SOUTHERN OREGON/NORTHERN CALIFORNIA COAST COHO FISHERY

HARVEST CONTROL RULE - RISK ASSESSMENT

AD HOC TECHNICAL WORKGROUP

WORKING DRAFT

10/5/2019

CONTENTS

1. EXECUTIVE SUMMARY

2. INTRODUCTION

statement of problem

The report describes work by an Ad Hoc Technical Work Group convened by the Council to develop a proposed harvest control rule for the Southern Oregon/Northern California Coast (SONCC) Coho Evolutionarily Significant Unit (ESU) for Pacific Fishery Management Council (Council, PFMC) consideration that would:

- allow fishing on abundant salmon stocks while not impeding the recovery of SONCC coho;
- establish harvest control rules in the form of fixed or tiered exploitation rates including consideration of control rules which reduce exploitation rates at low abundance levels, and which may include minimum or target spawner levels;
- assess a range of control rules including marine and freshwater fisheries combined, the marine and freshwater fisheries components, and marine fisheries only, affecting SONCC coho as appropriate, given potential data limitations, and what is feasible to accomplish within the timeline described below;
- evaluate the feasibility of considering the status of subcomponents of the ESU (e.g., Klamath and Trinity Rivers), marine and freshwater environmental conditions and other relevant factors as appropriate and as supported by the data available (similar to the Oregon Coast Natural coho salmon matrix).

The Council established an Ad Hoc SONCC Coho Technical Work Group (Workgroup, WG) with membership including technical representatives from:

- Pacific Fisheries Management Council
- NMFS West Coast Region (WCR)
- NMFS Northwest Fisheries Science Center (NWFSC)
- NMFS Southwest Fisheries Science Center (SWFSC)
- U.S. Fish and Wildlife Service
- Yurok Tribe
- Hoopa Valley Tribe
- California Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Contractors as deemed necessary or suggested by Workgroup participating entities

The work group was directed to:

- Collect and summarize relevant information regarding the status of SONCC coho, biological characteristics, magnitude and distribution of fishing mortality, and marine and freshwater environmental indicators.
- Develop a range of alternative harvest control rules.
- Analyze the biological risks and fishing related benefits of the alternative control rules.
- Assist the Council with developing a preferred harvest control rule alternative that can be recommended for adoption by the Council and to NMFS for ESA review within 18 months from the Workgroup's initial meeting.
- Consult with the Council's Scientific and Statistical Committee (SSC) and Salmon Technical Team (STT) on the analytical methods used to evaluate draft alternatives. The Workgroup may consult

with other Council Advisory Bodies and Technical Committees as necessary or as directed by the Council.

3. STATUS OF THE ESU

ESU & Population Structure

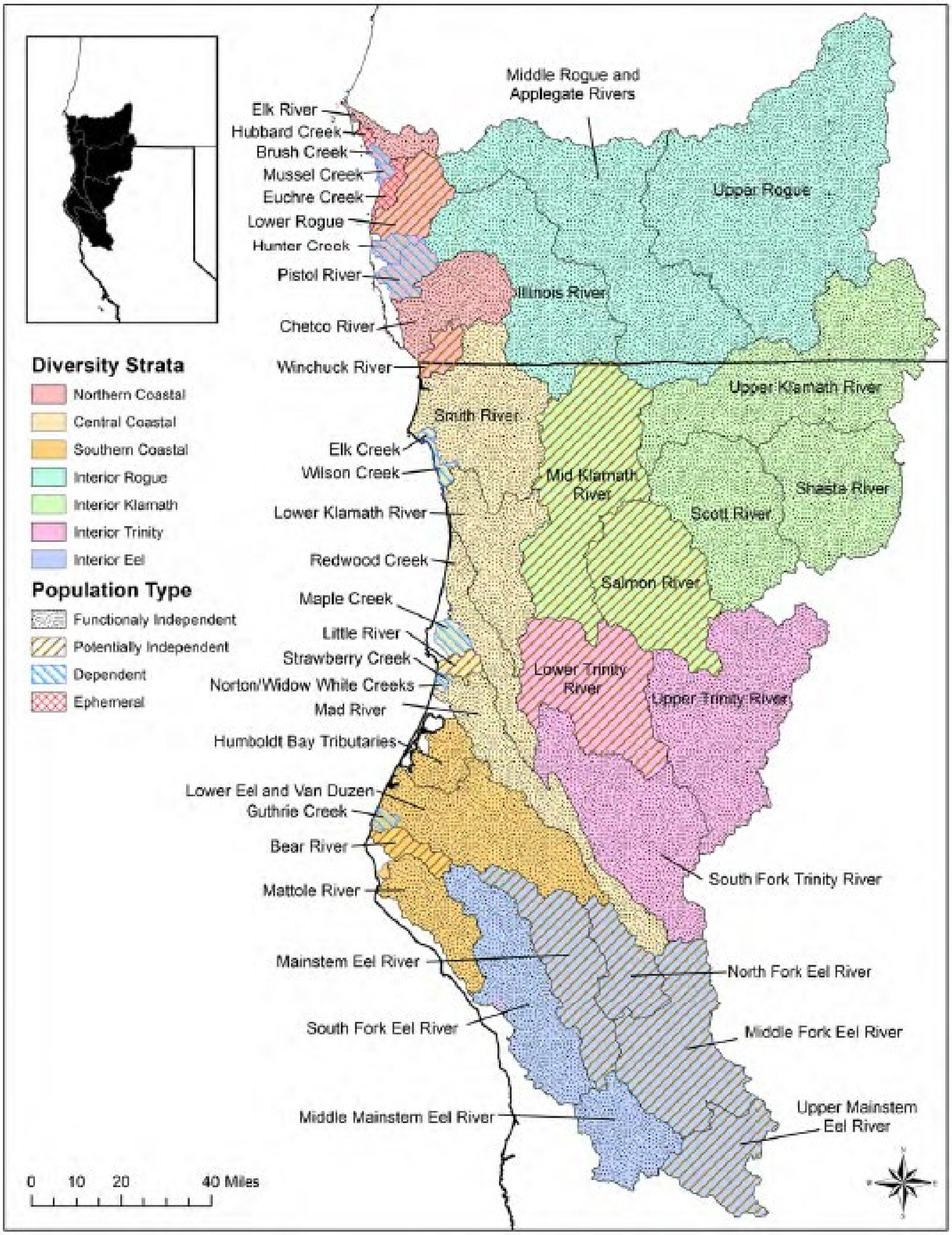

Figure 1. Population and diversity strata of the SONCC coho salmon ESU (NMFS 2014).

