**2	C222 w/ doubled Mark & doubled Unmarked Mis-Id Rates	0.0129	0.0055	0.0088	0.0046	0.0000	0.0000	0.0000	0.0000
C**a2c**	C222 w/ doubled Mark Mis-ID & Drop-off Rates	0.0137	0.0061	0.0099	0.0050	0.0000	0.0000	0.0000	0.0000
C2**bc**	C222 w/ doubled Unmark Mis-ID & Drop-off Rates	0.0132	0.0058	0.0095	0.0048	0.0000	0.0000	0.0000	-0.0001
C**abc**	C222 w/ doubled all three release Mortality Rates	0.0135	0.0062	0.0100	0.0051	0.0000	0.0000	0.0000	0.0000

Table 10. Results of a coho FRAM Sensitivity Analysis looking at three Mark Selective Fishery (MSF) parameters at two levels, utilizing a complete factorial design focused on Exploitation Rate (ER) in Ocean sport MSF (NOF + SOF) for four coho stocks (86-92 Base Period as used in 2008).

MSF Model Run		Evaluated Output ER in SOF & NOF Sport MSF for:				Effect Statistic			
		Columbia River		OCN	Thompson	Columbia River		OCN	Thompson
.cmd	parameter perturbed	Marked	UnMark	UnMark	Wild	Marked	UnMark	UnMark	Wild
C222	Pre-season 2007 abundance & 2007 fisheries (MSF and CNR), standard Mark Id Rates and Drop-off Rate	**0.3449**	**0.0836**	**0.0643**	**0.0091**				
C**a**22	C222 w/ doubled **Mark Mis-ID Rate**	0.3489	0.0890	0.0683	0.0096	0.0042	0.0061	0.0045	0.0007
C2**b**2	C222 w/ doubled **Unmark Mis-ID Rate**	0.3394	0.0883	0.0674	0.0096	-0.0059	0.0046	0.0029	0.0006
C22**c**	C222 w/ doubled **Drop-off Mortality Rate**	0.3614	0.1029	0.0788	0.0112	0.0169	0.0197	0.0148	0.0022
C**ab**2	C222 w/ doubled Mark & doubled Unmarked Mis-Id Rates	0.3429	0.0939	0.0714	0.0103	-0.0002	0.0001	0.0000	0.0000
C**a2c**	C222 w/ doubled Mark Mis-ID & Drop-off Rates	0.3665	0.1096	0.0838	0.0119	0.0005	0.0006	0.0005	0.0000
C2**bc**	C222 w/ doubled Unmark Mis-ID & Drop-off Rates	0.3556	0.1072	0.0815	0.0118	-0.0001	-0.0002	-0.0002	0.0000
C**abc**	C222 w/ doubled all three release Mortality Rates	0.3601	0.1140	0.0864	0.0124	-0.0001	-0.0003	-0.0002	0.0000

Table 11. Results of a coho FRAM Sensitivity Analysis looking at three parameters at two levels, utilizing a complete factorial design focused on fishery mortality output from non-treaty NOF Troll Mark Selective Fisheries.

Model Run		JULY TIME STEP						AUGUST TIME STEP					
.cmd	parameter perturbed	Mortality Output:			Effect Statistic:			Mortality Output:			Effect Statistic:		
		Land	Shak	CNR	Land	Shak	CNR	Land	Shak	CNR	Land	Shak	CNR
C222	Pre-season 2007 abundance & 2007 fisheries (MSF and CNR), standard Mark Id Rates and Drop-off Rate, MSF	**5748**	**530**	**1266**				**12857**	**1291**	**3374**			
Ca22	C222 w/ doubled **Mark Mis-ID Rate, MSF**	5748	567	1449	0	53	181	12857	1379	3824	0	127	440
C2b2	C222 w/ doubled **Unmark Mis-ID Rate, MSF**	5748	522	1221	0	-14	-47	12857	1265	3236	0	-43	-148
C22c	C222 w/ doubled **Drop-off Mortality Rate, MSF**	5748	1062	1266	0	544	1	12857	2585	3378	0	1323	4
Cab2	C222 w/ doubled Mark & doubled Unmarked Mis-Id Rates, MSF	5748	558	1400	0	-1	-3	12857	1347	3666	0	-4	-10
Ca2c	C222 w/ doubled Mark Mis-ID & Drop-off Rates, MSF	5748	1132	1450	0	17	0	12857	2758	3827	0	42	0
C2bc	C222 w/ doubled Unmark Mis-ID & Drop-off Rates, MSF	5748	1044	1222	0	-5	0	12857	2532	3239	0	-14	0
Cabc	C222 w/ doubled all three release Mortality Rates, MSF	5748	1113	1400	0	-7	2	12857	2697	3670	0	-16	6

