PACIFIC FISHERY MANAGEMENT COUNCIL

SOUTHERN OREGON/NORTHERN CALIFORNIA COAST COHO

FISHERY HARVEST CONTROL RULE - RISK ASSESSMENT

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1. EXECUTIVE SUMMARY

[TO BE COMPLETED FOR FINAL REPORT]

This risk assessment is very preliminary should be viewed as an illustration of basic concepts, the preliminary range of control rules that the Workgroup is currently evaluating, and the analytical approach that would be used to evaluate the control rules. The results will likely change substantially with further work. We recommend against using it to inform substantive policy guidance at this time.

- The risk assessment approach is based on a quantitative population viability analysis which uses stock-recruitment data for Southern Oregon/Northern California Coast (SONCC) coho populations. The Council has implemented similar modeling approaches for other stocks, including Klamath Fall Chinook, Lower Columbia River Fall Chinook, Lower Columbia River Coho, and Sacramento River Winter Chinook.

- The analysis will consider performance measures for conservation (spawning escapement, extinction risks) and for fishery performance (exploitation rate and harvest of SONCC coho).

- Information on natural production of SONCC coho is limited to five wild populations, population components, or population aggregates, some of which are subject to substantial hatchery influence. The work group also examined population parameters for Oregon Coast Natural and Lower Columbia River Natural coho populations in order to provide some context for interpretation of the limited SONCC coho data.

Progress toward developing a full evaluation of control rules has been slowed by several factors. Besides a variety of workload issues, wildfires in Oregon and California also directly and indirectly affected members of the Workgroup. Furthermore, the ongoing issues of working under COVID-19 restrictions remain a challenge and this has added considerably to agency workloads as they strive to fulfill their basic obligations for monitoring and reporting during the annual management cycle. In spite of these challenges, the Workgroup was able to compile much of the data necessary for the analysis, vet that information, develop a preliminary suite of control rules, agree on a preliminary risk assessment approach, identify strategies to address the limited nature of the available data, and conduct a preliminary assessment. We will have a better sense of the next steps once the Workgroup has had sufficient time to perform a more in-depth review of the preliminary risk assessment.

2. INTRODUCTION

This report describes work by the Pacific Fishery Management Council's (Council) ad-hoc Southern Oregon/Northern California Coast (SONCC) coho Salmon Workgroup (Workgroup) which was tasked with assessing a range of harvest control rules (HCR) for SONCC coho salmon for Council consideration. The report first provides background information, an overview of the workgroup process, and the role of the Workgroup. It then describes the status and factors affecting the SONCC coho salmon Evolutionarily Significant Unit (ESU), followed by a description of the fisheries impacting SONCC coho and the current management framework, and prospects for abundance forecasting. The main body of the document is devoted to an evaluation of potential control rules with regard to conservation and fisheries, using a risk assessment approach.

Background

The SONCC coho salmon ESU is listed as threatened under the Endangered Species Act (ESA) (70 FR 37160; 76 FR 50447; 81 FR 33468). A variety of factors contribute to the status of the ESU including habitat loss due to dam building, degradation of freshwater habitats due to a variety of agricultural and forestry practices, water diversions, urbanization, hatchery practices, over-fishing, mining, climate change, poor ocean conditions, and severe flood events exacerbated by land use practices (Good et al. 2005, Williams et al. 2016). Fisheries impact SONCC coho in both the ocean and freshwater although impacts across the fisheries are generally low. Council area salmon fisheries are managed consistent with provisions of the Pacific Coast Salmon Fishery Management Plan (FMP) for fisheries in Federal waters (3-200 nautical miles) off the coast of Washington, Oregon, and California. NMFS last consulted on the effects of Council fisheries on the SONCC coho salmon ESU under the ESA per Section 7(a)(2) in 1999 (NMFS 1999). In that opinion, NMFS concluded Council fisheries would jeopardize the ESU and developed a three-part Reasonable and Prudent Alternative that (1) requires that management measures developed under the FMP achieve an ocean exploitation rate on Rogue/Klamath coho hatchery stocks of no more 13 percent, (2) prohibits coho-directed fisheries and coho retention in Chinook-directed fisheries off of California, and (3) requires that sampling and monitoring of Council fisheries is conducted.

In 2018, the Hoopa Valley Tribe filed a lawsuit alleging a failure by NMFS to reinitiate Endangered Species Act (ESA) consultation regarding the impacts of ocean salmon fisheries on SONCC coho salmon. In March 2020, the parties reached a stipulated agreement to stay the litigation provided certain conditions are met. The stipulated agreement provides a timeline by which NMFS will confer with the Council on completion of a new SONCC coho harvest control rule and a timeline for ESA consultation, as warranted, on the effects of the control rule. At the April 2020 Council meeting, NMFS proposed a process and timeline for Council consideration to develop a control rule and the Council established an ad-hoc technical workgroup in response to the NMFS proposal. The Council approved the Terms of Reference for the workgroup at its June 2020 meeting. The Workgroup has met twice since then to compile data, define potential control rules, and develop its risk assessment model and approach. All meetings were open to the public. A detailed list of Workgroup meetings and presentations can be found online at the NMFS West Coast Region webpage.

Purpose and Need

The purpose the Council tasked the Workgroup with was to develop a proposed harvest control rule for the SONCC Coho Evolutionarily Significant Unit (ESU) for Council 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., Rogue River, Klamath and Trinity Rivers, Eel River), 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 the Ad Hoc SONCC Coho Technical Workgroup with membership including technical representatives from

- Pacific Fishery 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 Workgroup 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. (Terms of Reference, Appendix A)

The risk assessment addresses three fundamental questions regarding the assessment of control rule for SONCC coho salmon:

1. Can SONCC coho abundance or its components be predicted with sufficient accuracy and precision?
2. What are the effects of different fishing rates for SONCC coho salmon on Council fisheries?
3. Can alternatives be implemented with negligible effects on escapement and viability of wild SONCC coho salmon populations?

The Workgroup is focused exclusively on exploring the impacts of salmon fisheries through the assessment of control rules that apply to those fisheries as described in the Workgroup’s Terms of Reference. Considerations of other threats to SONCC coho salmon are outside the scope of the workgroup task and have been described in detail in the Final Southern Oregon/Northern California Coast (SONCC) Coho Salmon Recovery Plan, the 2016 5-year status review and various ESA biological opinions and other regulatory documents. NMFS considers other activities in the action area as part of the environmental baseline. The NMFS West Coast Region and its partners are addressing the broader suite of threats separately through recovery actions and through the various provisions of the ESA and other laws.

3. STATUS OF THE SONCC COHO SALMON ESU

ESU & Population Structure

The SONCC coho salmon ESU was listed as threatened under the ESA on May 6, 1997 (62 FR 24588). The listing was most recently reaffirmed on June 28, 2005 (70 FR 37160). Critical habitat for SONCC coho salmon was designated on May 5, 1999 (64 FR 24049). In 2005, the Final 4(d) protective regulations were published (70 FR 37160, June 28, 2005). The Final Southern Oregon/Northern California Coast (SONCC) Coho Salmon Recovery Plan was finalized in 2014 (NMFS 2014). Subsequently, NMFS evaluated the available information on the status of the ESU in its 2016 status review and concluded that there was no change in extinction risk (Williams et al. 2016); the ESU remains threatened. A new status review is underway and this document will be updated as appropriate as that information becomes available. The ESU includes coastal watersheds from the Elk River (Oregon) in the north to the Mattole River (California) in the south (Figure 1). The ESU is characterized by three large basins and numerous smaller basins across a diverse landscape. Three hatchery stocks, Trinity River Hatchery, Iron Gate Hatchery, and Cole Rivers Hatchery on the Rogue River are included in the ESU.

The SONCC coho salmon ESU is divided into seven diversity strata comprising 40 populations (Figure 1, Table 1)(NMFS 2014). The diversity strata are characterized by groups of populations that exhibit genotypic and phenotypic similarity due to exposure to similar environmental conditions or common evolutionary history (Williams et al. 2006). Each of the populations in the ESU is defined as one of four distinct types based on its posited historical functional role and role of recovery in the ESU (Table 1):

- *Functionally independent populations*: populations with a high likelihood of persisting over 100-year time scales and that conform to the definition of independent "viable salmonid populations" offered by McElhany et al. (2000).
- *Potentially independent populations*: populations with a high likelihood of persisting over 100-year time scales, but that were too strongly influenced by immigration from other populations to be demographically independent.
- *Dependent populations*: populations believed to have had a low likelihood of sustaining themselves over a 100-year time period in isolation and that received sufficient immigration to alter their dynamics and extinction risk.
- *Ephemeral populations*: populations that were both small enough and isolated enough that they were only intermittently present.

The distribution of SONCC coho salmon within the ESU's range is reduced and fragmented, as evidenced by an increasing number of previously occupied streams from which SONCC coho salmon are now absent (Williams et al. 2011, Williams et al. 2016). Extant populations can still be found in all major river basins within the range of the ESU (70 FR 37160). However, extirpations, loss of brood years, and sharp declines in abundance of SONCC coho salmon in several streams throughout the range of the ESU indicate that the SONCC coho salmon spatial structure is more fragmented at the population-level than at the ESU scale. Though population-level estimates of abundance for most independent populations are lacking, NMFS concluded in its most recent status review that none of the seven diversity strata currently supports a single viable population as defined by the Recovery Plan criteria, although all diversity strata are occupied.

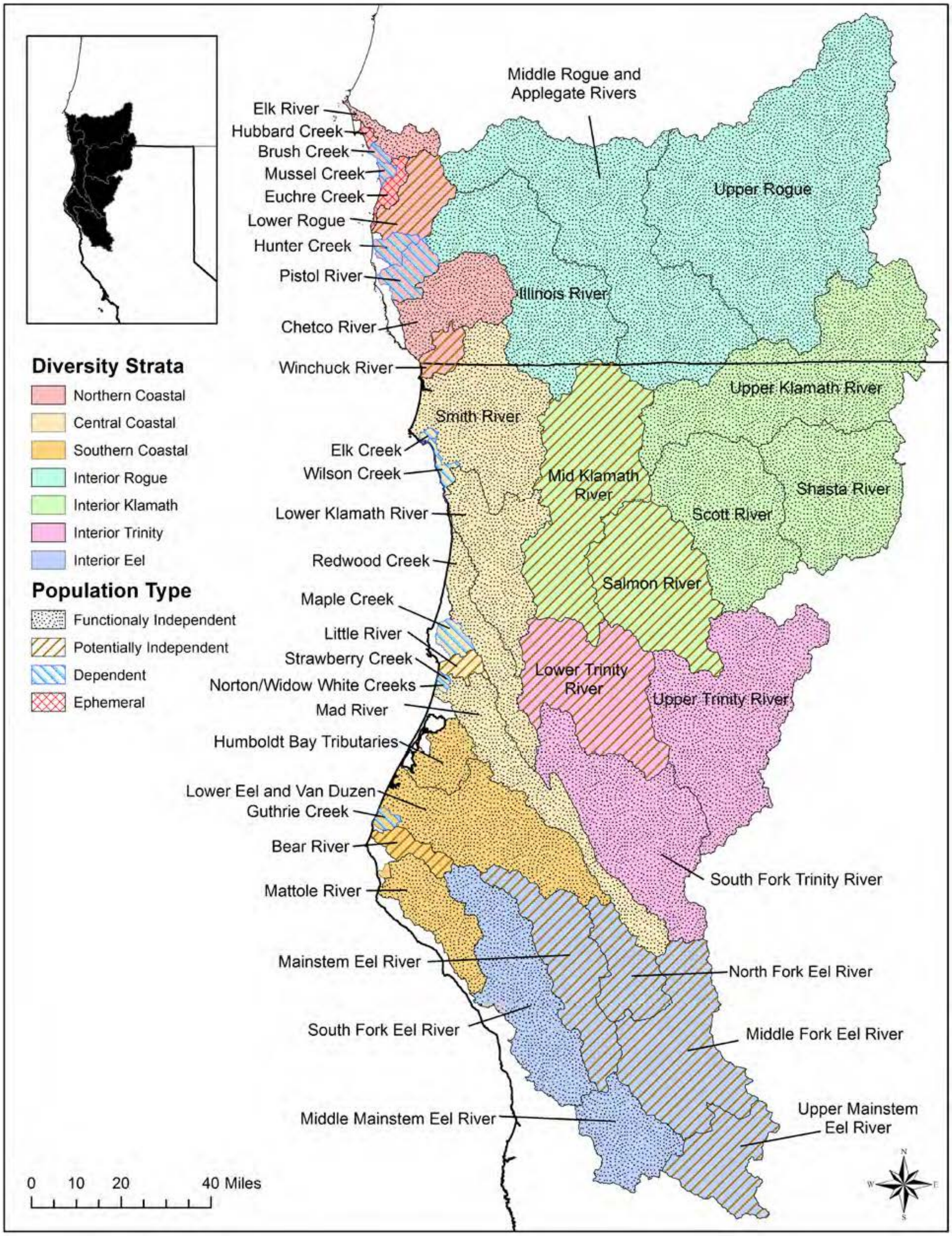

Figure 1. Population and diversity strata of the SONCC coho salmon ESU (NMFS 2014).

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.*

Table 1. Diversity strata, populations, current extinction risk, minimum target extinction risk and recovery criteria of SONCC coho salmon ESU (NMFS 2014). Core populations are noted in bold.

Natural Escapement

Quantitative population-level estimates of adult spawner abundance spanning a decade or more are scarce for independent or dependent populations of coho salmon in the SONCC ESU, although monitoring in California has improved considerably over that time due to the implementation of enhanced monitoring for some populations (e.g., video weirs, PIT-tag arrays). However, there is uncertainty about the level to which these efforts will be sustained in the future. For many populations, escapement information is limited to presence-absence data at best.

Population unit spatial scale data from the Oregon portion of the ESU are no longer collected and therefore no estimates at the population spatial scale are available for Oregon populations (Sounhein et al. 2014). The estimate of Rogue River coho salmon, that is a composite of several population units (Lower Rogue River, Illinois River, Middle Rogue/Applegate rivers, and Upper Rogue River), continues to be collected and is extremely valuable. Escapement estimation methods are described in more detail in Williams et al. (2016).

Table 2 summarizes the escapement data for populations for which the Workgroup concluded data are sufficient for the purposes of the risk assessment. The Workgroup is also discussing potential further aggregation for the purposes of control rule development. The group includes populations within five of the seven diversity strata in the ESU. The Illinois and Upper Rogue river populations in the Rogue River Basin, the Scott and Shasta rivers, and the Upper and Lower Trinity Rivers in the Trinity River Basin are core populations for ESU recovery. Freshwater Creek is one of the Humboldt Bay tributaries which is also a core population for ESU recovery. Hatchery fish contribute significantly to escapement for some of these stocks (Table 2 and Figure 2).

In California, the Workgroup concluded that escapement estimates with a decade or more of escapement information on which to conduct the risk assessment were only available for two populations (Shasta and Scott River), a component of the Upper Klamath River population (Bogus Creek), a component of the Humboldt Bay Tributaries population (Freshwater Creek) and two population aggregates (Rogue and Trinity; where aggregate is defined as a grouping of multiple populations). Escapement estimation methods are described in more detail in Williams et al. (2016).

Returns of naturally produced adults to the Rogue, Trinity, Shasta, and Scott Rivers have been highly variable. For example, wild coho salmon estimates derived from the beach seine surveys at Huntley Park on the Rogue River ranged from 414 to 24,481 naturally produced adults between 2003 and 2012 (Table 2). Similar fluctuations have been noted in the Trinity, Shasta, and Scott River populations. Overall, the average annual escapement is only 5,586 naturally produced fish. However, escapement data are sparse or lacking for the Eel, Smith, and Chetco Rivers, the other major populations in the ESU, as well as for the numerous smaller coastal populations. Actual escapement totals for the ESU are therefore likely to be higher than this estimate.

NMFS concluded in its most recent status review (Williams et al 2016) that many independent populations in the ESU are well below low-risk abundance targets, and several are below the high-risk depensation thresholds specified by the TRT and the Recovery Plan (NMFS 2014)(Table 1). The magnitude of escapements in many years as captured in Table 2 underscores that conclusion.

Though population-level estimates of abundance for most independent populations are lacking, it does not appear that any of the seven diversity strata currently supports a single viable population as defined by the TRT's viability criteria, although all diversity strata are occupied.

Table 2. Escapement of adult SONCC coho salmon for return years 2000 – 2019.

Return Year	Rogue River[1]		Freshwater Creek	Scott River		Shasta River		Bogus Creek[2]		Trinity River	
	Hatchery	Wild	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
2000	10,116	10,978	177							6,297	288
2001	14,013	12,015	701							15,770	2,945
2002	12,739	8,460	1,807							7,440	372
2003	7,296	6,805	731							10,991	3,264
2004	9,092	24,509	974					97	298	15,287	7,830
2005	5,339	9,957	789					41	46	9,974	1,728
2006	3,496	3,911	396					14	19	7,454	1,416
2007	2,275	5,136	262	0	1,529	5	244	71	126	1,612	940
2008	158	414	399	0	59	22	8	33	72	2,204	861
2009	518	2,566	89	0	76	2	7	2	3	1,718	438
2010	752	3,671	455	0	913	11	33	41	105	2,146	624
2011	1,157	4,545	624	0	344	42	17	80	27	2,403	991
2012	1,423	5,474	318	2	186	54	22	59	8	6,335	1,577
2013	1,999	11,210	155	0	2,631	61	99	353	85	8,935	3,948
2014	829	2,409	718	0	383	4	1	18	4	6,405	823
2015	1,620	4,072	449	0	188	0	43	4	9	166	459
2016	1,201	6,302	466	0	226	0	46	21	29	482	635
2017	886	4,526	535	4	364	0	38	8	29	107	34
2018	325	8,266	560	0	712	0	36	3	23	502	1
2019	195	2,156	303	0	338	0	50	5	47	358	63

[1]Escapement estimated at Huntley Park; inclusive of escapement to hatchery and natural areas.
[2]Bogus Creek is a tributary to the Upper Klamath and part of the Upper Klamath River population with a video weir to assess escapement.

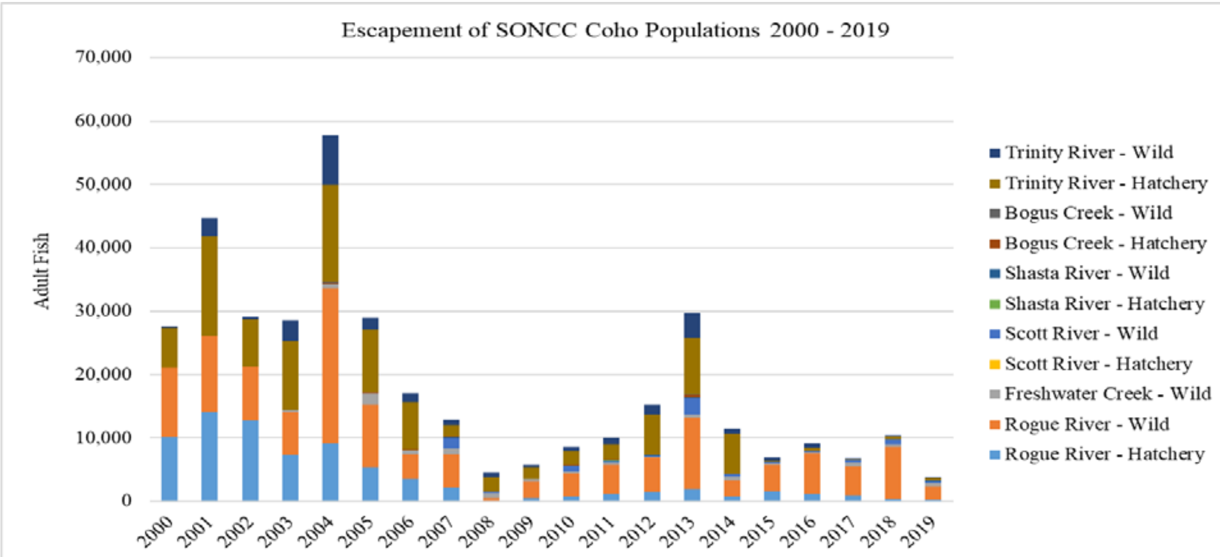

Figure 2. Trends in escapement for populations summarized in Table 2.

