APPENDIX E.
RISK ANALYSIS OF ALL-H RECOVERY STRATEGIES FOR TULE FALL CHINOOK

This chapter was drafted in 2010.

APPENDIX E. RISK ANALYSIS OF ALL-H RECOVERY STRATEGIES FOR TULE FALL CHINOOK

Tables

Figures

E.1. Introduction

This memo summarizes analyses of recovery strategies for Washington populations of Tule Fall Chinook based on objectives and the risk-based life cycle analysis framework described in the Washington Lower Columbia River Recovery Plan (WALCRP). Analyses are intended to: 1) clarify the definition and application of impact reduction targets identified in the plan, 2) plot a near-term and long-term trajectory toward recovery objectives, and 3) guide the development of recovery strategies for harvest, hatcheries, and other listing factors. Results will have direct application to the development of a biological opinion for fall Chinook fishery management and also inform future modeling efforts by NMFS.

The Recovery Plan identifies strategic targets for reductions in impacts of listing factors needed to meet population-specific viability and improvement objectives identified in the recovery scenario. Targets essentially serve as listing factor objectives and provide guidance for the scale of improvement that needs to be addressed by factor-specific measures. Targets are defined in terms of impact reduction objectives for habitat (tributary and estuary), hydropower, harvest, hatcheries, and ecological factors. The plan adopted an equitable sharing strategy identifying impact reductions proportional to the magnitude of the impact.

Recent consultations for harvest and hatchery actions have raised questions of the applicability of the impact reduction targets for use in identifying near term and long term recovery strategies consistent with the Recovery Plan. Targets do not explicitly identify an implementation schedule for factor-specific impact reductions. Targets describe factor-specific improvements required to achieve population objectives throughout the 100-year duration of the population risk assessment that drives the determination of viability. As such, targets might be assumed to implicitly represent factor-specific improvements that are collectively implemented in a near term time frame.

In practice, we know that some actions can be implemented immediately but others will require years to fully develop. Further, some actions can produce immediate dividends but benefits of other actions will take years to realize. For instance, many harvest reductions can provide immediate improvements in spawning escapement. In contrast, landscape-level process-based habitat actions may take years or even decades to realize full benefits.

A key question is whether to implement large reductions in factors with near term benefits (fisheries) in order to compensate for the lack of near-term benefits among the other factors (habitat and hatcheries). If so, then interpretation and application of the impact reduction targets identified in the plan must be qualified with identification of short term and long term strategies. In the long term, we know that recovery will require substantial contributions from all factors. What we want to know is whether we need to scale back fishery impacts even further in the meantime to bridge the interim period.

E.2. Strategy Description

Near-term and long-term abundance trends and risks to population viability were examined for three recovery implementation strategies involving different schedules for when fish benefits are realized.

E.2.1. Strategy 1 – Equivalent All-H Implementation

This strategy assumes that targeted improvements in all factors are immediately effective and maintained for the duration of the simulation. Results are equivalent to the impact reduction targets included in the Recovery Plan. While this is obviously an overly-optimistic implementation schedule, this strategy provides a useful reference point for comparative purposes. Population improvements are based on the gap between current and target viability as identified in the recovery scenario. Corresponding fishery impact rates were based on the proportional reduction strategy identified in the Recovery Plan. Analyses also examined the effects of other fishing rates assuming improvements in other factors consistent with benchmark rates.

E.2.2. Strategy 2 – Fishery Only

This strategy examines the effects of fishery impact reductions in the absence of other improvements. Fishery impacts are modeled as fixed annual rates and are implemented immediately. A range of fishery impacts are examined.

E.2.3. Strategy 3 – Front Loaded Incremental

This strategy involves gradual improvements in population status as a result of improvements due to habitat and other factors in concert with immediate reductions in fishery impacts. Gradual improvements are assumed to reflect the effects of implementation actions for non-fishery related actions including habitat and hatchery factors. Habitat and hatchery actions are not explicitly modeled in this simulation. Rather, benefits in terms of improvements in population productivity are assumed to accrue over time. The magnitude of improvement associated with non-fishery related actions was established based on recovery benchmark values identified in the Plan. Benefits of non-fishery actions are assumed to reach benchmark levels within 50 years.

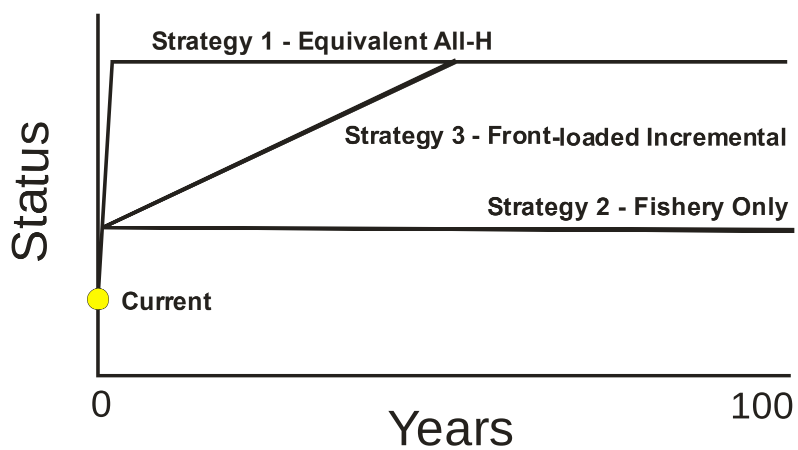

Figure E14-1. Example population trajectories associated with three recovery implementation strategies involving different schedules for when fish benefits are realized.

E.3. Analysis Methods

Viability risks associated with different implementation strategies were estimated using the PopCycle model. PopCycle is a simple stochastic stock-recruitment model developed for the analysis of population viability of Washington lower Columbia salmon and steelhead populations addressed by the Recovery Plan (Figure E14-2). The PopCycle model and its application were documented in Appendix E, Chapter 12 of the Recovery Plan. This analytical framework is consistent with the approach used in Oregon's CATAS and NMFS's SLAM models.

Viability risk was defined in this analysis as the probability of average abundance of a generation of salmon falling below a critical abundance threshold over the course of a simulation. Short term and long term risks were evaluated for 10 and 100 year periods, respectively. Initial population abundance values were assumed to be average for the prevailing habitat and environmental conditions (i.e. we're not currently at a low or high in recent patterns). Near-term ocean productivity patterns were assumed to consistent with historical patterns of variability (i.e. we don't know if we are currently in or entering a cycle of lower or higher than average productivity).

Simulations were based on the same population-specific input parameters used in Recovery Plan analysis (Table E14-1).[1] Analyses incorporated and were calibrated for consistency with EDT model results used in the Recovery Plan to evaluate habitat impacts, potential, and actions. Analyses were also calibrated for consistency with HSRG evaluations of hatchery actions. Baseline population capacity was estimated as the EDT-derived value under patient conditions. Baseline population productivity was estimated as the EDT-derived value under patient conditions reduced by HSRG estimates of the decrease in natural population productivity associated with the observed incidence of hatchery-origin fish in natural production areas and HSRG assumptions regarding the relative fitness of these hatchery-origin fish. For most tule populations, the HSRG assumed a 50% reduction in natural population productivity. The combined effect of poor habitat conditions reflected in EDT estimates and impacts of hatchery fish on productivity resulted in very low replacement rates of most populations and very high risks under high baseline fishing levels.

This simulations are based on natural populations and do not directly simulate the demographic effects of naturally-spawning hatchery fish. Simulations do incorporate reductions in population productivity assumed to be related to historical loss of fitness consistent with HSRG assumptions. Simulations do not do not include effects of continuing hatchery subsidies which reduce demographic risk (at least in the short term). Nor do simulations consider ecological impacts of hatchery releases which potentially increase demographic risk to an unknown degree.

[1] Tule fall Chinook risk analysis has been updated since distribution of the June 2009 working draft.

