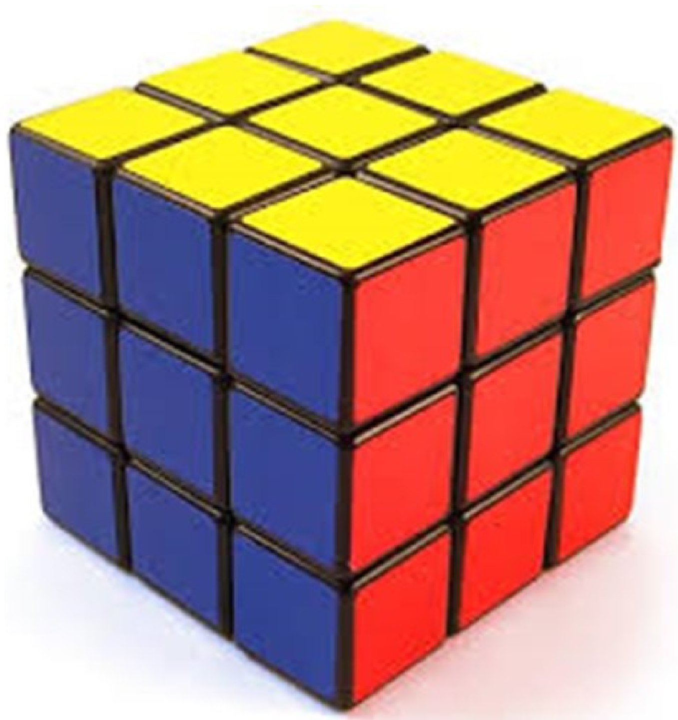
REVIEW OF ALLOWABLE FISHERY IMPACTS TO LOWER COLUMBIA RIVER NATURAL COHO

Lower Columbia Natural Coho Workgroup Report

Working Draft Analyses



August 17, 2014

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1 INTRODUCTION

Lower Columbia natural (LCN) coho were listed as threatened under the Endangered Species Act (ESA) in 2005. Ocean and Columbia River salmon fisheries are regulated in part to limit exploitation rates on this stock. Harvest control rules are based on an abundance-based matrix approach which identifies allowable fishery impacts based on parental spawner escapement and marine survival. The current LCN harvest matrix has been in place since 2006 when NMFS completed a biological consultation for this ESU following listing under the federal ESA in 2005. Current fishing levels were effectively established in 2006 and 2007 when NMFS implemented further reductions under federal rules relative to those in place since 2001 under state rules. A more conservative strategy was adopted, in part due to the limited amount of data on status of LCN natural coho population upon which the previous strategy was based. Since that time, formal recovery plans including LCN coho have been adopted (LCFRB 2010; ODFW 2010; NMFS 2013) and new information on stock status has also been collected.

Table 1. Harvest management matrix for LCN coho showing fishery exploitation rates based on parental escapement and marine survival index.

Parental Escapement (% of full seeding)		Marine Survival Index (based on return of jacks per hatchery smolt)			
		Critical (<.08%)	Low (<.15%	Medium (<.40%)	High (>.40%)
High	>0.75	<8%	<15%	<30%	<45%
Medium	0.75 to 0.50	<8%	<15%	<20%	<38%
Low	0.50 to 0.20	<8%	<15%	<15%	<25%
Very Low	0.20 to 0.10	<8%	<11%	<11%	<11%
Critical	<0.10	0-8%	0-8%	0-8%	0-8%

The Council began a review process of current LCN harvest control rules in 2013. The 2013 salmon methodology review included a risk analysis of LCN coho harvest policy (November 2013 Briefing Book, Agenda Item C.2.s, Attachment 2, available on the Council web site). At the November 2013 Council session, the Scientific and Statistical Committee suggested improvements and found the risk analysis to be “sound” and “suitable for ranking the relative risk of various harvest scenarios.” The Salmon Advisory Subpanel (SAS) recommended additional review and deliberations with stakeholders. The Council agreed, and formed the ad hoc Lower Columbia Natural Coho Workgroup (LRC Workgroup) to further explore existing and alternative harvest policies, working closely with the SAS as had been the case in developing a new control rule for the lower Columbia River natural tule Chinook stock.

At its March 2014 meeting, the Council appointed LRC Workgroup members representing primarily technical and policy staff from State, Federal, and Tribal agencies. The work group was directed to provide guidance on the development of alternative harvest control rules bringing new information on stock status into risk analyses and policy decisions made about a decade ago. The LRC Workgroup was expected to work closely with the SAS. This report summarizes new information, technical analyses developed by the LCN Work Group.

2 Lower Columbia Coho Status

2.1 Columbia River Run

Hatchery-origin fish comprise the large majority of the lower Columbia River coho run. Numbers can vary substantially from year-to-year as coho encounter widely-varying conditions for marine survival related to environmental conditions particularly including coastal upwelling.

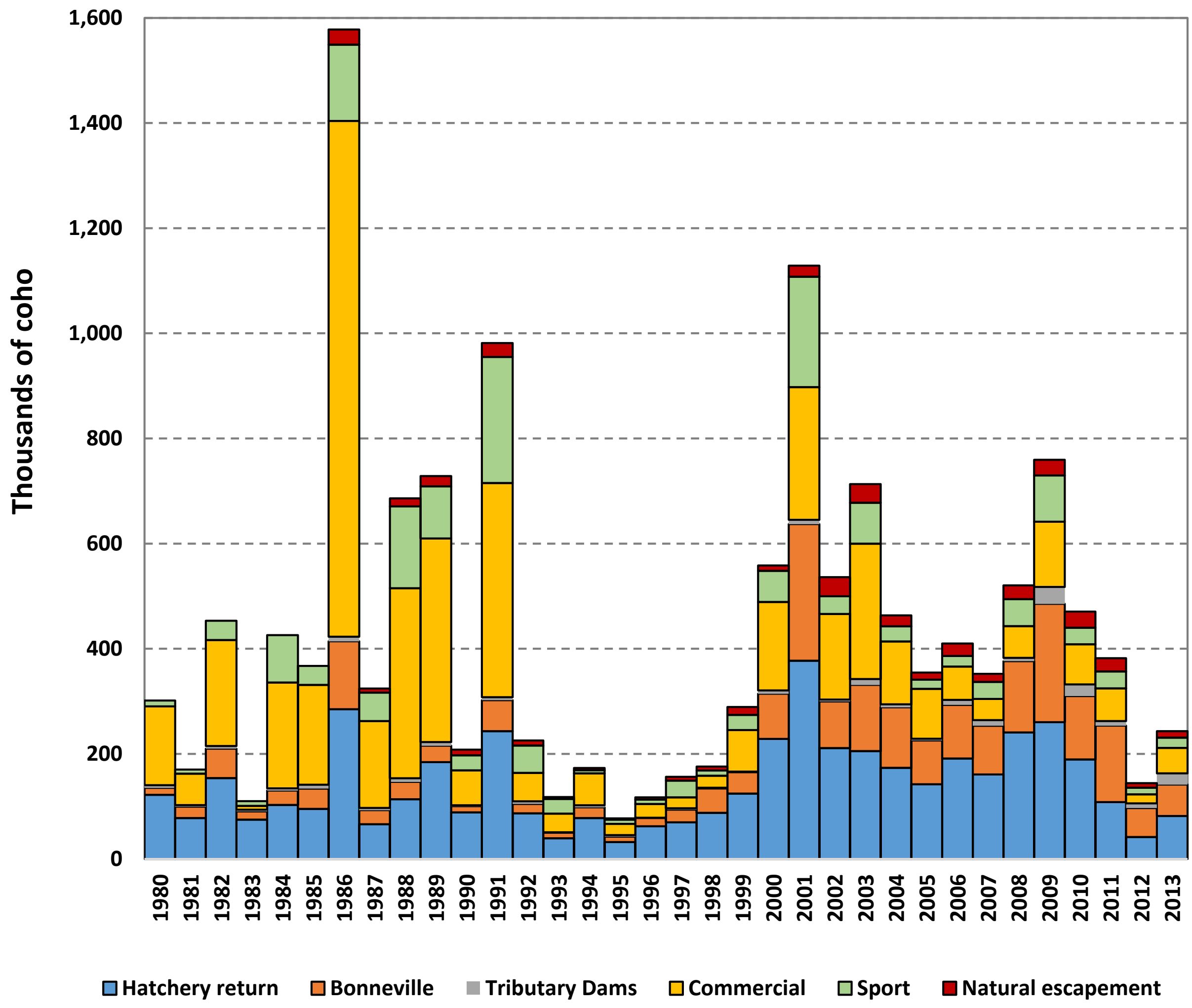


Figure 1. Columbia River return of coho, 1980-2013.

2.2 Lower Columbia River Natural

Salmon recovery plans adopted by Washington, Oregon, and NMFS, identify recovery objectives for LCN coho that designate a subset of all populations as primary targets for restoration to high levels of viability based on abundance, productivity spatial structure and diversity. A total of 16 of the 24 lower Columbia populations were identified in recovery plans as primary populations. The remainder were identified as contributing populations where recovery measures are expected to result in some improvement, or as stabilizing populations where measures are expected to prevent further declines. Of the primary populations, at least three were identified in each of the three spatial strata within the ESU. Primary populations of coho will require some of the most significant improvements in status, hence, will be most constraining to a viable recovery fishing strategy.

Previous application of the coho harvest matrix was based on Sandy and Clackamas coho which are two of the stronger populations in the ESU and the only two for which long-term stock assessment data were available. Over the last five to ten years, data has been collected on the status of additional natural populations.

Figure 2. Lower Columbia River coho populations – dark shading denotes "primary" populations identified in recover plans for improvement to high levels of viability.

Table 2. Lower Columbia River coho populations, recovery plan designations, stock assessment data availability, and stock-recruitment parameters for populations included in risk assessment. Seeding and stock-recruitment parameters are as reported in Kern and Zimmerman 2013 except Oregon population values are updated to include 2013 data.