Table 1. Populations, strata, current extinction risk, minimum target extinction risk and recovery criteria of SONCC coho salmon ESU (NOAA 014).

Stratum	Populations	Risk status	Risk goal	Recovery role	Recovery criteria	Depensation threshold[a]	Intrinsic potential
Northern Coastal Basin	Elk R	High	Low	Core	2,400	63	
	Brush Crk	High	Juveniles	Dependent	--	--	
	Mussel Crk	High	Juveniles	Dependent	--	--	
	Lower Rogue R	High	Moderate	Non-core 1	320	81	
	Hunter Crk	High	Juveniles	Dependent	--	--	
	Pistol Crk	High	Juveniles	Dependent	--	--	
	Chetco R	High	Low	Core	4,500	135	
	Winchuck R	High	Moderate	Non-core 1	230	57	
Central Coastal Basin	Smith R	High	Low	Core	6,800	325	
	Elk Crk	High	Juveniles	Dependent	--	--	
	Wilson Crk	High	Juveniles	Dependent	--	--	
	Lower Klamath R	High	Low	Core	5,900	205	
	Redwood Crk	High	Low	Core	4,900	151	
	Maple Crk/Big Lagoon	--	Juveniles	Dependent	--	--	
	Little R	Moderate	Moderate	Non-core 1	140	34	
	Strawberry Crk	--	Juveniles	Dependent	--	--	
	Norton/Widow White Crk	--	Juveniles	Dependent	--	--	
	Mad R	High	Moderate	Non-core 1	550	136	
Southern Coastal Basin	Humboldt Bay tributaries	Moderate	Low	Core	5,700	191	
	Lower Eel/Van Duzen R	High	Low	Core	7,900	394	
	Guthrie Crk	--	Juveniles	Dependent	--	--	
	Bear R	High	Juveniles	Non-core 2	--	--	
	Mattole R	High	Moderate	Non-core 1	1,000	250	
Interior Rogue R	Illinois R	High	Low	Core	11,800	590	
	Middle Rogue/Applegate R	High	Moderate	Non-core 1	2,400	603	
	Upper Rogue R	Moderate	Low	Core	13,800	689	
Interior Klamath	Middle Klamath R	Moderate	Moderate	Non-core 1	450	113	
	Upper Klamath R	High	Low	Core	8,500	425	
	Shasta R	High	Low	Core	4,700	144	
	Scott R	Moderate	Low	Core	6,500	250	
	Salmon R	High	Moderate	Non-core 1	450	114	
Interior Trinity	Lower Trinity R	High	Low	Core	3,600	112	
	South Fork Trinity R	High	Moderate	Non-core 1	970	242	
	Upper Trinity R	Moderate	Low	Core	5,800	365	
Interior Eel	Mainstem Eel R	High	Low	Core	2,600	68	
	Middle Mainstem Eel R	High	Low	Core	6,300	232	
	Upper Mainstem Eel R	High	Juveniles	Non-core 2	--	--	
	Middle Fork Eel R	High	Juveniles	Non-core 2	--	--	
	South Fork Eel R	Moderate	Low	Core	9,300	464	
	North Fork Eel R	High	Juveniles	Non-core 2	--	--	

[a] *Based on spawner per kilometer of intrinsic potential.*

Natural Escapement

Table 2. Natural spawning escapement data for SONCC coho.

Year	Population				

Hatcheries

From NOAA 2014 recovery plan

Table 3-5. Production levels at hatcheries thro

State	Hatchery	Coho Salmon Production
Oregon	Cole Rivers[1]	200,000 (released into Rogue River)
	Elk River[2]	Not Applicable
California	Iron Gate[3]	79,710
	Trinity River[3]	502,617
	Mad River[4]	Not Applicable
	Rowdy Creek	Not Applicable

[1] Data from ODFW 2014a
[2] Data from ODFW 2014b
[3] Data from ICF/Jones and Stokes 2010
[4] Data from CDFW 2013

ODFW Rogue coho summary material: The Cole Rivers smolt production goal was around 200,000 smolts for most years of the program, but was decreased in brood year 2013 (release year 2015) to 75,000 smolts as part of a production shift.

Factors affecting the ESU outside of fisheries

4. FISHERY DESCRIPTION FOR SONCC COHO

Current fishery harvests & impacts

From NOAA 2014 recovery plan:

> *Significant changes in fisheries harvest management have occurred in recent decades, resulting in substantial reductions in harvest of SONCC coho salmon. Currently, fishing-related incidental mortality of SONCC coho salmon occurs primarily from hooking and handling in Chinook-directed commercial and recreational fisheries off the coasts of California and Oregon. Incidental hooking and handling mortality occurs in the mark-selective hatchery coho salmon fishery in the Rogue River, and also in Chinook and steelhead-directed fresh water fisheries in both Oregon and California*
>
> *In establishing fishing seasons and regulations each year, the Pacific Fishery Management Council (PFMC) considers the potential impacts on various ESA-listed stocks within the region. Because there are no data on exploitation rates on wild SONCC coho salmon, Rogue and Klamath (R/K) hatchery stocks have traditionally been used as a fishery surrogate stock for estimating exploitation rates on SONCC coho. The annual coho salmon exploitation rate averaged approximately 5% from 2000 to 2013, with a maximum exploitation rate of approximately 10% in 2003 to a low of 1.6% in 2008. California's statewide prohibition of coho salmon retention maintains consistently low impacts from freshwater recreational fisheries on SONCC coho salmon.*

Include figure & table of annual rates

ESA Consultation Standard

Harvest control rules for ESA-listed salmon species are generally intended to avoid jeopardizing the continued existence of the species. NMFS' approach to making determinations regarding the effects of harvest actions involves analysis of effects of a proposed action on abundance, productivity, or distribution of the species (NMFS 2009). Determinations are ultimately based on whether the proposed action, taken together with any cumulative effects and added to the environmental baseline, can be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery of the affected species. The current consultation standard for SONCC coho calls for no more than a 13.0% AEQ exploitation rate in ocean fisheries on Rogue/Klamath hatchery coho (PFMC 2020).

Management Framework

- Current management framework tie to OCN matrix in 1999 biop
- Management objectives and provisions
- Basis of current SONCC management objective (tie to OCN matrix)
- Structure of OCN management matrix (SONCC part of southern group)
- Analysis of current Matrix efficacy
- Examples of other PFMC salmon management frameworks (?)