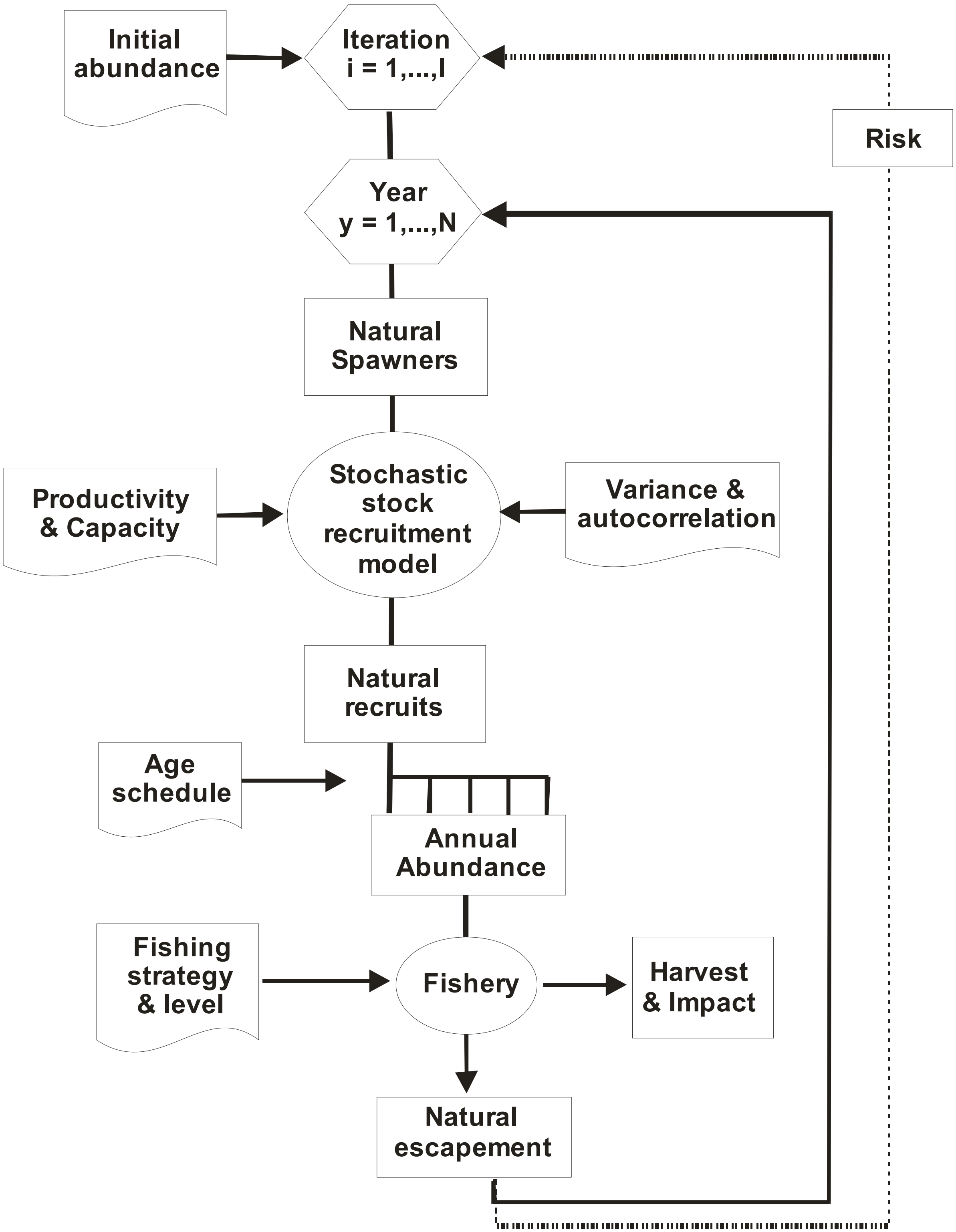

Figure E14-2. PopCycle model algorithm used as a basis for population viability analyses in the Washington lower Columbia River Recovery Plan.

Table E14-1. Model parameters and risk levels for Washington lower Columbia River tule fall Chinook populations.

Population	State	Data type[a]	EDT patient[b]		Hatchery impact[c]	Realized		Variability $[\sigma^2]$[f]	Autocorrelation (lag)[g]	Critical threshold[h]	Estimated risk[i]	Risk category[j]
			Cap.	R/S		N_{eq}[d]	R/S[e]					
Coast Fall												
Grays/Chinook	W	2	484	3.7	0.50	300	1.9	0.9	0.4	50	>99%	VH
Eloch/Skam	W	2	2,003	3.9	0.50	1,300	1.9	0.9	0.4	50	>99%	VH
Mill/Aber/Germ	W	2	1,418	4.4	0.49	1,000	2.2	0.9	0.4	50	>99%	VH
Cascade Fall												
Lower Cowlitz	W	2	10,324	5.9	0.50	8,200	3.0	0.9	0.4	250	79%	VH
Upper Cowlitz	W	2	--	--	--	--	--	--	--	250	na	VH
Toutle	W	2	4,568	3.1	0.50	2,400	1.6	0.9	0.4	150	>99%	VH
Coweeman	W	2	1,911	4.2	0.23	1,700	3.2	0.9	0.4	50	73%	VH
Kalama	W	2	1,560	3.9	0.50	1,000	2.0	0.9	0.4	50	>99%	VH
Lewis	W	2	1,491	3.3	0.50	800	1.7	0.9	0.4	50	>99%	VH
Salmon	W	3	--	--	--	--	--	--	--	50	>99%	VH
Washougal	W	2	1,747	3.8	0.50	1,100	1.9	0.9	0.4	50	>99%	VH
Gorge Fall												
L. Gorge	W/O	3	--	--	--	500	--	0.9	0.4	150	>99%	VH
U. Gorge	W/O	3	--	--	--	500	--	0.9	0.4	150	>99%	VH
White Salmon	W	3	--	--	--	--	--	--	--	50	>99%	VH

[a] 2 = Ecosystem Diagnosis and Treatment Model inference from habitat conditions (Beverton-Holt), 3= assumed based on limited data and representative species ranges (modeled as a hockey stick function).
[b] Estimated habitat capacity and productivity under current conditions as inferred from EDT analysis by WDFW.
[c] Reduction in population productivity (maximum value at low spawner numbers from Beverton-Holt function) estimated by the HSRG based on the incidence and source of hatchery-origin spawners in natural production areas.
[d] Pre-harvest equilibrium abundance parameter based on EDT patient values with productivity reduced by the HSRG hatchery impact.
[e] Pre-harvest population productivity parameter estimated from EDT patient productivity reduced by the HSRG hatchery impact.
[f] Stock-recruitment variance parameter.
[g] Autocorrelation in stock-recruitment variance based on species values derived by McElhany et al. 2006.
[h] Critical risk threshold identified for population based on basin size based on a geometric mean population size of less than the specified number of spawners in one generation.
[i] Probabilities of falling below threshold values under fishing rates prevalent prior to ESA listings (coho 50%,spring Chinook 50%, tule fall Chinook 65%, bright fall Chinook 50%, chum 5%, steelhead 10%).
[j] Risk categories based on critical risk threshold probability from population viability analysis included in this report (VH = very high risk of >60%, H = high risk of 26-60%. M = moderate risk of 5-25%, L = low risk of 1-5%, VL = very low risk of <1%).

E.4. Results

E.4.1. Strategy 1 – Equivalent All-H Implementation

Targets are based on population improvements and levels needed to reduce population-specific risks to target levels. The Recovery Plan estimated the viability of each Washington lower Columbia population based on the risk of wild spawner numbers falling below critical abundance thresholds within the next 100 years. Risks were estimated using the PopCycle model parameterized with estimates of current population, productivity, capacity, and variability based on the best available data for each population.

Risks of 60% or more led to assessments of very low viability in all 14 tule fall Chinook populations in the baseline time period which reflects conditions around the time of listing prior to 2000 (Table E14-2). Six of the 14 populations are targeted for improvement to high or very high levels of viability where long term risks are reduced to 5% or less (primary populations). Six additional populations are targeted for improvement to moderate risk levels of 25% or less (contributing populations). Two populations are targeted for limited improvements (stabilizing populations).

Short term risks are substantially lower than long term risks. A longer time period provides a greater opportunity for compounding effects of multiple poor production cycles to drive numbers to critical low levels. This result is sensitive to assumed starting conditions. Near-term risks would be greater if recent numbers were assumed to be considerably less than recent averages. Near term risks are also greater for the smaller, less productive populations which are closer to critical low abundance levels.

In order to reach recovery objectives, the life cycle risk modeling indicated that improvements in abundance and productivity on the order of 50% to 500% would be required for primary and contributing Coast and Cascade populations. Reliable model projections could not be developed for contributing gorge populations because of high uncertainty in the inherent productivity and capacity of the remaining habitat available to those populations. In this case, the Recovery Plan simply assumed that a 5-fold (500%) improvement in status would be needed to achieve target levels or at least produce enough fish in order to better evaluate recovery potential.

High long term risks under baseline conditions were associated with very high levels of fishery impacts around 65%. Loss of population capacity and productivity due to the cumulative long term effects of historical habitat, hatchery, and ecological factors have eliminated the ability of most populations to sustain high levels of fishing. Fishery impacts consistent with population recovery goals were estimated in the Recovery Plan to range from 26% to 60%. These estimates were based on proportional impact reductions (delta values) that assumed all impact reductions for fisheries and other factors were implemented and effective over the duration of the simulation.

The PopCycle model also identifies average abundance levels under baseline and objective conditions (Table E14-2).

Table E14-2. Summary of population objective including fishery impact targets for Washington lower Columbia River tule fall Chinook populations (LCFRB 2009). Populations are sorted by decreasing fishery impact targets.