	Population	State	Recovery Designation	Data years	Full seeding	Stock-recruit param.	
						Prod.	Capacity
Coast	Grays/Chinook	WA	Primary	2011-2012	1,100	2.09	1,500
	Eloch/Skam	WA	Primary	2011-2012	2,400	2.93	3,200
	Mill/Ab/Germ	WA	Contributing	2011-2012	--	--	--
	Youngs	OR	Stabilizing	2002-2013	--	--	--
	Big Creek	OR	Stabilizing	2002-2013	--	--	--
	Clatskanie	OR	Primary	2002-2013	1,200	5.33	3,400
	Scappoose	OR	Primary	2002-2013	1,200	2.21	4,400
Cascade	Lower Cowlitz	WA	Primary	2011-2012	3,900	3.50	5,400
	Upper Cowlitz	WA	Primary	2011-2012	--	--	--
	Cispus	WA	Primary	2011-2012	--	--	--
	Tilton	WA	Stabilizing	2011-2012	--	--	--
	Toutle SF	WA	Primary	2011-2012	3,200	2.43	5,000
	Toutle NF	WA	Primary	2011-2012			
	Coweeman	WA	Primary	2011-2012	900	2.64	1,500
	Kalama	WA	Contributing	2011-2012	--	--	--
	NF Lewis	WA	Contributing	2011-2012	--	--	--
	EF Lewis	WA	Primary	2011-2012	600	2.28	1,000
	Salmon	WA	Stabilizing	2011-2012	--	--	--
	Washougal	WA	Contributing	2011-2012	--	--	--
	Clackamas	OR	Primary	1974-2013	3,800	3.62	3,600
	Sandy	OR	Primary	1984-2013	1,300	4.18	1,500
Gorge	L Gorge	WA/OR	Primary	2011-2012	--	--	--
	U Gorge	WA	Primary[1]	--	--	--	--
	U Gorge/Hood	OR	Contributing	2002-2013	--	--	--

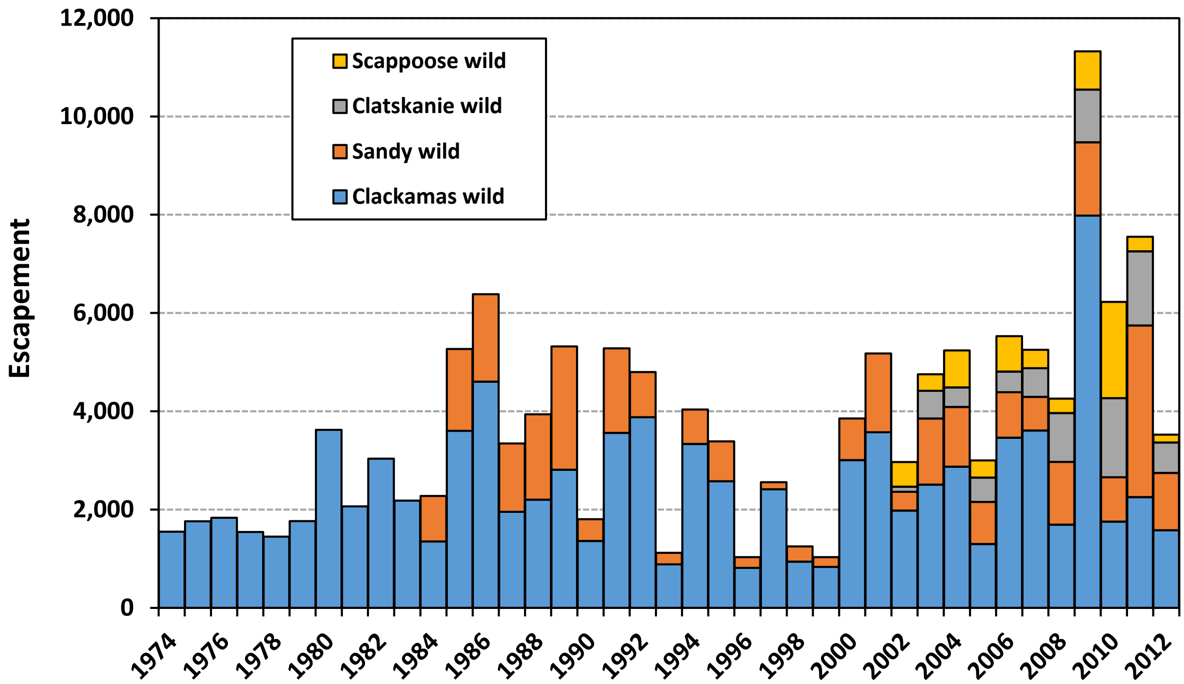


Figure 3. Escapement of LCN coho in selected Oregon tributaries. (Not all populations were surveyed in every year.)

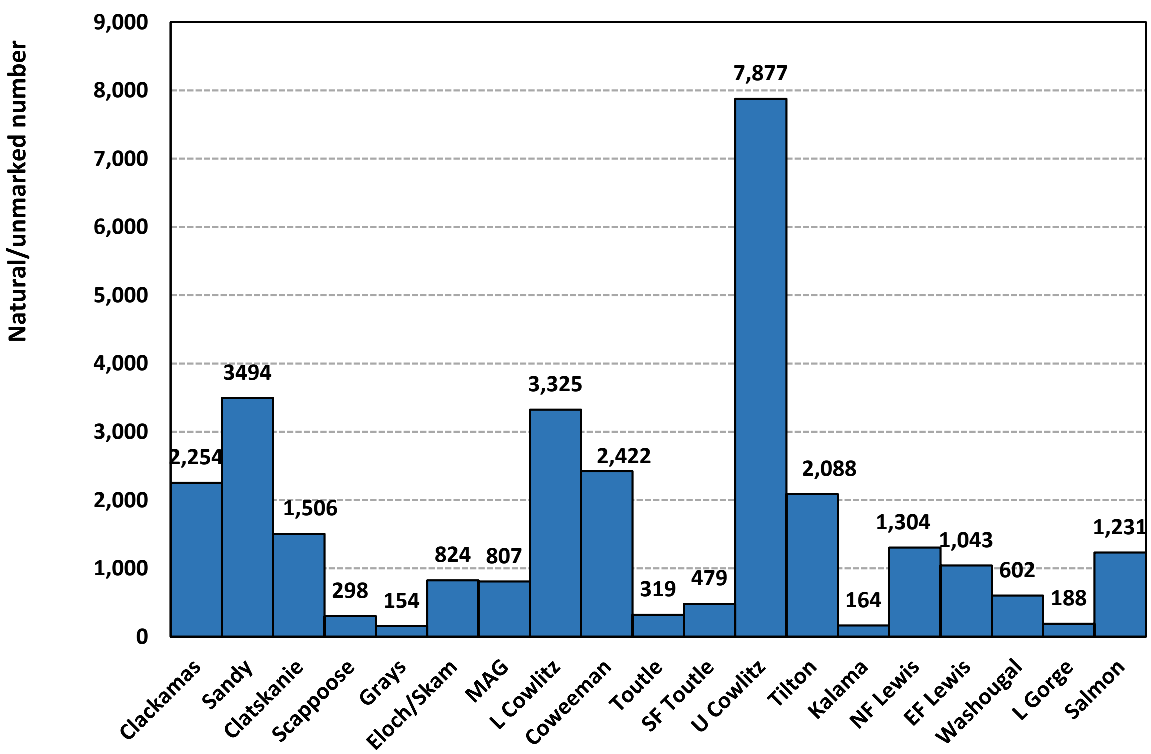


Figure 4. LCN coho abundance data by population for 2011.

2.3 Willamette coho

The Work Group reviewed current information on Willamette coho prepared by ODFW and NMFS. Willamette River tributaries upstream from Willamette Falls currently support naturally-produced coho that have often been the largest return of natural coho in the lower Columbia in recent years. Willamette coho were not included in the listed ESU, primarily because access was historically blocked by Willamette Falls. However, a naturally-producing population has become established following decades of hatchery releases, which were discontinued after 1996. Ladder counts at Willamette Falls provide some of the most accurate information on status of a naturally-producing coho population in the region.

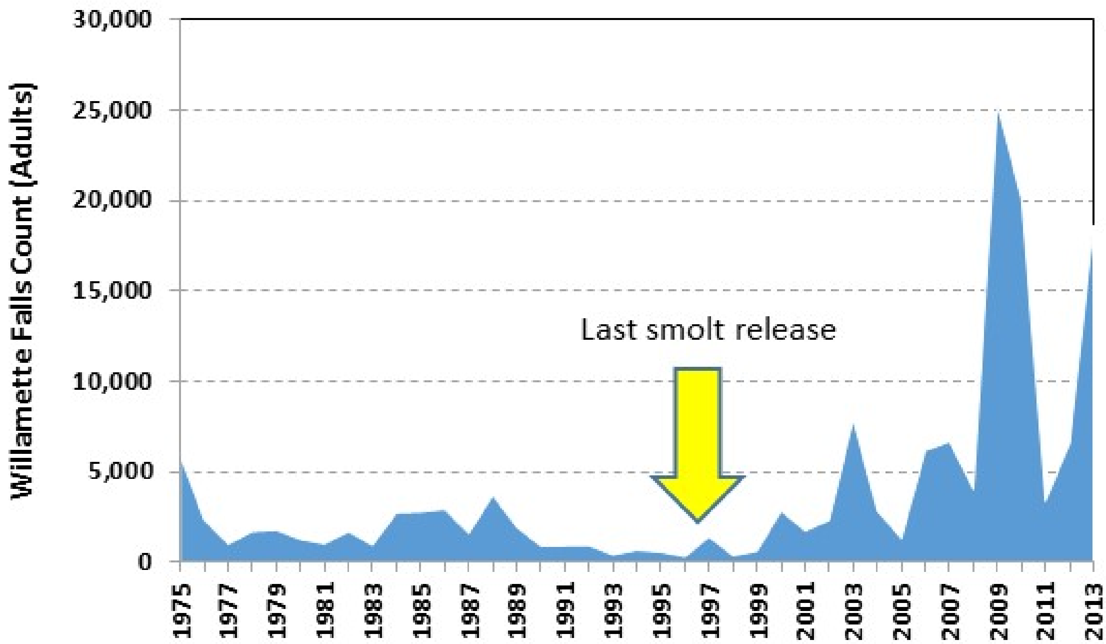


Figure 5. Willamette Falls coho counts.

The appropriate status of Willamette coho relative to the listed ESU and coho recovery goals has been debated by some. On the one hand, this population is not part of the ESU because it has colonized streams where it is not native. On the other hand, it appears to be a viable naturally-producing population which is the goal for the ESU.

The work group suggests that status of Willamette coho might inform our understanding of population dynamics and response to recent fishing patterns but does not change the need to develop effective fishing alternatives for management of listed coho populations throughout the designated ESU. The degree to which the Willamette population might be considered representative of other coho populations in the ESU is unknown. NMFS will review the classification of Willamette coho as part of the next formal 5-year status review scheduled for 2016. **<u>NMFS advises that their consultation will be based on the current ESU. Willamette coho is not part of the ESU. Therefore, NMFS will not use Willamette information in writing the Biological Opinion.</u>**

3 LCN Exploitation Rates

Annual exploitation rates of LCN coho have been substantially reduced from very high historical levels as management has shifted from maximizing harvest of hatchery fish to protecting natural populations. LCN coho are harvested in a wide range of marine and freshwater fisheries in Washington and Oregon as well as Canada.

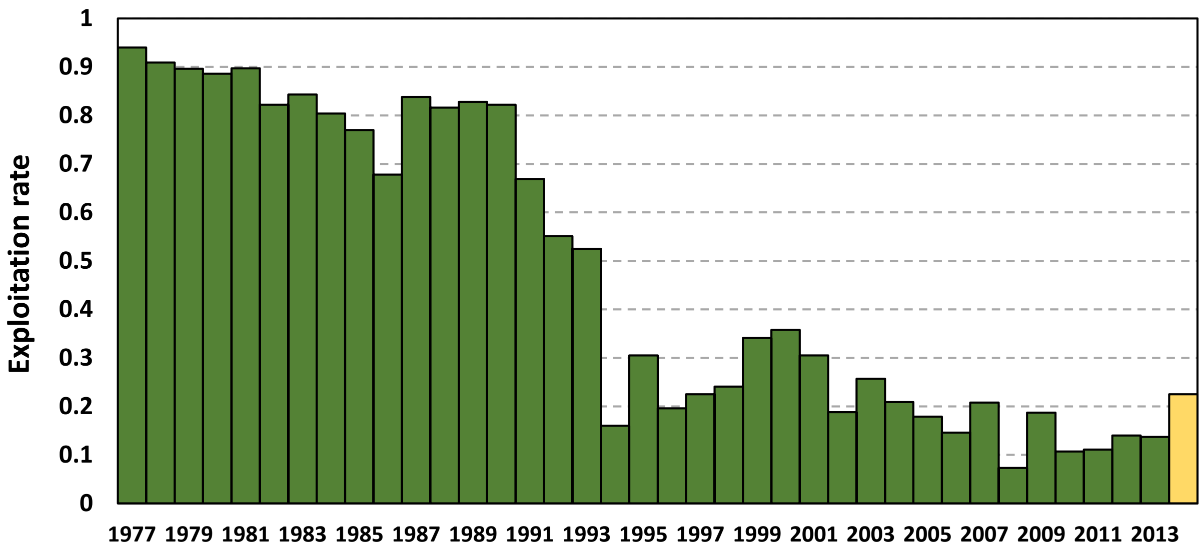


Figure 6. Annual exploitation rates of lower Columbia River natural coho, 1977-2013. The 2014 value is the preseason number.