5. ABUNDANCE FORECASTING

descriptions

evaluation of forecast error (sensitivity analysis for accuracy and precision)

Potential for forecast improvements

6. HARVEST CONTROL RULES CONSIDERED

candidate control rules (CRs)

(7 initial)

expectations to add more

7. WILD POPULATION RISK ASSESSMENT

The traditional approach to fishery effects analysis involved simple comparison of escapement and/or harvest numbers relative to goals. Fishery risk analyses consider the combined effects of fishing, fishery uncertainty, and variable production and survival on escapement levels that may threaten the long-term persistence or viability of a population or group of populations. Quantitative risk assessments for listed salmon species have widely taken the form of a Population Viability Analysis (PVA). PVAs use quantitative methods to predict the likely future status of a population or collection of populations of conservation concern (Morris and Doak 2002; Beissinger and McCullough 2002).

PVA models are particularly well-suited for fishery risk assessments because effects of exploitation rates on demographic risk can be directly quantified. Salmon PVA's typically utilize stochastic stock-recruitment models to estimate species survival and recovery likelihoods from population abundance, productivity and spatial structure, and population variability. This approach can also effectively evaluate fishing effects on populations of different productivity including weak populations that are most at risk of falling to critical low levels where they are no longer capable of sustaining themselves.

This assessment adapted and applied a PVA framework to evaluate risks associated with harvest control rule alternatives Southern Oregon Northern California Coastal Coho. Similar modeling approaches have previously been utilized by the Council in conservation risk analyses for other stocks including Klamath Fall Chinook (reference), Lower Columbia River Fall Chinook (reference), Lower Columbia River Coho (reference), and Sacramento Winter Chinook (reference).

Performance measures

Harvest control rules were evaluated based on performance measures for conservation and fishery performance/

Conservation metrics

Extinction risk can be generally defined as the probability that a listing unit or stock will be above some minimum size over a prescribed period of time. Salmon are believed to go extinct when population abundance and resilience are reduced to low levels where numbers "bottom out" under periods of low survival associated with variable environmental conditions.

Fishery performance metrics

Harvest

Exploitation rate

Frequency of occurrence

Population aggregates considered

Run reconstructions are currently being compiled for SONCC coho.

Information is also being compiled for other natural coho populations from the Columbia River and the Oregon coast to identify a representative range of potential values. In the event that parameters cannot be developed for SONCC coho, other populations might ultimately be used as proxies.

Methods

Model Description

Conservation risks associated with different harvest control rules were estimated using a simple stochastic life cycle model built around the salmon stock-recruitment function. This model estimates annual run size, harvest and spawner numbers over a prescribed number of years (Figure 17). The model estimates average and frequencies of values over a prescribed number of iterations (typically 1,000). The model can simultaneously simulate wild and hatchery populations. The wild population may be parameterized to represent a single population or an aggregate of populations.

Number of wild fish is estimated from recruitment generated by a stock-recruitment function from the brood year number of spawners. Recruits are defined as freshwater equivalent numbers available to the ocean fishery. Recruits are estimated as an ocean adult cohort. The model apportions annual numbers of fish from this cohort among years based on an input age schedule. The annual run is subjected to fishing with the surviving wild population spawning to seed the next wild generation and the hatchery adults dead-ending into the hatchery. The model does not simulate straying of hatchery fish into the wild population. Wild population parameters are thus assumed to represent an equilibrium contribution of hatchery fish and any changes in hatchery contributions due to changes in fishery strategy are not captured. While it is computationally simple to simulate hatchery strays, assumptions regarding their effects on population productivity over time would be highly subjective.

Random annual variability is introduced into the model in the stock-recruitment relationship for the wild population and at the juvenile-to-adult survival stage for the hatchery population. Variances are proportional to survival or productivity, log-normally distributed, annually autocorrelated, and partially correlated in between hatchery and wild fish. Log-normal distributions provide for the occasional very high survival or productivity years that we see periodically. Autocorrelation means that poor survival or production years are generally more likely to be followed by poor years, and good years by good years.

The model includes optional inputs to apply fishing rates in each year to calculate harvest and fishery effects on population dynamics. Either fixed or abundance-based rates may be utilized. Input parameters allow for forecast errors which introduce uncertainty and variability into model estimates, notably including errors in predicting which fishing rate tier should be operated in. Inputs also allow for normal differences in target and actual fishing rates which result from a variety of factors mostly related to lack of predictability in stock composition, fishery catch rates, etc.

Viability risk was defined in this analysis as the probability of average abundance of a generation of salmon falling below a critical abundance threshold (CRT) over the course of a simulation. A quasi-extinction risk threshold (QET) was defined as a population size where functional extinction occurs due to the effects of small population processes (McElhany et al. 2006). The model assumes that extinction occurs if the average annual population size over a moving generational average falls below a threshold at any point in a modeled trajectory. Extinction risk is thus estimated as the proportion of all iterations where the moving generational average spawner number falls below the threshold at any point in each simulation period.

The model is built in Microsoft Excel using Visual Basic. A simple interface page facilitates model use and review of results (Figure 2).

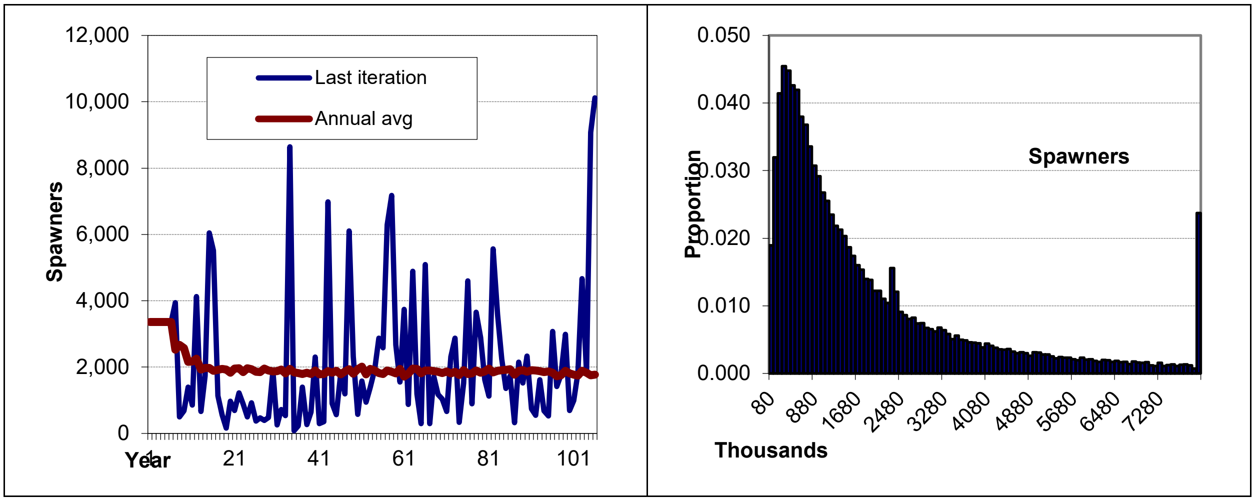

Figure 2. **Example stochastic simulation results showing annual patterns and frequency distribution of spawning escapements.**