		Viability		Risk			Improve-		Fishery impact		Abundance	
Population	Scen.[1]	Base[2]	Obj.[3]	10 yr[4]	100 yr[5]	Obj.[6]	ment[7]	delta[8]	Base.[9]	Bench.[10]	Base[11]	Bench[12]
Lower Cowlitz	C	VL	M+	4%	79%	15%	50%	-8%	65%	60%	2,900	4,200
Coweeman	P	VL	H+	3%	73%	<5%	80%	-18%	65%	53%	600	1,300
Kalama	C	VL	M	25%	>99%	25%	110%	-21%	65%	51%	400	800
Mill/Aber./Germ.	P	VL	H	20%	>99%	5%	155%	-28%	65%	47%	400	1,250
Eloch./Skam.	P	VL	H	18%	>99%	5%	150%	-29%	65%	46%	500	1,500
Toutle	P	VL	H+	43%	>99%	<5%	265%	-32%	65%	44%	800	6,100
Washougal	P	VL	H+	24%	>99%	<5%	190%	-34%	65%	43%	400	1,800
Lewis	P	VL	H+	40%	>99%	<5%	280%	-42%	65%	38%	300	2,200
Grays/Chinook	C	VL	M+	78%	>99%	15%	500%	-61%	65%	26%	100	1,300
Lower gorge	C	VL	M	--	>99%	25%	>500%[11]	-50%[13]	65%	33%[13]	200	800
Upper gorge	C	VL	M	--	>99%	25%	>500%[11]	-50%[13]	65%	33%[13]	200	800
White Salmon	C	VL	M	--	>99%	25%	>500%[11]	-50%[13]	65%	33%[13]	200	800
Upper Cowlitz	S	VL	VL	--	>99%	--	--	-0%	65%	--	--	--
Salmon	S	VL	VL	--	>99%	--	--	-0%	65%	--	--	--

[1] Scenario designation for population objective: Primary, Contributing, Stabilizing.
[2] Population viability in pre-listing baseline period (Very Low, Low, Moderate, High, Very High).
[3] Population viability objective. ("+" values refer to intermediate values between the specified viability and the next highest category)
[4] 10 year population risk in pre-listing baseline period.
[5] 100 year population risk in pre-listing baseline period (generally corresponds to baseline viability category).
[6] Risk (100 yr) consistent with scenario and viability objectives (VL: <1%, L: 1-5%, M: 6-25%, H: 26-60%, VH: >60%).
[7] Population improvement needed to reach objective risk target (described in terms of density-independent increase in population productivity).
[8] Reduction in impact of each individual factor (harvest, hatchery, habitat, estuary, ecological) required to achieve population improvement.
[9] Fishery impact in pre-listing baseline period.
[10] Fishery impact benchmark at population objective assuming proportional reductions in impacts of all factors (benchmark= (1-delta) x baseline).
[11] Approximate average spawner abundance estimated by the model based on population parameters during the pre-listing baseline period. This would be the expected number under baseline conditions in the absence of hatchery-origin natural spawners or their offspring. (Note that abundance objectives specified in the Recovery Plan are medians rather than averages.)
[12] Approximate average spawner abundance projected under benchmark assumptions of equivalent reductions in impacts of all factors.
[13] Default values assumed for populations where viability is very low but production parameters are highly uncertain.

E.4.2. Strategy 2 – Fishery only

High fishing rates approaching 65% prior to 1999 were associated with very high population risks for Lower Columbia River tule Fall Chinook due to historical habitat and hatchery impacts on abundance, productivity, diversity, and spatial distribution. Risks were estimated to be very high (>60%) even for the strongest remaining populations including those currently designated for recovery to high levels of viability (Figure E14-3, Table E14-3).

Most populations cannot be restored to target viability levels with fishing reductions alone. Significant improvements in habitat quality and hatchery effects are also required. The sensitivity of long-term risks to fishery impacts varies with population status. Long-term population risks can be substantially reduced by reducing fishery impacts only for populations with significant intrinsic capacity or productivity. For instance, fishery impact reductions from 65% to 50% are projected to reduce risks by over half for Cowlitz and Coweeman populations. Small and unproductive populations such as the Grays/Chinook are less affected and cannot be brought to high levels of viability even at very low fishing rates.

Incremental benefits of fishery reductions progressively decrease at lower and lower fishing rates. Fishing rates below which population viability is largely independent of the effects of fishing are sometimes referred to as *de minimis* fishing rates. Definition of an appropriate *de minimis* rate depends of the specification of an acceptable risk level. Rates may vary among populations in relation to differences on abundance and productivity.

Average abundance over the 100-year period of the simulation increases in direct proportion to the reduction in fishing rate. Improvements are greatest in the most productive populations such as the Cowlitz, and least in relatively unproductive populations such as the Grays. While low population risks may be relatively insensitive to fishing at low impact rates, abundance is consistently sensitive to fishing at all impact levels. Thus, while reductions to very low fishing rates do not substantially affect risk, they do translate into ever larger numbers of spawners.

Beyond a certain level, additional increases in abundance do not correspond to decreased risk because: 1) normal variation in numbers due to variable ocean conditions is unlikely to result in low numbers that fall below fixed critical population levels used to define risk, and 2) too few fish are affected by low harvest rates to substantially affect escapement and risk in the low return years. Increased abundance levels associated with lower fishery impact rates can restore escapements to target recovery levels more quickly than could be accomplished by reliance on habitat actions with delayed benefits. However, reductions in fishery impacts needed to reach long term goals in the near term will substantially exceed targets levels identified based on a strategy of equitable sharing of the recovery "burden."

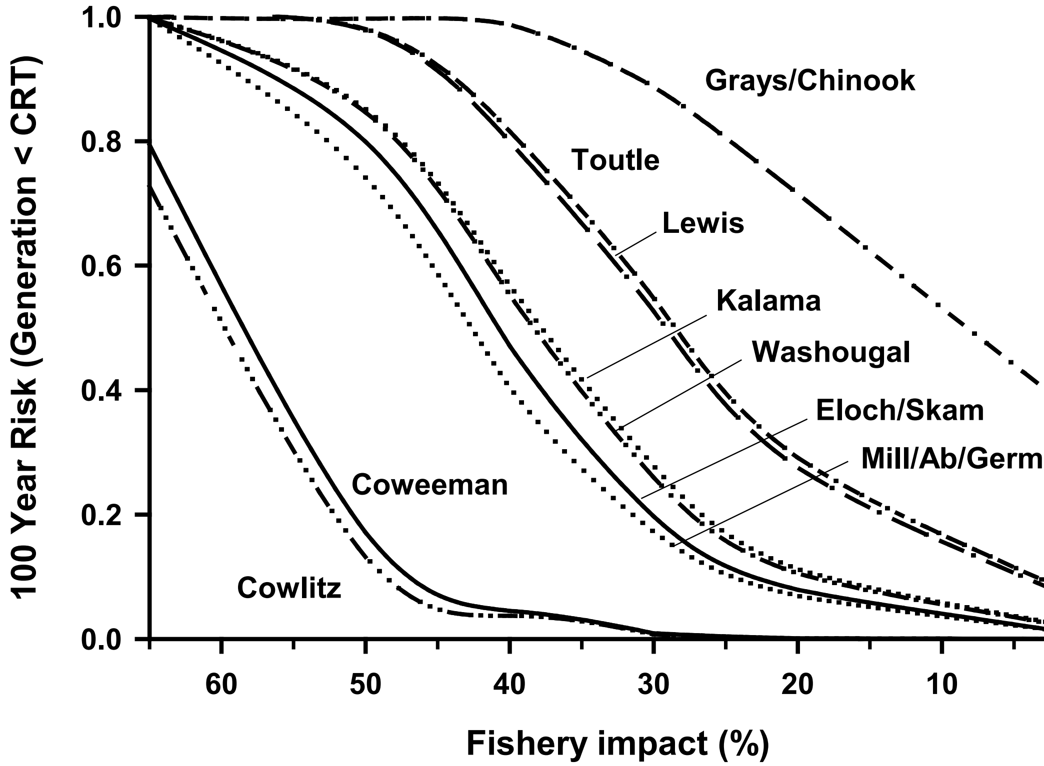

Figure E14-3. **Effect of fishing on risk of falling below critical abundance threshold for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).**