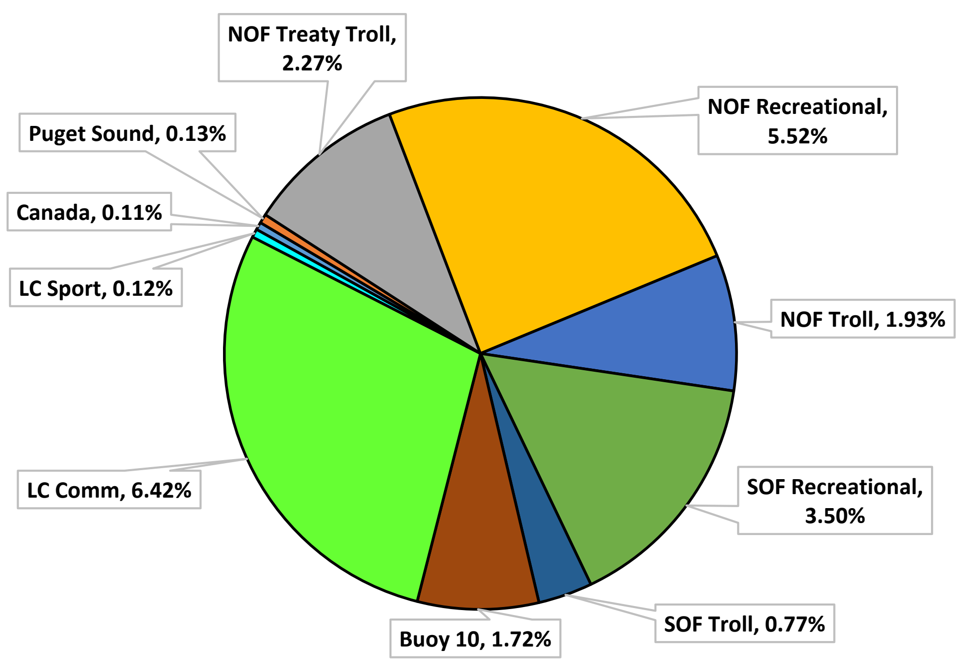


Figure 7. Distribution of expected 2014 fishery impacts on lower Columbia River natural coho salmon.

During recent years, exploitation rates have been limited from 8 to 22.5%. Exploitation rate has been limited to 15% in six of the last ten years. The weighted average exploitation rate during this period was 16%. Post-season rates have averaged approximately 1% less than pre-season limits during this period.

Relatively small differences in fishing rate limits can have substantial implications to fishery opportunity. For instance, fishing rates can be identified in the ocean or Columbia River fisheries corresponding to no coho target fisheries, full coho retention fisheries, and maximum potential rates given other constraints.

Table 3. Lower Columbia Natural adult coho conservation objectives and fishery impacts.[a]

Year	Objective	Pre-season	Post- season
2005	≤0.15	0.10	0.179
2006	≤0.15	0.10	0.146
2007	≤0.20	0.13	0.208
2008	≤0.08	0.08	0.073
2009	≤0.20	0.20	0.187
2010	≤0.15	0.15	0.107
2011	≤0.15	0.15	0.111
2012	≤0.15	0.15	0.14
2013	≤0.15	0.15	0.137
2014	≤0.225		
Avg.		*0.134*	*0.143*

[a] *rates do not include Columbia River tributary fisheries.*

Table 4. Frequency occurrence of specific conservation objectives for LCN coho, 2005-2013.

Rate	N	Frequency
8%	1	10%
15%	6	60%
20%	2	20%
22.5%	1	10%

Table 5. Fishery implications of conservation objectives.

Exploitation Rate	Fishery
10%	No retention
10-20%	Mark-selective
20-25%	Coho target
30%	Maximum usable

4 ANALYSIS OF CURRENT MATRIX EFFICACY

The current harvest control rule is based on a matrix approach that determines allowable fishery impacts based on parental spawner escapement and marine survival. This matrix is complex, including specific harvest rates for 20 combinations of five escapement and four survival index categories. This complexity makes it difficult for managers and fishers to understand and evaluate the implications of different alternatives.

The Work Group examined the technical basis of the general matrix strategy and the specific definition of categories. Based on this examination, it was concluded that the current matrix complexity may not be necessary or entirely effective. Harvest rates are the same for many matrix cells and several categories and cells seldom or never occur. Natural coho abundance and recruits per spawner was strongly correlated with a marine survival index based on hatchery jacks/smolt, so there is a justifiable rationale for a related abundance-based harvest strategy. However, abundance was weakly related to parental escapement which calls into question the definition of five parental escapement categories, particularly since natural coho escapement is also measured with substantial error in most populations.

4.1 Marine Survival Index

Marine survival of LCN coho is highly variable. The high marine survival category (>0.4%) has not been achieved by LCN coho. Returns of lower Columbia hatchery adult coho are highly correlated with the marine survival index based on jack returns per smolts – this indicates that this MSI provides a relatively robust forecast of adult returns and hence, marine conditions which likely affected both hatchery and wild coho.

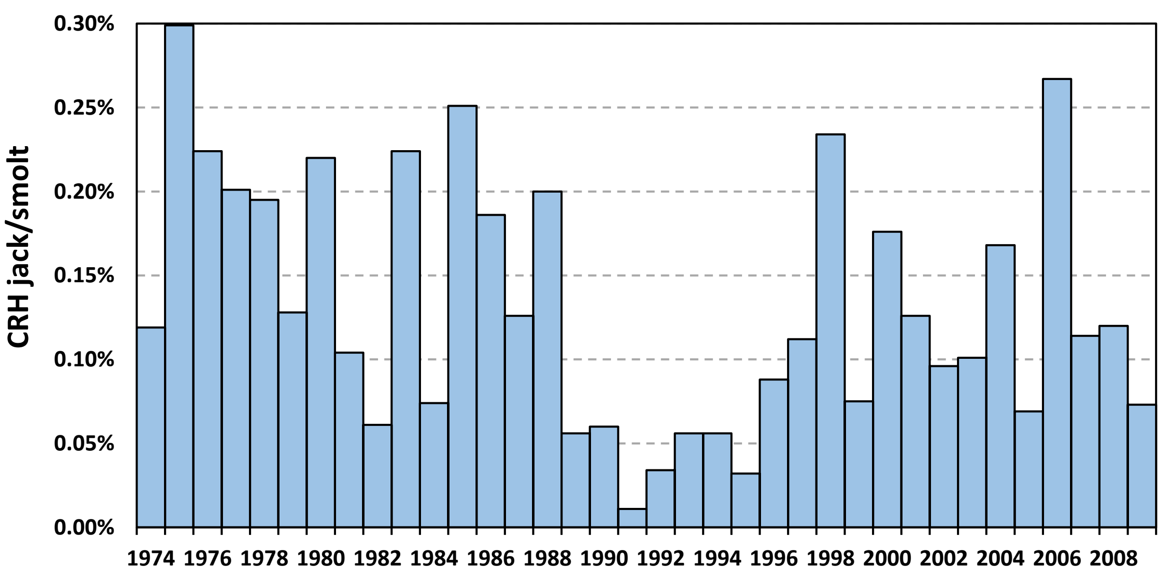


Figure 8. Marine survival index based on the percentage return of hatchery smolts returning after one year in the ocean as jacks, 1974-2009.

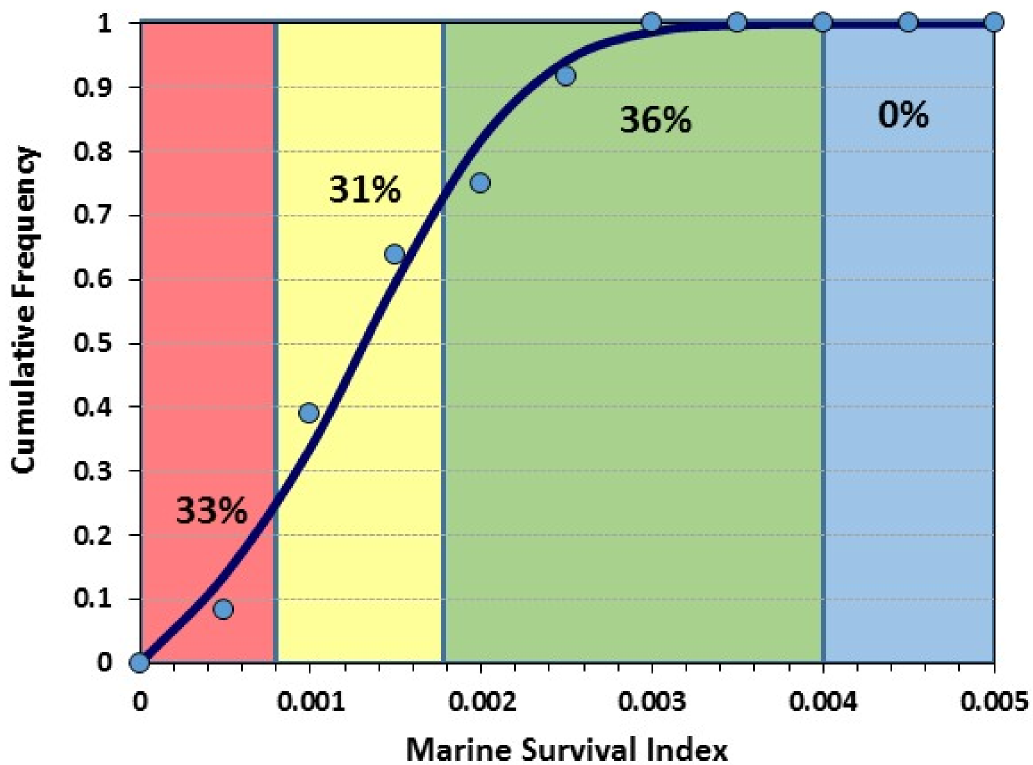


Figure 9. Cumulative frequency distribution of Columbia River hatchery coho marine survival index, 1974-2009. Categories identified in the LCN coho harvest matrix are identified along with observed frequencies for each category.