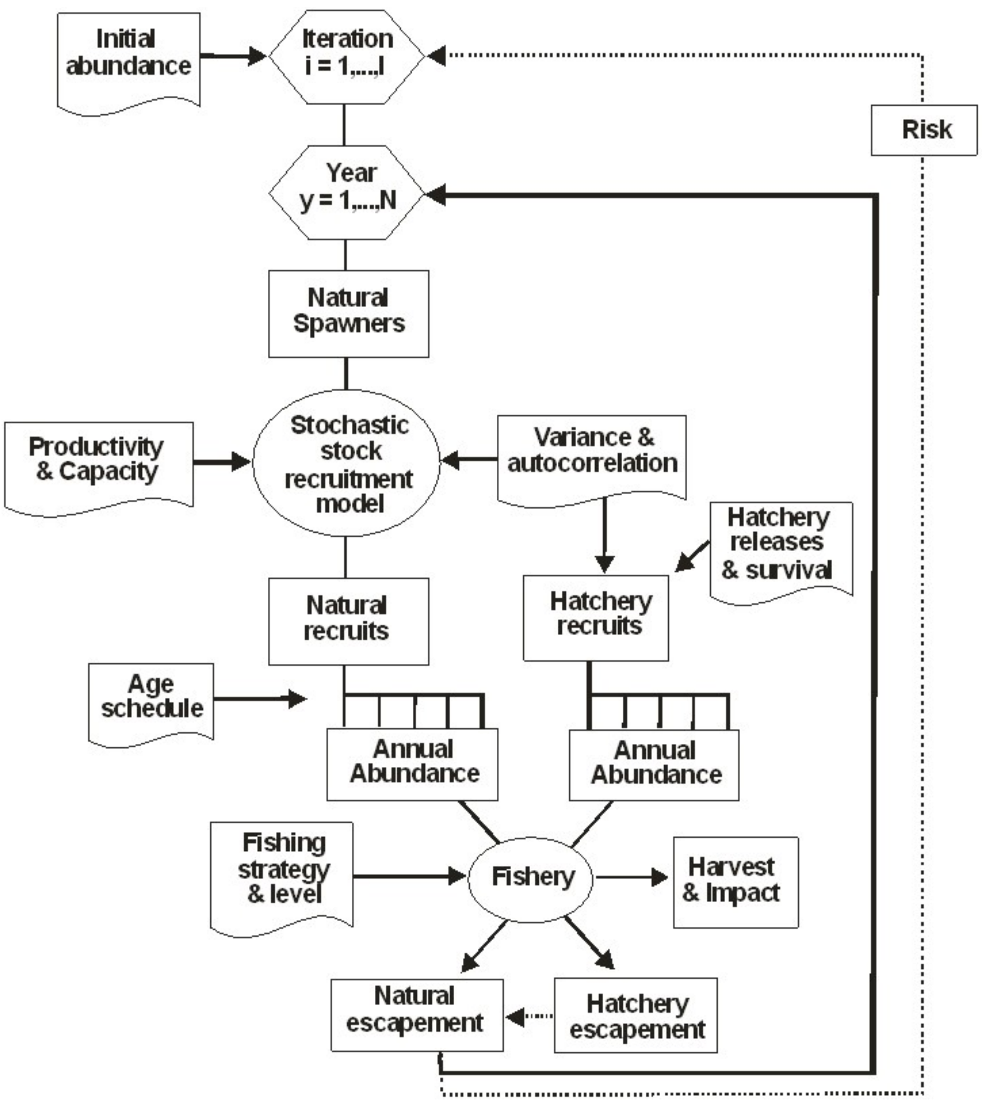

Figure 3. **Conceptual depiction of model algorithm.**

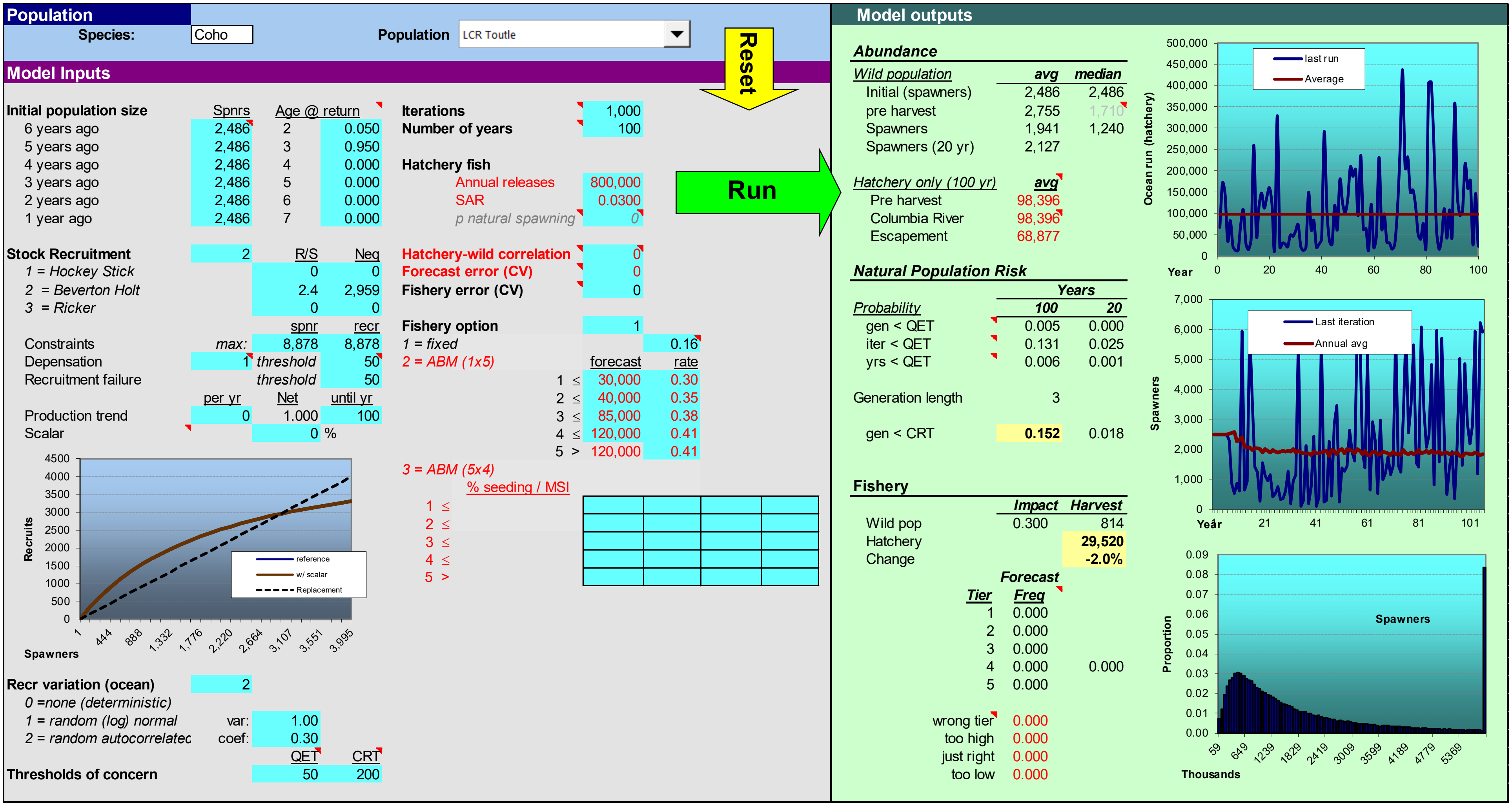

Figure 4. Model interface.

Stock-Recruitment Function

The model stock recruitment function was based on the Beverton-Holt functional forms.

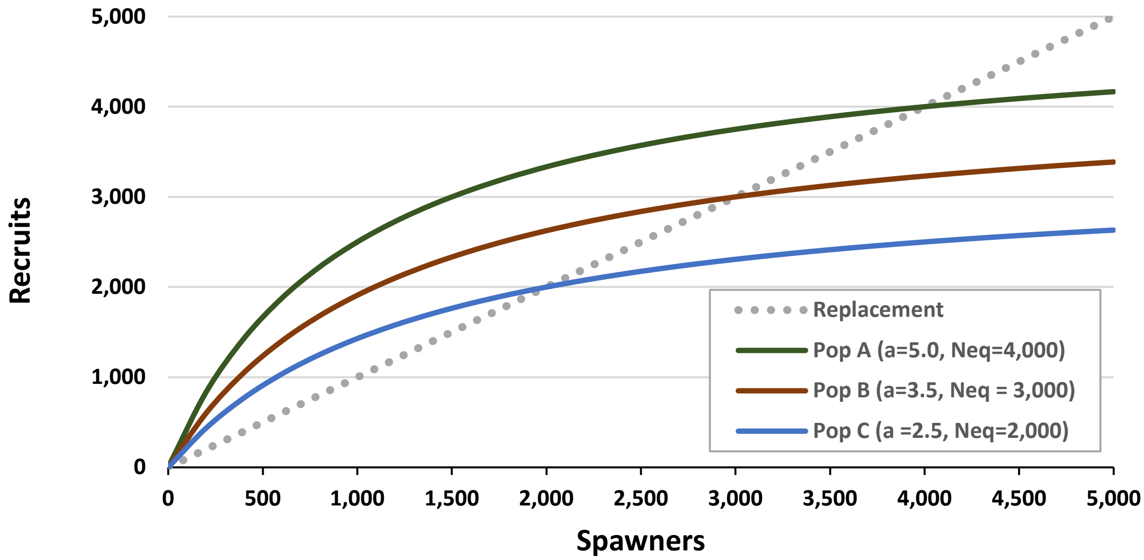

Figure 5. Examples of Beverton-Holt stock-recruitment curves.

The Beverton-Holt form of the relationship is:

$$R_y = \{a\ S_y / [1 + (S_y\ (a - 1) / N_{eq})]\}\ e^{\varepsilon}$$

where

- R_y = recruits,
- S_y = spawners,
- a = productivity parameter (maximum recruits per spawner at low abundance),
- N_{eq} = parameter for equilibrium abundance,
- e = exponent, and
- ε = normally-distributed error term ~ $N(0, \sigma^2)$.

Stock-Recruitment Variance

The stochastic simulation model incorporated variability about the stock-recruitment function to describe annual variation in fish numbers and productivity due to the effects of variable freshwater and marine survival patterns (as well as measurement error in stock assessments). This variance is modeled as a lognormal distribution (e^{ε}) where ε is normally distributed with a mean of 0 and a variance of σ_z^2 .

The model allows for simulation of autocorrelation in stock-recruitment variance as follows:

$$Z_t = \emptyset\ Z_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_e^2)$$

where

- Z_t = autocorrelation residual,
- $\emptyset$ = lag autoregression coefficient,
- ε_t = autocorrelation error, and
- σ_e^2 = autocorrelation error variance.

The autocorrelation error variance (σ_e^2) is related to the stock-recruitment error variance (σ_z^2) with the lag autoregression coefficient:

$$\sigma_e^2 = \sigma_z^2\,(1 - \emptyset^2)$$

Model simulations using the autocorrelated residual options were seeded in the first year with a randomly generated value from N(0, σ_z^2).