Hatcheries

Hatcheries provide benefits to the status of salmon by reducing demographic risks and preserving genetic traits for populations at low abundance in degraded habitats. In addition, hatcheries help to provide harvest opportunity. Hatchery-origin fish may also pose risk to listed species through genetic, ecological, or harvest effects. More details on how hatchery programs can affect ESA-listed salmon and steelhead can be found in Appendix C of NMFS (2018a), incorporated here by reference, and summarized below.

Three artificial propagation programs are part of the SONCC coho salmon ESU: the Cole Rivers Hatchery (Rogue River), Trinity River Hatchery, and Iron Gate Hatchery (Klamath River) coho salmon programs (70 FR 37160, June 28, 2005). Annual production goals at these hatcheries are 75,000, 300,000, and 75,000 coho smolts, respectively. In addition to coho, steelhead and Chinook are also reared and released at Cole Rivers, Trinity River Hatchery and Iron Gate Hatchery, and three other hatcheries within the area of the SONCC Coho ESU. These are Mad River (steelhead only) and Rowdy Creek hatcheries in California and the Elk River Hatchery in Oregon. Annually, these hatcheries release approximately 14,177,000 salmonids into rivers within the SONCC coho ESU. Hatchery production in the area of the SONCC coho ESU is in Table 3 below and the hatchery programs releasing coho are described below.

Coded-wire tags from releases from the Iron Gate and Cole Rivers hatcheries are used to estimate fishing impacts in ocean fisheries. The following provides a description of each of the three major hatchery programs and Table 3 summarizes the current production at each of the facilities.

Cole Rivers Hatchery (ODFW):

Cole M. Rivers Hatchery is located on the Rogue River (RM 157) downstream of Lost Creek Dam in the Upper Rogue River population of the SONCC coho ESU. The hatchery was constructed by the US Army Corps of Engineers (USACE) in 1973 to mitigate for spawning and rearing areas blocked by the construction of Lost Creek, Applegate, and Elk Creek Dams. The hatchery facility is used for adult collection, spawning, egg incubation and rearing of spring Chinook, coho, summer steelhead, and winter steelhead, and egg incubation and rearing of fall Chinook and rainbow trout (ODFW 2020).

The Cole Rivers Hatchery programs are operated to augment harvest opportunities. The management goals for the coho program are to: 1) provide an artificial reserve to retain future management options in the recovery of Rogue Basin coho; 2) provide monitoring opportunities for Rogue River coho related to ocean distribution and marine survival and to provide information on incidental harvest mortality of wild coho; and 3) provide fish for commercial and recreational harvest while minimizing potential impacts to wild populations in the Rogue River Basin (ODFW 2020).

The current production goals are to produce 75,000 coho smolts at 10 fish/pound. The production goal was decreased from 200,000 smolts in brood year 2013 (reference?). The smolts are released directly from the hatchery in late April. All coho are adipose fin-clipped and 25,000 are tagged with coded-wire tags (CWT) prior to release. The return goal is 2,060 adult coho to mitigate for wild coho production lost from the construction of federal dams in the upper Rogue River Basin. Adults return to the hatchery from October to January. Broodstock are from adults that volitionally enter the hatchery trap. Spawning occurs from November through January.

Escapement goals for coho released from the Cole Rivers program are to achieve low rates of hatchery coho on spawning grounds (ODFW 2020). Adverse hatchery-related effects pose a medium risk to coho populations in the Rogue Basin. Available information suggests that the incidence of hatchery fish spawning in the wild is likely in the range of 5 to 15 percent (NMFS 2014).

Iron Gate Hatchery (CDFW)

Iron Gate Hatchery (IGH) is located on the Klamath River (RM 190) at the base of Iron Gate Dam and is located within the Upper Klamath River population of the SONCC coho ESU. The hatchery was constructed by PacificCorp after completion of Iron Gate Dam in 1961. The hatchery program was required to mitigate for loss of spawning and rearing habitat resulting from the operations and maintenance of the PacifiCorp hydroelectric project. The IGH coho program is operated as an integrated recovery program to aid in the recovery and conservation of Upper Klamath coho by conserving genetic resources and reducing short-term extinction risks prior to future restoration of fish passage above Iron Gate Dam.

Coho production began in 1965 at IGH with eggs originating from Cascade hatchery in Oregon. Several other transfers occurred from around the region. Since 1976, IGH has used Klamath River coho as broodstock. Current production goals are to produce 75,000 coho smolts. Actual releases have averaged 86,781 (range 22,236 to 155,480) from 1998 to 2010 (CDFW 2014). On average, the releases have produced approximately 866 returning adults annually since 2000, however the annual average has dropped to 296 adult coho returns since 2010. Coho smolts are reared 15 fish/pound and are released directly from the hatchery in early April. All coho are marked externally with a left maxillary clip. Adipose fin-clips and CWTs are not used currently to mark fish. Broodstock are collected from hatchery and wild adults returning to the IGH fish ladder and nearby Bogus Creek. Adult coho return to the hatchery from October to December. (CDFW 2014).

Adverse hatchery-related effects pose a medium risk for SONCC coho in the Middle Klamath and a very high stress in the Upper Klamath River. Bogus Creek coho represent the largest naturally spawning population in the Upper Klamath population however hatchery origin strays into Bogus Creek averaged 28 percent of the escapement from 2004-2011 (CDFW 2014). Hatchery coho salmon into the Shasta River averaged 30 percent of the escapement from 2007-2010 (CDFW 2011).

Trinity River Hatchery (CDFW)

Trinity River Hatchery (TRH) is located on the Trinity River (RM 110) at the base of Lewiston Dam in the Upper Trinity River population of the SONCC coho ESU. The hatchery was constructed by the US Bureau of Reclamation after completion of the Lewiston Dam in 1963 to mitigate for the loss of salmonid habitat due to the construction of the Trinity and Lewiston dams and the operation of the Central Valley Project.

The TRH coho program is operated to provide fish for harvest in a manner consistent with the conservation of the Trinity coho population while meeting TRH mitigation requirements. The hatchery is operated as an integrated program to increase total adult abundance, productivity and fitness while minimizing genetic divergence of hatchery broodstock from the naturally spawning population.

The current production goals are to produce 300,000 coho smolts (recently reduced from a production goal of 500,000). The goal may be revised in the future based on a review of performance metrics and could range from 150,000 to 500,000 (NMFS 2020). Coho smolts are reared from 10 to 12 fish/pound and are released directly from the hatchery in early March. All coho are marked externally with a right maxillary clip. Adipose fin-clips and CWTs are not used currently to tag and mark fish. Broodstock are collected from hatchery and wild origin adults returning to the TRH fish ladder.

Actual releases have averaged 479,921 (range 287,720 to 545,851) from 2001 to 2015 (CDFW 2017). TRH Coho broodstock originated from an in-river weir in the early 1960s with some augmentation from out-of-basin sources to boost production. Out of basin transfers include eggs imported from the Eel River and Cascade Hatchery (CDFW 2017). Only endemic Trinity River broodstock has been used since 1971.

Escapement goals for coho released from the TRH program are to achieve a proportion of hatchery-origin spawners in natural areas (pHOS) of less than 30% in the Upper Trinity population and the program will strive to achieve a pHOS of 5% for coho populations in the South Fork Trinity River and Lower Trinity River (NMFS 2020). Adverse hatchery-related effects pose a very high risk in the Trinity River. Hatchery-origin coho salmon make up most of the spawning run to the Trinity River each year where pHOS has ranged from 36% to 100% across the Trinity River populations (NMFS 2014)

Table 3. Releases of hatchery salmonids within the SONCC Coho ESU (ODFW 2016; 2020; CDFW 2014; 2017; NMFS 2019; 2020).

State	Hatchery	Species	Release Goal	Marking/Tagging	Release Location
Oregon	Cole Rivers	Coho	75,000	Adipose Clip + CWT	Rogue River
		Spring Chinook	1,700,000	Adipose Clip + CWT	Rogue River
		Winter Steelhead	132,000	Adipose Clip	Rogue River
		Summer Steelhead	220,000	Adipose Clip	Rogue/Applegate Rivers
	Elk River	Fall Chinook	325,000	Adipose Clip + CWT	Elk River
		Fall Chinook	200,000	Adipose Clip + CWT	Chetco River
California	Iron Gate	Coho	75,000	Left Maxillary Clip	Klamath River
		Fall Chinook	6,000,000	Adipose Clip + CWT	
	Trinity River	Coho	300,000	Right Maxillary Clip	Trinity River
		Fall Chinook	4,300,000	Adipose Clip + CWT	
		Steelhead	448,000	Adipose Clip	
	Mad River	Steelhead	172,000	Adipose Clip	Mad River
	Rowdy Creek	Fall Chinook	150,000	Adipose Clip	Smith River
		Steelhead	80,000	Adipose Clip	Smith River

Factors affecting the ESU outside of fisheries

In addition to fisheries, factors contributing to the status of the ESU include habitat loss due to dam building, degradation of freshwater habitats due to a variety of agricultural and forestry practices, water diversions, urbanization, hatchery practices, over-fishing, mining, climate change, ocean conditions, and severe flood events exacerbated by land use practices (Good et al. 2005, NMFS 2014, Williams et al. 2016). The lack of floodplain and channel structure is a key limiting stress in nearly all coastal populations and about half of interior populations (NMFS 2014). Sedimentation and loss of spawning gravels associated with poor forestry practices and road building are particularly chronic problems that can reduce the productivity of salmonid populations. Late 1980s and early 1990s droughts and unfavorable ocean conditions were identified as further likely causes of decreased abundance of SONCC coho salmon (Good et al. 2005). From 2014 through 2016, the drought in California reduced stream flows and increased temperatures, further exacerbating stress, disease, and decreasing the quantity and quality of spawning and rearing habitat available to SONCC coho salmon. Ocean conditions have been unfavorable in recent years (2014 to present) due to El Niño conditions and the warm water "Blob" which impacted the U.S. west coast, and reduced ocean productivity and forage for SONCC coho salmon. The Scott and Shasta Rivers, both core populations from the Klamath River, are substantially impacted by water diversions annually.

Coho salmon are particularly vulnerable to climate change due to their need for year-round cool water temperatures, as they rear for one or more years in freshwater, unlike some other salmonid species (Moyle 2002). By increasing air and water temperatures, climate change is expected to decrease the amount and quality of coho salmon habitat, reducing the productivity of populations and exacerbating the decline of the species. Climate change effects on stream temperatures within Northern California are already apparent. For example, in the Klamath River, Bartholow (2005) observed a 0.5°C per decade increase in water temperature since the early 1960s.

In coastal and estuarine ecosystems, the threats from climate change largely come in the form of sea level rise and the loss of coastal wetlands. Sea levels will likely rise exponentially over the next 100 years, with possibly a 50-80 cm rise by the end of the 21st century (IPCC 2007). This rise in sea level will alter the habitat in estuaries and either provide increased opportunity for feeding and growth or in some cases will lead to the loss of estuarine habitat and a decreased potential for estuarine rearing. Marine ecosystems face an entirely unique set of stressors related to global climate change, all of which may have deleterious impacts on growth and survival while at sea. In general, the effects of changing climate on marine ecosystems are not well understood given the high degree of complexity and the overlapping climatic shifts that are already in place (e.g., El Niño, La Niña, Pacific Decadal Oscillation) and will interact with global climate changes in unknown and unpredictable ways. Overall, climate change is believed to represent a growing threat, and will challenge the resilience of salmonids in Northern California, including SONCC coho salmon.

4. FISHERY DESCRIPTION FOR SONCC COHO

Current fishery impact distribution and assessment

Coho salmon from this ESU are primarily distributed off the coast of California and southern Oregon (NMFS 2016). Overfishing in non-tribal fisheries was identified as a significant factor in the decline of coho salmon (62 FR 24588, May 6, 1997). Significant overfishing occurred from the time marine survival turned poor for many stocks (ca. 1976) until the mid-1990s when harvest was substantially curtailed or prohibited. Tribal harvest was not considered to be a major factor for the decline of coho salmon in either the Klamath River basin or Trinity River basin (62 FR 24588, May 6, 1997).

Significant changes in fisheries harvest management have occurred in recent decades, resulting in substantial reductions in harvest of SONCC coho salmon. Because coho salmon-directed fisheries and coho salmon retention have been prohibited off the coast of California since 1996, the ocean exploitation rate of SONCC coho salmon is generally low and attributable to hooking and handling in Chinook-directed commercial and recreational fisheries off the coasts of California and Oregon. Low impacts are also associated with primarily mark selective and some limited non-mark selective coho salmon fisheries off of the Oregon coast.

Because wild SONCC coho salmon are not tagged and monitored in ocean fisheries, Rogue and Klamath hatchery stocks have traditionally been used as a fishery surrogate stock for estimating ocean exploitation rates on SONCC coho salmon. Natural-origin Rogue/Klamath basin coho salmon ocean exploitation rates were estimated using the Fishery Regulation and Assessment Model (FRAM), which relies on coded-wire tag recovery data from the late 1980s and early 1990s (Figure 3). The ocean exploitation rate has been low and relatively stable since the early 1990s (average of 5.4% for years 1994–2019)(Figure 3) which contrasts sharply with the much higher rates estimated for the 1980s and early 1990s (average of 50.8% between 1986 and 1993)(Williams et al. 2016).

Impacts to SONCC coho from freshwater recreational fisheries are likely low and result from incidental mortalities in fisheries targeting Chinook and steelhead in California and Oregon and hatchery coho in the Rogue River, Oregon (Williams et al 2016, NMFS 2014). Retention of coho is prohibited in California and the mark-selective fisheries in Oregon are relatively small scale. From creel surveys conducted in 1998 and 1999, ODFW estimated an incidental fishery related mortality of 5% on wild Coho during mark-selective coho fisheries in the Rogue River (Matt Falcy, Personal communication). However, additional work is needed to estimate current levels of incidental fishing mortality.

Tribal fisheries in the Klamath and Trinity basins impact SONCC coho salmon through direct harvest and incidental mortalities in fisheries targeting other species. Klamath Basin tribes (Yurok, Hoopa, and Karuk) harvest coho salmon for subsistence and ceremonial purposes (CDFG 2002).

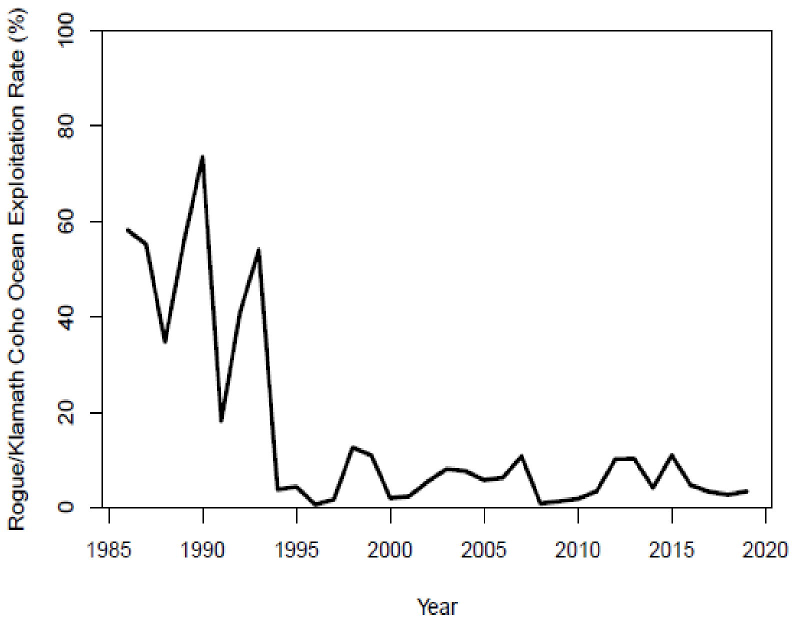

Figure 3. Trends in ocean exploitation rates on SONCC coho: 1985-2019 (Jon Carey, personal communication).

Management Framework

Ocean Fisheries

Ocean fisheries under the jurisdiction of the PFMC are managed consistent with the provisions of a biological opinion completed by NMFS in 1999. 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, spatial structure and diversity 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.

NMFS last consulted on the effects of Council fisheries on the SONCC coho salmon ESU under the ESA per Section 7(a)(2) in 1999 (NMFS 1999). At that time the Council proposed to manage SONCC coho under the provisions of Amendment 13 to the Pacific Coast Salmon Fishery Management Plan (FMP). Amendment 13 disaggregated management of Oregon Coast Natural (OCN) coho by establishing a matrix based control rule based on marine survival and the parent spawner status for four OCN sub-stocks, the most southern of which was the Oregon component of the SONCC ESU1 (Table 4). In that opinion, NMFS concluded that neither the FMP nor Amendment 13 provided specific protection for the California populations in the ESU apart from the limitation on harvest rates determined by the status of the Oregon coho stocks and the acknowledgment that the Council manages all stocks listed under the ESA consistent with NMFS'

[1] Management for OCN coho was subsequently modified by Amendment 16 which removed the southern sub-stock from the management matrix. Management for SONCC coho remain under the provisions of the 1999 opinion.

ESA consultation standards. NMFS concluded that the absence of conservation goals for the California component of the ESU would jeopardize the SONCC coho salmon ESU. NMFS developed a three-part Reasonable and Prudent Alternative that requires that (1) management measures developed under the FMP achieve an ocean exploitation rate on Rogue/Klamath coho hatchery stocks of no more 13 percent, which includes all harvest-related mortality. This was the lowest exploitation rate specified under Amendment 13 for OCN coho sub-aggregates (Table 4); (2) prohibits coho-directed fisheries and coho retention in Chinook-directed fisheries off of California, and (3) requires sampling and monitoring of Council fisheries.

NMFS' rationale in choosing the exploitation rate ceiling of 13 percent as explained in the 1999 opinion was that little information was available on natural coho spawning escapement levels in rivers of the California component of the SONCC ESU, such that the status of parent spawner recruitment was difficult to assess. Ocean exploitation rates on Rogue/Klamath coho at the time varied between 5 and 12 percent (NMFS 1999, also see Figure 3 above). The choice of a 13 percent ceiling on the exploitation rate was conservative given the limited data on the ESU and was meant to ensure that fishing mortality rates on California coho would not increase until an adequate assessment of parent spawner recruitment rates was possible. Ocean exploitation rates have generally been well below the ceiling; averaging 5.5 percent from 2010 to 2019.

Table 4 Management for Oregon coho under Amendment 13 to the PFMC salmon FMP (NMFS 1999).

	Marine Survival		
	Low	**Medium**	**High**
High Parent Spawning Escapement	**≤15%**	**≤30%**	**≤35%**
Medium Parent Spawning Escapement	**≤15%**	**≤20%**	**≤25%**
Low Parent Spawning Escapement	**≤15%**	**≤15%**	**≤15%**
38% Below Low Parent Spawning Escapement	**≤13%**	**≤13%**	**≤13%**

Fisheries under state and tribal jurisdiction

Oregon freshwater recreational fisheries for coho are mark-selective (adipose fin-clipped) within the SONCC area.

Coho retention in California recreational fisheries is currently prohibited.

Hoopa Valley Tribal Council manages fisheries for the benefit of its membership and conservation of the resource. The individual tribal member fishery (ITMF) includes harvest of hatchery-origin and natural-origin coho salmon by gill net and hook and line. A mark selective harvest of hatchery-origin coho is implemented annually through the deployment of a floating resistance board weir at the southern boundary of the Hoopa Valley Reservation. The weir is operated Monday through Friday between the hours of 1700-0900 and fish are removed from traps, sorted by species and selected for. All natural-origin coho are released upstream of the weir to continue migration. Total coho harvest from both the ITMF and weir fisheries have been reported (1991-2019) to co-managers and parsed into natural/hatchery origin, age-2 or age-3 categories.