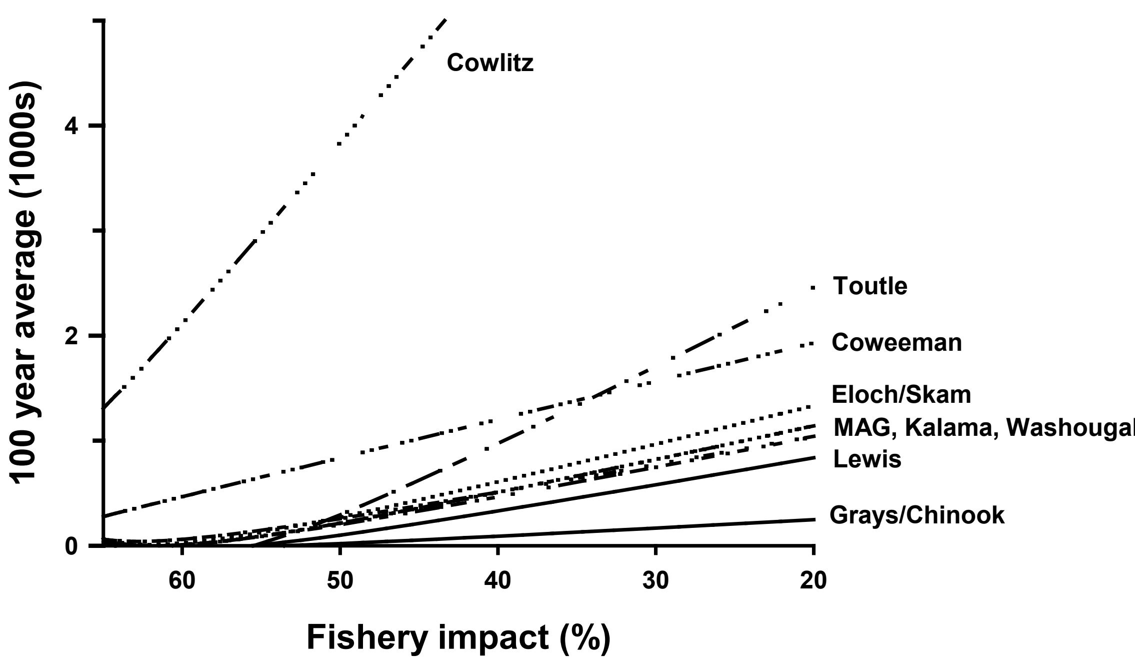

Figure E14-4. **Effect of fishing on risk abundance for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).**

Table E14-3. Estimated risks of falling below critical abundance thresholds (defined by the TRT) under different fishery impact rates for lower Columbia River populations of tule fall Chinook targeted for improved viability. (Strategy 2: No improvements in other factors is assumed.)

		Fishery impact rate						Abundance		
Population	**(years)**	**65%[1]**	**50%**	**40%**	**30%**	**20%**	**0%**	**65%**	**50%**	**0%**
Grays/Chinook	100	0.999	0.997	0.987	0.887	0.715	0.350	10	20	408
	10	0.777	0.507	0.350	0.239	0.175	0.085	60	107	339
Eloch/Skam	100	0.997	0.799	0.471	0.197	0.079	0.006	58	270	2,070
	10	0.181	0.056	0.023	0.010	0.005	0.002	295	516	1,492
Mill/Ab/Germ	100	0.996	0.741	0.404	0.172	0.069	0.007	56	257	1,582
	10	0.200	0.058	0.029	0.013	0.006	0.002	253	436	1,204
Lower Cowlitz	100	0.794	0.171	0.045	0.009	0.001	0.000	1,307	3,838	12,646
	10	0.043	0.008	0.003	0.001	0.000	0.000	2,452	4,077	10,366
Toutle	100	0.999	0.980	0.816	0.548	0.291	0.063	71	293	3,987
	10	0.428	0.176	0.101	0.055	0.029	0.010	453	811	2,553
Coweeman	100	0.727	0.132	0.037	0.007	0.000	0.000	277	835	2,659
	10	0.033	0.004	0.003	0.001	0.000	0.000	542	893	2,222
Kalama	100	0.998	0.851	0.568	0.278	0.112	0.015	43	199	1,617
	10	0.252	0.080	0.037	0.018	0.009	0.003	232	406	1,172
Lewis	100	0.999	0.978	0.799	0.527	0.275	0.056	25	100	1,355
	10	0.400	0.161	0.088	0.050	0.028	0.009	166	298	918
Washougal	100	0.998	0.846	0.553	0.260	0.105	0.014	46	214	1,785
	10	0.235	0.073	0.034	0.016	0.008	0.003	250	439	1,279

[1] Baseline condition prior to listing

Fishery risk calculations vary considerably in short term versus long term calculations (Figure E14-5). For instance, fishing the Elochoman-Skamokawa population of fall Chinook at 65% results in 99% chance of falling below the critical risk threshold in a 100 year period but just an 18% risk of falling below the critical risk threshold in a 10 year simulation. Even relatively high fishing rates are extremely unlikely to drive numbers to low levels within a couple of fish generations starting at recent average numbers.

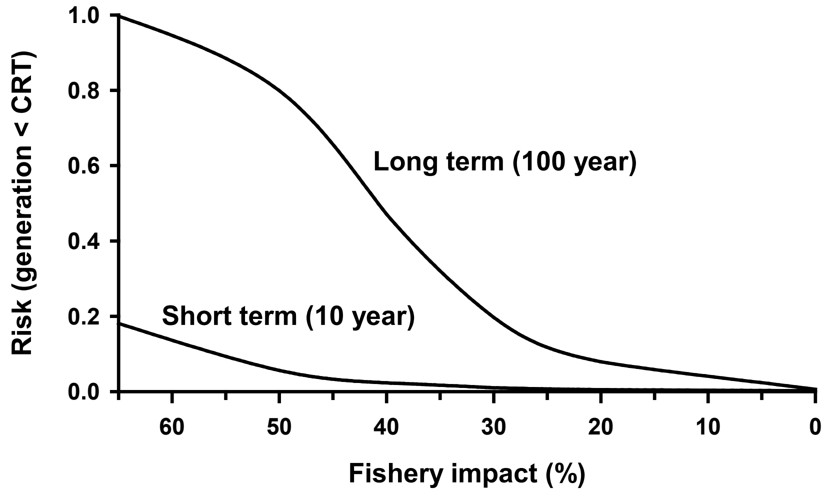

Figure E14-5. Effect of fishing on long term (100 year) and short term (10 year) risks of falling below critical abundance threshold for Elochoman-Skamokawa fall Chinook. (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).

Average abundance is much less sensitive than risk to short term versus long term effects (Figure E14-6). Long term abundance levels are slightly more sensitive than short term abundance because of the multiplying of the stock-recruitment function. Where short term fishery reductions increase escapement in existing cohorts, long term reductions both increase escapement and increase recruitment from the greater escapements. In the Elochoman-Skamokawa population simulation, long term average abundance was less than short term average abundance because of a continuing long term declining trend in numbers under baseline fishery impact levels.

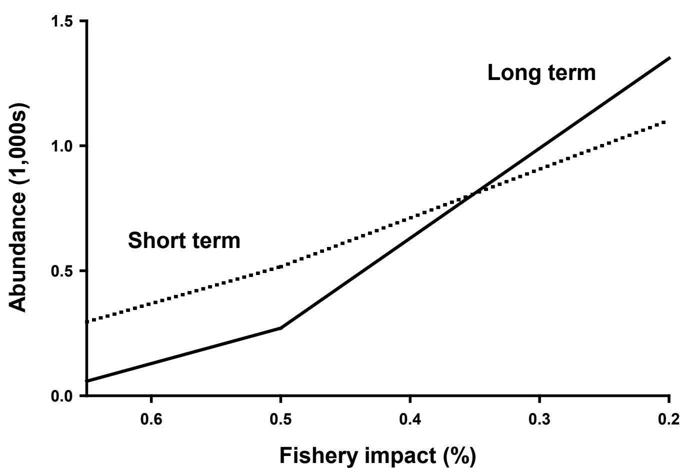

Figure E14-6. Effect of fishing on long term (100 year) and short term (10 year) abundance for Elochoman-Skamokawa fall Chinook. (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).

Short term risks, like long term risks, decline rapidly with reductions in fishing from historically high fishery impact rates (Figure E14-7). Incremental benefits of fishery reductions progressively decrease at lower and lower fishing rates. Short term low population risks are projected to be 5% or less in all Washington Coast and Cascade strata populations, except Grays/Chinook, at harvest rates of 30% or less. Short term low population risks are projected to be 1% or less in all populations, except

Grays/Chinook, Toutle, and Lewis, at harvest rates of 25% or less. Note that these generalizations apply to a fixed impact fishing strategy. An abundance-based strategy can reduce risks in low run years when annual numbers can be forecast. Average abundance within the short term increases in proportion to the reduction in fishery impacts (Figure E14-8).

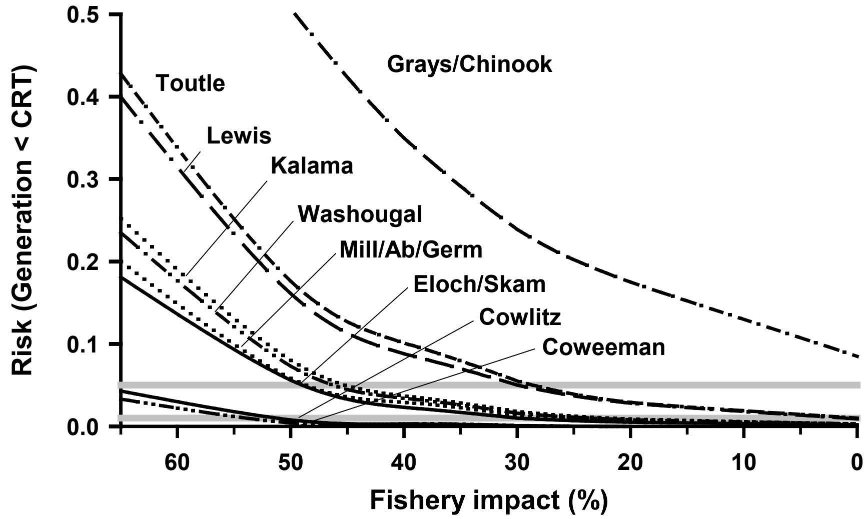

Figure E14-7. Effect of fishing on risk of falling below critical abundance threshold for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).