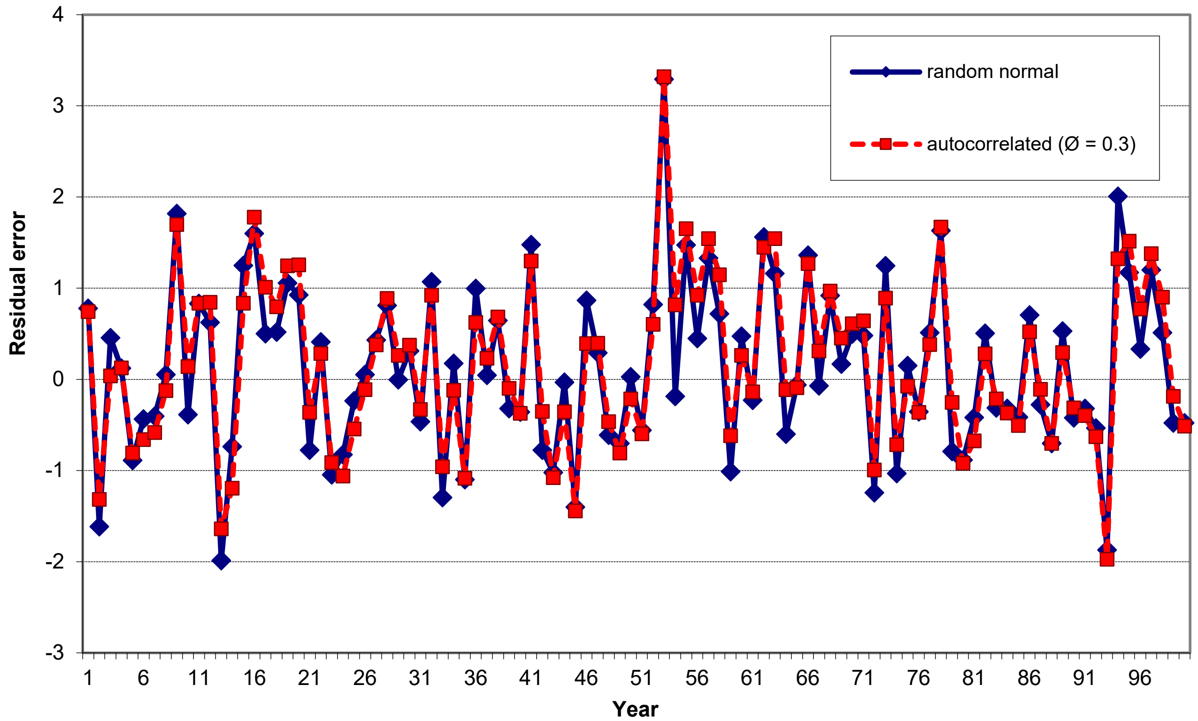

Figure 6. Examples of autocorrelation effect on randomly generated error patterns (σ_z^2 = 1).

Depensation & Recruitment Failure Thresholds

The model provides options to limit recruitment at low spawner numbers consistent with depensatory effects of stock substructure and small population processes. Options include 1) progressively reducing productivity at spawner numbers below a specified recruitment depensation threshold (RDT) and/or 2) setting recruitment to zero at spawner numbers below a specified recruitment failure threshold (RFT):

$$R' = R * (1 - \text{Exp}((\text{Log}(1 - 0.95) / (RDT - 1)) * S)) \text{ when } S > RFT$$

$$R' = 0 \text{ when } S < RFT$$

where

R' = Number of adult recruits after depensation applied,
R = Number of adult recruits estimated from stock-recruitment function,
S = spawners, and
RDT = Recruitment depensation threshold (spawner number).

(Initial) analyses of fishery effects were based on a recruitment failure threshold of 50 (equal to the QET) and a recruitment depensation threshold equal to the CRT. Thus, spawning escapements of fewer than 50 spawners are assumed to produce no recruits and the depensation function reduces productivity of spawning escapements of under the CRT value in any one year.

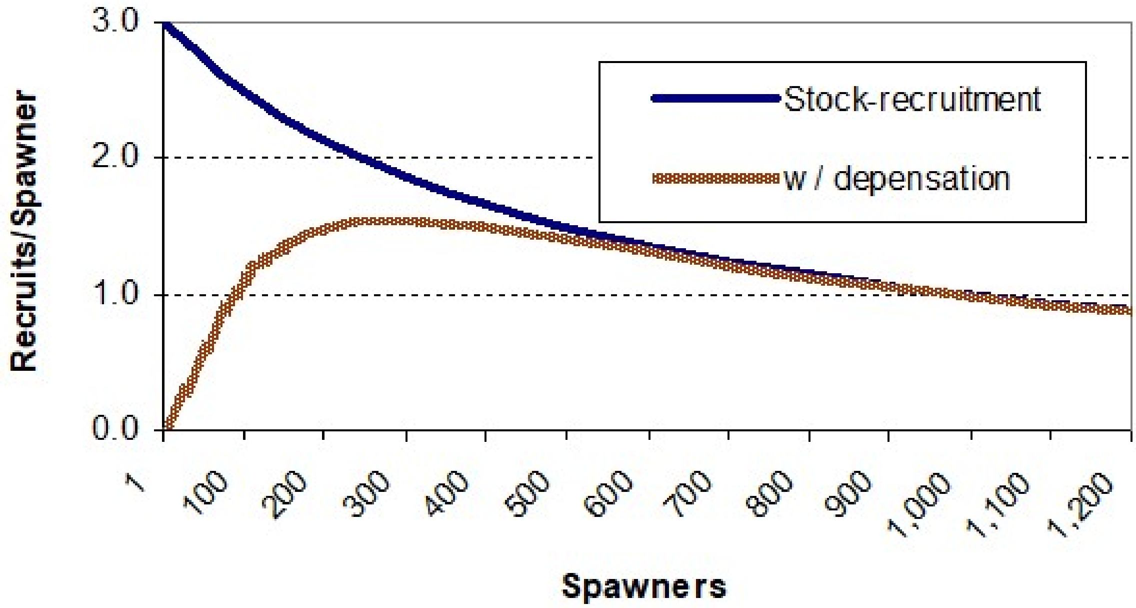

Figure 7. Example of depensation function effect on recruits per spawner at low spawner numbers based on a Beverton-Holt function (a = 3.0, Neq =1,000, γ =500).

Annual Abundance

Numbers of naturally-produced fish ($N_{.y}$) destined to return to freshwater in each year are estimated from a progressive series of recruitment cohorts based on a specified age composition:

$$N_{.y} = \Sigma N_{xy}$$

$$N_{xy} = R^*_{y-x}\, m_x$$

where

- N_{xy} = Number of mature naturally-produced adults of age x destined to return to freshwater in year y, and
- m_x = Proportion of adult cohort produced by brood year spawners that returns to freshwater in year x

Fisheries & Harvest

Annual numbers are subject to optional fishing rates. This option is useful for adjusting future projections for changes in fisheries and evaluating the effects of alternative fishing strategies and levels. Fishery impact is defined in the model in terms of the adult equivalent number of fish that die as a result of direct and indirect fishery effects:

$$IN_y = N_{.y}\, fN_y \text{ and } IH_y = H_{.y}\, fH_y$$

where

- IN_y = fishery impact in number of naturally-produced fish,
- fN_y = fishery impact mortality rate on naturally produced fish including harvested catch and catch-release mortality where applicable,
- IH_y = Fishery impact in number of hatchery-produced fish, and
- fH_y = fishery impact mortality rate including harvested catch and other mortality where applicable.

Input Parameters

Initial values for input parameters are examples for demonstration purposes. Examples were taken from a variety of sources. Examples are approximate placeholder to be replaced based on more comprehensive analysis of the available information.

Table 3. (Example) Model input variables and parameters used for fishery risk analysis.