Examples of other PFMC salmon management frameworks

A variety of fishery management strategies are currently employed in salmon fisheries for other stocks managed under the FMP in addition to the fixed exploitation rate strategy currently in place for SONCC coho salmon as described above. These strategies are primarily abundance based and employ a variety of estimators or indicators related to natural fish abundance including abundance forecasts, brood year spawner numbers, marine survival, and ocean conditions related to marine survival. Indicators might be based on wild or hatchery fish at an aggregate or indicator population level.

Fishery management strategies have also involved different combinations of exploitation rates and abundance or marine survival thresholds at which different rates are applied. For example, single year alternatives might be based on annual run size expectations while multi-year alternatives might also include extra conditions on adoption of higher or lower rates (for instance, limits if coming off successive low run years). Different rates and thresholds might be selected depending on the desired balance of conservation risks and fishery objectives.

These examples can help identify a range of indicators and approaches to consider for application to SONCC coho salmon. This section reviews examples of strategies employed in other fisheries throughout the region. Section 6 provides further discussion regarding control rules under evaluation by the Workgroup.

Puget Sound Coho

Puget Sound coho stocks are managed under the 2019-2028 Pacific Salmon Treaty Agreement using a stepped harvest rate control rule (Figure 4) (Southern Coho Management Plan Chapter 5, Annex IV, Article XV, PST 2019). Under this control rule, exploitation rate ceilings are determined on the basis of age-3 abundance, where abundance is divided into three zones defined by two breakpoints defined as:

$$A = \frac{MSST}{1-F_{low}}, \quad \text{breakpoint between critical and low abundance,}$$

$$B = \frac{S_{MSY}}{1-MFMT}, \quad \text{breakpoint between low and normal abundance.}$$

MSST = minimum stock size threshold
MFMT = maximum fishing mortality threshold
MSY = maximum sustainable yield

The exploitation rate ceiling has a maximum value of maximum fishing mortality threshold (MFMT; F_{MSY}) when N > B, is reduced to a low exploitation rate (F_{low}) when A < N < B, and further reduced to a critical exploitation rate ($F_{critical}$) to allow for *de minimis* impacts not to exceed 0.20 when N < A. For all Puget Sound coho stocks, the critical/low spawning escapement breakpoint and low exploitation rate are used to define minimum stock size threshold (MSST).

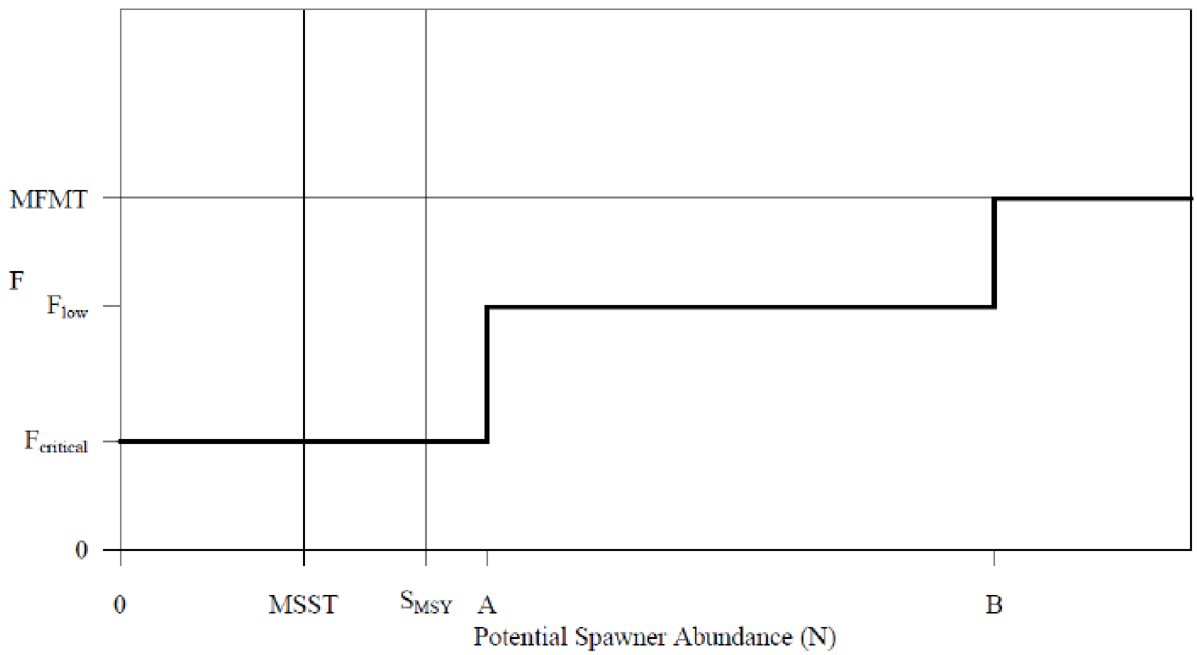

Figure 4. Control rule for Puget Sound coho. Abundance is pre-fishery ocean age-3 abundance in spawner equivalent units, and F is the exploitation rate.

Oregon Coast Natural and Columbia River coho

An abundance-based exploitation strategy was adopted by the Council in 1997 for management of fisheries for Oregon Coast natural (OCN) coho and in 2005 for Columbia River natural (LCN) coho. The maximum allowable exploitation rates for OCN vary in response to changes in observed brood year-specific parental spawner abundance and marine survival conditions (Table 5).

Table 5. Harvest management matrix identifying allowable fishery impacts and ranges of resulting recruitment based on parental spawner abundance and marine survival (OCN work group revisions to original Council matrix).

Parent Spawner Status[a/]	Marine Survival Index (Wild adult coho salmon survival as predicted by the two-variable GAM ensemble forecast)			
	Extremely Low <2%	Low 2%-4.5%	Medium >4.5%-8%	High >8%
High Parent Spawners > 75% of full seeding	E ≤ 8%	J ≤ 15%	O ≤ 30%	T ≤ 45%
Medium Parent Spawners > 50% & ≤ 75% of full seeding	D ≤ 8%	I ≤ 15%	N ≤ 20%	S ≤ 38%
Low Parent Spawners > 19% & ≤ 50% of full seeding	C ≤ 8%	H ≤ 15%	M ≤ 15%	R ≤ 25%
Very Low Parent Spawners > 4 fish per mile & ≤ 19% of full seeding	B ≤ 8%	G ≤ 11%	L ≤ 11%	Q ≤ 11%
Critical Parent Spawners ≤4 fish per mile	A 0 – 8%	F 0 – 8%	K 0 – 8%	P 0 – 8%

Sub-aggregate and Basin Specific Spawner Criteria Data

Sub-aggregate	Miles of Available Spawning Habitat	100% of Full Seeding	"Critical"		Very Low, Low, Medium & High		
			4 Fish per Mile	12% of Full Seeding	19% of Full Seeding	50% of Full Seeding	75% of Full Seeding
Northern	899	21,700	3,596	NA	4,123	10,850	16,275
North-Central	1,163	55,000	4,652	NA	10,450	27,500	41,250
South-Central	1,685	50,000	6,740	NA	9,500	25,000	37,500
Southern *(Removed per adoption of Amendment 16)*							
Coastwide Total	*3,747*	*126,700*	*14,988*		*24,073*	*63,350*	*95,025*

a/ Parental spawner abundance status for the OCN aggregate assumes the status of the weakest sub-aggregate.

Columbia River Upriver Bright Fall Chinook

The parties to U.S. v. Oregon are currently operating under the 2018-2027 Management Agreement. This agreement provides specific fishery management constraints for upriver spring, summer, and fall Chinook, coho, sockeye and steelhead. Fall season fisheries in the Columbia River Basin below the confluence of the Snake River are managed according to the abundance-based harvest rate schedule shown in Table 6. In this table, Upriver Bright (URB) stock Chinook harvest rates are used as a surrogate for Snake River wild Fall Chinook harvest rates. Upriver Bright Fall Chinook escapement goals include 60,000 adult Fall Chinook (natural and hatchery) management goal above McNary Dam. Total harvest rates in combined Treaty

Indian and non-Indian Columbia River fisheries increase with increased run size based on forecasted returns to the Columbia River.

Table 6. Columbia River Fall Management Period Chinook Harvest Rate Schedule for upriver bright fall Chinook including the listed Snake River wild component.[1]

Expected URB River Mouth Run Size	Expected River Mouth Snake River Natural Origin Run Size	Treaty Total Harvest Rate	Non-Treaty Harvest Rate	Total Harvest Rate	Expected Escapement of Snake R. Natural Origin Past Fisheries
<60,000	<1,000	20%	1.50%	21.50%	784
60,000	1,000	23%	4%	27.00%	730
120,000	2,000	23%	8.25%	21.25%	1,375
>200,000	5,000	25%	8.25%	33.25%	3,338
	6,000	27%	11%	38.00%	3,720
	8,000	30%	15%	45.00%	4,400

[1] If the Snake River natural fall Chinook forecast is less than level corresponding to an aggregate URB run size, the allowable mortality rate will be based on the Snake River natural fall Chinook run size.

Sacramento River Winter Chinook

In 2017, the Council adopted a new control rule that specifies the maximum forecast age-3 impact rate for the area south of Point Arena, California (Figure 5). The fishing regime for Sacramento River Winter Chinook maintains the fishery season and size restrictions that were part of the Reasonable and Prudent Alternative in the previous biological opinion. When the age-3 escapement absent fishing is forecasted to be 3,000 or more, the maximum forecast age-3 impact rate on Sacramento winter-run Chinook is 0.20. Between age-3 escapement absent fishing levels of 3,000 and 500, the maximum forecast age-3 impact rate decreases linearly from 0.20 to 0.10. At age-3 escapement absent fishing levels less than 500, the maximum forecast age-3 impact rate decreases linearly from 0.10 to zero.

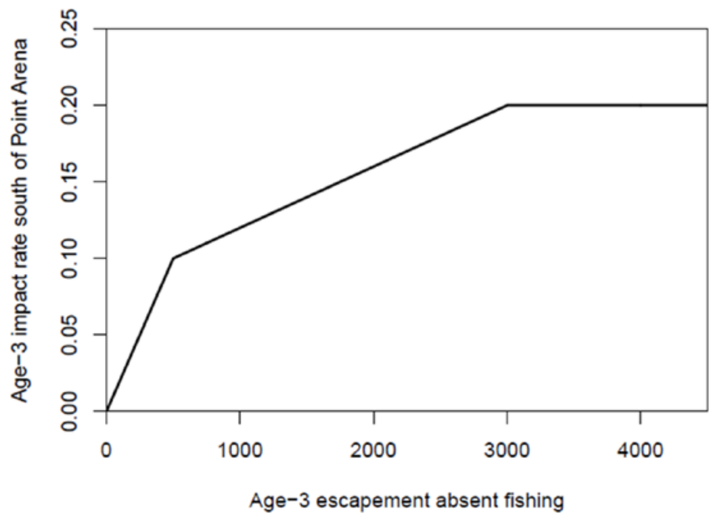

Figure 5 Sacramento River winter Chinook impact rate control rule, which specifies the maximum forecast age-3 impact rate for the area south of Point Arena, California, as a function of forecasted age-3 escapement absent fishing.

5. ABUNDANCE FORECASTING

The Council tasked the Workgroup with evaluating harvest control rules (HCR) 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. The feasibility and effectiveness of several of the types of control rules under evaluation by the Workgroup will depend in part on whether abundance can be predicted with reasonable accuracy and precision. Effective conservation-based management objectives would ideally be based on population-specific forecasts of wild fish.

This section reviews: 1) current methods of forecasting SONCC coho salmon as part of the Oregon Production Index public hatchery aggregate; 2) data considerations in the feasibility of forecasting SONCC coho salmon; and 3) the methods available and next steps.

Background

The implementation of an abundance-based HCR requires that the ocean abundance of the SONCC coho salmon ESU, or representative components thereof, be forecast prior to the fishing season. Under the existing assessment management framework, the ocean abundance of hatchery-origin SONCC coho salmon is forecasted annually as part of a larger Oregon Production Index public hatchery (OPIH) forecast process. More specifically, the Oregon Production Index Technical Team (OPITT) generates a forecast of aggregate hatchery-origin coho salmon abundance from across the OPI range (from the Columbia River to Northern California) using a sibling regression model. A subset of this aggregate forecast is then apportioned to Rogue-Klamath based the total number of smolts release from three facilities (Trinity River Hatchery [TRH], Iron Gate Hatchery [IGH], Cole Rivers Hatchery [CRH]) for the brood in question.

In contrast to hatchery-origin fish, the abundance of natural-origin SONCC coho salmon is not forecasted at the present time. Here we consider the possibilities for doing so in general terms, focusing on questions of:

> (Q1) statistical methods—what forecasting approach(es) might be appropriate for SONCC coho salmon?
>
> (Q2) data adequacy—what populations have run reconstruction data, with a record of sufficient length? Among those populations, which are likely to be monitored consistently going forward and that support timely reporting of estimates (i.e., practical requirements for future implementation)? The Workgroup will discuss these questions further at its subsequent meetings as related to developing a range of control rules for Council consideration.

Forecast Considerations and SONCC Coho Salmon

Salmon abundance forecasts are made at varying levels of spatial scale or biological resolution (e.g., population, metapopulation, basin, stock aggregate, etc.), for hatchery- and/or natural-origin fish separately, and even for indices of abundance/production (e.g., Sacramento Index) rather than 'true' population abundance itself, with the choice being governed largely by data availability and management needs. For SONCC coho salmon in particular, the present forecasting framework encompasses three hatchery components (IGH, TRH, CRH) only; and it remains to be seen what will be feasible given data availability for other populations within the ESU, as well as necessary for HCR implementation.

Forecasts of salmon abundance are generated using models that come in many forms and degrees of complexity, ranging from simple moving averages of abundance in prior years to complex population or life cycle models. Yet all typically fall into one of three broad categories (nomenclature after Velez-Espino et al. 2019): sibling regression models, mechanistic models, and time series models, each of which may also include environmental covariates that correlate with survival during outmigration or early marine stages.

Sibling regression models predict the abundance of older age classes during year *t* based on the prior year's abundance for younger (sibling) age classes from the same brood in year *t* - 1 (for coho salmon, jacks). Mechanistic models are varied in form and complexity (Table 7), but typically predict abundance in year *t* by modeling the survival process for a cohort/cohorts, seeded with some empirical information in prior years (e.g., outmigrant abundance, spawner abundance in parent generation, etc.). Examples here include 'return rate' forecasts that apply recent estimates of survival or predictions of survival, often with underlying environmental covariate relationships, to observations of outmigrant abundance for the brood of interest (e.g., Washington's Lower Columbia Natural coho populations). For a more complex example of a mechanistic model, preseason predictions of Sacramento Winter Run Chinook are made using a life cycle/population model that includes a variety of environmental influences on riverine, estuarine, and early marine survival, among other factors. Lastly, time series models can be used to predict abundance from observations of abundance in prior years alone. Again, while this approach can be relatively simple and straightforward (e.g., moving-average predictions, Oregon Coastal Natural [OCN] Lakes coho salmon), time series models can also be complex and varied, including covariates and/or autoregressive terms, among other possibilities.

For SONCC coho salmon applications, the best choice of forecasting method(s) from those described above and/or the ESU components will be heavily influenced by data availability (Table 7). At the most basic level (e.g., 3-year moving average), for example, a forecast could conceivably be made for any population for which a few years of escapement data exist, given that appropriate adjustments for incidental marine and freshwater fishery-related and natural mortality can also be made for each run year. With this small of a dataset, however, there is essentially no way to meaningfully assess forecast performance. For populations having a decade or more of demographic (e.g., smolt-to-adult survival) or abundance data (smolt abundance, jack abundance, parent-generation spawners, etc.), the possibilities are more varied, and include sibling regressions, mechanistic models, more complex time-series models, hybrids of these methods, or even other statistical approaches (e.g., Rupp et al. 2012, OCN Rivers).

While data volume is a precursor to a meaningful assessment of forecast feasibility, other data-related factors may influence success in the SONCC coho salmon context. First, reasonably strong statistical relationships between predictor variables (e.g., jack abundance, environmental variables, etc.) and the ocean abundance of coho salmon at the start of the fishing season are necessary. Though perhaps obvious, observation error may be exceptionally high for some populations in the

ESU due to their late spawn timing and the flashy hydrology of many streams in the region, making it difficult to detect and apply underlying predictive relationships. Late spawn timing may also determine when the age-specific estimates of escapement (i.e., jacks) needed to forecast abundance using sibling regression methods typically become available, possibly influencing feasibility in practical terms.

Available Data & Next Steps

Given the considerations outlined here and in the review of available population data summarized in Chapter 3, Table 2 above, the workgroup determined there are three population aggregates and one population for which forecasting may be feasible, the Rogue River in Oregon, and the Klamath Basin, the Trinity River Basin, and Freshwater Creek in California. While these populations/aggregates reflect a fraction of the ESU, they span much of the ESU's geographic range and integrate a moderate level of population and physiographic diversity (see Chapter 3). The datasets available for these populations range ca. one to two decades in length for ocean abundance and escapement and generally have shorter histories for smolt abundance monitoring. Using these data, the workgroup will assess the feasibility of forecasting abundance for each of the population/population aggregates using multiple methods. The workgroup could then assess forecast performance through a retrospective evaluation, and develop recommendations for implementation, should an abundance-based HCR be adopted.

Table 7. Methods for forecasting of the ocean abundance of coho salmon in year *t*. For the fields under 'Historical and annual data needs', X = required. Note also that estimates for environmental covariates are also needed on a timely basis if they are part of the forecast model (applicable to all).

Forecast type	Conceptual structure	Model complexity	Data burden	Historical and annual data needs			Comments
				Adult N (Ad_t)	Jack N (Ja_t)	Outmigrant or juvenile N (Sm_t)[1]	
Sibling regression	$Ad_t \sim Ja_{t-1}$	Moderate-High	Moderate	X	X		Timely estimates of jack abundance in prior year needed (lags on ageing?).
Mechanistic model	e.g., $Ad_t \sim S. \times Sm_{t-1}$	Moderate-High	Moderate-High	X	~	X	Data needs depend on type of model (e.g., survival estimates [*S.*] are needed for return rate models).
Time series model	$Ad_t \sim f(Ad_{t-1}, Ad_{t-2} \ldots Ad_{t-n})$	Low-High	Low	X	~		Complexity can vary widely.

[1] *Parent-generation spawner abundance may be a suitable alternative here (i.e., $Ad_t \sim \beta Sp_{t-3}$)*

6. HARVEST CONTROL RULES CONSIDERED

The workgroup has developed an initial suite of control rules for preliminary analysis with the risk assessment model. The range of this initial set of control rules is consistent with the Terms of Reference and the Purpose and Need portion of section 2 in this report. In particular, the workgroup has developed fixed control rules and control rules with tiers that reduce exploitation rates at low abundance levels. Furthermore, the initial suite of control rules includes those that apply to marine and freshwater fisheries combined and marine fisheries only.

Figure 6 displays an initial set of constant exploitation rate control rules. Control rule 1 is specified as a total (marine and freshwater) exploitation rate of zero, and is included only to provide a reference for population outcomes in the absence of fisheries. Control rules 2-4 specify constant total exploitation rates of 7, 13, and 26 percent, respectively. Control rules 5-7 specify constant ocean exploitation rates of 7, 13, and 26 percent, respectively. For comparison, the present HCR is a static 13% marine ER, and 7% and 26% reflect approximately half and twice this rate. Control rule 6 represents the status quo control rule for Rogue-Klamath coho.