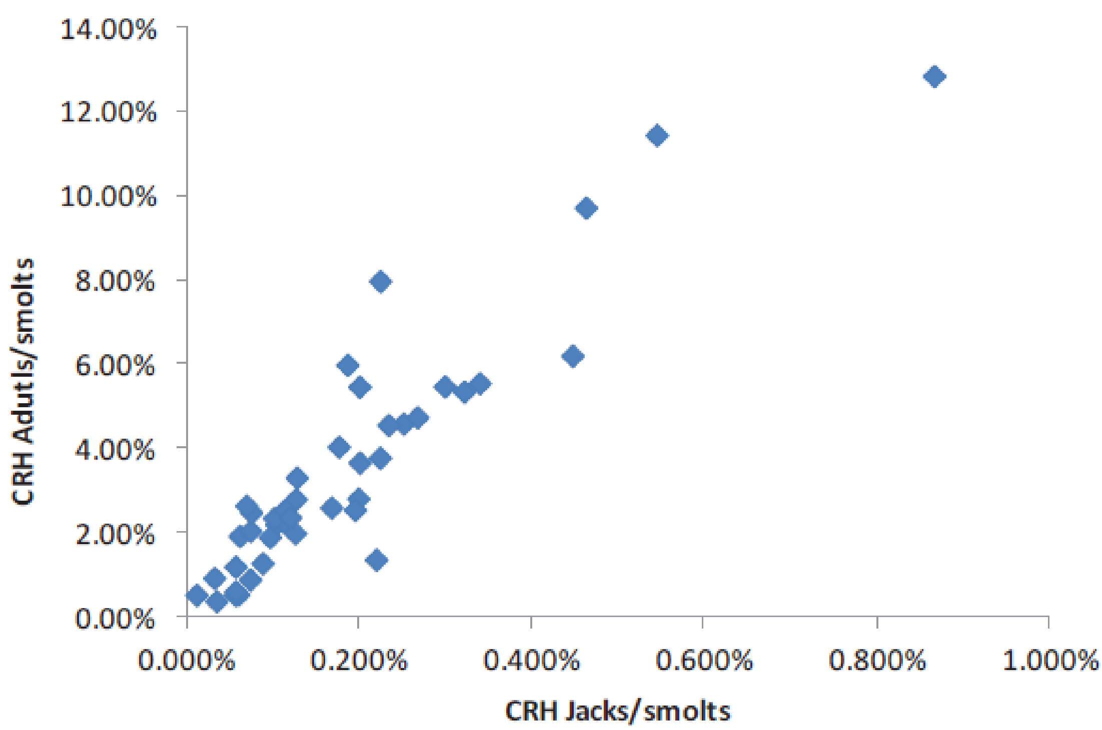


Figure 10. Relationship between returns of Columbia River hatchery jacks and adults in the following year, 1974-2009.

4.2 Population Seeding Levels

Spawner abundance is very weakly correlated with subsequent returns for LCN coho populations where data is sufficient to evaluation these relationships. Marine survival index counts for a much larger proportion of the variability in return. This pattern is commonly seem among coho populations throughout the eastern Pacific.

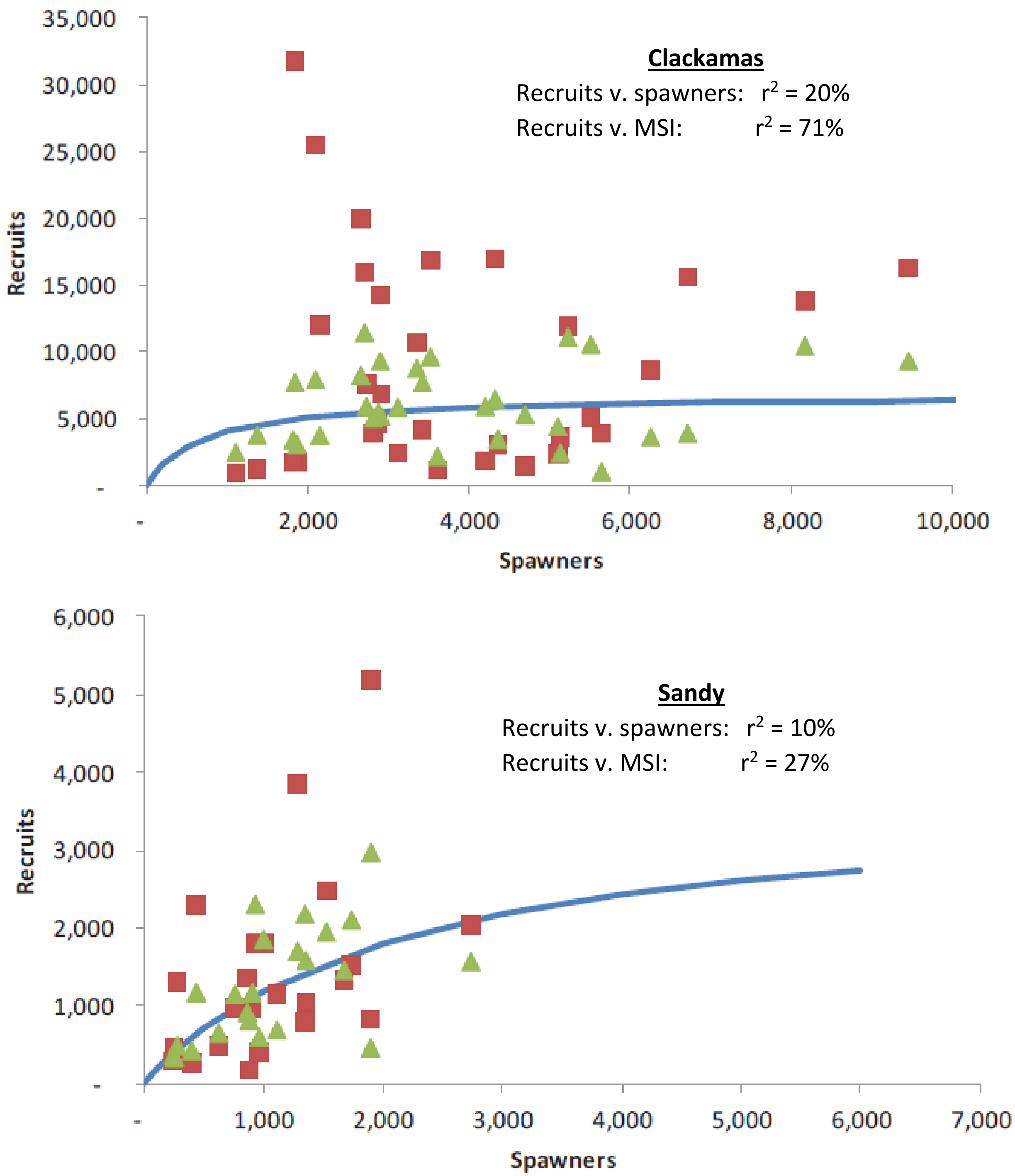


Figure 11. Stock-recruitment relationships for Clackamas (top) and Sandy (bottom) natural coho populations (Kern and Zimmerman 2013).

Seeding levels of less than 40% of full seeding estimates are rarely if ever observed among lower Columbia River coho populations. In part, this reflects the low capacity and productivity of these populations in the current habitat conditions.

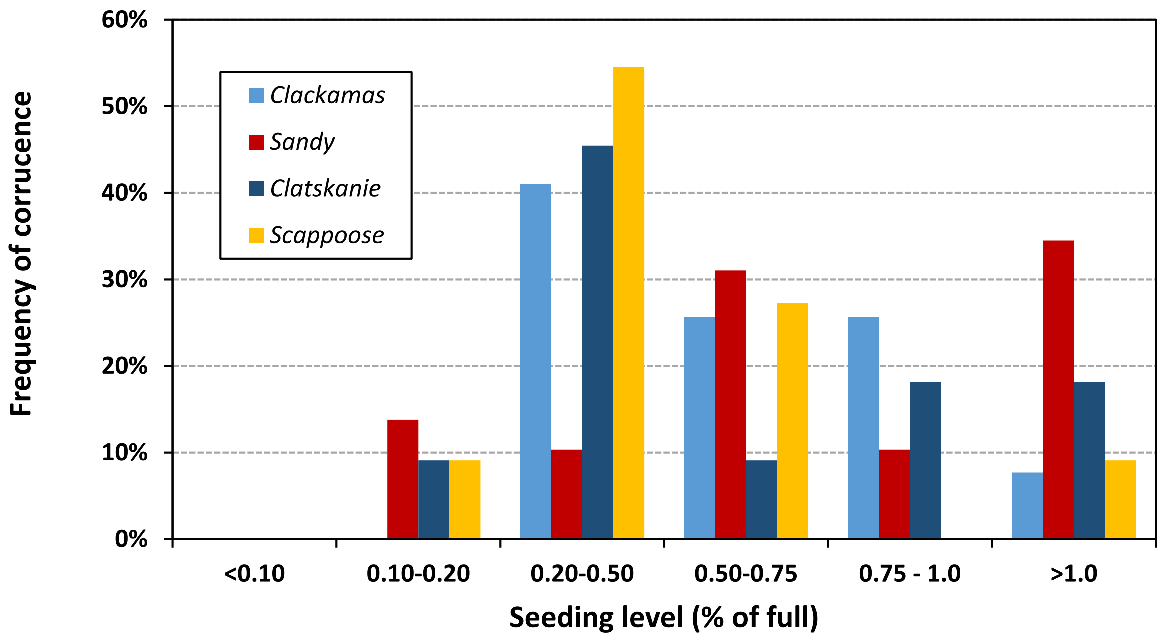


Figure 12. Frequency distribution of seeding relative to full seeding levels for Oregon LCN populations, 1974-2012 (as available).

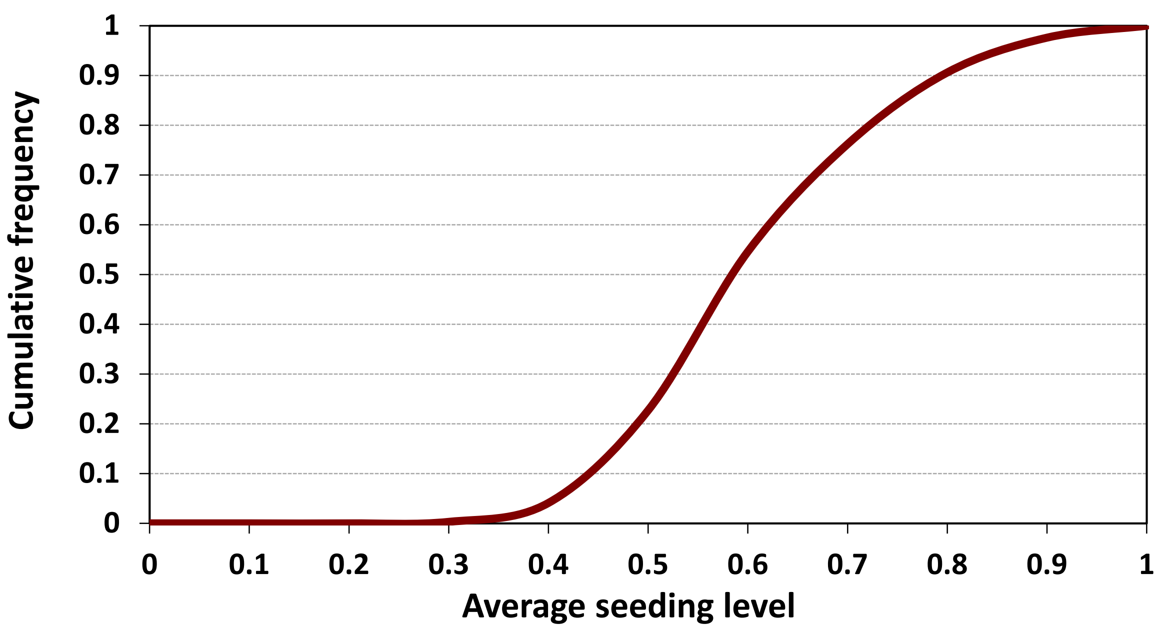


Figure 13. Cumulative frequency distribution for average seeding level of selected primary LCN coho populations in risk assessment model simulations based on historical stock-recruitment data and normal variation in marine survival. Populations include Clatskanie, Scappoose, Elochoman/Skamokowa, Grays/Chinook, Clackamas, Sandy, L Cowlitz, Toutle, Coweeman, and EF Lewis.

4.3 Cell Frequency of Occurrence

Many cells in the current matrix are rarely or never utilized because cell thresholds were based on values which have not been observed in the historical data. Prospective projects using the risk model indicate that many cells will not be utilized under normal variation in parental seeding or marine survival. Historical threshold values were based on fish population dynamics theory and the best available data at the time. However, subsequent analysis based on empirical data indicates that the historical matrix design is unnecessarily complicated and may not achieve the desired effects.