Variable or parameter	Notation	Value
Initial spawner abundance	$S_{y-6},\ldots,S_{y-1}$	Equilibrium abundance @ avg. fishing rate
Stock-recruitment		
Function	Option 2	Beverton-Holt
Productivity	p	Pop A = 5.0; Pop B = 3.5; Pop C = 2.0
Equilibrium abundance	N_{eq}	Pop A = 4,000; Pop B = 2,500; Pop C = 1,000
Maximum spawner constraint	lim S_y	(10) (N_{eq})
Maximum recruit constraint	lim R_y	(10) (N_{eq})
Production trend	PT	0%
Recruitment failure threshold	RFT	50
Critical risk threshold	CRT	Pop A = 300; Pop B = 200; Pop C = 100
Recruitment stochasticity		
Variance	σ^2	1.0
Autocorrelation	$\emptyset$	0.3
Age schedule	$m_2,\ldots,m_7$	Age 2 = 0.05; Age 3 = 0.95
Run size forecast error (CV)	E_f	TBD
Fishery implementation error (CV)	E_i	0.5

Stock-Recruitment Parameters

This example analysis references approximate values identified for other coho populations based on LCR values estimated by Kern and Zimmerman (2013) and M. Falcy (unpublished data) (Table 6, Figure 9). For initial demonstration purposes, this draft assessment identified three general categories of populations and modeled representative abundance and productivity parameters for each category (Table 3).

Table 4. Example Beverton-Holt stock-recruitment parameters representing a range of potential coho population sizes and intrinsic productivities in Oregon Coast Natural and Lower Columbia River populations.

Category	Abundance	Productivity	CRT	Viability	Examples
A	4,000	5	300	Highest	High 25th percentile value
B	2,500	3.5	200	Intermediate	Median value
C	1,000	2.0	100	Lowest	Low 10th percentile

Table 5. Example stock-recruitment parameters (Beverton-Holt) for Oregon Coast Natural and Lower Columbia River populations of coho salmon.

Population	CRT	Neq	R/S
Rogue aggregate	300	6,000	3.0
LCR Clackamas	300	2,606	3.6
LCR Clatskanie	200	2,726	5.3
LCR Coweeman	100	919	2.6
LCR Cowlitz L	300	3,848	3.5
LCR Eloch/Skam	300	2,078	2.9
LCR Grays/Chinook	200	788	2.1
LCR Lewis EF	200	546	2.3
LCR Sandy	300	1,146	4.2
LCR Scappoose	200	2,427	2.2
LCR Toutle	200	2,959	2.4
OCN Necanicum	100	1,013	2.6
OCN Nehalem	300	8,595	5.3
OCN Tillamook	200	3,031	2.3
OCN Nestucca	100	2,187	3.5
OCN Siletz	100	2,118	2.5
OCN Yaquina	200	3,971	4.4
OCN Alsea	200	3,261	2.8
OCN Siuslaw	300	8,686	5.7
OCN Siltcoos	200	3,010	4.8
OCN Tahk	100	2,027	3.9
OCN Lump	300	5,237	4.8
OCN Mump	200	2,876	4.0
OCN Nump	100	1,952	1.6
OCN Sump	200	3,344	3.6
OCN Tenmile	300	4,610	4.8
OCN Coos	300	8,004	5.8
OCN Coquille	300	7,348	4.6
OCN Beaver	100	701	3.6

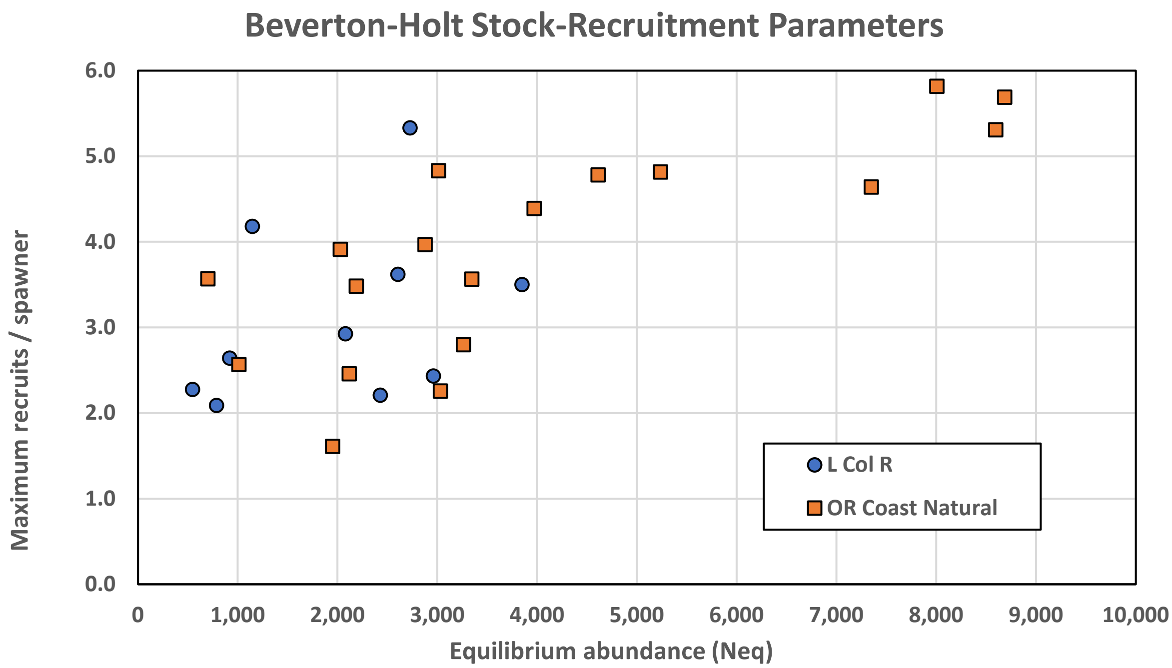

Figure 8. Example stock-recruitment parameters (Beverton Holt) for Oregon Coast Natural and Lower Columbia River populations of coho salmon.

Age Composition

Example analyses use placeholder values of 5% age 2 and 95% age 3.

Variation in Survival & Recruitment

Annual variability in natural production of the wild population is incorporated in the stock-recruitment relationship. The variance in recruits per spawner was parameterized with a variance of 1.0 in example simulations. Variance was assumed to be auto-correlated with a coefficient of 0.30. These parameters were based on average hatchery survival rate in the 2014 lower Columbia River harvest control rule assessment.

Forecast & Fishery Errors

Forecast and fishery errors were based on data reported earlier in this report. Forecast error was estimated to have a CV of (TBD). Fishery implementation error was estimated to have a CV of 0.50 (placeholder).