Model Run		SEPTEMBER TIME STEP						JANUARY THROUGH DECEMEBER					
.cmd	parameter perturbed	Mortality Output:			Effect Statistic:			Mortality Output:			Effect Statistic:		
		Land	Shak	CNR	Land	Shak	CNR	Land	Shak	CNR	Land	Shak	CNR
C222	Pre-season 2007 abundance & 2007 fisheries (MSF and CNR), standard Mark Id Rates and Drop-off Rate, MSF	**3794**	**363**	**900**				**22399**	**2186**	**7094**			
Ca22	C222 w/ doubled **Mark Mis-ID Rate, MSF**	3794	387	1026	0	35	124	22399	2331	7854	0	215	746
C2b2	C222 w/ doubled **Unmark Mis-ID Rate, MSF**	3794	355	861	0	-12	-42	22399	2143	6873	0	-69	-237
C22c	C222 w/ doubled **drop-off Mortality Rate, MSF**	3794	726	903	0	372	3	22399	4374	7102	0	2238	8
Cab2	C222 w/ doubled Mark & doubled Unmarked Mis-Id Rates, MSF	3794	378	983	0	-1	-3	22399	2283	7603	0	-4	-15
Ca2c	C222 w/ doubled Mark Mis-ID & Drop-off Rates, MSF	3794	775	1031	0	12	0	22399	4666	7863	0	72	1
C2bc	C222 w/ doubled Unmark Mis-ID & Drop-off Rates, MSF	3794	713	864	0	-3	-1	22399	4287	6880	0	-23	-1
Cabc	C222 w/ doubled all three release Mortality Rates, MSF	3794	758	985	0	-5	2	22399	4569	7611	0	-30	10

APPENDIX TABLE A.

Standard and manipulated values of two parameters (Shaker mortality rate and Drop-off/Drop-out rate) examined in this Chinook sensitivity analysis.

Chinook Outfile: stk2008sfm56splitCVAEQfix.out											
		Standard Shaker Mortality by Time Step:				Sublegals encountered?			Doubled	Other Mortality by Fishery	
Fishery #	Fishery Name	Step 1	Step 2	Step 3	Step 4	Step 2	Step	Steps 1&4	Shaker	Standard	Doubled
Fishery 1	Southeast Alaska Troll	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0080	0.0160
Fishery 2	Southeast Alaska Net	0.3	0.3	0.3	0.3	no	no	n.a.	0.6000	0.0300	0.0600
Fishery 3	Southeast Alaska Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0360	0.0720
Fishery 4	North/Central British Columbia Net	0.3	0.3	0.3	0.3	no	no	n.a.	0.6000	0.0300	0.0600
Fishery 5	West Coast Vancouver Island Net	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0300	0.0600
Fishery 6	Strait of Georgia Net	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0300	0.0600
Fishery 7	Canada Juan de Fuca Net (Area 20)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0300	0.0600
Fishery 8	North/Central British Columbia Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0690	0.1380
Fishery 9	North/Central British Columbia Troll	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0170	0.0340
Fishery 10	West Coast Vancouver Island Troll	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0170	0.0340
Fishery 11	West Coast Vancouver Island Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0690	0.1380
Fishery 12	Strait of Georgia Troll	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0170	0.0340
Fishery 13	North Strait of Georgia Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0690	0.1380
Fishery 14	South Strait of Georgia Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0690	0.1380
Fishery 15	BC Juan de Fuca Sport	0.123	0.123	0.123	0.123	yes	yes	yes	0.2460	0.0690	0.1380
Fishery 16	NT Cape Flattery-Quillayute Troll (Area 3-4)	0.255	0.255	0.255	0.255	yes	yes	n.a.	0.5100	0.0500	0.1000
Fishery 17	T Cape Flattery-Quillayute Troll (Area 3-4)	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0500	0.1000
Fishery 18	Cape Flattery-Quillayute Sport (Area 3-4)	0.14	0.14	0.14	0.14	yes	yes	n.a.	0.2800	0.0500	0.1000
Fishery 19	Cape Flattery-Quillayute Net (Area 3-4)	0.3	0.3	0.3	0.3	no	no	n.a.	0.6000	0.0300	0.0600
Fishery 20	NT Grays Harbor Troll (Area 2)	0.255	0.255	0.255	0.255	yes	yes	n.a.	0.5100	0.0500	0.1000
Fishery 21	T Grays Harbor Troll (Area 2)	0.255	0.255	0.255	0.255	n.a.	yes	n.a.	0.5100	0.0500	0.1000
Fishery 22	Grays Harbor Sport (Area 2)	0.14	0.14	0.14	0.14	n.a.	yes	n.a.	0.2800	0.0500	0.1000
Fishery 23	NT Grays Harbor Net	0.3	0.3	0.3	0.3	n.a.	no	n.a.	0.6000	0.0300	0.0600
Fishery 24	T Grays Harbor Net	0.3	0.3	0.3	0.3	n.a.	no	n.a.	0.6000	0.0300	0.0600
Fishery 25	Willapa Net	0.3	0.3	0.3	0.3	n.a.	no	n.a.	0.6000	0.0300	0.0600

APPENDIX TABLE A (continued).

Standard and manipulated values of two parameters (Shaker mortality rate and Drop-off/Drop-out rate) examined in this Chinook sensitivity analysis.