Table 6. Projected frequency of occurrence of combinations of marine survival and parental seeding level (average of all populations) under the current matrix.

Parental Escapement (% of full seeding)		Marine Survival Index (based on return of jacks per hatchery smolt)			
		Critical (<.08%)	Low (<.15%	Medium (<.40%)	High (>.40%)
High	**>0.75**	6%	11%	8%	0%
Medium	**0.75 to 0.50**	16%	29%	20%	0%
Low	**0.50 to 0.20**	3%	5%	3%	0%
Very Low	**0.20 to 0.10**	0%	0%	0%	0%
Critical	**<0.10**	0%	0%	0%	0%

Table 7. Pros and cons for including seeding level in the harvest matrix.

Drop

- Measurement error
- Unknowns/Assumptions
- Population complexity
- Returns not strongly correlated
- Risks not sensitive
- Risk-equivalent alternatives
- Simplify application

Keep

- Established practice
- Stock-recruitment theory
- Perception value

5 RISK ASSESSMENT

Conservation risks associated with alternative fishing strategies were analyzed with the same methodology developed by ODFW and WDFW for LCN coho in 2013 using an adaptation of the Lower Columbia River tule fall Chinook risk model.

5.1 Methodology

5.1.1 Model Description

The model analyzes effects of fishing on natural population status using a stochastic stock-recruitment model in a Population Viability Analysis framework like that employed in salmon ESA status assessments and recovery plans. Spawner-recruit functions and full seeding levels were developed for all populations. Methods varied depending on available data, accounting for differences between the Washington and Oregon recovery plans. Relative risk and opportunity for a range of harvest strategies and harvest matrices was evaluated using a stochastic population viability analysis (PVA). This analysis incorporated new information from eight populations, in addition to the Clackamas and Sandy populations, into the framework for evaluating alternative harvest management matrices for LCN coho.

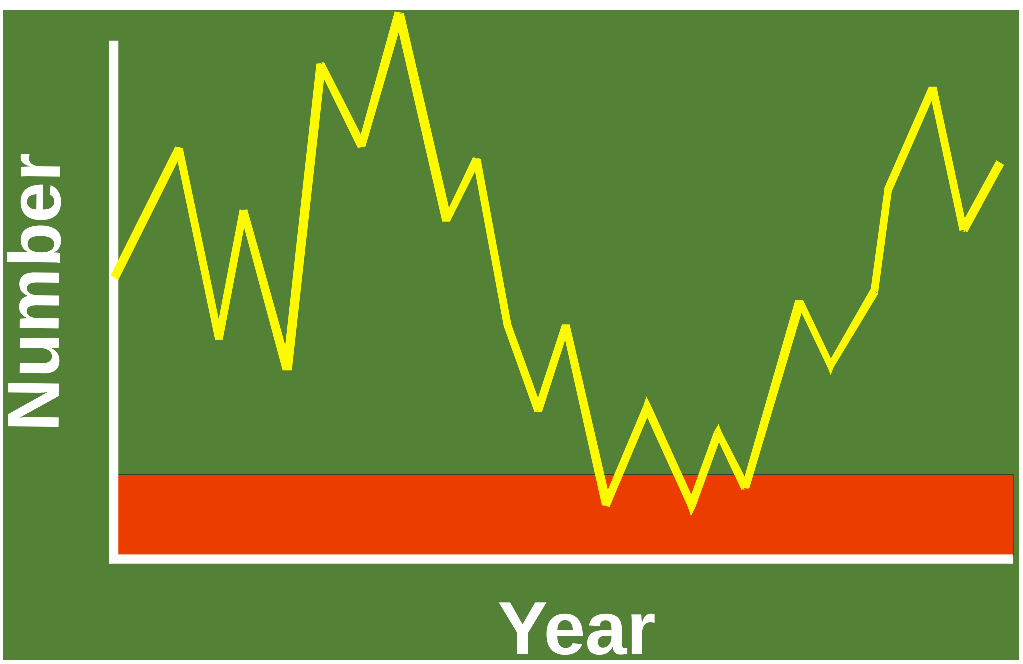


Figure 14. Population risks are assessed In the population viability analysis based on the projected frequency of falling below a critical population level of concern.

5.1.2 SSC Review of Methodology

The 2013 LCN assessment was vetted in a 2013 salmon methodology review (November 2013 Briefing Book, Agenda Item C.2.s, Attachment 2, available on the Council web site). At the November 2013 Council session, the Scientific and Statistical Committee evaluated the data reconstruction techniques used and technical aspects of the PVA. They concluded that the analysis framework is suitable for ranking the relative risk of various harvest scenarios. Numerical estimates of extinction risk from the model should be considered as index values only, and in no way represent actual probabilities of extinction. The analysis is complex, and the SSC identified several areas where alternative analytical techniques could be applied. However, the basic technique and application are sound, and relative rankings of scenarios are not likely to be greatly affected by the statistical refinements suggested.

One strength of the proposed analysis framework is that it characterizes the relative risk from alternative harvest scenarios to the entire LCN coho evolutionarily significant unit, rather than simply the two healthiest populations (the Sandy and Clackamas). The SSC recommended using the shorter 1993 to 2009 data sets for the Sandy and Clackamas populations and subsequent analyses incorporated this refinement.

The SSC noted that populations used in the analysis do not exactly match those in the Fishery Regulation and Assessment Model (FRAM) model and suggested that differences will need to be reconciled before a resulting harvest strategy can be applied. However, upon further evaluation, the LCN technical work group found that significant revisions to FRAM would not be required.

The SSC also noted that continued monitoring of LCN coho populations should help refine capacity and productivity estimates for Oregon populations and allow for empirical estimates for Washington populations. Investigation of alternative metrics to better represent marine survival of LCN coho, similar to approaches used for the OCN coho harvest matrix, were also recommended for future examination.

5.1.3 Populations Considered

Previous application of the coho harvest matrix was based on Sandy and Clackamas coho which are two of the stronger populations in the ESU and the only two for which long-term stock assessment data were available. Rates were previously indexed to Sandy and Clackamas coho seeding levels in part because data on other coho populations was quite limited. However, Sandy and Clackamas may or may not be representative of many of the weaker populations in the ESU. Therefore, reduced fishing rates were implemented as a precautionary measure for protecting significant coho populations throughout the ESU.

Since the federal listing of coho in 2005, substantial new information on the status of natural coho populations has been collected by ODFW and WDFW. This data now provides a means of conducting a formal risk assessment to demonstrate the likely effects of proposed harvest strategies as identified by NMFS in a 2011 guidance letter. This risk assessment incorporates recent data which now provides an empirical basis for assessment of representative populations in addition to the Sandy and Clackamas.

The work group assessed conservation risks of the fishery strategy based on effects on primary populations, as designated by ESA salmon recovery plans and representative of all three spatial strata of the Evolutionary Significant Unit (ESU). An essential objective of the fishing strategy for LCN coho is to avoid jeopardizing long term viability or precluding recovery of LCN coho. Primary populations include a subset of all populations as identified as primary targets for restoration to high levels of viability based on abundance, productivity spatial structure and diversity. Primary populations of coho will require some of the most significant improvements in status, hence, will be most constraining to a viable recovery fishing strategy.

Seeding levels used in matrix strategies as a basis for selecting fishing rates were based on a based on ten primary LCN populations where reasonably robust assessment data is available. These populations include Clatskanie, Scappoose, Elochoman/Skamakowa, Grays/Chinook (Coast Strata), and Clackamas, Sandy, Lower Cowlitz, Toutle, Coweeman, and East Fork Lewis (Cascade strata). Seeding level of parental escapement is expressed as a percentage of the full seeding level. Percentages greater than 100% are set at 100%. Full seeding levels for Oregon populations were defined based on a combination of stock-recruitment and habitat analyses. Full seeding levels for Washington populations were defined as equilibrium abundance in stock-recruitment parameters inferred with the Ecosystem Diagnosis and Treatment Model from assessments of the available habitat quantity and quality.

Viability risks associated with alternative fishing strategies were calculated with the model for each population. The work group compared effects of fishing strategies on LCN risk based on: 1) median risk value for all populations and 2) average risk value for the five highest risk populations among those evaluated. The five weakest populations were selected to provide a precautionary assessment of fishery-related risks. These populations were at the greatest absolute risk and the most sensitive to changes in exploitation rates. These populations were identified by model sensitivity analysis to differences in fixed exploitation rates.

5.1.4 Alternative Model Structures

The workgroup evaluated a number of alternative matrix structures as follows:

Model 1 - Current Matrix (Sandy-Clackamas Seeding)

Parental Escapement (% of full seeding)		Marine Survival Index (based on return of jacks per hatchery smolt)			
		Critical (<.08%)	Low (<.15%	Medium (<.40%)	High (>.40%)
High	>0.75	<8%	<15%	<30%	<45%
Medium	0.75 to 0.50	<8%	<15%	<20%	<38%
Low	0.50 to 0.20	<8%	<15%	<15%	<25%
Very Low	0.20 to 0.10	<8%	<11%	<11%	<11%
Critical	<0.10	0-8%	0-8%	0-8%	0-8%

Model 2 – Fixed Rate

- Same rate in every year regardless of seeding level or marine survival

Model 3 – Current Matrix (Population Average Seeding)

- Same categories and rates as Model 1.

Model 4 – 1x4 Matrix

Marine Survival Index			
Critical	Low	Medium	High
ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%

Model 5 – 1x5 Matrix

Marine Survival Index				
Critical	Low	Medium	High	V High
ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%

Model 6 – Continuous

Marine Survival Index	
Critical	Low - High
ER ≤10%	ER 10 - 30%

Model 7 – 2x5 Matrix

Marine Survival Index				
Critical	Low	Medium	High	V High
ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%
ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%	ER ≤__%