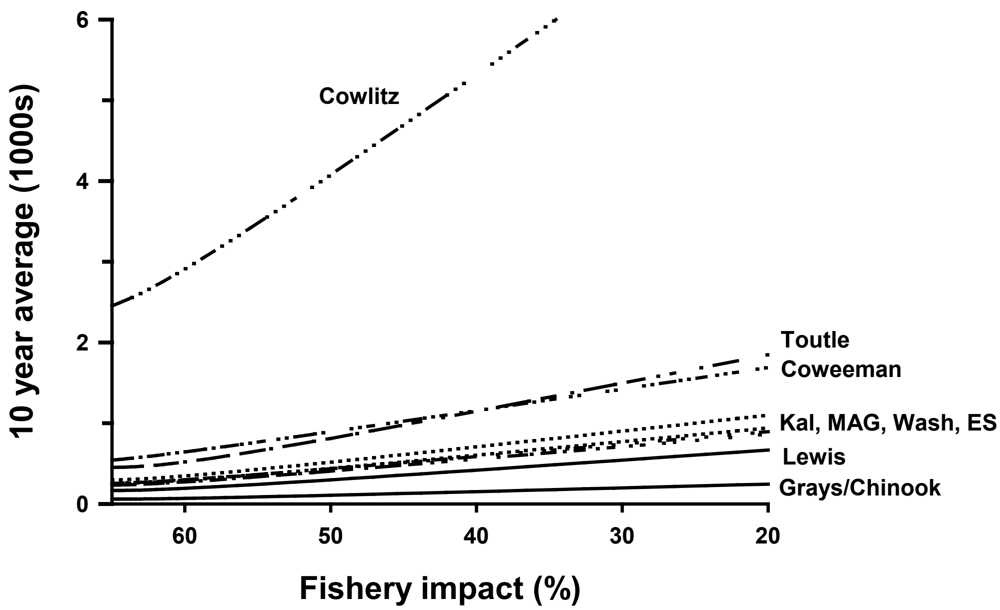

Figure E14-8. Effect of fishing on abundance for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 2 results based on fishery reductions in the absence of improvements in other factors).

E.4.3. Strategy 3 – Front Loaded Incremental

Long term and short term risks associated with different fishing levels and incremental improvement levels are depicted in Figure E14-9 and Table E14-4. Corresponding average 100-year and 10-year spawner numbers are depicted in Figure E14-9 and Table E14-4.

Incremental improvement levels are based on the targeted improvements for each population less the harvest component of the improvement. This is equivalent to the benefit of gradually implementing all of the benchmark improvements in non-fishery factors within the next 50 years. Full effects are not realized in this simulation example until 50 years and improvements are evenly apportioned over the intervening period.

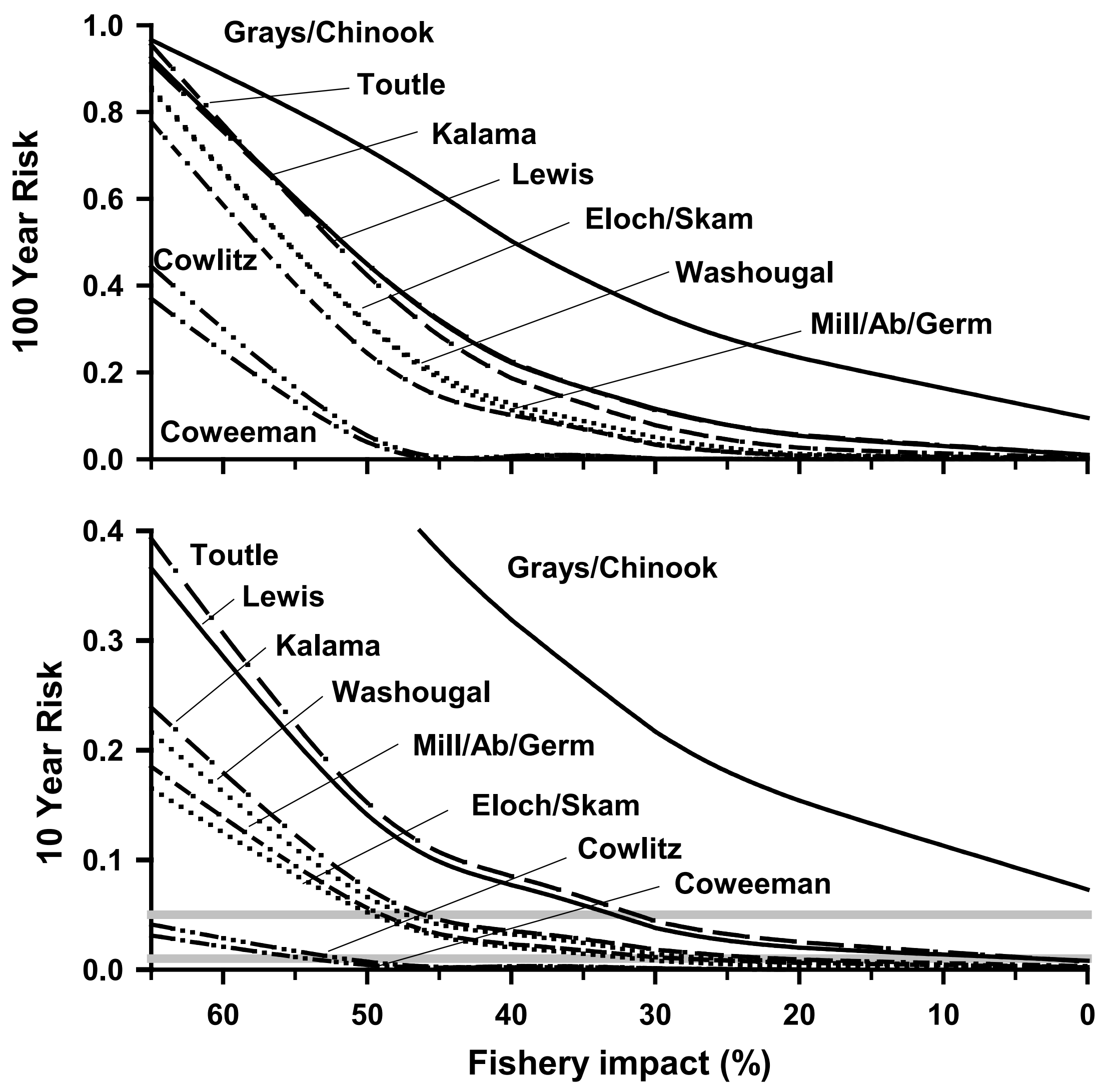

Figure E14-9. Effect of fishing on long term (100 year) and short term (10 year) risk of falling below critical abundance threshold for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 3 results based on immediate fishery reductions and incremental improvements in other factors).