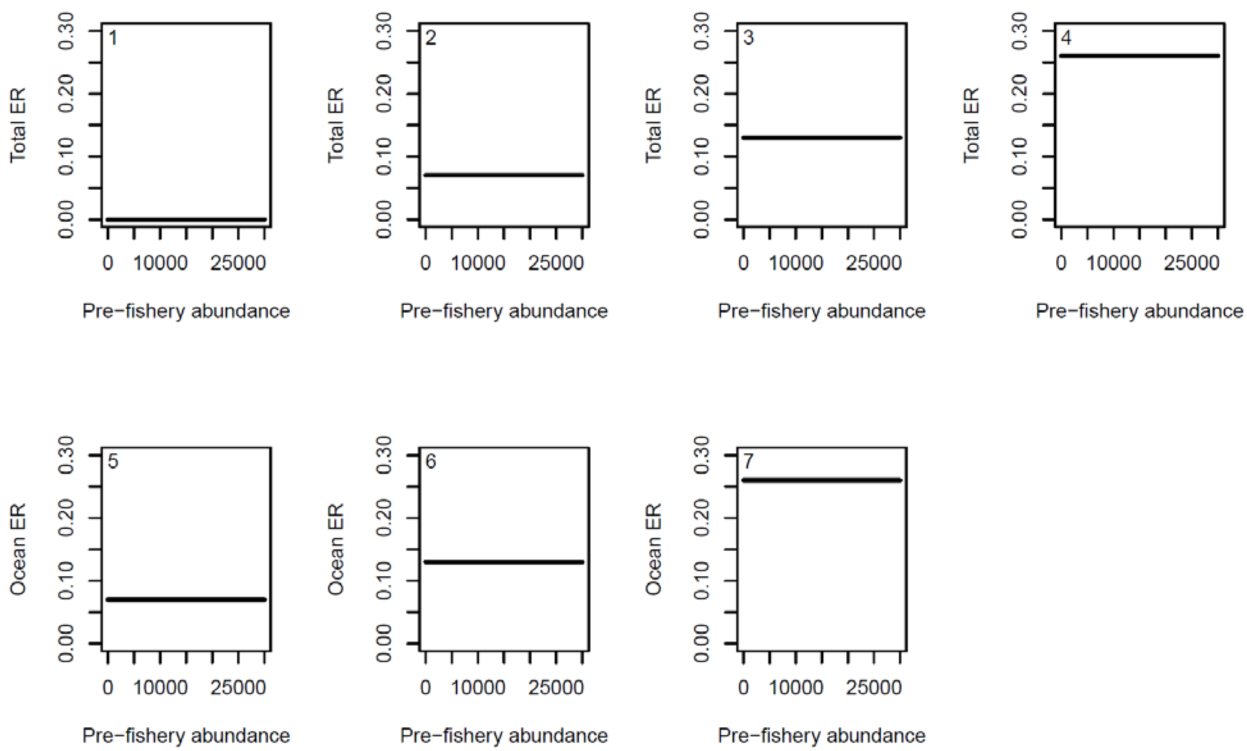

Figure 6 Graphical depiction of control rules 1-7. Control rules 1-4 specify constant total exploitation rates and control rules 5-7 specify constant exploitation rates that apply only to ocean fisheries.

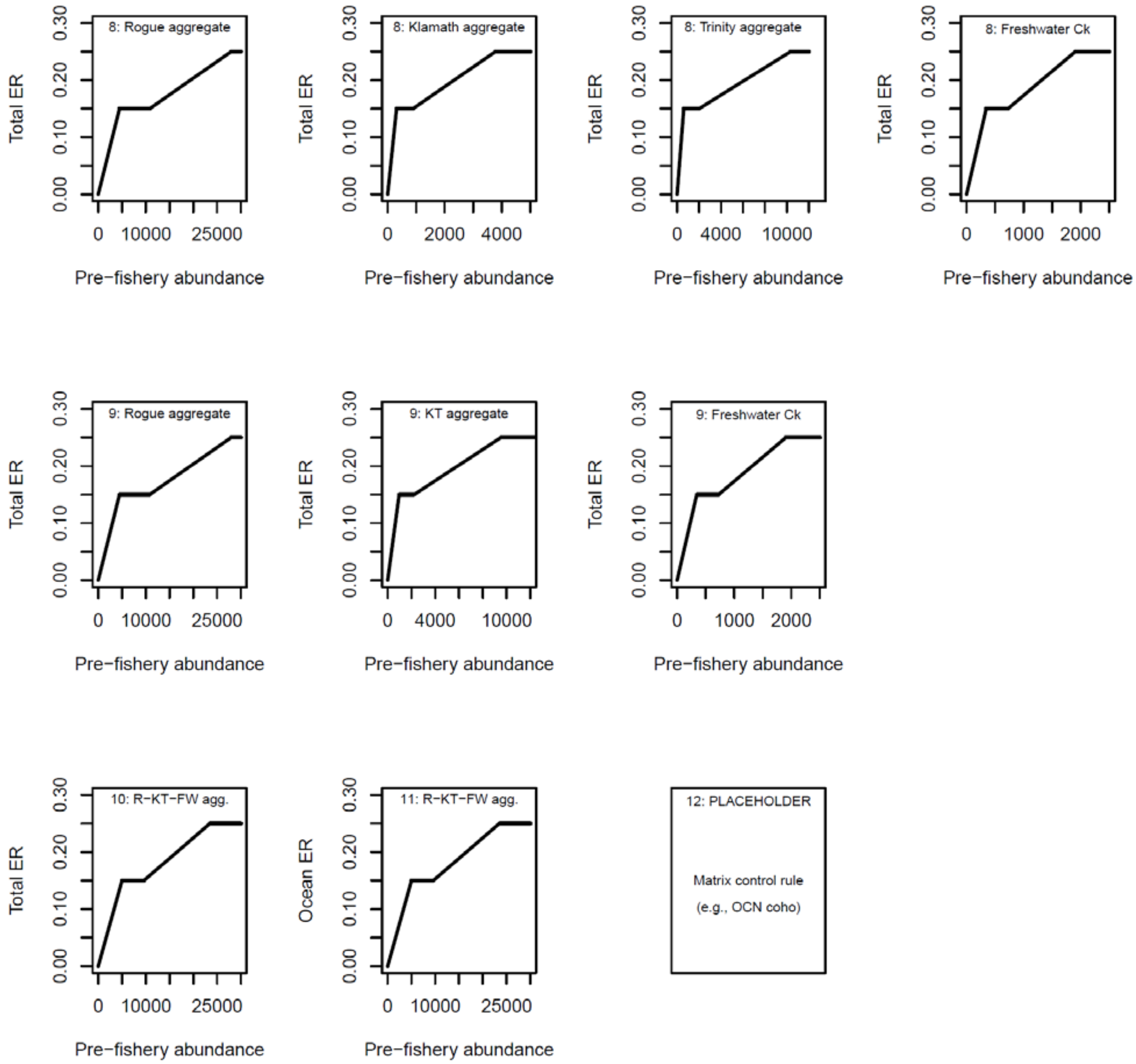

Figure 7. **Graphical depiction of control rules 8-12. Control rules 8 and 9 consist of systems of harvest controls for various SONCC coho population aggregates and are specified as abundance-based limits to total exploitation rates. Control rules 10 and 11 apply to total SONCC coho abundance (for components with sufficient data), which includes Rogue aggregate abundance (R), Klamath-Trinity aggregate abundance (KT), and Freshwater Creek (FW). Control rule 10 specifies limits to the total exploitation rates while control rule 11 applies only to ocean fisheries. Control rule 12 is not currently specified but is reserved as a placeholder for a potential matrix-based control rule similar to that used for Oregon Coastal Natural (OCN) coho.**

Figure 7 displays an initial set of abundance-based control rules and a placeholder for a potential matrix-based control rule. Each of the control rules in Figure 7 (with exception of the placeholder for control rule 12) have the same basic form, which is depicted in Figure 8. These abundance based control rules specify a cap on the exploitation rate (Y3 in Figure 8) at “high” abundance (> X4). As abundance decreases below abundance level X4, the allowable exploitation rate decreases linearly until abundance level X3. Between "moderate" abundance levels X3 and X2, the control rules specify a "moderate" level of the exploitation rate, Y2. When abundance is predicted to be low (below X2), the exploitation rate decreases linearly from Y2 to X1 (an exploitation rate of zero). For each of the control rules in Figure 7, the "moderate" level of abundance (between X2 and X3) is defined as the middle 50 percent of the distribution of past abundances. The 25th percentile of the abundance distribution lies below X2, while the 75th percentile of the abundance distribution lies between X3 and X4, with X4 defined as the highest observed past abundance level. The constant exploitation rates specified at moderate and high abundances are 15 and 25 percent, respectively, for each control rule.

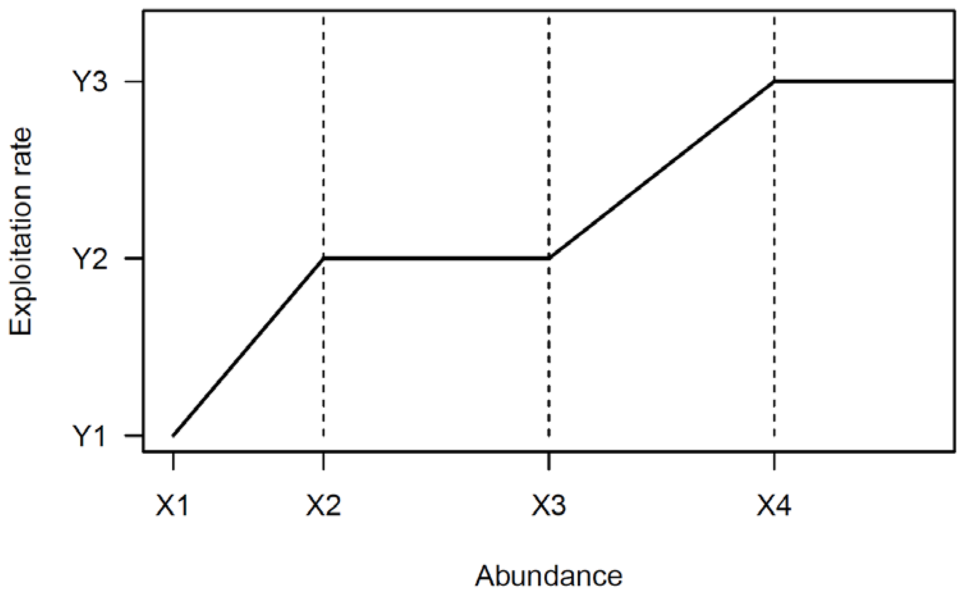

Figure 8. General form of control rules 8-11. Reference abundance and exploitation rate levels are defined in the text.

Control rule 8 represents a system of harvest controls applied independently to four components of the SONCC coho ESU (Figure 7). The Rogue aggregate applies to a multi-population aggregate of coho abundance as estimated at Huntley Park in the lower Rogue River. The Klamath aggregate applies to a multi-population aggregate of coho abundance, including Bogus Creek, Shasta River, and Scott River, all of which are tributaries to the Klamath River. The Trinity aggregate applies to a multi-population aggregate of coho abundance which applies to coho spawning in natural areas in the upper Trinity River. Finally, Freshwater Creek is a component of the Humboldt Bay tributaries population. Application of control rule 8 would require that each of the four components be at or below the maximum total exploitation rates specified for that component.

Control rule 9 is equivalent to control rule 8, but the Klamath and Trinity aggregates were combined into a single KT aggregate. Control rules 10 and 11 both apply to the total Rogue, Klamath, Trinity, and Freshwater Creek abundances. Control rule 10 specifies maximum allowable total exploitation rates while control rule 11 specifies maximum allowable ocean exploitation rates. A summary of control rule attributes can be found in Table 8.

Table 8. Attributes of candidate control rules. The number of separate components column refers to the number of discrete harvest controls within a particular control rule.

Control Rule	Form	Number of separate components	ER type	Minimum ER	Maximum ER	ER at median abundance
1	constant ER	1	Ocean and FW	0.00	0.00	0.00
2	constant ER	1	Ocean and FW	0.07	0.07	0.07
3	constant ER	1	Ocean and FW	0.13	0.13	0.13
4	constant ER	1	Ocean and FW	0.26	0.26	0.26
5	constant ER	1	Ocean	0.07	0.07	0.07
6	constant ER	1	Ocean	0.13	0.13	0.13
7	constant ER	1	Ocean	0.26	0.26	0.26
8	N-based ER	4	Ocean and FW	0	0.25	0.15
9	N-based ER	3	Ocean and FW	0	0.25	0.15
10	N-based ER	1	Ocean and FW	0	0.25	0.15
11	N-based ER	1	Ocean	0	0.25	0.15
12	matrix-based ER		placeholder: not yet developed			

While the basic configuration of the abundance-based control rules allows for reduced exploitation rates at low abundances, the specific abundance breakpoints and levels of exploitation rate are not based on biological attributes of the population components or aggregates. This information was not available in time to incorporate into these preliminary control rules. Rather, these control rules were parameterized by the distributions of past abundance and an examination of past exploitation rates. It is possible that the form and parameterization of these control rules could be modified in the future. Furthermore, the workgroup expects to expand the potential control rules based on further analysis and Council guidance.

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, Lower Columbia River Fall Chinook, Lower Columbia River Coho, and Sacramento Winter Chinook salmon.

Performance measures

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

Conservation metrics

Spawning escapement is simply the numbers of natural-origin adults in a population that reach the spawning grounds. ESA status is typically measured based on geometric mean which is the nth root of the product of n years. Geometric means are used instead of arithmetic averages as a truer measure of status which avoid disproportionate effects of periodic large escapements which can skew the average. Both means and variability in escapement are important. It does little good to avoid extinction on average when extinction occurs during periods of low escapement. Run size available to ocean or freshwater fisheries may also be an important metric in some situations.

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

Exploitation rate is the percentage of returning adults that are harvested or otherwise impacted by the fisheries. Exploitation rate affects how many fish of the subject stock or populations are harvested but, for nontarget stocks, often drives access and harvest of more abundant natural or hatchery stocks in mixed stock fisheries

Harvest is the number of the subject stock taken by the fisheries. Harvest of other associated stocks affected by subject stock limits is also an important number in mixed stock fisheries.

Frequency of occurrence of various exploitation rates or rate strata may also be an important consideration in mixed stock fisheries.

Populations considered

SONCC Coho

Risk assessments based on population viability are typically based on populations representative of the ESA-listed and fishery management units. Populations and population strata have previously been defined by the ESA Recovery Plan for SONCC coho (Table 9).

In the case of SONCC coho, stock assessment data appropriate for estimating key stock-recruitment parameters is available for five areas representing populations, portions of populations or population aggregates:

1. Rogue River is an aggregate of three interior populations based on long-term seine sampling data at Huntley Park on the lower Rogue.
2. Bogus Creek represents a portion of the upper Klamath River population. Hatchery influence is historically very high (NMFS 2014).
3. Shasta River is a population in the interior Klamath stratum of the ESU. Hatchery influence is historically high (NMFS 2014).
4. Scott River is a population in the interior Klamath stratum of the ESU.
5. Trinity River is an aggregate of all three Trinity populations based on weir sampling. There is very low abundance in lower and South Fork Trinity, hence, 90% of the coho are believed to be for the Upper Trinity. This is consistent with observations that approximately 85-90% of coho in any given year are marked hatchery fish. Hatchery influence is historically very high (NMFS 2014).

Spawner and recruit estimates (Table 10) were based on run reconstructions for the subject populations. Run reconstructions identify total numbers of spawners and natural-origin adults recruiting to ocean fisheries from progeny from each brood year of spawners. Recruitment estimates are age-3 ocean recruits (prior to ocean fisheries). They are river mouth returns for age-3 fish (accounting for escapement and any river harvest) expanded by the ocean impact rate. See Appendix B for methods used to estimate recruits.

Beverton-Holt spawner-recruit functions were fit to population data fit using simple least squares model for each population independently and using a simple Bayesian hierarchical model with a shared temporal pattern (M. Liermann, NOAA, personal communication). The basic parameters for a Beverton-Holt function include:

Productivity - maximum recruits per spawner as spawners approach zero
Capacity - asymptotic number of recruits at large numbers of spawners
Neq - Equilibrium abundance defined by the replacement point where spawners equal recruits
SD - Error term in the stock-recruitment fit to the data
Smax - Maximum number of spawners observed in the data

Rmax - maximum number of recruits observed in the data

In the least squares fits, autocorrelation of errors among years was also examined based on an independent calculation from residuals of the model fit. The autocorrelation parameter is labeled "Acor".

The Bayesian model formulation was:

$$R_{p,y} = \frac{S_{p,y}}{\frac{1}{prod_p} + \frac{S_{p,y}}{cap_p}} e^{w_{p,y}+z_y}$$

Recruits, Rp,y, for each year, y, and population, p, is modeled using a spawner-recruit function while assuming log-normal error with a common temporal component shared among populations. Here, Sp,y is spawners, $prod_p$ is the population specific productivity parameter, cap_p is the population specific capacity parameter, and wp,y and zy are the population specific and common residuals respectively. The residuals are modeled as, wp,y~normal (0,σp) and zy~normal (0,σtot), where common temporal pattern is constrained to some to 0, ∑zy=0. The productivity and capacity parameters are modeled using a hierarchical structure, where they each come from common log normal distributions.

$$\log(prod_p) \sim normal(\mu prod, \sigma prod)$$

$$\log(cap_p) \sim normal(\mu cap, \sigma cap)$$

Vague normal, normal (0,100), and gamma, gamma (0.001,0.001), priors are applied to the mean, μ, and precision (1/σ2) hyper prior parameters respectively.

Results of stock-recruit analyses are detailed in Table 11 and 9 through Figure 17. Least squares and Bayesian methods produced slightly different estimates of stock recruitment parameters (Table 11) but corresponding curves were very similar (Figure 10 - Figure 15). Fits of the stock-recruitment function to the data were generally poor with wide credible intervals identified to parameters for all populations. The Bayesian model reduced some of the extreme parameter estimates and produced wide credible intervals for many of the parameters (Figure 9). Least square parameters are within the 80% credible interval for the posterior estimates for the Bayesian fits (Figure 9).

Annual patterns of variability do not appear to be strongly correlated among California populations of SONCC coho. In plot of residuals versus year in least squares spawner-recruit fits, all populations except Freshwater Creek had large recruits for 2010, but otherwise there does not to be much of a common pattern in time across the populations (Figure 16). In the Bayesian analysis, there did not appear the populations shared much of their residual variability although the time series were relatively short. The average standard deviation for the population specific residuals, zp,y, was 0.94, while the standard deviation for the shared residuals was 0.31. The median auto correlation for the common trend is -0.01.

Table 9. Populations, strata, current extinction risk, minimum target extinction risk and recovery criteria of SONCC coho salmon ESU (NMFS 2014).