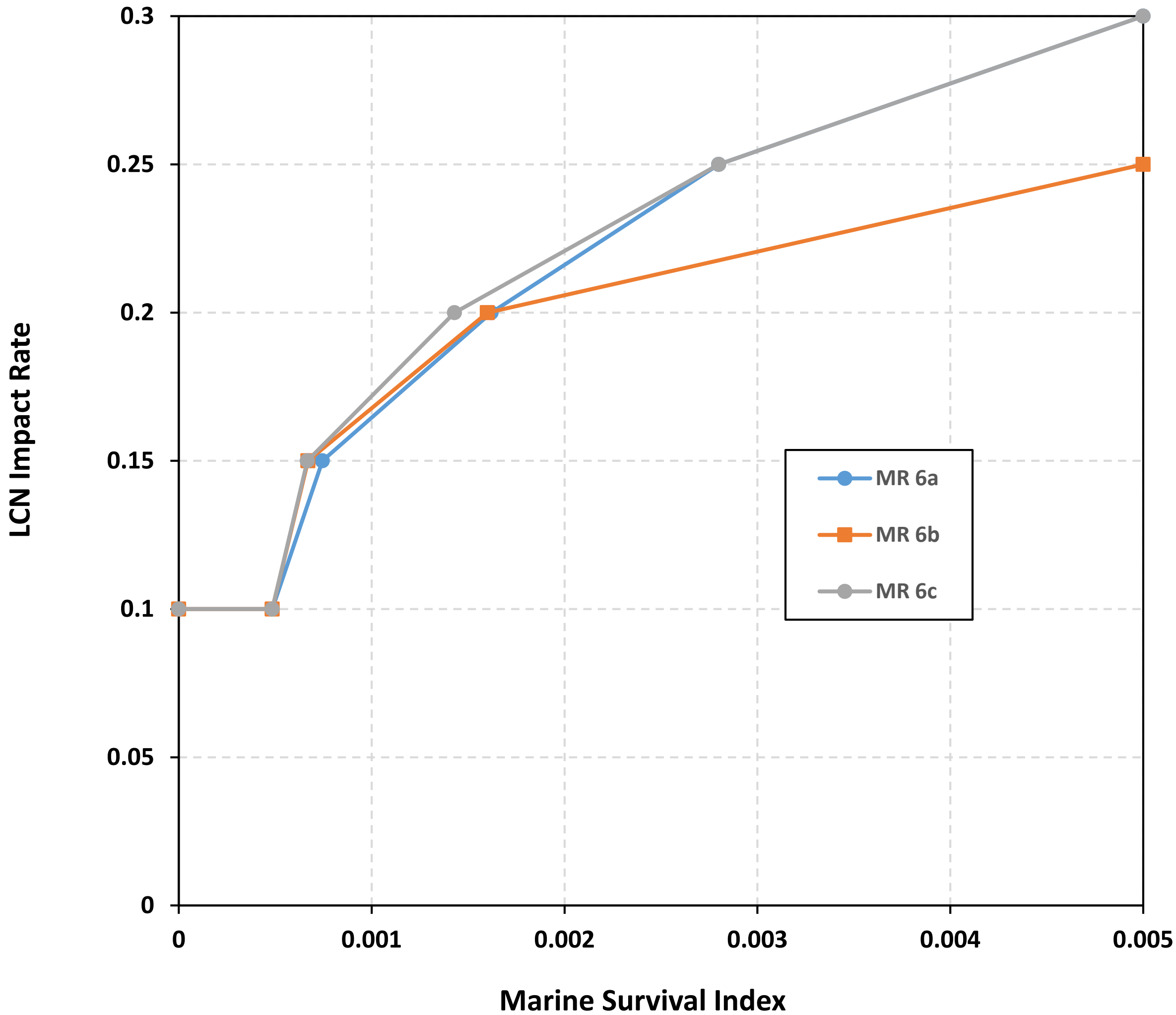


Figure 15. Examples of continuous models.

5.2 Results

5.2.1 Population risk sensitivity to fishing

Risks are relatively insensitive to fishing within the 10 to 30% range of exploitation under consideration for LCN coho for all but the smaller, less-productive populations evaluated. The median value for all populations considered in this analysis is also relatively insensitive to fishing rates in the current range due to inclusion of the larger, more productive populations in the ESU. The high risk average is more sensitive to fishing rates in the current range and represents the weaker populations among those targeted in the recovery plan for high levels of viability or substantial levels of improvement. We should also note that the ESU also includes smaller, less productive populations identified as stabilizing or contributing in the recovery plans. These populations were not modeled but will also be expected to be relatively insensitive to effects of fishing – risks will be high even when little or no fishing mortality occurs.

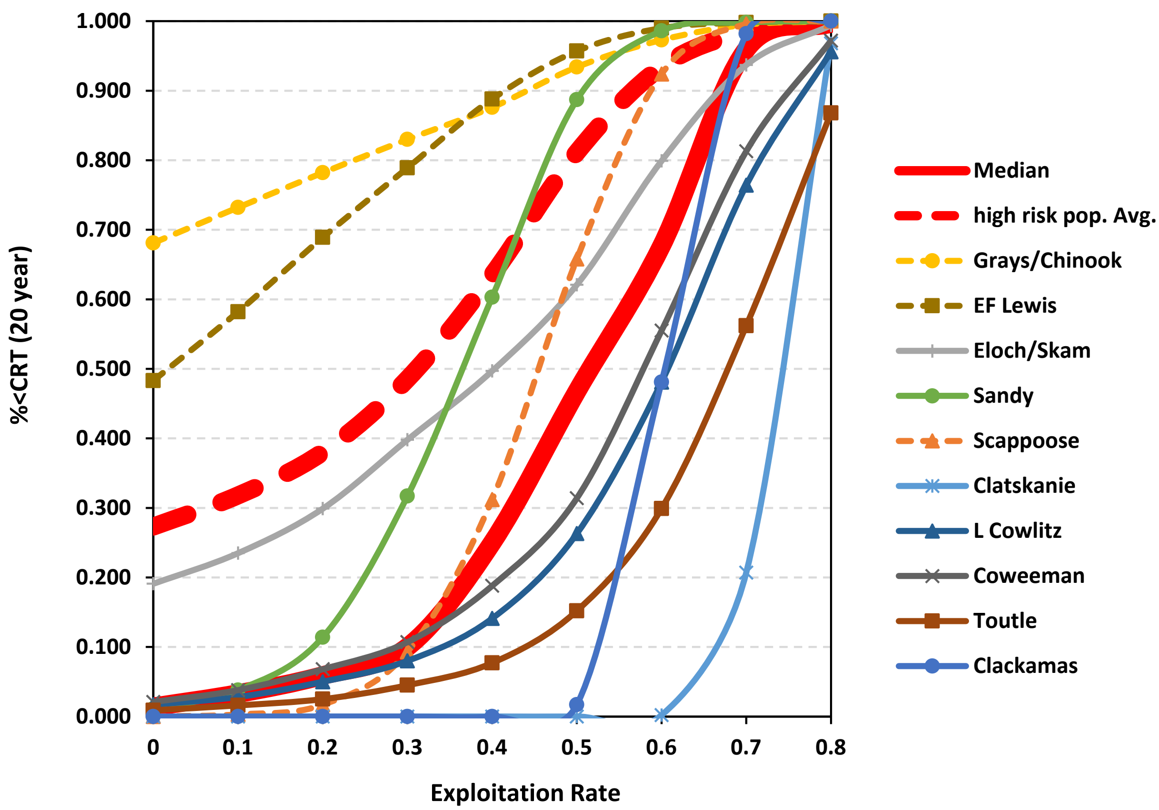


Figure 16. Population risk response to fixed annual exploitation rates and depiction of summary metrics utilized for comparison of the relative effects of alternative fishery strategies. Metrics included median risk value for all populations and average risk value for the five highest risk populations among those evaluated. Risk is based on the frequency of simulations where wild spawning escapement falls below critical levels during three successive years over a 20-year period.

5.2.2 Effects of Fishery Alternatives

1. Comparable levels of risk can be achieved with a variety of exploitation rate strategies. For instance, the current coho matrix produces population risk levels equivalent to a fixed 15-16% harvest rate. However, abundance-based management defined by a matrix approach can provide significant fishery benefits by allowing increased opportunity during large return years when risks of low escapement are negligible.
2. Neither median nor the 5-population average risks are particularly sensitive to exploitation rate strategy within the range under consideration.
3. Small levels of risk are associated with a greater frequency of higher exploitation rates in years of good marine survival indices.
4. Effective exploitation rates and risks are not particularly sensitive to low seeding levels because of a very low incidence of occurrence.
5. Risks are directly and positively correlated with effective exploitation rates.
6. It will be difficult to significantly reduce already-low fishery-related risk levels and further risk reductions would have significant fishery repercussions. Unlike tule Fall Chinook, current low fishing levels for LCN coho may not provide room for a “win-win” strategy where both reduced risk and increased flexibility can be achieved. The win-win solution was possible for Fall Chinook where fishing rates because substantially greater and within an effective range. A number of alternative fishery strategies might increase fishery opportunities with no or little effective increase in wild population risk. A key consideration will be whether marginal increases in model-derived risks relative to the current level are significant in the broader context of current coho information and status.

Table 8. Model runs.

						Effective	Risk	
Model	**No.**	**Structure**	**Rates (%)**	**Frequencies (%)**	**Seeding categories**	**ER**	**median**	**5 high**
actual	--	--	8/15/20/22.5	10/60/20/10	--	16.0%	--	--
1	a	Current (Sandy/Clack)	8/11/15/20/25/30/38+	24/0/54/17/0/5/1	0/0.10/0.20/0.50/0.75	15.1%	0.044	0.342
2	a	Fixed	0	100	--	0%	0.014	0.273
2	b	Fixed	8	100	--	8%	0.028	0.307
2	c	Fixed	12	100	--	12%	0.037	0.329
2	d	Fixed	16	100	--	16%	0.050	0.354
2	e	Fixed	18	100	--	18%	0.053	0.366
2	f	Fixed	19	100	--	19%	0.056	0.372
2	g	Fixed	20	100	--	20%	0.059	0.380
3	a	Current (all pops)	8/11/15/20/25/30/38+	24/0/48/20/0/8/1	0/0.10/0.20/0.50/0.75	15.7%	0.045	0.346
4	a	1 x 4	8/15/20/25	10/70/11/9	--	15.7%	0.046	0.350
4	b	1 x 4	10/15/20/25	10/25/60/5	--	18.0%	0.054	0.364
4	c	1 x 4	**8/15/20/25**	10/25/60/5	--	17.8%	0.054	0.363
5	a	1 x 5	8/15/20/25/30	10/65/15/5/5	--	15.7%	0.046	0.349
5	b	1 x 5	**10/15/20/25/30**	**10/35/45/5/5**	--	18.0%	0.053	0.364
5	c	1 x 5	10/15/20/25/30	**10/20/55/10/5**	--	19.0%	0.056	0.369
5	d	1 x 5	10/15/20/25/30	**10/10/55/20/5**	--	20.0%	0.059	0.377
6	a	Continuous	10/10-15/15-20/20-25/25-30	5/15/53/22/5	--	18.0%	0.054	0.363
6	b	Continuous	10/10-15/15-20/20-25/25-30	5/10/58/27/0	--	18.0%	0.054	0.363
6	c	Continuous	10/10-15/15-20/20-25/25-30	5/10/50/30/5	--	18.6%	0.055	0.368
7	5b1	2 x 5	10/15/20/25/30	= 10/35/45/5/5	--	18.0%	0.053	0.364
			10/10/15/20/25	0/100 =	**0/.3**			
7	5b2	2 x 5	10/15/20/25/30	= 14/36/40/5/4	--	17.5%	0.051	0.361
			10/10/15/20/25	12/88 =	**0/.5**			
7	5b3	2 x 5	10/15/20/25/30	= 12/39/30/5/3	--	16.3%	0.047	0.350
			10/10/15/20/25	38/62 =	**0/.6**			

Effective exploitation rate is the weighted average in all years.

Median risk includes all model populations.

5-high risk is the average for the 5 highest risk and most sensitive model populations.