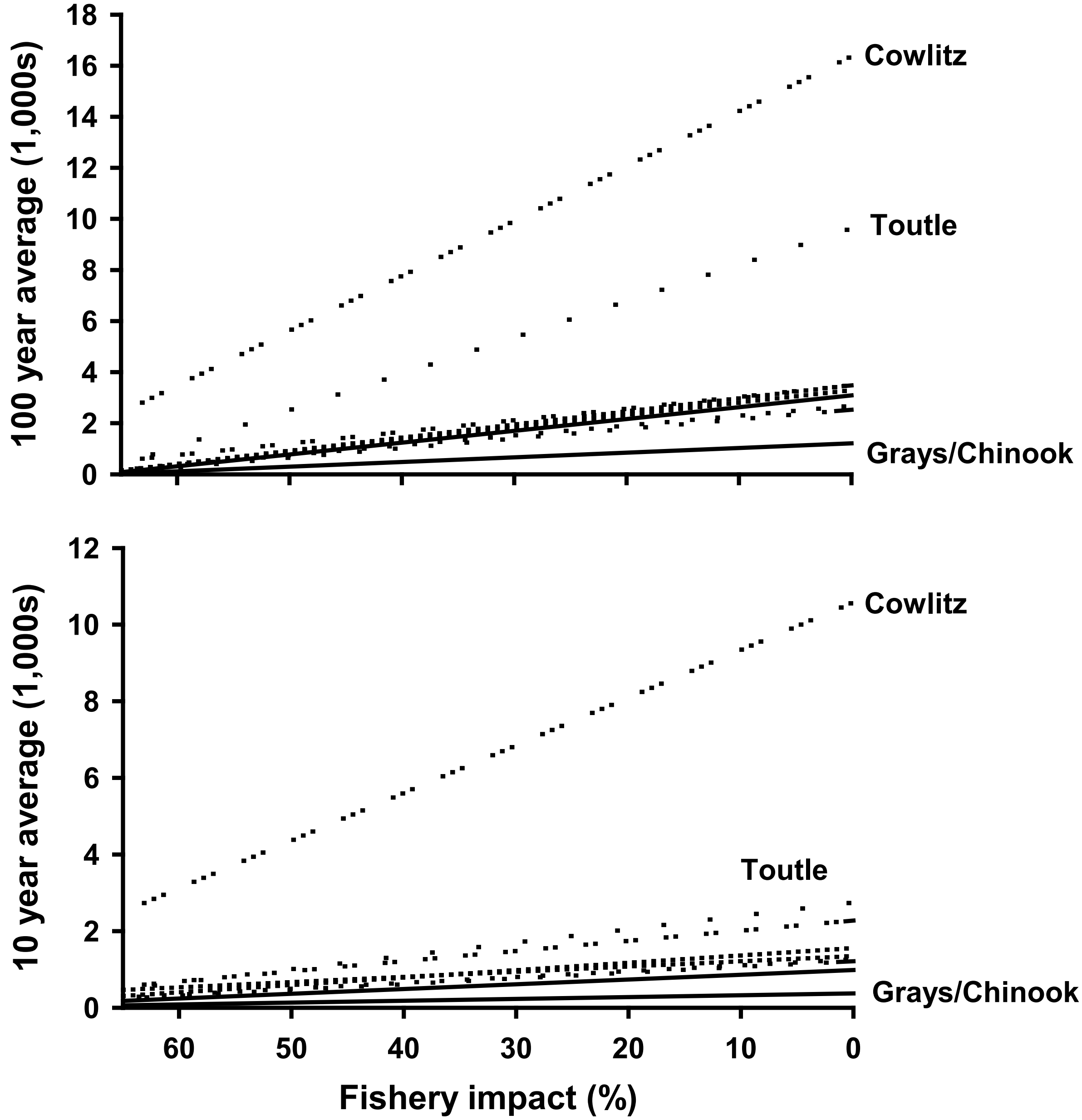

Figure E14-10. Effect of fishing on long term (100 year) and short term (10 year) average abundance for lower Columbia River populations of tule fall Chinook targeted for recovery to high levels of viability (Strategy 3 results based on immediate fishery reductions and incremental improvements in other factors).

Table E14-4. Estimated risks of falling below critical abundance thresholds (defined by the TRT) and corresponding increases in abundance at different fishery impact rates under gradual long term improvements in productivity (Strategy 3) of lower Columbia River populations of tule fall Chinook targeted for significant improvement in viability.

	Improvement			Period	Risk @ fishery impact rate						Average abundance @ fishery impact rate					
Population	Net[1]	Obj.[2]	Per yr[3]	(years)	65%	50%	40%	30%	20%	0%	65%	50%	40%	30%	20%	0%
Grays/Chin.	500%	184%	2.108%	100	0.966	0.714	0.503	0.339	0.234	0.095	21	182	376	586	787	1,210
				10	0.746	0.458	0.319	0.217	0.154	0.073	61	116	160	208	260	371
Eloch./Skam.	150%	62%	0.970%	100	0.856	0.309	0.113	0.035	0.008	0.002	147	813	1,391	1,949	2,480	3,482
				10	0.165	0.052	0.020	0.008	0.003	0.002	305	536	714	907	1,113	1,554
Mill/Ab/Germ	155%	68%	1.048%	100	0.778	0.244	0.101	0.033	0.009	0.002	170	742	1,159	1,563	1,946	2,672
				10	0.185	0.056	0.023	0.011	0.006	0.002	262	454	598	752	914	1,255
L. Cowlitz	50%	31%	0.545%	100	0.444	0.054	0.007	0.001	0.000	0.000	2,403	5,565	7,815	9,941	12,076	16,364
				10	0.041	0.007	0.002	0.001	0.000	0.000	2,498	4,160	5,363	6,618	7,911	10,584
Toutle	265%	128%	1.663%	100	0.913	0.449	0.225	0.113	0.056	0.010	376	2,360	3,957	5,422	6,946	9,628
				10	0.393	0.152	0.085	0.044	0.025	0.007	478	865	1,176	1,524	1,904	2,746
Coweeman	80%	34%	0.588%	100	0.370	0.039	0.005	0.001	0.000	0.000	516	1,252	1,711	2,155	2,596	3,481
				10	0.031	0.004	0.003	0.001	0.000	0.000	553	913	1,170	1,436	1,709	2,271
Kalama	110%	50%	0.814%	100	0.955	0.423	0.187	0.078	0.026	0.003	78	517	937	1,351	1,762	2,523
				10	0.239	0.074	0.035	0.018	0.009	0.003	238	419	558	709	869	1,212
Lewis	280%	115%	1.538%	100	0.926	0.449	0.222	0.116	0.054	0.010	77	628	1,152	1,658	2,164	3,086
				10	0.366	0.141	0.077	0.038	0.020	0.008	175	316	428	552	687	981
Washougal	190%	78%	1.161%	100	0.851	0.313	0.127	0.050	0.012	0.002	138	785	1,324	1,851	2,356	3,289
				10	0.216	0.066	0.032	0.014	0.007	0.002	260	459	613	780	959	1,342

[1] Population improvement needed to reach objective risk target (described in terms of density-independent increase in population productivity).
[2] Aggregate 50-year improvement in productivity associated with non fishery-related factors identified by recovery plan targets.
[3] Annual improvement in productivity associated with non fishery-related factors identified by recovery plan targets.

E.4.4. Strategy Comparison

Figure E14-11 illustrates the difference in effect of fishery impact reductions on risk under the three implementation schedule strategies. The example is for the Elochoman-Skamokawa fall Chinook which is a typical lower Columbia River population.

Risk responds similarly to reductions in fishing in all three recovery strategies although risk levels are related to the magnitude and timing of impact reductions. Long term risks are greatest when only fishery reductions are implemented and least when all benchmark reductions are implemented immediately. Long term risks of the front-loaded (fishery) incremental (other factor) strategy are intermediate.

Short term risks are practically the same in the fishery-only and front loaded incremental strategies as would be expected with the lack of near-term improvements in the other limiting factors. Short term risks would be substantially lower if it were practical to implement all targeted reductions in the near term.

The fishery-only strategy provides a useful point of reference for risk levels under historical baseline conditions. Curve origins (y-axis intercepts) at a 65% fishery impact rate are the risk levels in the pre-listing base period (>99%% long term, 18% short term).

The equivalent all-H curve for long term risk also illustrates the definition of the harvest rate benchmark value (46%) for this population as the point where population risks are reduced to 5% by the combination of fishery and other factor impact reductions (depicted with a circle).

Note that because strategy 1 and 3 lines are relatively close together, only small reductions in fishery impacts are needed to offset the long term effects on risk of the delay in realizing the benefits of the non-fishery related factors. However, much larger reductions in fishing rates would be needed to offset the short term effect on risk of the delay in realizing the benefits of non-fishery related factors.

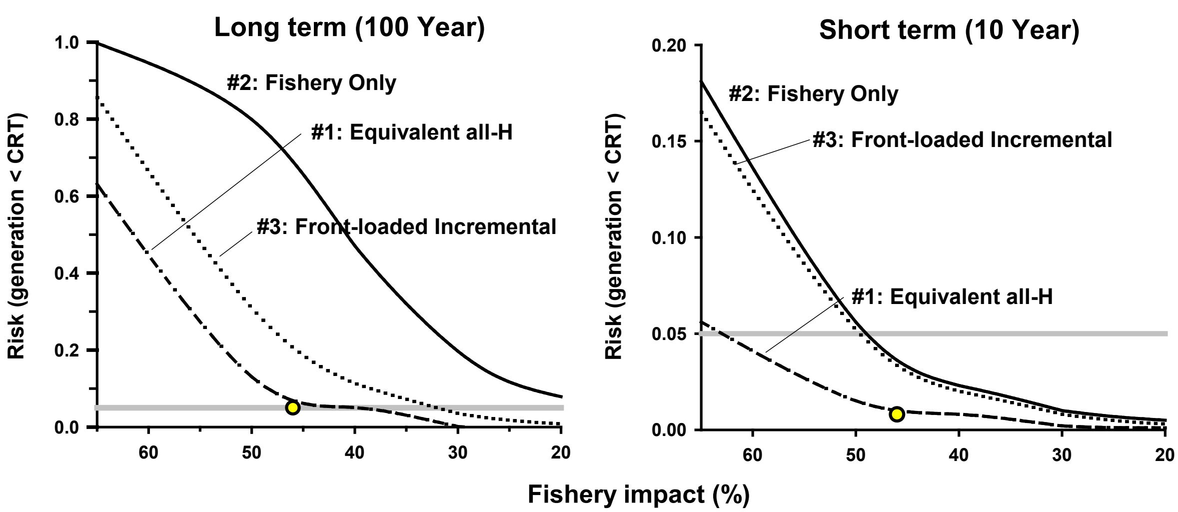

Figure E14-11. Effect of fishing on long and short term risks of falling below critical abundance threshold for Elochoman-Skamokawa fall Chinook under alternative recovery strategies.