Stratum	Populations	Risk status	Risk goal	Recovery role	Recovery criteria	Depensation threshold[a]	Intrinsic potential	Analysis populations
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		--
Interior Rogue R	Illinois R	High	Low	Core	11,800	590		Rogue
	Middle Rogue/Applegate R	High	Moderate	Non-core 1	2,400	603		
	Upper Rogue R	Moderate	Low	Core	13,800	689		
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		--
Interior Klamath	Middle Klamath R	Moderate	Moderate	Non-core 1	450	113		--
	Upper Klamath R	High	Low	Core	8,500	425		Bogus Crk
	Shasta R	High	Low	Core	4,700	144		Shasta R
	Scott R	Moderate	Low	Core	6,500	250		Scott R
	Salmon R	High	Moderate	Non-core 1	450	114		--
Interior Trinity	Lower Trinity R	High	Low	Core	3,600	112		Trinity R
	South Fork Trinity R	High	Moderate	Non-core 1	970	242		
	Upper Trinity R	Moderate	Low	Core	5,800	365		
Southern Coastal Basin	Humboldt Bay tributaries	Moderate	Low	Core	5,700	191		Freshwater Crk.
	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 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	--	--		--

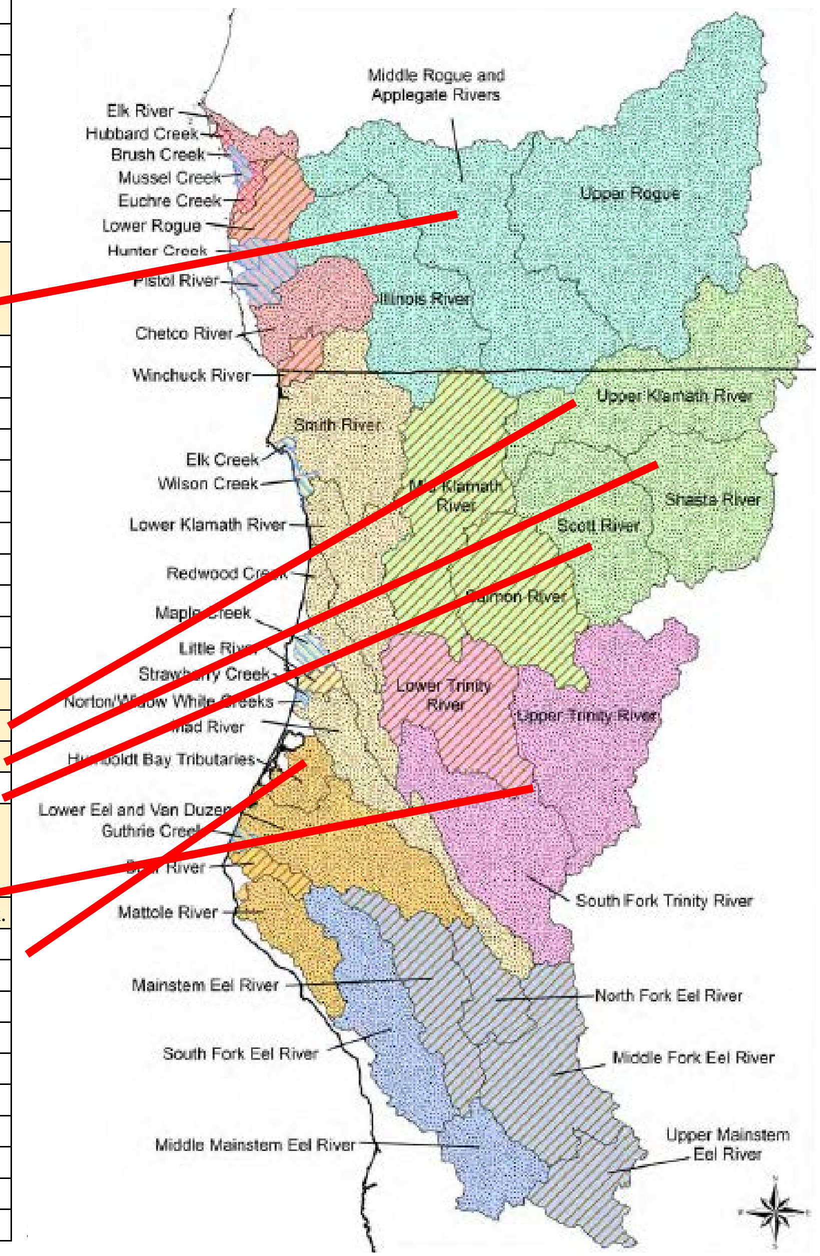

Table 10. Spawner (Spnrs) and age-3 recruit (Recr) data for natural-origin populations of SONCC coho.

Year	Rogue R.		Bogus Crk.		Freshwater Crk.		Scott R		Shasta R.		Trinity R.	
	Spnrs	Recr	Spnrs	Recr	Spnrs	Recr	Spnrs	Recr	Spnrs	Recr	Spnrs	Recr
1996	6,076	1,637	--	--	--	--	--	--	--	--		
1997	8,253	11,995	--	--	--	--	--	--	--	--	2,892	389
1989	2,484	13,528	--	--	--	--	--	--	--	--	5,995	3,850
1999	1,638	10,749	--	--	--	--	--	--	--	--	1,692	589
2000	11,895	8,608	--	--	177	795	--	--	--	--	6,585	4,384
2001	13,514	27,972	--	--	701	1,058	--	--	--	--	18,715	10,342
2002	10,618	11,035	--	--	1,807	833	--	--	--	--	7,812	2,983
2003	7,907	4,512	--	--	731	419	--	--	--	--	14,255	1,869
2004	25,823	5,933	395	254	974	291	--	--	--	--	23,117	1,343
2005	10,410	470	87	100	789	403	--	--	--	--	11,702	1,471
2006	4,243	2,842	33	9	396	90	--	--	--	--	8,870	622
2007	5,394	4,356	197	184	262	463	1,529	1,016	249	55	2,552	973
2008	448	5,194	105	66	399	644	59	386	30	38	3,065	1,375
2009	2,800	6,440	5	18	89	354	76	224	9	34	2,156	2,139
2010	4,187	13,813	146	221	455	173	913	3,410	44	147	2,770	5,753
2011	4,920	2,782	107	15	624	750	344	419	59	3	3,394	1,039
2012	5,784	5,042	67	18	318	504	188	239	76	55	7,912	1,014
2013	12,374	7,950	438	48	155	489	2,631	254	160	52	12,883	811
2014	2,632	4,936	22	43	718	553	383	384	5	39	7,228	59
2015	4,530	9,525	13	47	449	577	188	799	43	40	625	79
2016			51	62	466	313	226	367	46	54	2,901	123

Table 11. Beverton-Holt stock-recruitment parameter fits.[2]

Population	Method of fit	Prod	Cap	Neq	SD	SD_{resid}	acor	Smax	Rmax
Rogue	Approximate	6.0		6,000					
Bogus	Least squares	2.4	96	56	0.95	--	0.00	438	254
	Bayesian	6.5	81	63	0.99	0.91	-0.18	438	254
Freshwater	Least squares	33.5	463	449	0.60	--	0.16	1,807	1,058
	Bayesian	13.8	495	447	0.73	0.64	0.15	1,807	1,058
Scott	Least squares	6.0	774	646	0.76	--	0.02	2,631	3,410
	Bayesian	11.9	634	569	0.83	0.73	-0.10	2,631	3,410
Shasta	Least squares	107.4	40	40	0.95	--	-0.51	249	147
	Bayesian	11.9	55	48	1.08	1.00	-0.43	249	147
Trinity	Least squares	0.4	2,604	-4093	1.23	--	0.53	23,117	10,342
	Bayesian	7.5	1,082	794	1.36	1.29	0.57	23,117	10,342

[2] *Parameter estimates are preliminary and may be refined.*

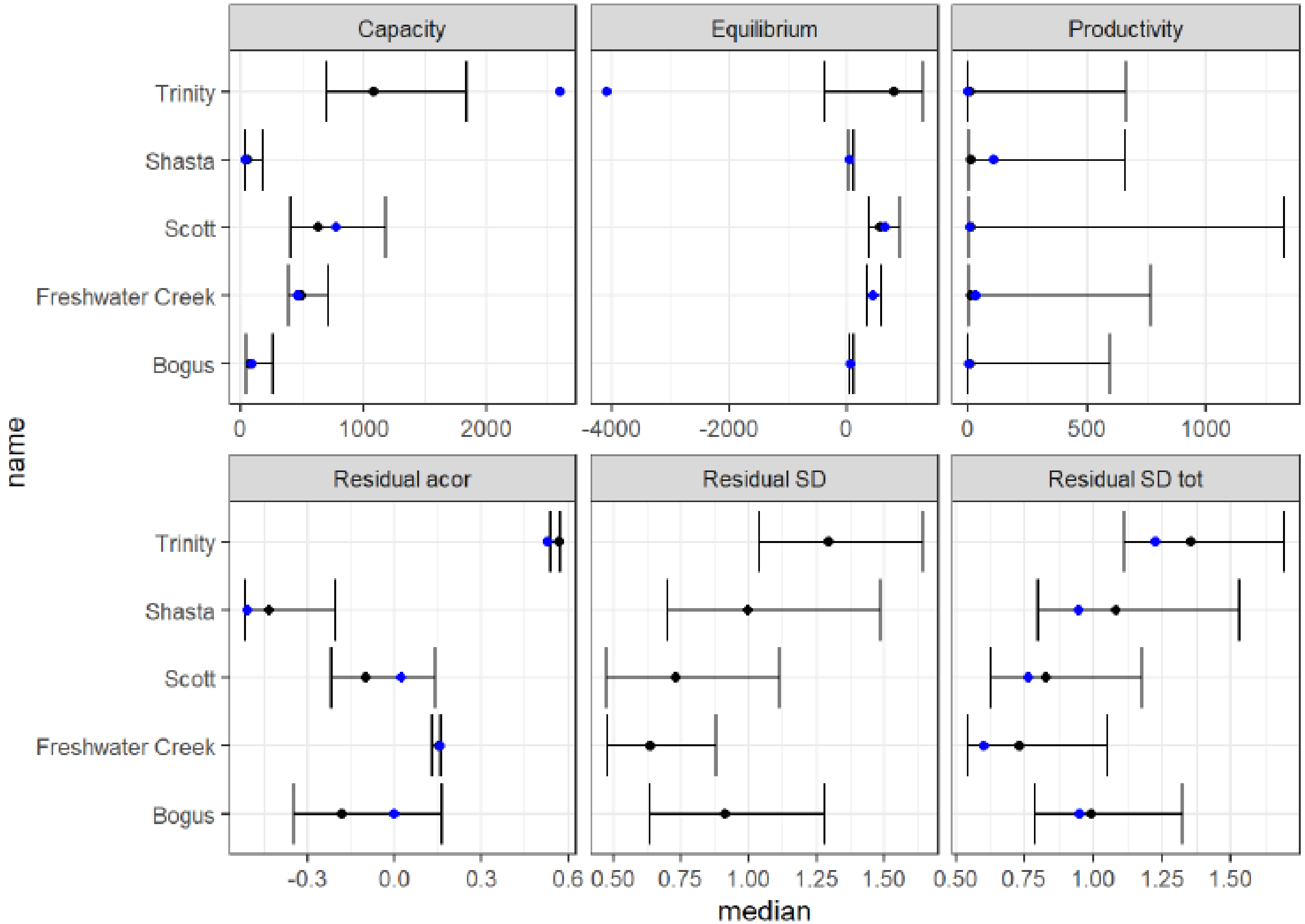

Figure 9. Plot of the population specific parameters with the blue points representing the least squares fit and the black points and bars representing the median and 80% credible interval for the posterior estimates for the Bayesian fits.

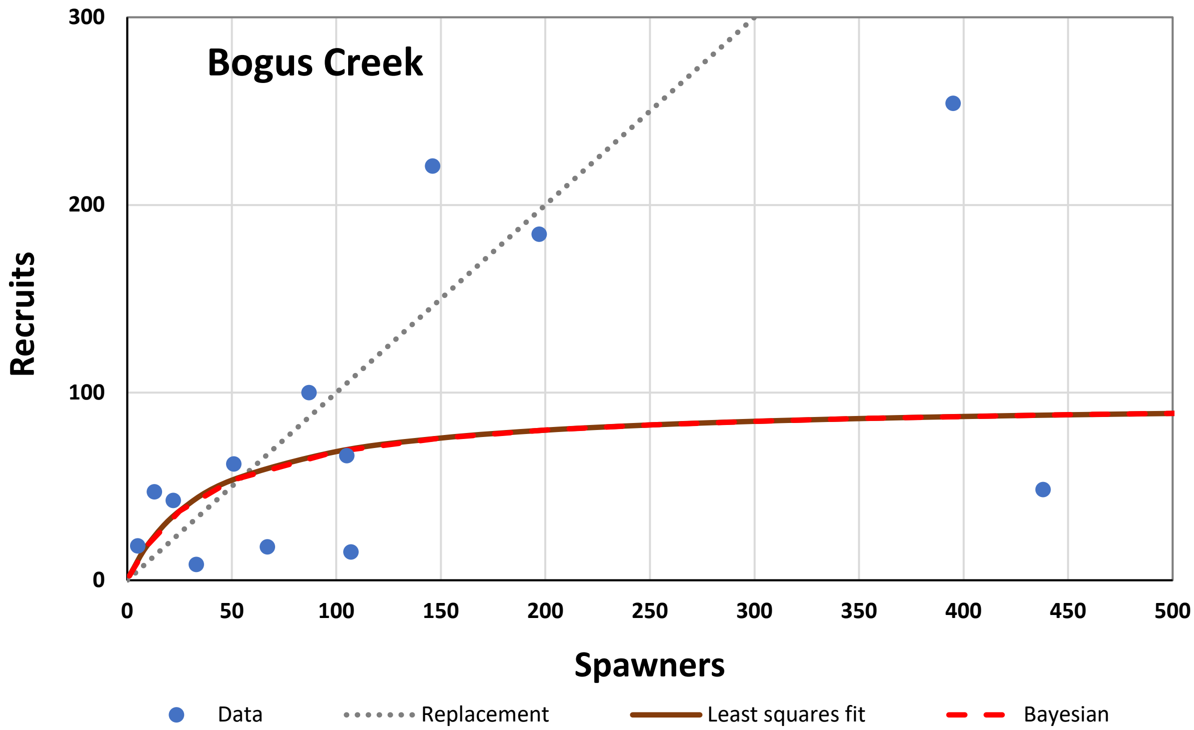

Figure 10.Spawner-recruit relationship for Bogus Creek.

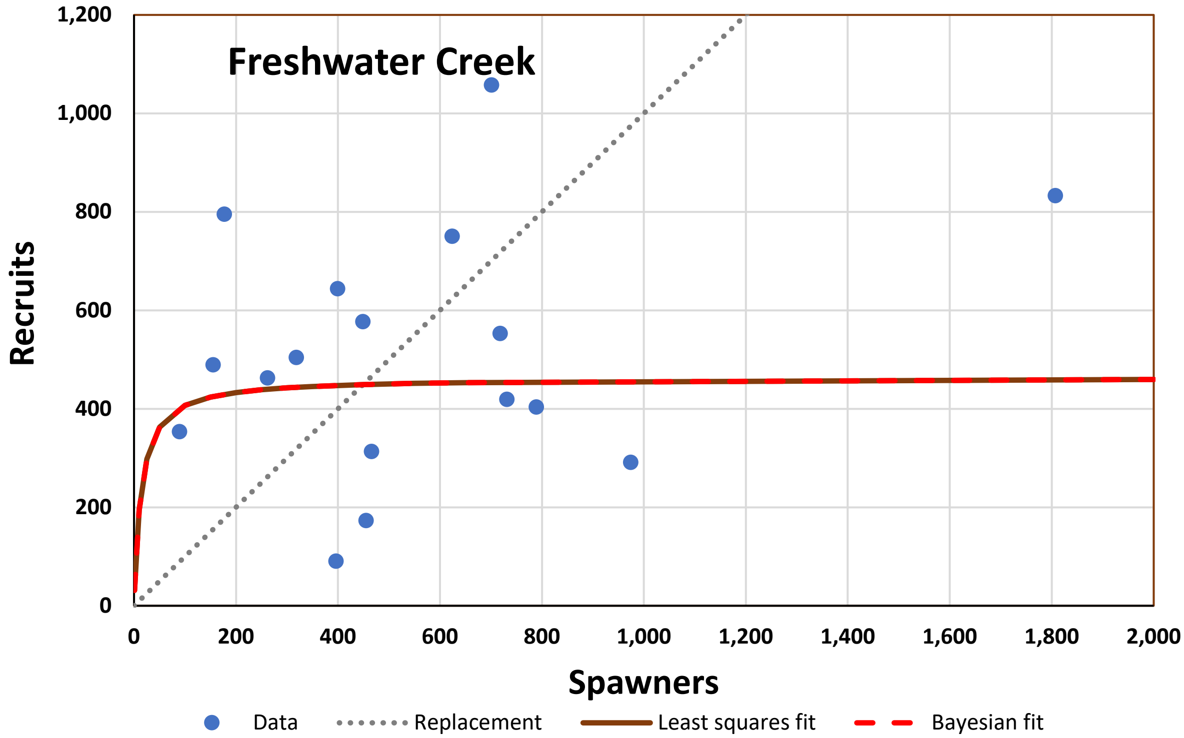

Figure 11.Spawner-recruit relationship for Freshwater Creek coho.

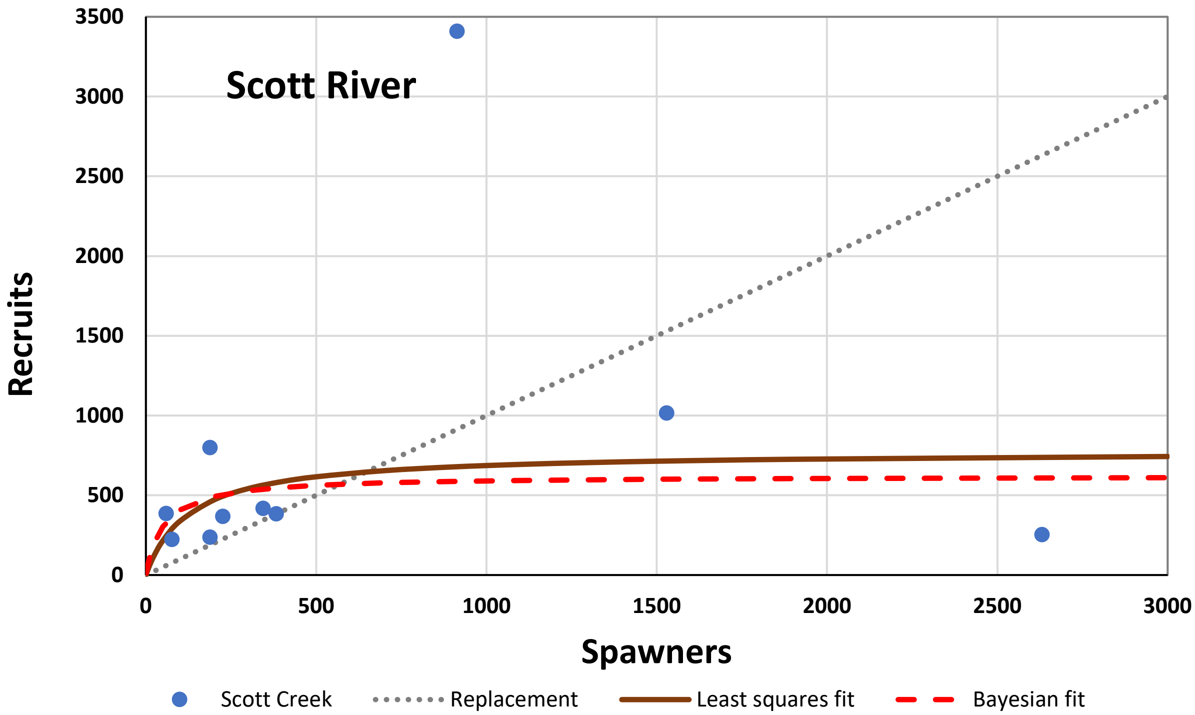

Figure 12.Spawner-recruit relationship for Scott River coho.