Chinook Outfile: stk2008sfm56splitCVAEQfix.out		Standard Shaker Mortality by Time Step:				Sublegals encountered?			Doubled	Other Mortality by Fishery	
Fishery #	Fishery Name	Step 1	Step 2	Step 3	Step 4	Step 2	Step 3	Steps 1&4	Shaker	Standard	Doubled
Fishery 26	NT Columbia River Troll (Area 1)	0.255	0.255	0.255	0.255	yes	yes	n.a.	0.5100	0.0500	0.1000
Fishery 27	Columbia River Sport (Area 1)	0.14	0.14	0.14	0.14	yes	yes	n.a.	0.2800	0.0500	0.1000
Fishery 28	Columbia River Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0300	0.0600
Fishery 29	Buoy 10 Sport	0.14	0.14	0.14	0.14	n.a.	no	n.a.	0.2800	0.0500	0.1000
Fishery 30	Orford Reef-Cape Falcon Troll (Central OR)	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0500	0.1000
Fishery 31	Orford Reef-Cape Falcon Sport (Central OR)	0.14	0.14	0.14	0.14	yes	yes	**no**	0.2800	0.0500	0.1000
Fishery 32	Horse Mountain-Orford Reef Troll (KMZ)	0.3	0.3	0.3	0.3	yes	yes	**no**	0.6000	0.0500	0.1000
Fishery 33	Horse Mountain-Orford Reef Sport (KMZ)	0.23	0.23	0.23	0.23	yes	yes	**no**	0.4600	0.0500	0.1000
Fishery 34	Southern California Troll	0.3	0.3	0.3	0.3	yes	yes	**no**	0.6000	0.0500	0.1000
Fishery 35	Southern California Sport	0.23	0.23	0.23	0.23	yes	yes	yes	0.4600	0.0500	0.1000
Fishery 36	Area 7 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 37	NT San Juan Net (Area 6A,7,7A)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0100	0.0200
Fishery 38	T San Juan Net (Area 6A,7,7A)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0100	0.0200
Fishery 39	NT Nooksack-Samish Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 40	T Nooksack-Samish Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0100	0.0200
Fishery 41	T Juan de Fuca Troll (Area 5,6,7)	0.255	0.255	0.255	0.255	yes	yes	yes	0.5100	0.0500	0.1000
Fishery 42	Area 5/6 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 43	NT Juan de Fuca Net (Area 4B,5,6,6C)	0.3	0.3	0.3	0.3	n.a.	yes	no	0.6000	0.0300	0.0600
Fishery 44	T Juan de Fuca Net (Area 4B,5,6,6C)	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0300	0.0600
Fishery 45	Area 8 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 46	NT Skagit Net (Area 8)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 47	T Skagit Net (Area 8)	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0200	0.0400
Fishery 48	Area 8D Sport	0.2	0.2	0.2	0.2	n.a.	**no**	n.a.	0.4000	0.0500	0.1000
Fishery 49	NT Stilly-Snohomish Net (Area 8A)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 50	T Stilly-Snohomish Net (Area 8A)	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0200	0.0400
Fishery 51	NT Tulalip Bay Net (Area 8D)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400

APPENDIX TABLE A (continued).

Standard and manipulated values of two parameters (Shaker mortality rate and Drop-off/Drop-out rate) examined in this Chinook sensitivity analysis.

Chinook Outfile: stk2008sfm56splitCVAEQfix.out		Standard Shaker Mortality by Time Step:				Sublegals encountered?			Doubled	Other Mortality by Fishery	
Fishery #	Fishery Name	Step 1	Step 2	Step 3	Step 4	Step 2	Step 3	Steps 1&4	Shaker	Standard	Doubled
Fishery 52	T Tulalip Bay Net (Area 8D)	0.3	0.3	0.3	0.3	no	no	no	0.6000	0.0200	0.0400
Fishery 53	Area 9 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 54	NT Area 6B/9 Net used for Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 55	T Area 6B/9 Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 56	Area 10 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 57	Area 11 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 58	NT Area 10/11 Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 59	T Area 10/11 Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 60	NT Area 10A Net	0.2	0.2	**0.2**	0.2	n.a.	**yes**	no	0.4000	0.0200	0.0400
Fishery 61	T Area 10A Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 62	NT Area 10E Net	0.3	0.3	0.3	0.3	n.a.	**no**	**no**	0.6000	0.0200	0.0400
Fishery 63	T Area 10E Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 64	Area 12 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 65	NT Hood Canal Net (Area 12,12B,12C)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0100	0.0200
Fishery 66	T Hood Canal Net (Area 12,12B,12C)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 67	Area 13 Sport	0.2	0.2	0.2	0.2	yes	yes	yes	0.4000	0.0500	0.1000
Fishery 68	NT Deep S. Puget Sound Net (13,13D-K)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 69	T Deep S. Puget Sound Net (13,13D-K)	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 70	NT Area 13A Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 71	T Area 13A Net	0.3	0.3	0.3	0.3	n.a.	no	no	0.6000	0.0200	0.0400
Fishery 72	Freshwater Sport	0.2	0.2	0.2	0.2	n.a.	no	no	0.4000	0.0500	0.1000
Fishery 73	Freshwater Net	0.3	0.3	0.3	0.3	no	no	n.a.	0.6000	0.0200	0.0400