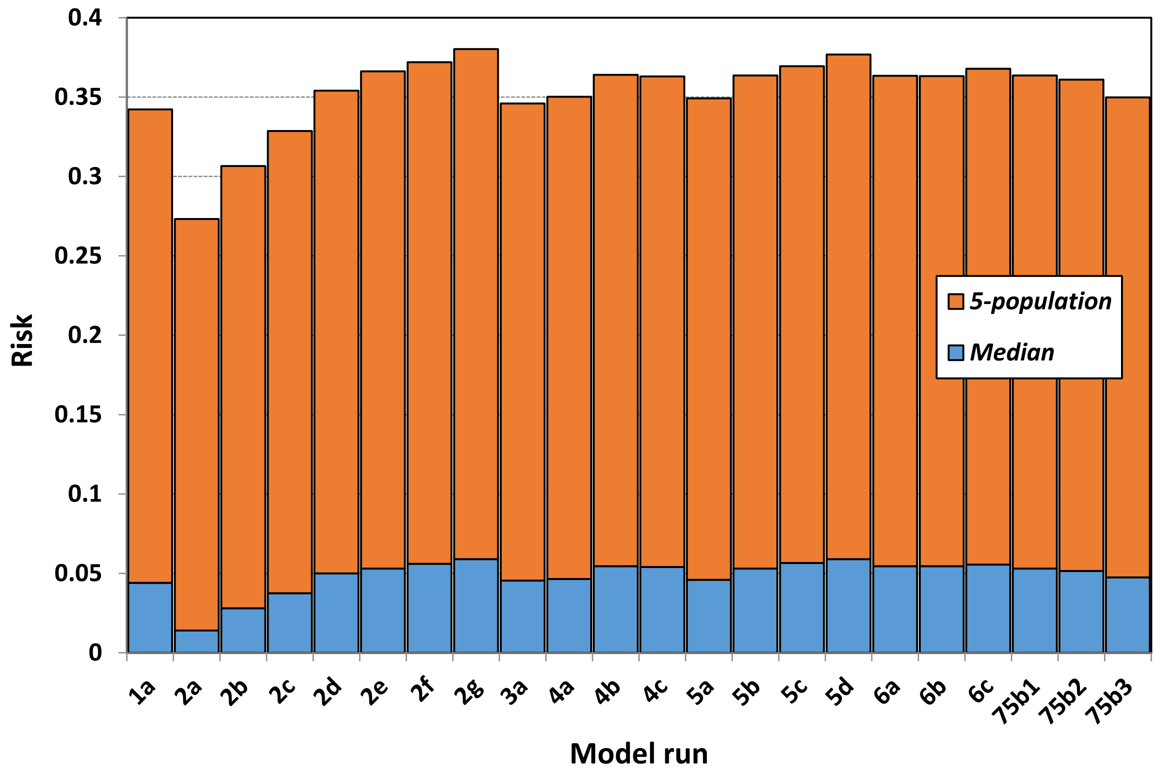


Figure 17. LCN population risks corresponding to alternative exploitation rate strategies.

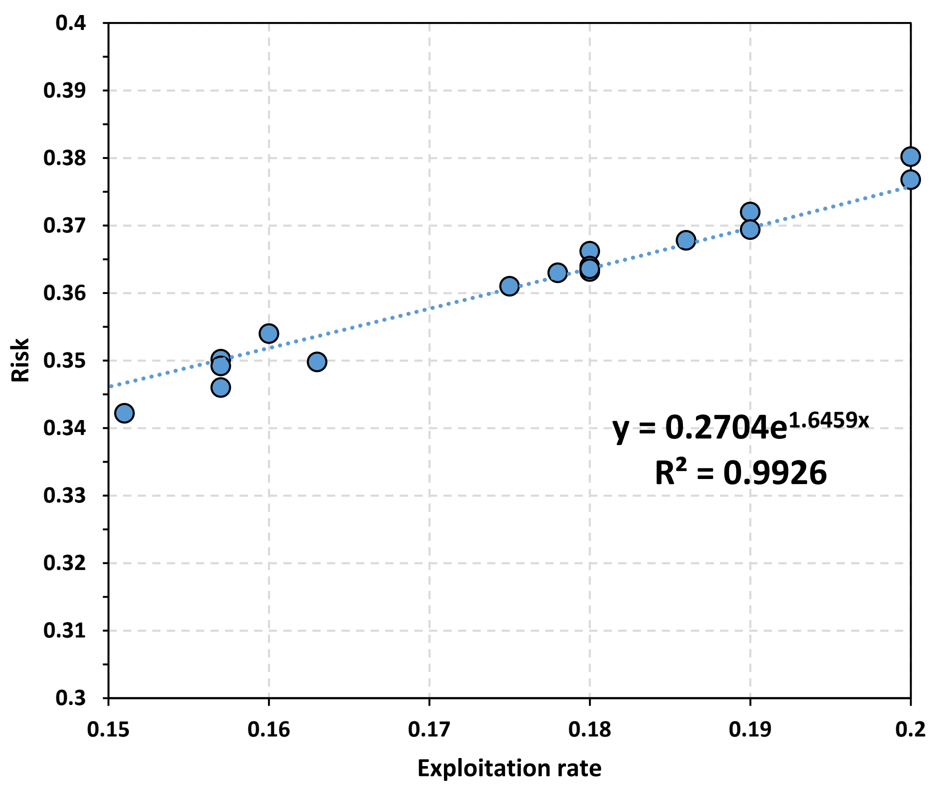


Figure 18. Relationship of effective exploitation rate and average risk for the 5 highest risk and most sensitive model populations.

5.2.3 Key Uncertainties

- Productivity parameters of representative populations.
- Productivity and abundance trends (especially relative to marine survival and seeding levels).
- Hatchery-related assumptions, hatchery fractions, and effects of hatchery management.
- Target vs. limit outcomes of allowable rates.
- Population-specific exploitation rates relative to early/late, hatchery/wild run timing.
- Similar marine survival patterns

5.3 Effect of Fishing on Hatchery-Origin Spawners

The work group examined the technical feasibility of evaluating risk tradeoffs between fishing effects on spawning escapements and the incidence of hatchery-origin strays in natural production areas. Hatchery-origin coho dominate the Columbia River return and these fish are primarily produced for fishery mitigation purposes. Consequently, it is difficult to separate fishery and hatchery effects in considerations of natural coho population status. As a result, recovery plans adopted by Washington, Oregon and NMFS include a series of closely-related and complementary fishery and hatchery measures including:

a) Elimination of some hatchery programs.
b) Changing production and release sites to meet HSRG criteria.
c) Establishing wild fish refuges.
d) Considering weirs (although difficult for coho)
e) Collecting data on natural escapements of hatchery-origin fish.
f) Fishery measures.

In this fishery risk assessment, conservation risks of fishery alternatives are being evaluated based on the frequency of critical low natural spawning escapements which potentially reduce long-term population viability. Higher fishing rates can increase risk by increasing the likelihood of small escapements. Higher fishing rates might also reduce risk by removing larger numbers of hatchery fish which impact natural population productivity. Higher productivity will increase long-term viability as populations are less likely to fall to critical low levels and more likely to rebound quickly. The 2013 coho risk assessment discussed this relationship but did not incorporate changes to productivity that might accrue from reduced hatchery spawning.

The impact of hatchery-origin spawners on wild productivity is uncertain and subject to considerable debate. However, the *Hatchery Scientific Review Group* (HSRG) has developed tools for evaluating hatchery spawner impacts on natural population productivity based on a number of assumptions. These relationships were used in a comprehensive hatchery review for the Columbia Basin by the HSRG, and were included as a component of the Washington recovery plan. These efforts led to the implementation of a series of hatchery reforms, which, for coho, included elimination of some programs, program changes, establishment of wild fish refuges, and increased stock assessment.

The Work Group will examined the feasibility of including fishery-hatchery interaction effects in assessing conservation risks based on tools developed by the HSRG. Results of this exploration follow and suggest that increased harvest opportunity afforded in mark selective fisheries can produce nominal reductions in risk by decreasing hatchery-origin spawners in natural spawning areas. This may partially ameliorate risks associated with higher fishing rates although quantification of the associated benefit is subject to numerous assumptions.

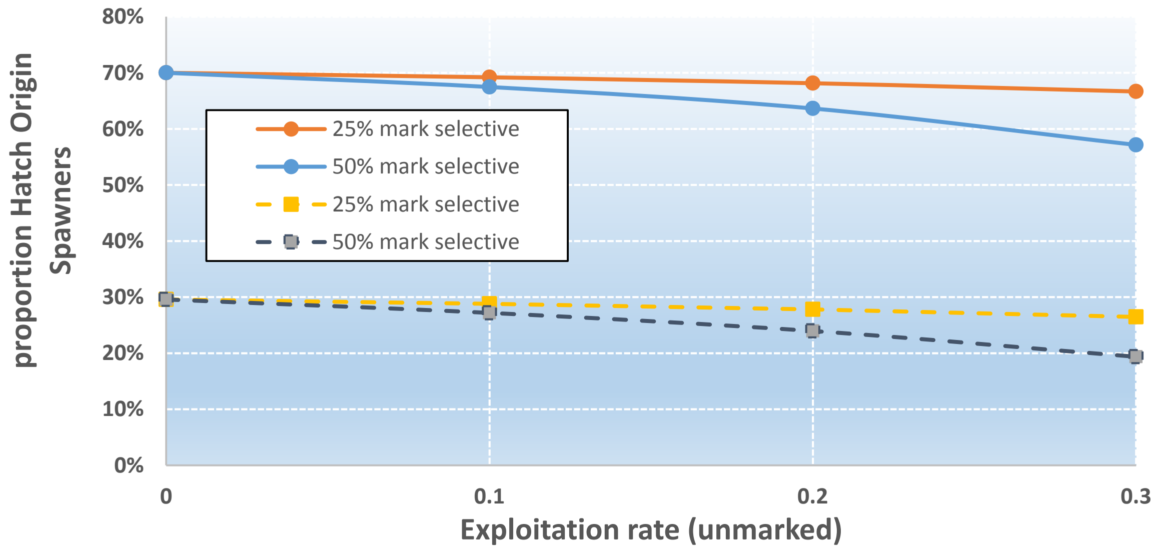


Figure 19. Hypothetical example of the effect of exploitation in mark-selective fisheries on the incidence of hatchery-origin spawners in natural production areas.

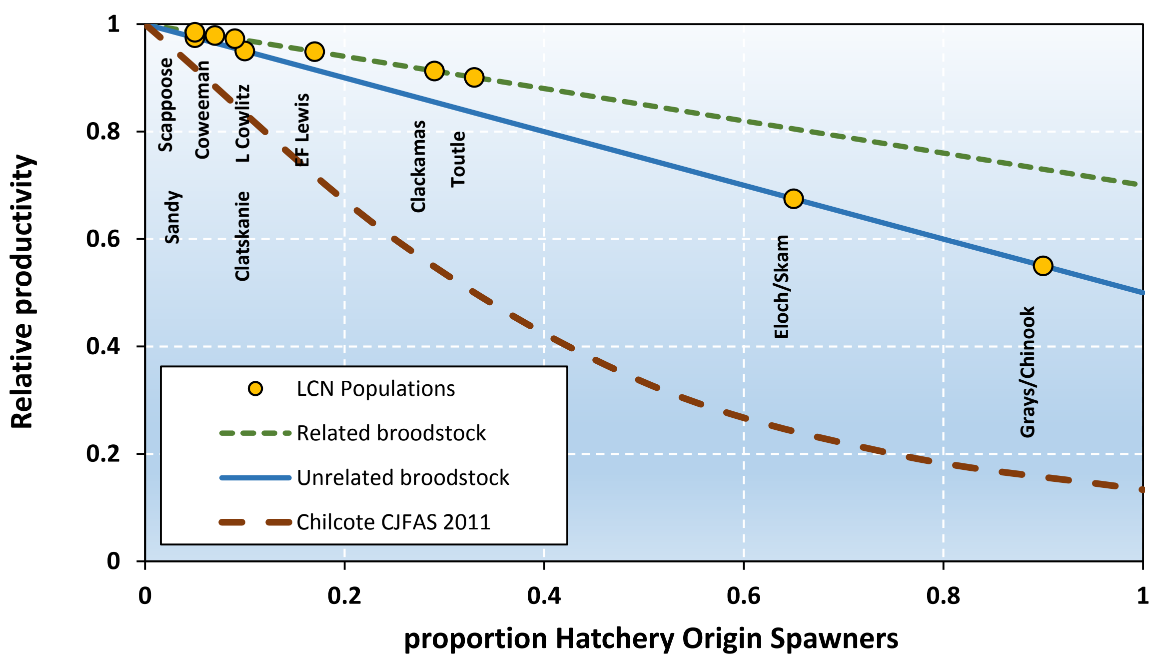


Figure 20. Example relationships of relative productivity to the proportion of hatchery spawners based on population-specific hatchery contributions and relative fitness assumptions documented in the Washington salmon recovery plan. Alernative assumptions by Chilcote et al. (2011) are also depicted.