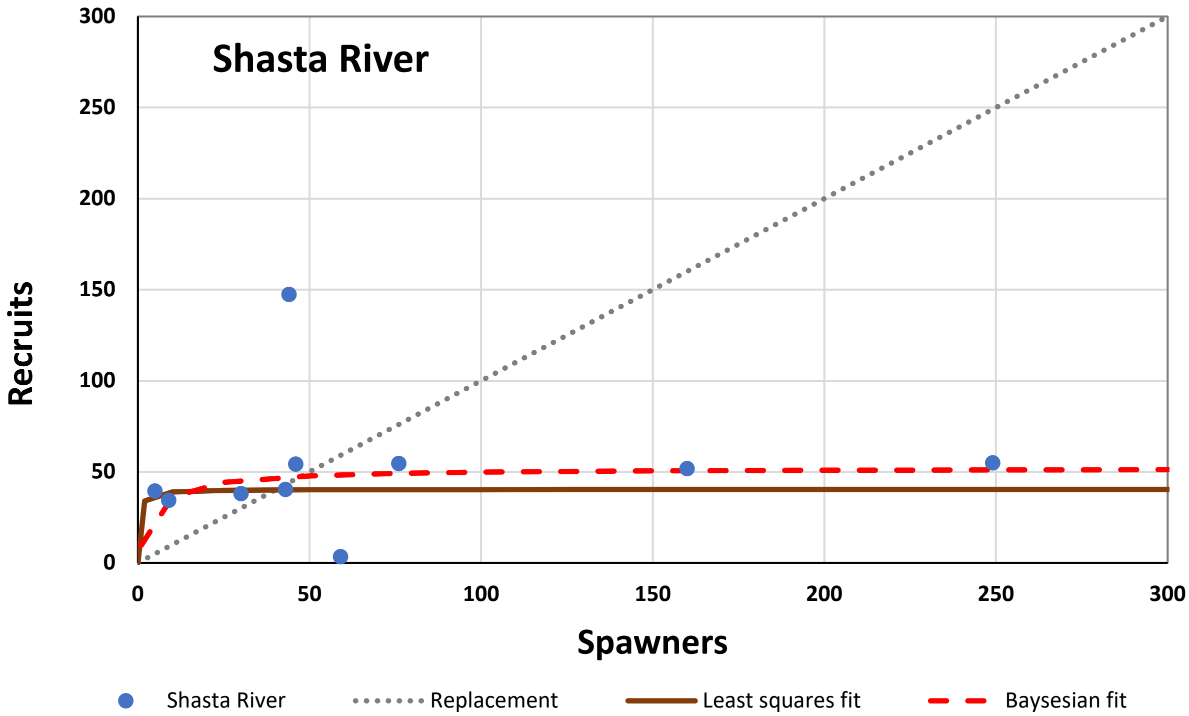

Figure 13.Spawner-recruit relationship for Shasta River coho.

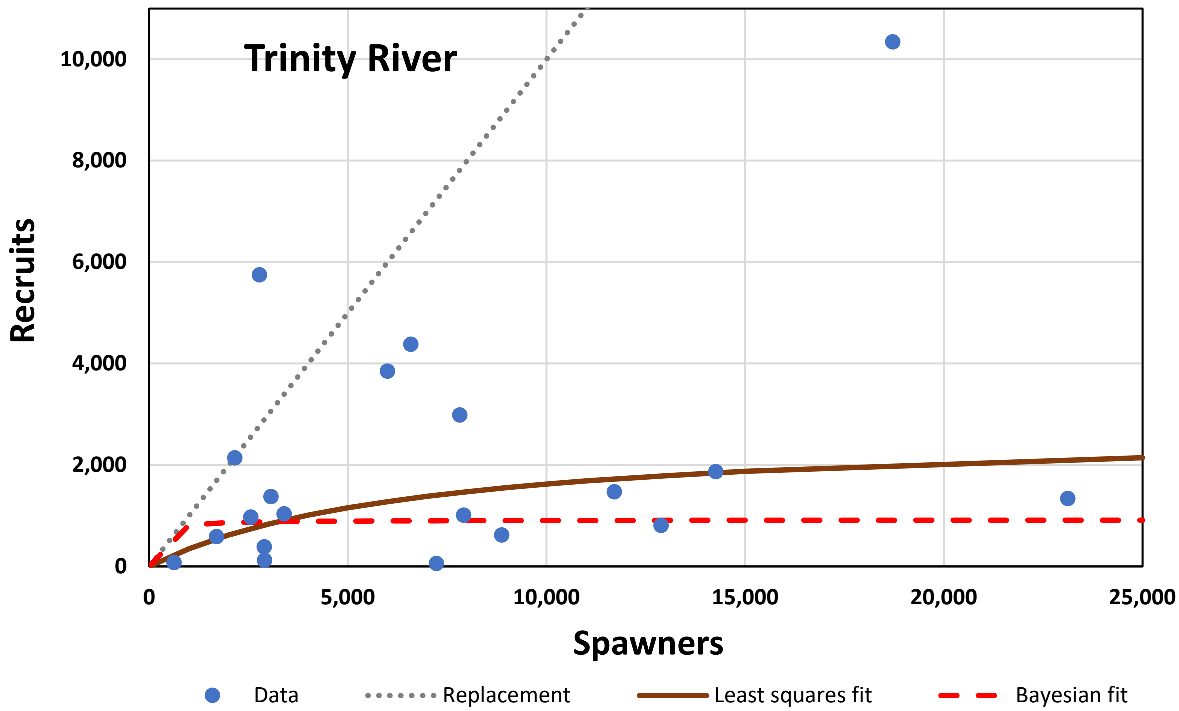

Figure 14.Spawner-recruit relationship for the Trinity River.

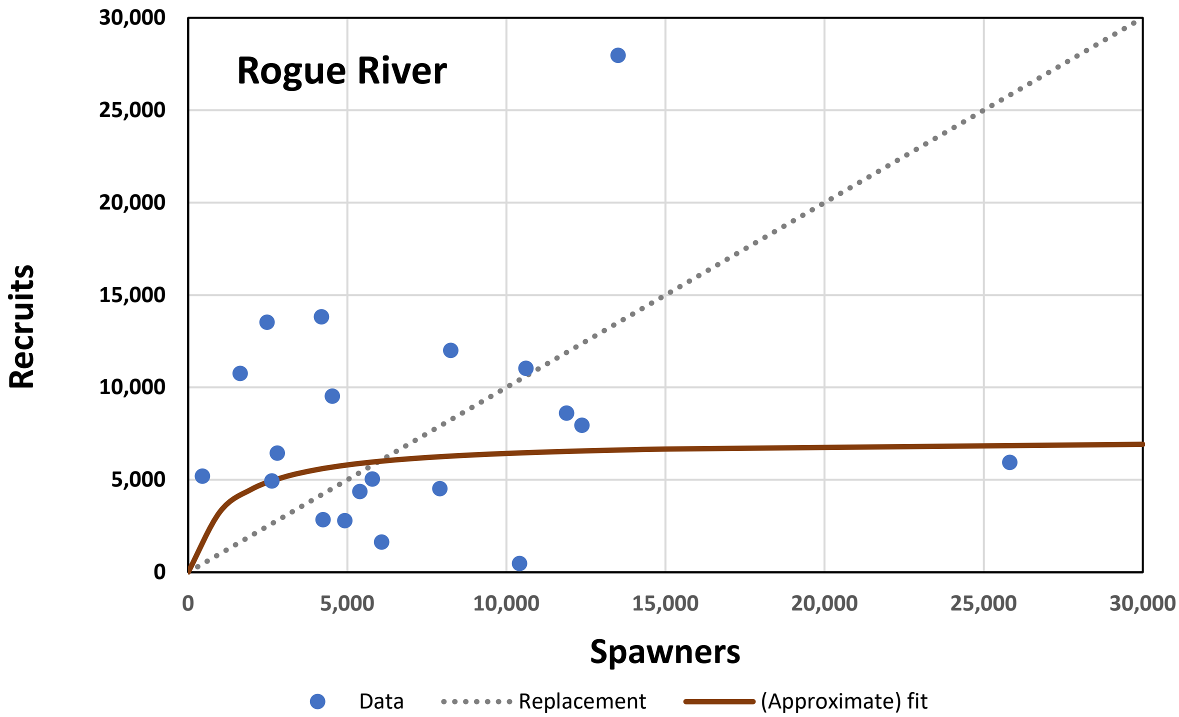

Figure 15.Spawner-recruit relationship for Rogue River coho.

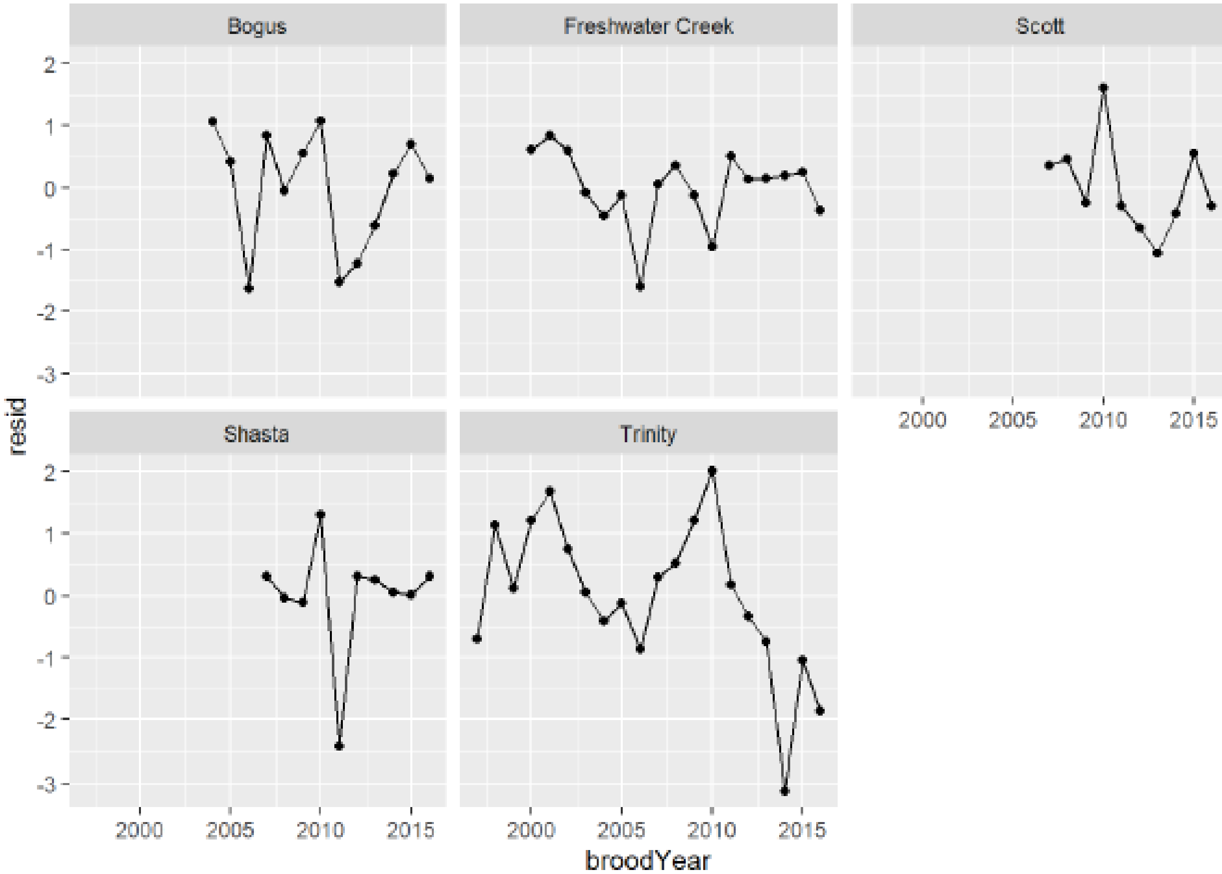

Figure 16.Plot of residuals (resid) versus brood year in least squares spawner-recruit fits.

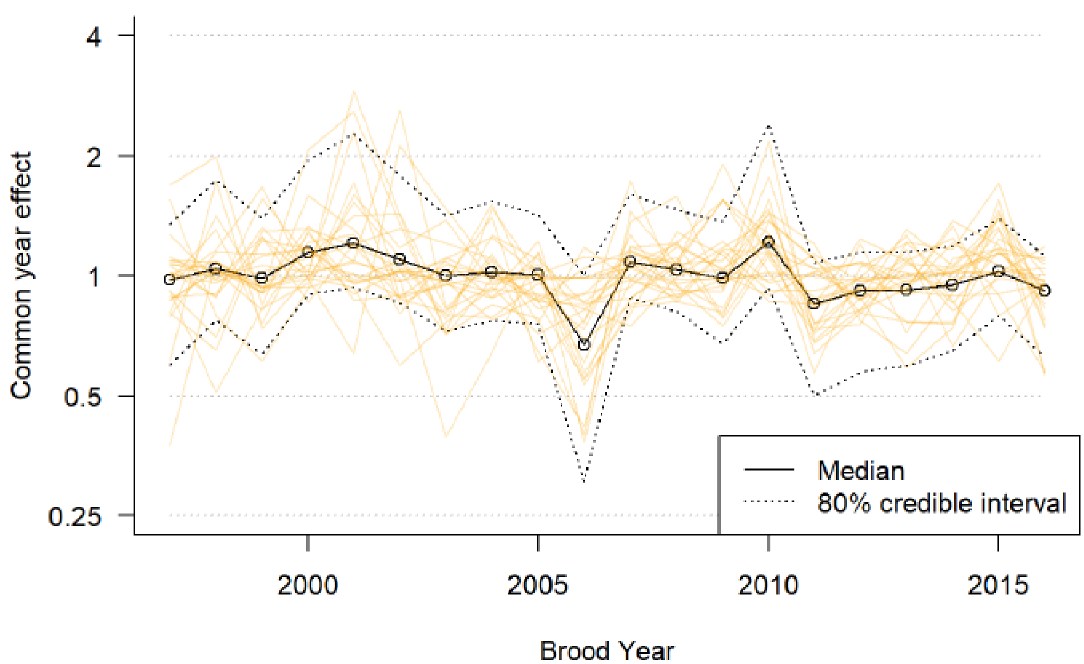

Figure 17.Shared temporal pattern among populations based on Bayesian model along with 80% credible interval and example trajectories from the posterior.

Other Coho Reference Populations

Information on stock-recruitment relationships is also available for Oregon Coast Natural and Lower Columbia River coho populations. The work group also documented this information in order to identify a representative range of potential values in other ESUs. This information is potentially useful for placing estimates for SONCC into a broader context, with the qualification that characteristics of different ESUs may be inherently different. Values for lower Columbia River coho were documented in Kern and Zimmerman (2013). Information for Oregon Coast Natural coho was provided by M. Falcy (Oregon Department of Fish and Wildlife) and M. Liermann (NOAA).[3]

Table 12. Example stock-recruitment parameters (Beverton-Holt) for Lower Columbia River and Oregon Coast Natural populations of coho salmon.

Stock	Pop	CRT	prod	cap	Neq	SD	acor	Smax	Rmax
Lower Columbia River	Clackamas	300	3.6	3,356	2,606	0.40	0.33		
	Clatskanie	200	5.3	1,479	2,726	1.00	0.30		
	Coweeman	100	2.6	5,386	919	1.00	0.30		
	Cowlitz L	300	3.5	3,157	3,848	1.00	0.30		
	Eloch/Skam	300	2.9	1,511	2,078	1.00	0.30		
	Grays/Chinook	200	2.1	974	788	1.00	0.30		
	Lewis EF	200	2.3	1,507	546	0.56	-0.09		
	Sandy	300	4.2	4,433	1,146	0.79	-0.26		
	Scappoose	200	2.2	5,025	2,427	1.00	0.30		
	Toutle	200	2.4	3,356	2,959	0.40	0.33		
Oregon Coast Natural	Alsea		2.39	9,908	5,462	1.07	0.57	28,418	30,146
	Beaver		12.66	1,874	1,715	0.89	0.25	6,564	7,633
	Coos		57.54	11,718	11,398	0.95	0.29	38,880	45,209
	Coquille		7.97	15,095	13,172	0.92	0.2	56,109	59,220
	Floras		38.99	1,712	1,646	1.08	0.33	11,329	11,925
	LowUmpqua		65.38	9,160	8,959	0.81	0.16	36,942	42,956
	MidUmpqua		61.38	5,035	4,915	0.8	0.45	20,033	21,236
	Necanicum		13.24	1,213	1,113	0.89	0.48	5,825	6,659
	Nehalem		38.53	8,566	8,175	1.08	0.69	33,052	35,555
	Nestucca		19.6	2,055	1,934	1.07	0.4	16,753	17,577
	NorthUmpqua		15.02	2,588	2,319	0.8	0.74	16,728	9,892
	Salmon		18.79	309	268	1.5	0.32	3,707	4,279
	Siletz		2.67	8,626	5,261	1.08	0.51	33,094	35,206
	Siltcoos		82.74	4,372	4,294	0.86	0.03	8,025	8,693
	Siuslaw		28.34	11,028	10,560	0.93	0.6	55,695	58,363
	Sixes		33.77	198	189	1.31	-0.25	608	659
	SouthUmpqua		20.01	7,778	7,242	1.01	0.38	51,088	53,147
	Tahkenitch		39.21	3,085	2,981	1.01	0.24	10,681	11,243
	Tenmile		57.34	7,490	7,302	0.94	0.2	20,385	21,458
	Tillamook		4.67	5,697	4,403	0.98	0.47	20,550	23,360
	Yaquina		20.66	5,217	4,909	1.03	0.41	25,582	29,747

[3] *Parameter estimates are preliminary and may be refined.*

Note that there is a very strong shared year effect among OCN populations (Figure 18). Autocorrelation is also noteworthy for OCN coho populations. The median auto correlation for the common trend is 0.5. This is in distinct contrast to SONCC coho populations where neither shared year effects or autocorrelation were strong.

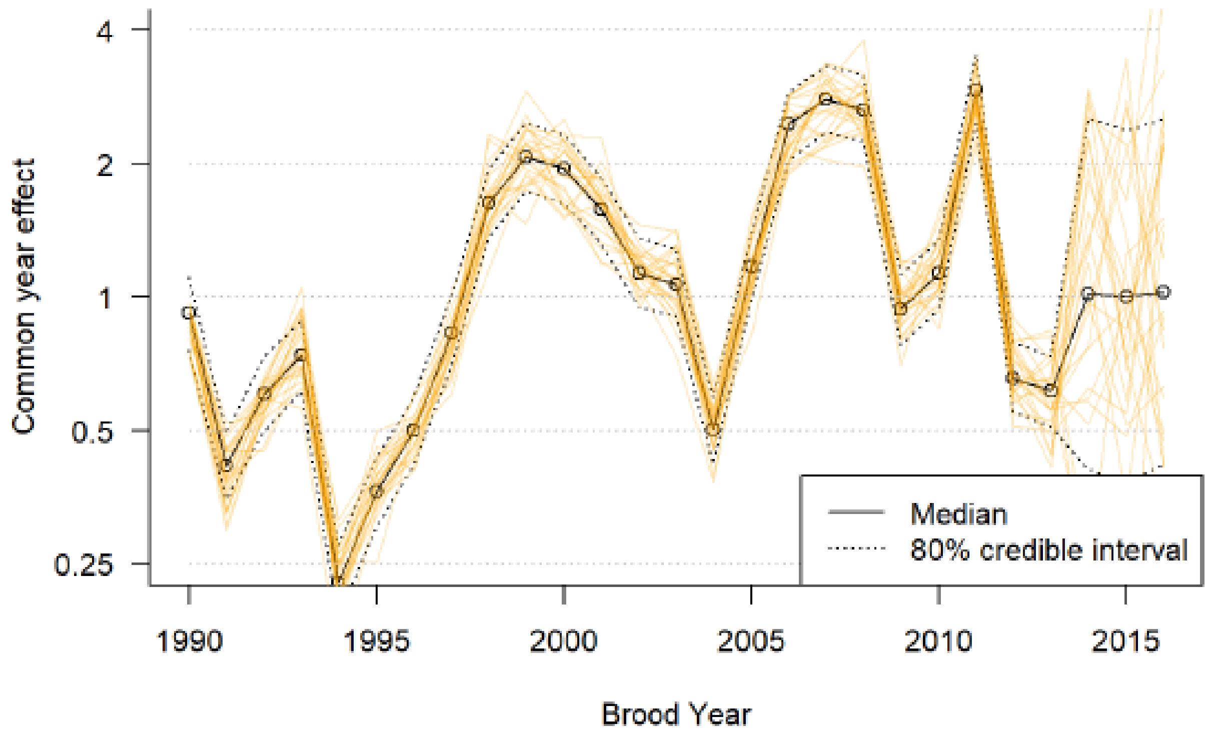

Figure 3. Shared temporal pattern among OCN populations based on Bayesian model along with 80% credible interval and example trajectories from the posterior.

Population Comparisons

Figure 19 compares stock-recruitment parameters among populations where information is available. Parameters are distributed across a wide range with SONCC stocks generally at low levels of equilibrium abundance and moderate levels of productivity in relation to Oregon Coast and Lower Columbia River populations.