In long term simulations, abundance patterns are similar for both the equivalent all-H and the front loaded incremental strategies. Numbers are slightly less in the front-loaded incremental strategy because impact reductions in non-fishery factors are less then benchmark values for the first 50 years of the simulation. Note that because these lines are relatively close together, only small reductions in fishery impacts are needed to offset the effects on abundance of the delay in realizing the benefits of the non-fishery related factors.

In contrast, abundance patterns in short term risks are essentially the same for the front-loaded incremental and fishery only strategies, both of which are less than the equivalent all-H strategy with its much more immediate impact reductions. Because strategy 1 and 3 lines are relatively farther apart, larger reductions in fishery impacts would be needed to offset the short term effects on abundance of the delay in realizing the benefits of the non-fishery related factors.

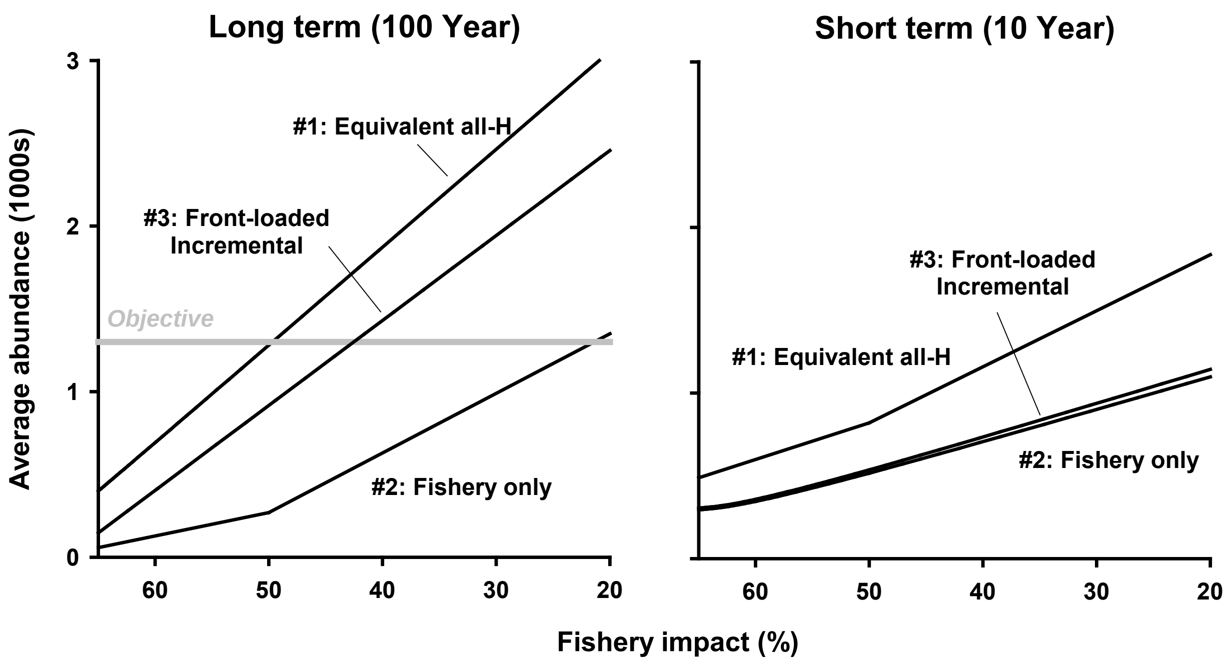

Figure E14-12. Effect of fishing on long term and short term average abundance for Elochoman-Skamokawa fall Chinook under alternative recovery strategies. The <u>average</u> abundance objective for this population is 1,300 (equivalent to a <u>median</u> spawner abundance of 900 identified in the Recovery Plan).

Table E14-5 summarizes results of fishery analyses of long term and short term risks for each population and strategy. Results can be used to identify fishery impact rates consistent with any given set of risk tolerances.

For instance, near term fishery impacts might be established based on projected long term risks under different assumptions for the level and timing of contribution from other factors. In this case, fishery impact rates of 26% or less will reduce long term risks to levels consistent with viability objectives identified in the recovery scenario for all Coast and Cascade strata populations of tule fall Chinook in the Washington lower Columbia if equivalent reductions are other factors are implemented at the same time (Strategy 1). Fishery reductions alone cannot meet long term risk objectives for the weakest populations if no other factors were addressed over the 100 year time period (Strategy 2). Fishery impact rates of 10% or less would be required to meet long term risk objectives if other factors were gradually improved to benchmark target levels by the end of a 50 year time period (Strategy 3).

Near term fishery impacts might also be established based on short term risks in the interim until improvements in other factors can be realized. However, even a very low 1% risk standard over the next 10 years cannot be achieved in the weak populations in the absence of improvements in other factors. Short term fishery impacts of 25-55% are projected to be adequate to reduce short term risks of the stronger populations to the 1% level. Short term fishery impacts of 25-35% are projected to be adequate to reduce short term risks of all populations except the Grays to the 5% level under Strategy 2 where only fishery reduction are realized in the near term. Short term risks under 8.5% cannot be achieved for the Grays population due to very low current productivity estimates for that population.

Table E14-5. Fishery impact rates associated with population risk objective levels under alternative implementation strategies including: 1) equivalent all-H (benchmark rates), 2) fishery only, and 3) front-loaded incremental. Populations are sorted by impact rates for long term risks.

	Long term risk (100 yr)				Short term risk (10 yr)			Short term risk (10 yr)		
Population	**Risk[1]**	**1**	**2**	**3**	**Risk[2]**	**2**	**3**	**Risk[3]**	**2**	**3**
Grays/Chinook	15%	26%	--	10%	1%	--	5%	5%	--	--
Toutle	<5%	44%	--	14%	1%	0%	5%	5%	28%	35%
Lewis	<5%	38%	--	14%	1%	0%	0%	5%	30%	33%
Washougal	<5%	43%	5%	25%	1%	20%	25%	5%	45%	46%
Kalama	25%	51%	29%	43%	1%	20%	25%	5%	45%	48%
Mill/Aber./Ger.	5%	47%	17%	33%	1%	25%	28%	5%	47%	48%
Eloch./Skam.	5%	46%	16%	32%	1%	30%	32%	5%	48%	49%
Coweeman	<5%	53%	37%	47%	1%	55%	55%	5%	65%	65%
Lower Cowlitz	15%	60%	49%	56%	1%	55%	55%	5%	65%	65%

[1] Long term risk levels correspond to objective consistent with target viability identified in the recovery scenario.
[2] A 1% short term risk level was analyzed to represent a more conservative standard than the long term risk level.
[3] Recommended risk level for use as an interim benchmark application.

E.5. Discussion

This analysis highlights the poor current status of lower Columbia River tule Fall Chinook and the large improvements that will be required to meet recovery objectives. Low habitat capacity and productivity due to watershed-scale land use impacts are compounded by further reductions in productivity resulting from hatchery effects on most populations. Historical high fishing rates cannot be sustained by these depleted populations without driving numbers to very low levels from which recovery is uncertain.

Analyses confirm that significant reductions in fishery impacts from historical high levels will produce large and immediate increases in escapement with corresponding reductions in risk. For instance, a reduction in average impacts from the pre-listing baseline of 65% to the 2009 target level of 38% was projected to increase average spawning escapement by almost two-fold [(1-0.65)/(1-0.35) = 1.77 ≈ 77% increase].

The viability/risk benefits of fishery reductions depend on population productivity. Relatively modest fishery reductions are adequate to achieve target escapements and risk levels for the larger, more-productive populations such as the Cowlitz and Coweeman. However, even complete fishery closures will not increase numbers to target viability levels for small, unproductive populations such as the Grays. Low replacement values mean that larger escapements simply do not produce enough fish to rebound from periodic critically low levels. Without significant increases in population productivity associated with habitat and hatchery improvements, the additional escapement provided by severe fishery restrictions does not translate into large reductions in fishery risk. It will be very difficult to achieve all tule recovery objectives without the benefit of compounding improvements in multiple factors.

Risks are sensitive to the timing of improvements associated with recovery actions. Impact reduction targets identified in the June working draft Recovery Plan do not meet long recovery objectives when implementation or realization of benefits is significantly delayed from the current time frame. Targets in the June working draft plan describe equivalent improvements if all factors are addressed in a proportional and timely manner. Targets were originally developed to demonstrate the order of magnitude of improvement in each factor category needed to meet the population recovery objectives. Targets did not originally contemplate the pace or timing of implementation of recovery actions. Targets continue to provide guidance for the scale of long term changes in each factor needed to meet recovery objectives. However, because it is not realistically feasible to achieve all targeted habitat and hatchery productivity improvements within the next 5-10 years, the application of the targets to implementation strategies must be qualified accordingly.