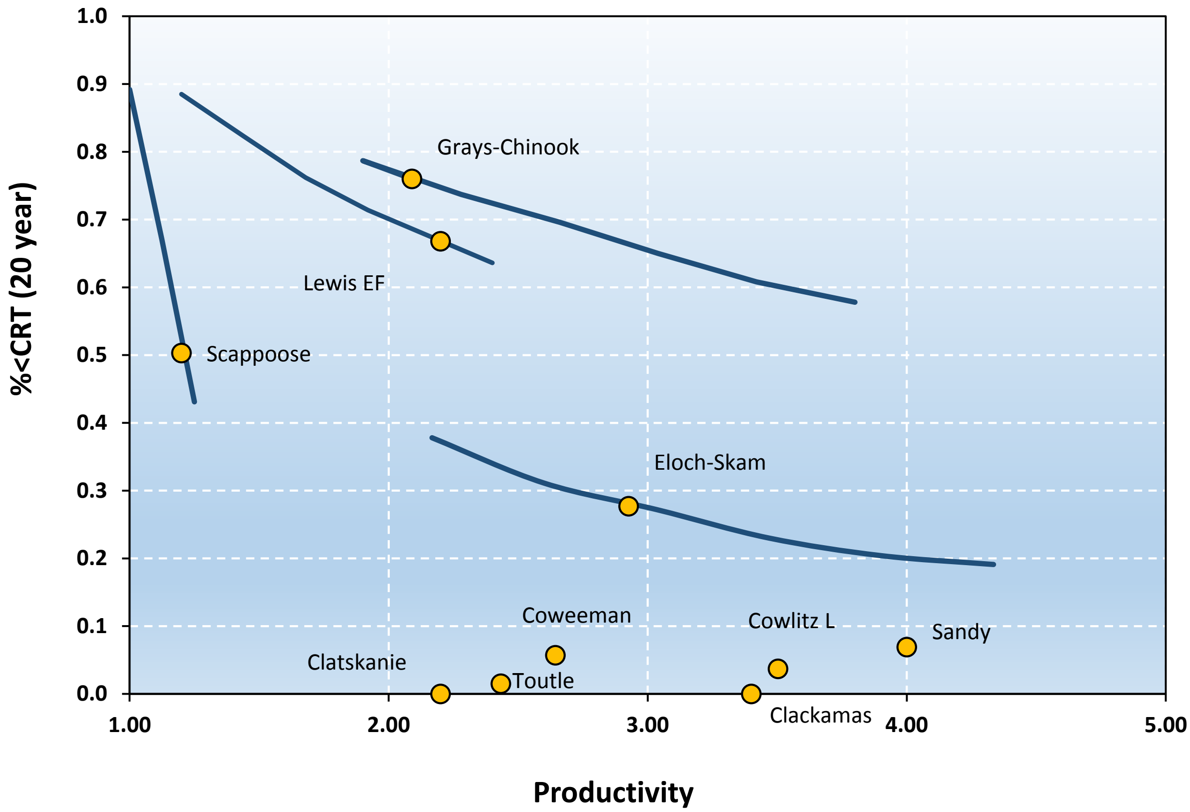


Figure 21. Relationship of risk to population productivity based on risk model sensitivity to changes in hatchery origin spawners from zero to 100%. Points represent current levels.

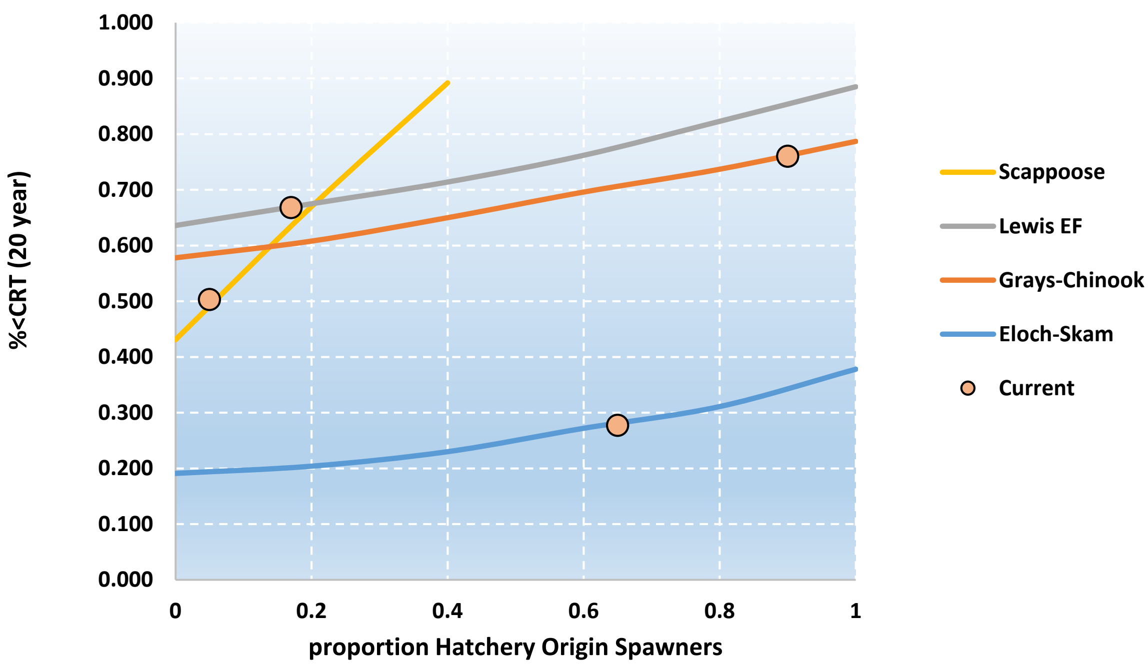
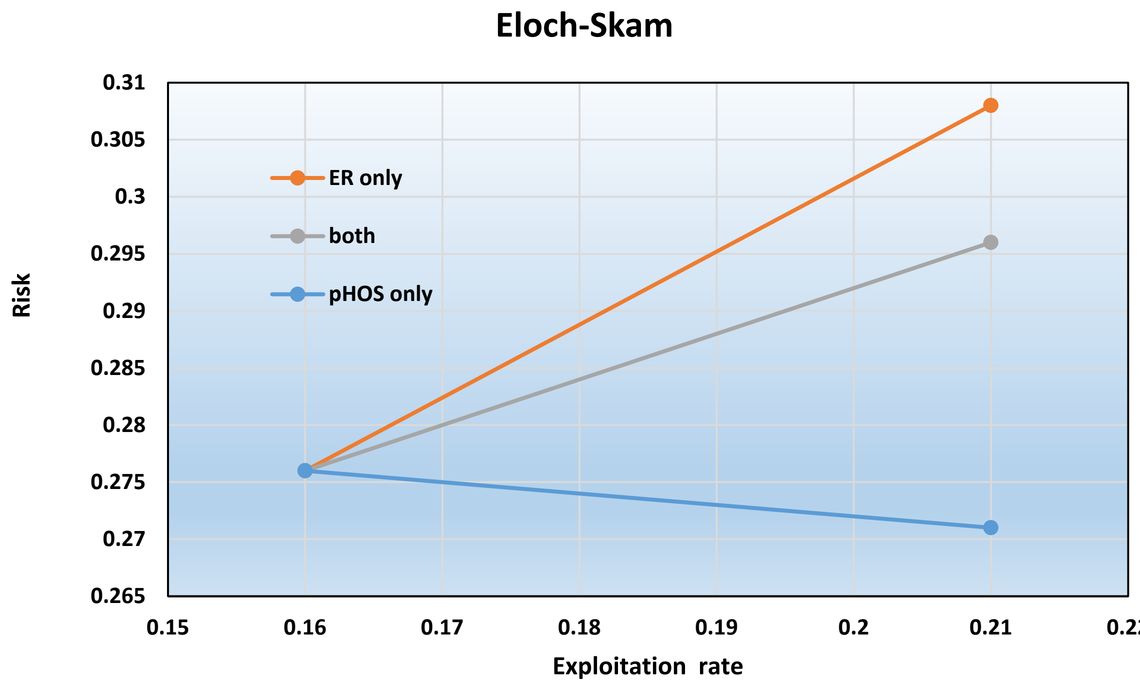


Figure 22. Relationship between hatchery contribution and risk based on model simulations of changes in population productivity associated with changes in the proportion of hatchery-origin spawners.



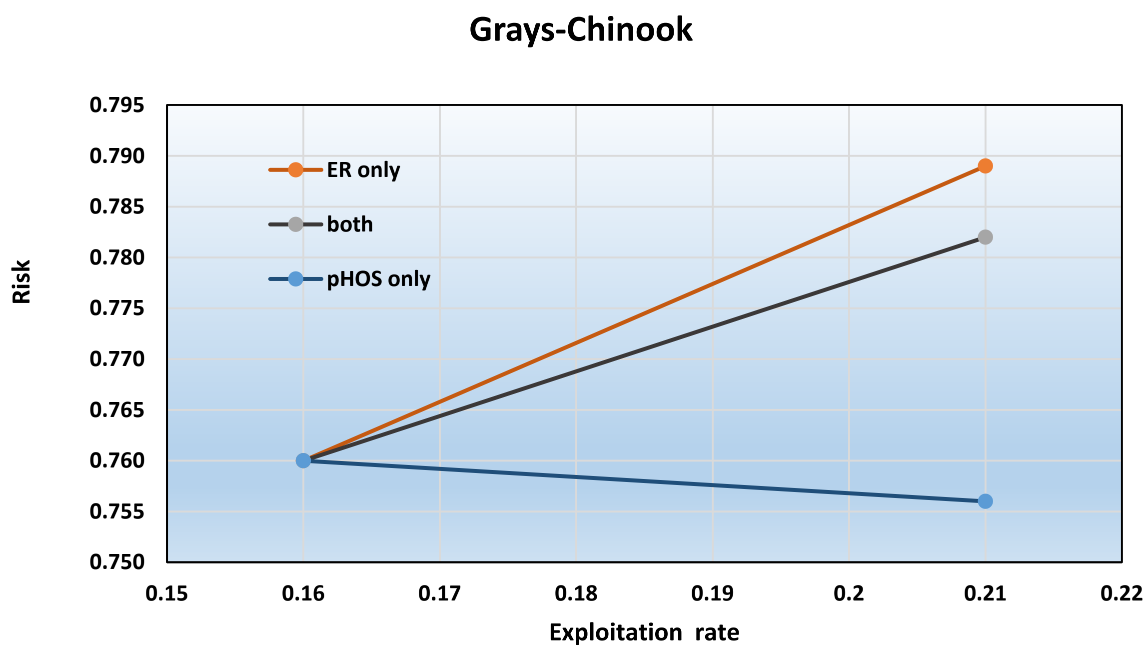


Figure 23. **Effects of increased exploitation on risk with and without consideration of hatchery contributon effects. This example assumes that all of the increase in exploitation occurs in a mark-selective fishery with 20% catch and release mortality.**

6 REFERENCES

Chilcote et al. 2011. Canadian Journal of Fisheries and Aquatic Sciences.

Kern, J. C., and M. Zimmerman. Harvest strategy risk assessment for lower Columbia River coho. ODFW and WDFW report to the Pacific Fishery Management Council.

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