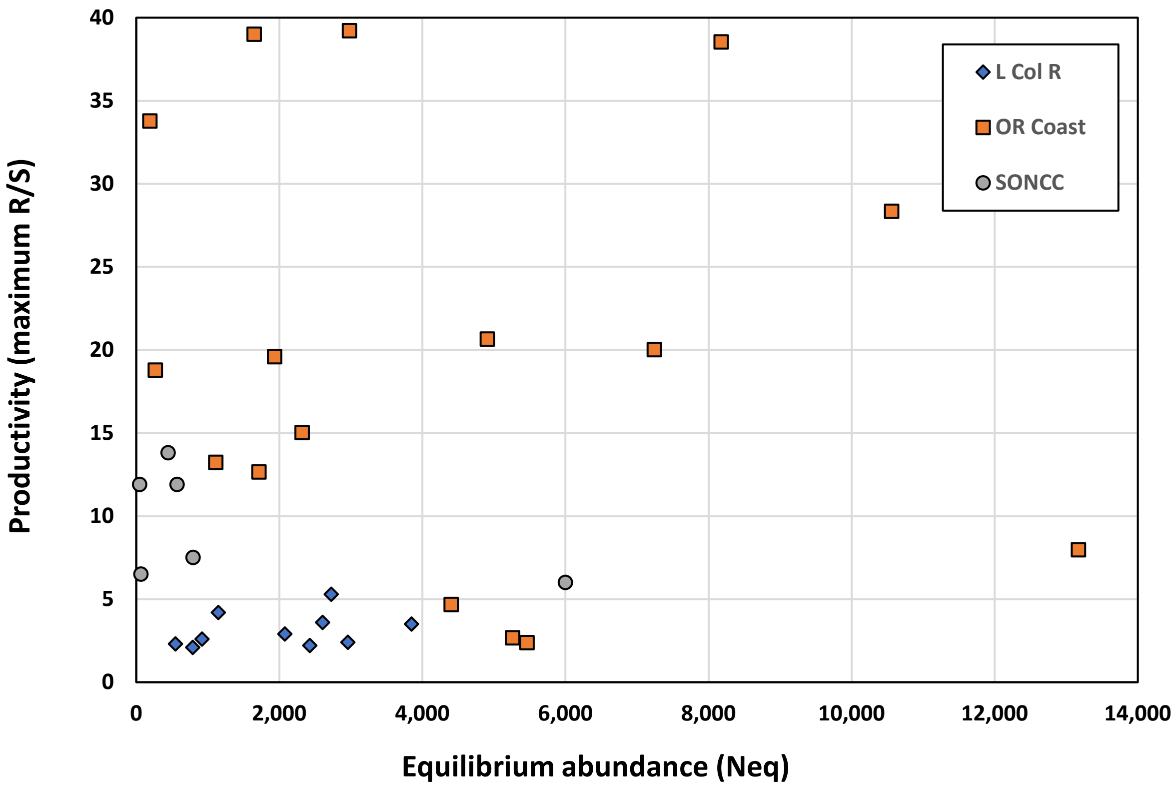

Figure 49.Example stock-recruitment parameters (Beverton Holt) for Oregon Coast Natural and Lower Columbia River populations of coho salmon. (OCN populations where productivity exceeds 50 recruits per spawner are omitted from the plot).[4]

[4] *Parameter estimates are preliminary and may be refined.*

Risk Assessment Model

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 (Figures 20 and 21). 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.

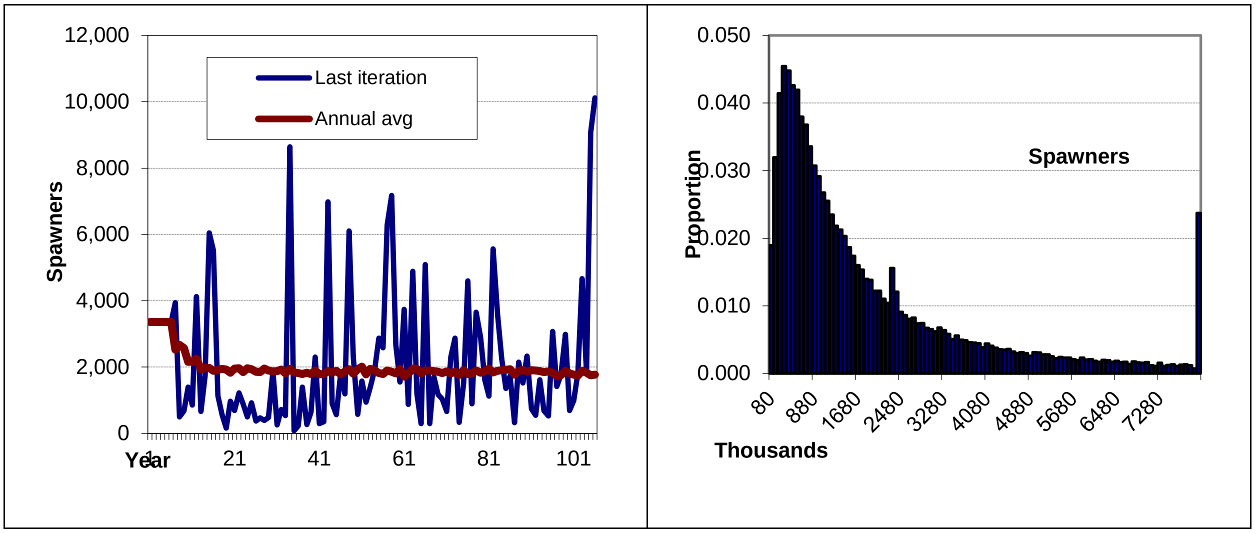

Figure 20.Example stochastic simulation results showing annual patterns and frequency distribution of spawning escapements.

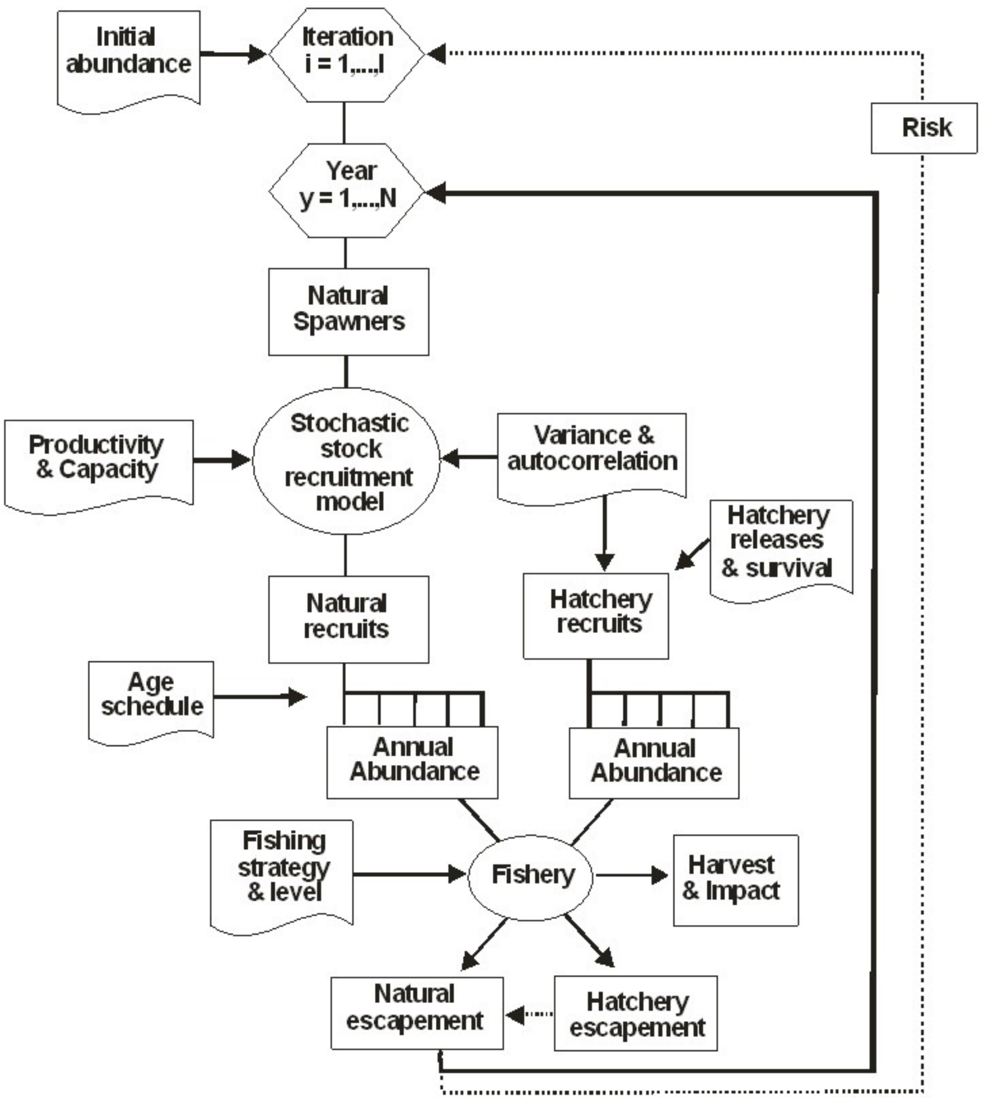

Figure 21.Conceptual depiction of model algorithm.

The model is built in Microsoft Excel using Visual Basic. A simple interface page facilitates model use and review of results (Figure 22).

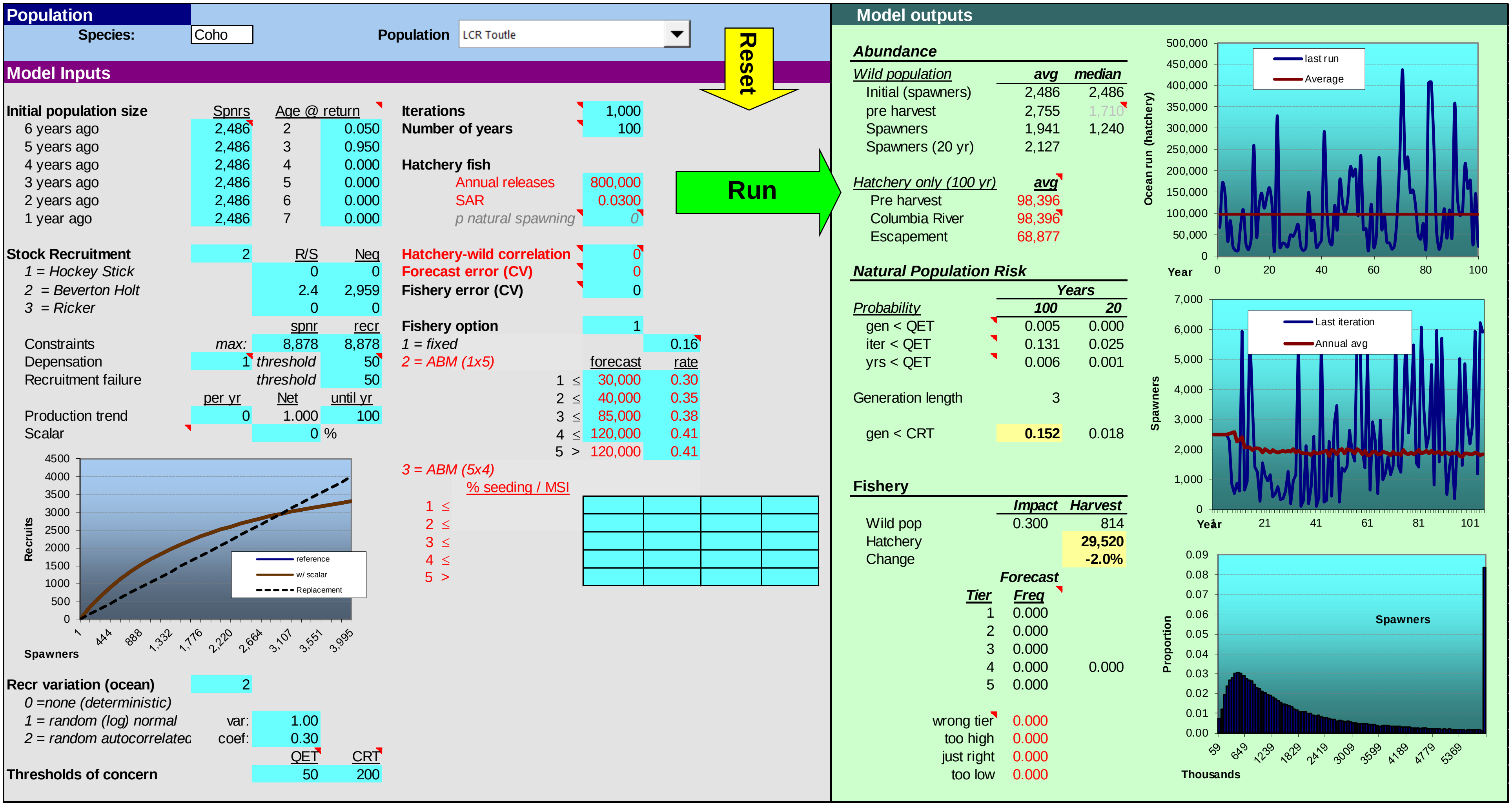

Figure 22.Model interface.

Model Functions

Stock-Recruitment

The model stock recruitment function was based on the Beverton-Holt functional forms (Figure 23).

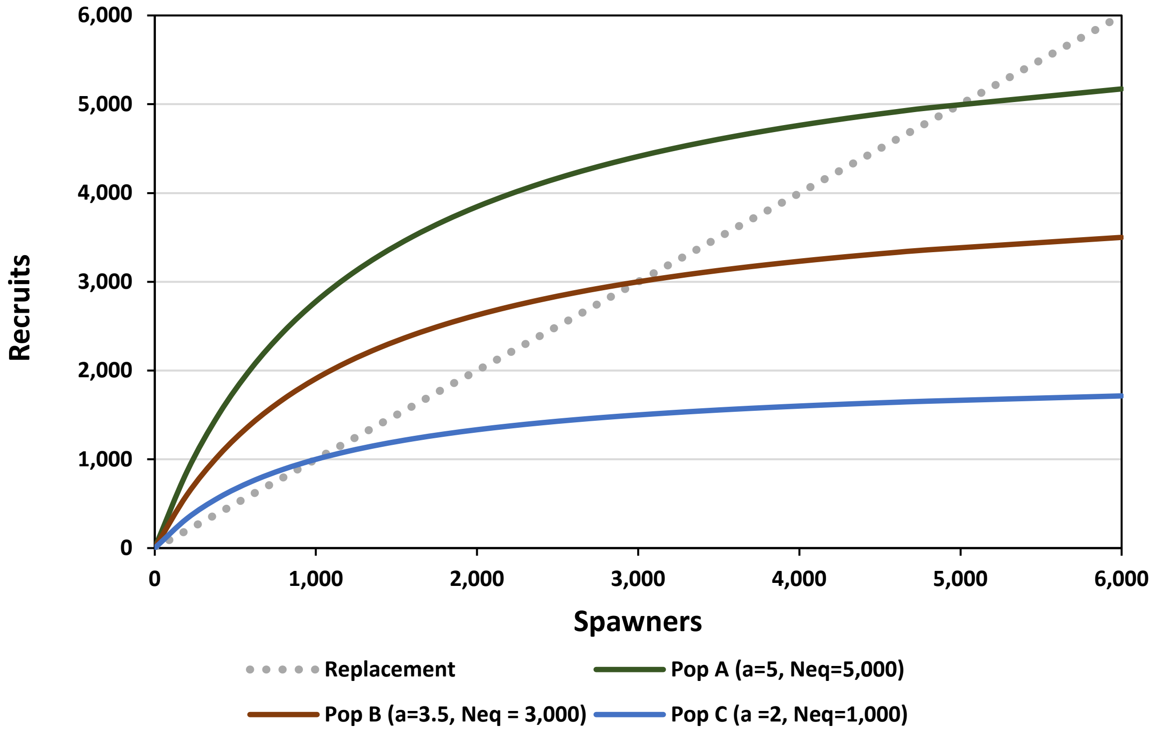

Figure 23.Examples of Beverton-Holt stock-recruitment curves.

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, σ^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:

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

where

Z_t = autocorrelation residual,
$Ø$ = 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:

$$\sigma_e^2 = \sigma_z^2 (1- Ø^2)$$

Model simulations using the autocorrelated residual options were seeded in the first year with a randomly generated value from N(0, σ_z^2). See Figure 24 for an example of the effect of autocorrelation on residual errors.

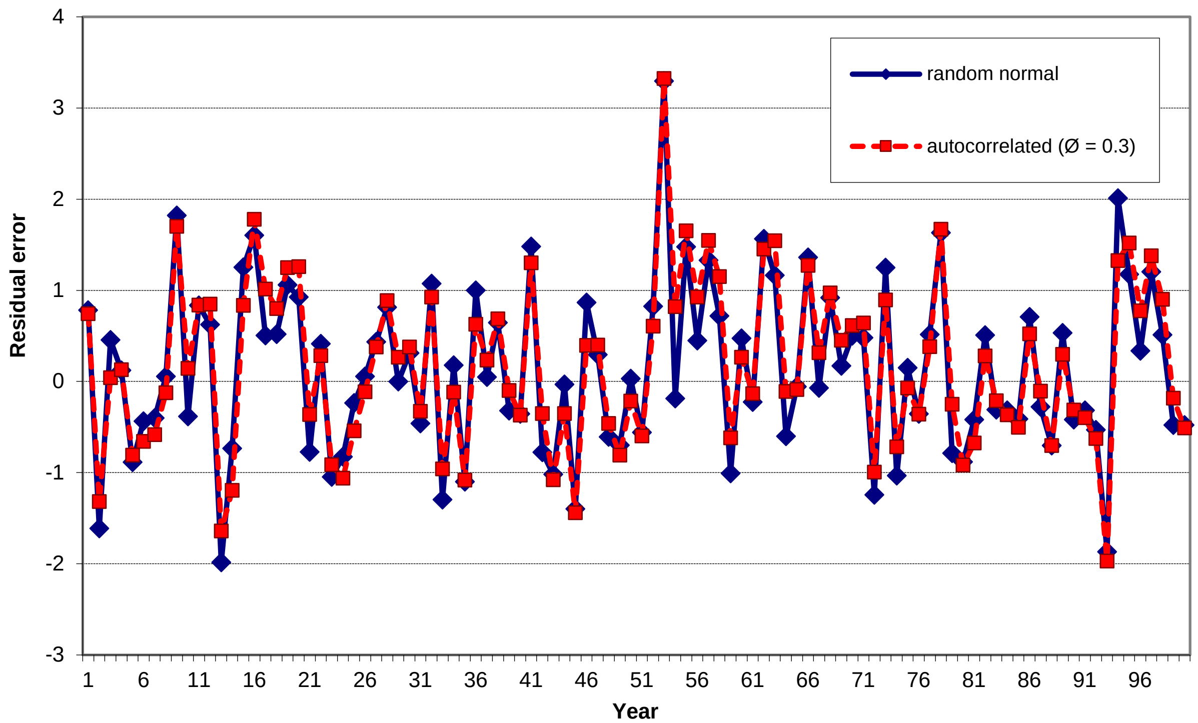

Figure 24.Examples of autocorrelation effect on randomly generated error patterns (σ_z^2 = 1).

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 (Figure 25). 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):

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

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

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.