Conservation risks

Critical risk thresholds were generally based on values identified for ESA status assessments and recovery plans where available. (Example values are placeholders.) Wild population risks were based on a QET of 50 estimated as a moving average of years in one generation of the species in question (3 years for coho) as per (McElhany et al. 2006). Estimates of absolute risk are extremely sensitive to the selection of this parameter which is why model-derived risks are most useful for relative comparisons among risk factors. While there is an extensive amount of literature on the relationships among extinction risk, persistence time, population abundance, and level of variation in demographic parameters, there are no simple generic abundance levels that can be identified as viable (McElhany et al. 2000). Because empirical data on actual extinction and conservation risk levels is lacking, this QET value was based on theoretical numbers identified in the literature based on genetic risks. Effective population sizes between 50 and 500 have been identified as levels which theoretically minimize risks of inbreeding depression and losses of genetic diversity, respectively (Franklin 1980, Soule 1980, Thompson 1991, Allendorf et al. 1997).

Simulations

A series of model simulations were conducted to:

1. Evaluate the effects of exploitation rate on risk for wild populations in each abundance/productivity category.
2. Describe short versus long term risks associated with exploitation rates.
3. Explore the effect of abundance tier selection on population risks.

Population sensitivity to exploitation rates was evaluated based on simulations of A, B, and C population types to a series of fixed annual ERs ranging from 0.0 to 0.50.

Results

Effects of alternatives on populations or population aggregates

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 (e.g. category B populations). Smaller less productive populations are less affected and cannot generally be brought to high levels of viability over the long term even at very low fishing rates (e.g. category C populations).

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 in abundance and productivity.

Average abundance of a natural population increases in direct proportion to the decrease in fishing rate over the 100-year period of the simulation. Improvements are greatest in the most productive populations and least in relatively unproductive populations. While risk of falling below a critical small-population threshold 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.

Table 6. Modeled effects of different exploitation rates on short term (20-year) and long term (100-year) risks falling below critical wild population abundance thresholds of generic example natural coho populations

Outcome	Population category	Exploitation rate					
		0	10	20	30	40	50
Risk (20 yr)	A	0.001	0.001	0.005	0.033	0.161	0.532
	B	0.001	0.005	0.027	0.099	0.444	0.853
	C	0.058	0.154	0.408	0.766	0.980	1.000
Risk (100 yr)	A	0.000	0.000	0.000	0.005	0.028	0.099
	B	0.000	0.000	0.002	0.018	0.071	0.211
	C	0.004	0.013	0.047	0.127	0.372	0.635

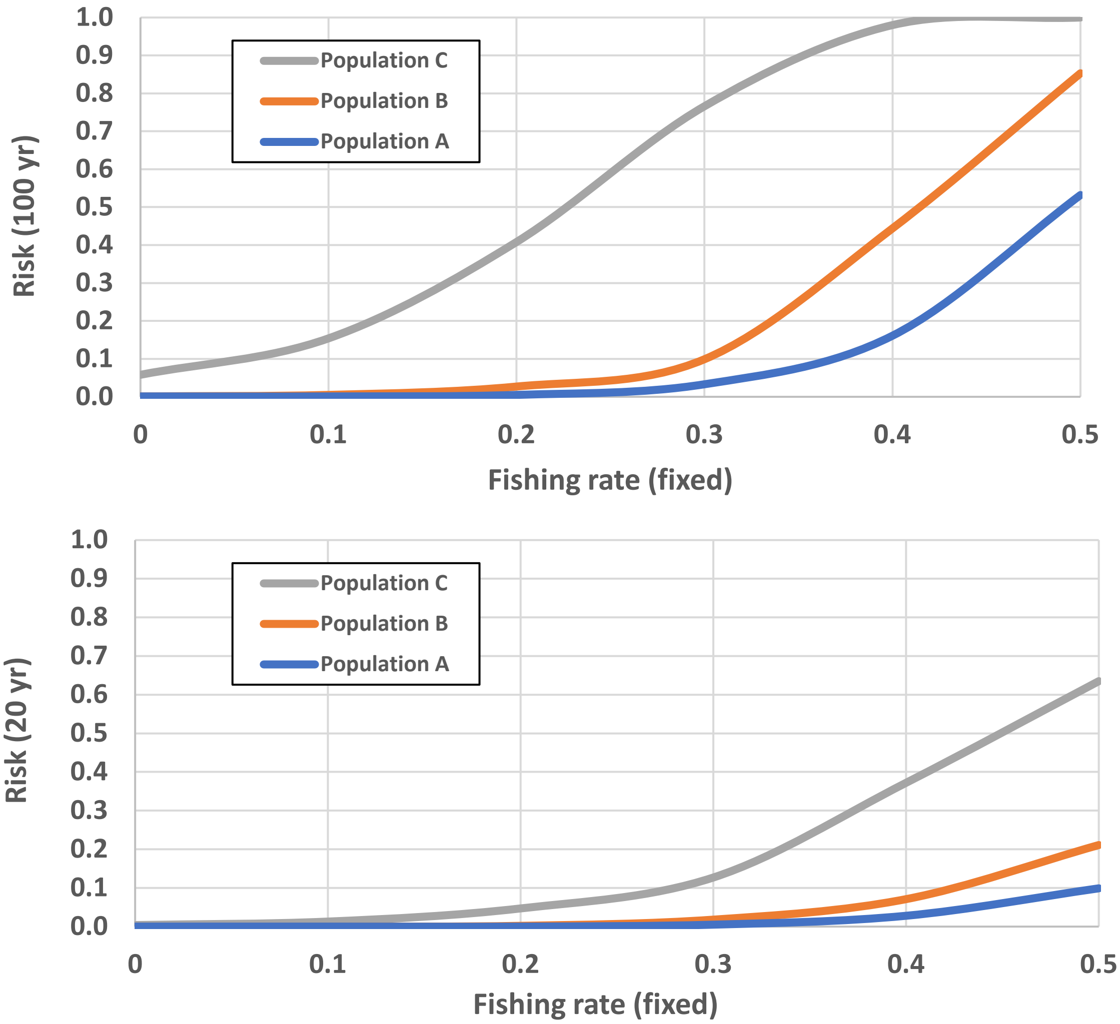

Figure 9. **Modeled effects of different exploitation rates on long-term risk of falling below critical wild population abundance thresholds, median wild abundance by population, and average total harvest of hatchery and wild tule fall Chinook.**

Effects of alternatives on fisheries performance measures

To be completed

Discussion

Key uncertainties and underlying assumptions

Data limitations / needs

8. SUMMARY

Tabular summary of the alternatives relative to performance metrics (highlight strengths and weaknesses)

Next steps - solicitation of input from Council and SAS for CR ideas

9. REFERENCES

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10. APPENDICES