One alternative would be to require greater long term improvements in habitat or hatchery actions in order to achieve an equivalent benefit and offset delays in implementation and realization of effects. For instance, a 50% habitat improvement target effectively assumes that the 50% improvement is achieved in the near term and is effective for the duration of the 100 year risk assessment. Since immediate improvement is not realistic, then something greater than a 50% improvement might be required in the long term in order to offset the greater near term risk of a delay in implementation or realization of the habitat benefit. However, the scale of necessary habitat improvements is already very large and the feasibility of even greater long term improvements is questionable.

Another alternative is to implement greater reductions in factors with near term benefits (fisheries) in order to offset delays in realization of benefits from other factors including habitat improvements. Risk analyses presented herein provide a useful illustration of how fishery impact rates may be established as part of a time-specific implementation schedule in order to balance near term and long term recovery objectives when targets for habitat improvements cannot be met in the near term.

Working draft targets for fishery reductions might be revised based on this analysis to include both: A) long-term targets that reflect equivalent improvements if all factors are addressed on an equitable and timely manner, and B) near-term benchmarks that reflect a policy choice to implement greater reductions in order to offset the effects of delayed realization of habitat and hatchery improvements. Benchmarks could be represented as a range rather than a single value. The high end would be the same as the current values (as represented in equivalent all-H improvements reflected in strategy #1). The low end would be based on fishery levels that achieve long term risk objectives when benchmark improvements in other factors are gradually realized over a 50-year time period (as represented in the front-loaded incremental strategy reflected in strategy #3).

Benchmark ranges would be population-specific. For example, the range for the relatively small and unproductive Grays population might be from 10% to 26%. The range for the relative large and productive Cowlitz population might be 56 to 60%. It is important to note that benchmark values are not objectives but rather reference points intended to guide and focus recovery actions and to place necessary factor-specific improvements into context.

Analyses of the front-loaded incremental (#3) and equivalent all-H strategies (#1) suggest that recovery targets can be effectively achieved by timely and significant improvements in multiple factors. However, it is apparent from this analysis that a significant period of time will be required to effectively implement the suite of actions required for recovery. It may simply not be realistic to implement the scale of improvement needed to immediately reduce risks to target levels. It may be no more feasible to zero out fisheries than to achieve very large near term improvements in habitat and hatchery effects. An effective recovery strategy will achieve long term objectives at some point in time but some level of risk will necessarily be accepted in the interim. Near-term reductions in impacts will reduce risks from current levels but it will clearly take some period of time to realize long term objectives.

We note that near-term fishery reductions greater than the equivalent all-H values reflected in the June 2009 working draft of the Recovery Plan will require the fisheries to shoulder a disproportionate of the recovery “burden” in order to compensate for delays in meeting recovery objectives among other sectors. Equitable sharing was a key concept in the draft recovery planning process.

Model sensitivity analysis to the effects of fishing rate on risk highlight the diminishing benefits of fishery reductions as impacts approach low levels. Sensitivity analysis demonstrated that initial reductions in fishing from high levels produce large population benefits in reducing risk and increasing abundance. However, benefits of further reductions gradually reach a point of diminishing returns (from a risk standpoint) as too few fish are being impacted by fishing to significantly affect risk or abundance either way. This counters a common misconception that even very low rates of fishing pose high risks at low run population sizes. Lower fishing rates simply do not affect enough fish to substantially affect long term risk. A population with inherently low abundance and productivity will survive or go extinct independent of the influence of a low fishing rates because viability is limited by the low productivity. Use of modeling to identify patterns of sensitivity to changes in population parameters such as fishery impact rates is a fairly robust application of this type of life cycle analysis, and much less dependent on absolute estimates of model input values.

Analyses show that near-term risks associated with any given level of fishery impact are substantially lower than long term risks. This allows for some flexibility to consider phased impact reduction strategies over an interim period while a full complement of recovery actions is implemented.

Absolute estimates of fishing rates required to reach a specified level of risk or abundance (e.g. X%) depend on the formulation, parameters, and assumptions of the modeling analysis. A critical assumption of this analysis was that habitat and hatchery objectives will be gradually realized within the next 50 years. If habitat and hatchery improvements are greater or less than target values or take more or less time to achieve, then absolute estimates of related fishing values will vary. The other strategies evaluated in this risk analysis (#1: equivalent all-H, and #2: fishery only) provide sideboards on the degree of potential differences in target fishery impacts related to differences in the timing of implementation of improvements in other factors.

This analysis did not directly consider the effects of continuing contributions of hatchery-origin fish to natural production but the fact that some level of hatchery contribution is expected to continue must be considered in the interpretation of analysis results. This analysis estimated risks expected for natural populations in the absence of significant continuing hatchery contributions. Hatchery contributions will effectively reduce demographic extinction risks in the near term by increasing numbers above levels that would be achieved if hatchery-origin natural spawners were excluded. Thus, this analysis overestimates demographic risks in the near term where significant numbers of hatchery-origin fish continue to contribute to natural production. Of course, the continuing presence of hatchery fish will also delay the realization of productivity improvements needed to meet long turn recovery goals. These tradeoffs warrant careful consideration in the design of an effective temporal recovery strategy.

Analyses also suggest that small differences in fishery impacts on the order of plus or minus 3-5% do not appreciably affect either short term or long term risk as impacts are reduced to moderate or low levels. Thus the effects of small differences in fishery impacts (e.g. 32%, 35% or 38%) are marginal in comparison with the significance of the need to implement substantive habitat improvements in a timely fashion in order to meet long term viability objectives. This provides some flexibility to tailor fishery impact reduction strategies to the reality and needs of the specific fisheries that are affected. This analysis focused on wild population risks and did not attempt to identify fishery-specific implications of any given level of impact. We recognize that relatively small changes in allowable fishery impacts can have a very large effect on fishery opportunity and access to hatchery and healthy wild stocks.

Note that recovery objectives are fundamentally identified based on risk. Abundance targets identified in the recovery plan were derived based on levels estimated to achieve objective risk levels in conjunction with corresponding productivity, spatial structure, and diversity improvements. Analyses demonstrate that simply meeting abundance objectives without corresponding increases in underlying habitat productivity does not meet the population viability objectives. Marginal benefits of increasing escapement to the theoretical capacity of the existing habitat are very low when habitat quality is poor.

This analysis example focuses on a fixed harvest rate analysis but a similar approach can be used to evaluate mark-selective, abundance-based, or phased reduction fishery strategies. The analysis evaluated population-specific fishery effects which might also form the basis for the development of population-specific fishery strategies. For instance, populations that can support greater fishery impacts might be subject to greater impacts in terminal fisheries focused on hatchery fish. Populations lower in the basin (Grays) might also be subject to lower fishery impacts than populations higher in the basin (Washougal) where they must transit a larger portion of Columbia River mainstem fisheries. Thus, while this analysis broadly discusses aggregate fishery impact rates, it potentially oversimplifies the time and area potential to implement more population-specific objectives.

While this analysis was largely focused on the fishery implications of different recovery strategy implementation schedules, results also inform habitat and hatchery implementation planning. This approach considered the fishery implications of a gradual improvement schedule of benefits equal to benchmark values for habitat and hatchery improvements realized over a 50-year period. More specific analyses of habitat and hatchery actions can test whether this assumption is realistic. Risks corresponding to other implementation schedules can also be analyzed in a similar fashion. We note that analysis of recovery strategies involves two separate but related questions: 1) how and when does any given suite of actions affect fish population parameters related to viability, and 2) how do these population-level effects translate into viability based on risk, and productivity objectives. Population Viability Analysis models including PopCycle are well suited to evaluate population-level risk. Detailed analysis of action effects is better suited to other mechanistic modeling tools such as EDT or AHA. It can be tempting to try to roll both of these steps into one comprehensive model but this runs the risk of creating too many moving parts to effectively parameterize and interpret. A more compartmentalized and stepwise approach to these analyses is recommended.

Analysis of factor-specific implementation schedule alternatives using the PopCycle model and input data had the benefit of providing a consistent analytical framework with the Recovery Plan assessment of status and objectives. Use of a different model formulation and/or different input data could potentially provide different absolute estimates of abundance and risk under any given recovery strategy. However, the relative effects of factor-specific implementation schedules on risk would be expected to be similar in alternative models using a similar stochastic, stock-recruitment based life cycle, population viability analysis approach. Additional modeling would be useful to further explore the sensitivity of these conclusions to alternative treatments. We always want to assure that model conclusions are robust and not unique to peculiarities of any given formulation. However, where alternative models are applied, critical steps in understanding any differences in results will include: 1) complete documentation of model relationships, inputs, and assumptions, 2) comprehensive sensitivity analyses to evaluate model performance, 3) careful calibration and cross validation of results to existing empirical data, and 4) side-by-side model comparisons using equivalent inputs to identify systematic differences in results. These can be difficult and time-consuming tasks but their importance to the development of transparent and defensible analysis results cannot be overstated.

Ultimately, one of the greatest values of model analyses like these is that they force clear articulation of the questions of concern and standards or criteria by which answers will judged. At a minimum, this analysis provides one example of how alternative recovery implementation strategies can be analyzed using life cycle modeling tools.