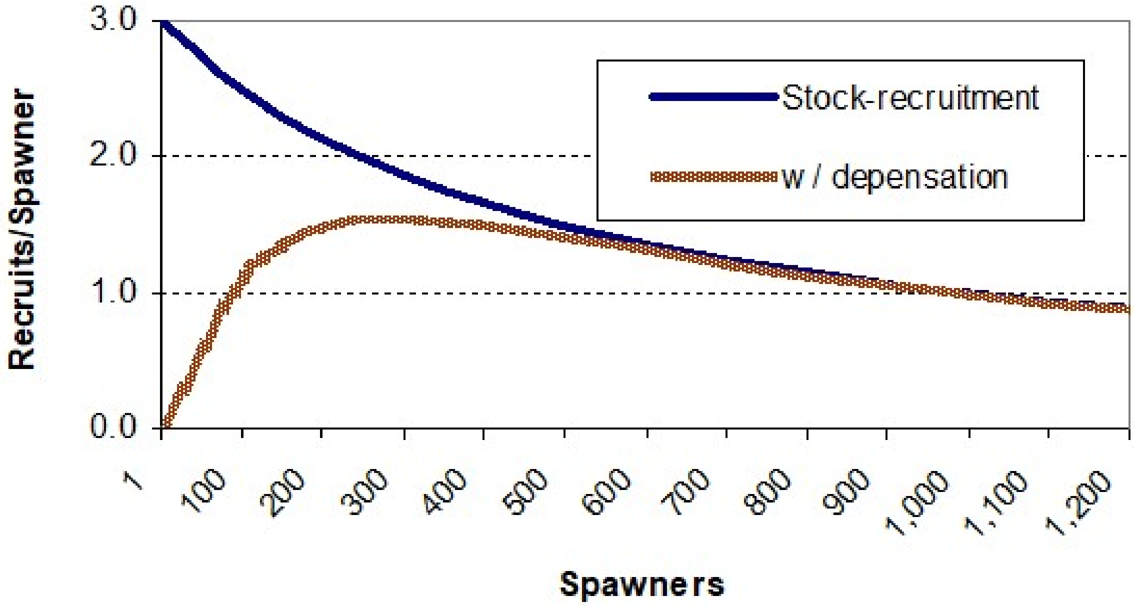

Figure 25.Example of depensation function effect on recruits per spawner at low spawner numbers based on a Beverton-Holt function (a = 3.0, Neq =1,000, γ =500).

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:

$$IN_y = N_{.y}\, fN_y$$

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,

Model Input Parameters

Initial values for input parameters were based on data available for SONCC coho and supplemented with information on Oregon Coast and Lower Columbia River coho populations and/or risk assessments (Table 13).

Table 13. Preliminary 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	Population-specific
Equilibrium abundance	N_{eq}	Population-specific
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	Population-specific
Recruitment stochasticity		
Variance	σ^2	Population-specific
Autocorrelation	Ø	Population-specific
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

Model input parameters for the stock-recruitment function (Table 14) were based on analyses of SONCC populations documented earlier in this chapter. Productivity and equilibrium abundance values were based on Bayesian estimates. Variance estimates were based on the average of all SONCC populations.

In addition, model sensitivity analyses were conducted for three generic populations representing a range of abundance and productivity levels. The range of population values was based on values identified for SONCC coho (this report), Oregon Coast Natural coho (this report) and lower Columbia River coho (Kern and Zimmerman (2013) (Table 12, Figure 18). Generic values for stock-recruitment parameters were selected to represent a range values observed for all populations.[5] Variance and autocorrelation parameters were based on the Oregon Coast Natural population average which represents the best available long-term data set available for coho.

Age Composition

Analyses use values of 5% age 2 and 95% age 3. These values are assumed to be generally representative of natural coho in the absence of empirical estimates for most populations.

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.

Table 14. 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.

Population	Abundance	Productivity	σ^2	Auto correlation	Critical Risk Threshold
SONCC Rogue	6,000	6.0	0.82	0	1,882
SONCC Bogus	63	6.5	0.82	0	50[a]
SONCC Freshwater	447	13.8	0.82	0	100 [a]
SONCC Scott	569	11.9	0.82	0	250
SONCC Shasta	48	11.9	0.82	0	144
SONCC Trinity	794	7.5	0.82	0	719
Generic A	5,000	5.0	0.48	0.5	1,500
Generic B	3,000	3.5	0.48	0.5	900
Generic C	1,000	2.0	0.48	0.5	300

[a] *Assessment information includes only a portion of the total population.*

Conservation risks

Critical risk thresholds (CRTs) for SONCC coho populations were based on depensation thresholds identified in the ESU Recovery Plan (Table 1). Combined values of individual populations were used where SONCC populations included an aggregate of individual populations. Generic populations used a range of CRTs based on 30% of the current equilibrium abundance.[6]

All simulations assumed that extinction occurs at a quasi-extinction threshold (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

[5] *Preliminary estimates of productivity values derived by Beverton-Holt function fits to data are higher than representative values selected for this exercise.*

[6] *Considered to generally be consistent with the scale of CRTs defined for SONCC populations.*

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).

Forecast & Fishery Errors

Forecast and fishery errors were based on data reported earlier in this report. Fishery implementation error was initially estimated to have a CV of 0.50 based generally on the observed range of annual variability in exploitation rates estimated for SONCC coho. Forecast error was not included at this time pending further investigation of forecast potential.

Simulations

A series of model simulations were conducted to:

1. Evaluate the effects of fixed exploitation rates on risk for wild populations of SONCC coho as well as generic populations. Simulations include fixed total rates identified by the work group (0, 7, 13, 26) as well as higher rates intended to illustrate risk sensitivity for a range of populations.[7]
2. Describe short versus long term risks associated with exploitation rates.

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

Evaluations of the effects of abundance-based harvest control rules have not yet been completed.

Results

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.

[7] Note that preliminarily in this report simulations are based on total exploitation rates which include both ocean and freshwater harvest.

Average abundance of a natural population increases in direct proportion to the decrease in fishing rate over the 100-year period of the simulation (Table 15). 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 (Figure 26). Thus, while reductions to very low fishing rates do not substantially affect risk, they do translate into ever larger numbers of spawners.

Table 15. Modeled effects of different exploitation rates on short term risk (20-year), long term risk (100-year) and mean abundance (100-year) for generic and SONCC natural coho populations

Outcome	Population	Exploitation rate					
		0	7	13	26	40	50
Risk (20 yr)	Generic A	0.000	0.000	0.000	0.003	0.124	0.552
	Generic B	0.000	0.000	0.001	0.015	0.349	0.858
	Generic C	0.002	0.005	0.041	0.359	0.964	1.000
	Rogue	0.397	0.516	0.648	0.927	0.999	1.000
	Bogus	1.000	1.000	1.000	1.000	1.000	1.000
	Freshwater	0.110	0.179	0.268	0.645	0.988	1.000
	Scott	0.854	0.931	0.966	0.999	1.000	1.000
	Shasta	--	--	--	--	--	--
	Trinity	1.000	1.000	1.000	1.000	1.000	1.000
Risk (100 yr)	Generic A	0.000	0.000	0.000	0.001	0.029	0.117
	Generic B	0.000	0.000	0.000	0.004	0.063	0.229
	Generic C	0.000	0.001	0.004	0.041	0.267	0.617
	Rogue	0.075	0.110	0.164	0.369	0.706	0.896
	Bogus	0.995	0.998	1.000	1.000	1.000	1.000
	Freshwater	0.011	0.020	0.034	0.123	0.423	0.706
	Scott	0.294	0.381	0.457	0.671	0.905	0.985
	Shasta	--	--	--	--	--	--
	Trinity	0.959	0.983	0.992	1.000	1.000	1.000
Mean Abundance (100yr)	Generic A	4,800	4,400	4,000	3,100	2,100	1,500
	Generic B	2,880	2,580	2,280	1,740	1,080	660
	Generic C	920	780	660	400	20	0
	Rogue	5,760	5,280	4,800	3,840	2,640	1,920
	Bogus	0	0	0	0	0	0
	Freshwater	430	390	360	260	60	0
	Scott	560	510	470	370	200	30
	Shasta	--	--	--	--	--	--
	Trinity	770	710	650	510	330	150

[a] *Shasta R. not simulated pending resolution of questions regarding critical risk thresholds.*

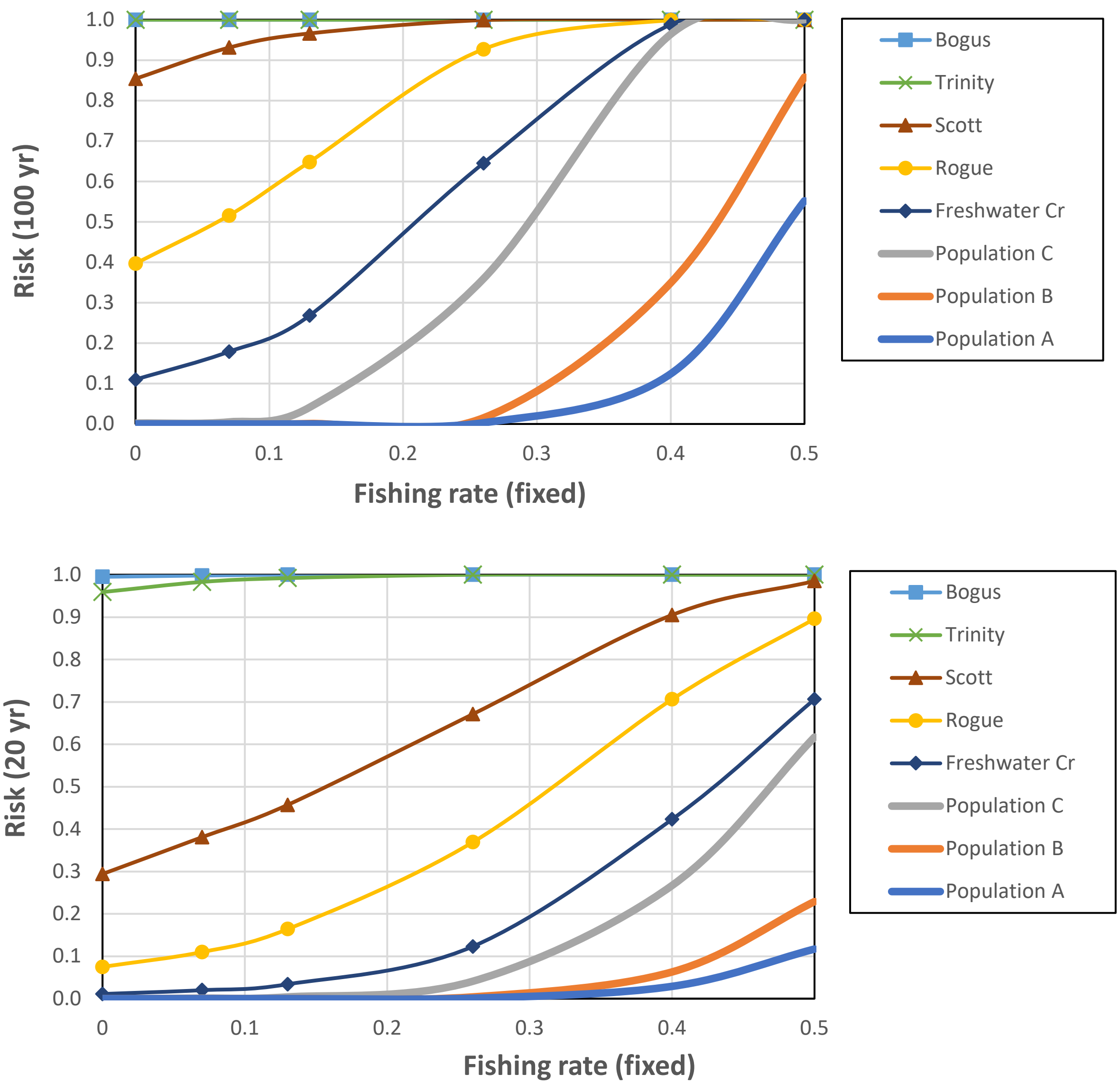

Figure 26. **Modeled effects of different exploitation rates on long-term risk of falling below critical wild population abundance thresholds, median wild abundance by population, and average total harvest of hatchery and wild tule fall Chinook.**

8. SUMMARY

This risk assessment is very preliminary should be viewed as an illustration of basic concepts, the preliminary range of control rules that the Workgroup is currently evaluating, and the analytical approach that would be used to evaluate the control rules. The results will likely change substantially with further work. We recommend against using it to inform substantive policy guidance at this time.

- The risk assessment approach is based on a quantitative population viability analysis which uses stock-recruitment data for Southern Oregon/Northern California Coast (SONCC) coho populations. The Council has implemented similar modeling approaches for other stocks, including Klamath Fall Chinook, Lower Columbia River Fall Chinook, Lower Columbia River Coho, and Sacramento River Winter Chinook.
- The analysis will consider performance measures for conservation (spawning escapement, extinction risks) and for fishery performance (exploitation rate and harvest of SONCC coho).
- Information on natural production of SONCC coho is limited to five wild populations, population components, or population aggregates, some of which are subject to substantial hatchery influence. The work group also examined population parameters for Oregon Coast Natural and Lower Columbia River Natural coho populations in order to provide some context for interpretation of the limited SONCC coho data.

Progress toward developing a full evaluation of control rules has been slowed by several factors. Besides a variety of workload issues, wildfires in Oregon and California also directly and indirectly affected members of the Workgroup. Furthermore, the ongoing issues of working under COVID-19 restrictions remain a challenge and this has added considerably to agency workloads as they strive to fulfill their basic obligations for monitoring and reporting during the annual management cycle. In spite of these challenges, the Workgroup was able to compile much of the data necessary for the analysis, vet that information, develop a preliminary suite of control rules, agree on a preliminary risk assessment approach, identify strategies to address the limited nature of the available data, and conduct a preliminary assessment. We will have a better sense of the next steps once the Workgroup has had sufficient time to perform a more in-depth review of the preliminary risk assessment.

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10. APPENDICES

Appendix A: Workgroup Terms of Reference

Southern Oregon/Northern California Coast Coho Fishery
Ad Hoc Technical Workgroup
Terms of Reference and Timeline
(June 16, 2020)

1. Purpose

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).

2. Membership

- The Council will establish an Ad Hoc SONCC Coho Technical Work Group (Workgroup, WG).
- Membership will include 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 Workgroup will choose from among its members a Chair and a Vice-Chair. The Vice-Chair will act in instances where the Chair is unavailable. The Council will be responsible for administrative and logistical support.

3. Milestones

- 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.

4. Timeline

- Pre-meet: Presentation of TORs and timeline at the April 2020 Council meeting
  - Council decides by May 31, 2020 whether to consider a process to develop the SONCC control rule and initiate workgroup
- Pre-meet:
  - preseason abundance forecast feasibility meeting with WCR and SWFSC (workgroup already in place);
  - invitations sent to participating parties;
  - NMFS (WCR, NWFSC & SWFSC) staff participants assigned and ready to engage (likely 4-6 technical staff [2-3 from the region and science center respectively, or potential contractors] successful implementation will require permanent staff to engage and carry through into the future);
  - FR notice of time/location of first workgroup meeting finalized (Council staff); Workgroup meetings will be open to public.

- June 2020: initial first meeting (on-line)
  - introductions;
  - discussion/agreement on purpose of group (as defined by the Council);
  - establish ground rules and operating procedures;
  - develop proposed timeline;
  - group selection of Chair and Vice-Chair;
  - approve final Terms of Reference for Council endorsement
  - coordination/outline of tasks;
  - discussion/catalog of current control rules and status information available;
  - establish criteria for alternative control rules (e.g., acceptable risk to ESU, distribution among populations or tributaries);
  - discussion of potential methods to evaluate alternative control rules;

- discussion of potential development of abundance forecasts methods and a river harvest model; identify data gaps, estimate workload and timeline needed to complete.
- group assignment to address data gaps, and suggested alternate control rules, and investigate potential forecast/model development for discussion at next meeting;
  - <u>define/assign specific tasks and products expected with due date</u>
- date/location confirmed for next meeting, FR notice of time/location (Council staff).

- August 2020: second meeting (on-line)
  - updates/additional population information provided to address data gaps identified at June (first) Workgroup meeting;
  - group discussion of harvest control rule alternatives and the data necessary (e.g., forecast dependent, data used for environmental variables, stock subcomponents) for each are identified; potential alternatives are narrowed if possible,
  - group assignment to begin drafting analysis of each potential control rule, due prior to the November (third) Workgroup meeting;
  - date/location confirmed for next meeting, FR notice of time/location (Council staff).

- October 2020: third meeting
  - options for current forecasting/escapement methodology presented (if so – the following bullets are pushed to June 2021; if not – disregard this bullet);
  - draft analysis report (risk assessment) for proposals presented to Workgroup indicating relative risk of each potential harvest control rule (HCR) identified in second meeting to ESU (and other criteria, e.g., acceptable risk on the relative strength of the various contributing populations such as Trinity River Basin populations, environmental indicators);
  - discussion if suite of alternatives is adequate/possible revision of alternatives,
    - IF HCR alternatives are added based on initial draft report, these items will all repeat during next meeting;
  - discussion/questions of analysis for each HCR alternative;
  - Workgroup assignment to update draft risk assessment accordingly per discussions;
  - Workgroup assignment to present HCR alternatives and draft risk assessment report to each parties' respective constituency; schedule meeting to present to Council's Model Evaluation Workgroup (MEW), Salmon Technical Team (STT), and Council's Scientific and Statistical Committee (SSC) for methodology and analytical reviews as necessary; meetings to occur prior to, or during the November 2020 Council meeting;
  - Prepare document with range of alternatives, preliminary recommendation and draft report for Chair and Vice-Chair to present Workgroup report to the Council at the November 2020 Council meeting;
  - date/location confirmed for next meeting, FR notice of time/location (Council staff).

- January 2021: fourth meeting (on-line)
  - discuss input received from Council presentation and parties' constituencies
    - update alternatives per discussions and input from SAS, SSC, and other tribal or state input sources outside Workgroup;

- group assignment to revise report for updated alternatives per external recommendations;
- group assignment to present alternatives and revised report to each parties' respective constituency in time to present for March or April Council meeting

- April 2021: fifth meeting
  - Schedule meeting to present to Council's Salmon Advisory Subpanel (SAS) and other advisory bodies as necessary in preparation for April 2021 Council meeting;
  - Chair and Vice-Chair presents Workgroup recommendation to the Council for consideration in selection of a preliminary preferred alternative;
  - date/location confirmed for next meeting, FR notice of time/location (Council staff).

- June 2021 webinar : sixth meeting
  - Consider additional guidance provided at the April 2021 meeting
  - Group assignment to revise report for updated alternatives per external recommendations;
  - group assignment to present alternatives and revised report to each parties' respective constituency in time to present for September 2021 Council meeting.

- October 2021: seventh meeting
  - Discuss final alternatives for public review and comment (September if necessary);

Prepare for November 2021 Council meeting: draft Workgroup report for Chair and Vice-Chair to provide to the Council for adoption of final preferred alternative recommendation. Council transmits recommendation to NMFS via signed letters for Section 7 consultation.

Appendix B: Estimation of Recruits

Estimates of age-3 recruits for various components of the SONCC coho salmon ESU are needed for fitting stock-recruit relationships as described in Section 7. Here, recruits are defined as the abundance of age-3 fish prior to exposure to ocean fisheries in the year of river return. They represent the total number of age-3 fish, of a particular origin, that escaped, died in freshwater fisheries, or died in ocean fisheries.

For wild SONCC coho populations with little to no freshwater fishing impacts, recruits (R) are defined as the age-3 escapement (E) expanded by the ocean exploitation rate (F), $R = \frac{E}{(1-F)}$. Recruits for the Rogue aggregate and Freshwater Creek were estimated in this manner.

Wild SONCC coho populations in the Klamath Basin are exposed to Tribal fisheries in the lower Klamath River and in the Trinity River. There are also some data on illegal recreational harvest of coho in the Klamath and Trinity rivers (coho fisheries have been prohibited by the state of California since 1996). Therefore, when estimating recruits for Klamath Basin populations, harvest mortalities from these fisheries must be taken into account. Furthermore, there is escapement of natural-origin coho to both hatcheries in the Basin (IGH and TRH). These fish need to be taken into account when estimating escapement for natural origin fish from the Klamath Basin populations or population aggregates considered here (Bogus Creek, Shasta River, Scott River, and Trinity River).

For populations along the Klamath River (Bogus Creek, Shasta River, and Scott River) escapement is determined by summing natural-origin escapement to the respective watersheds and the number of fish that originated in those watersheds that strayed into IGH. We estimated the number of fish that were likely to have strayed to IGH on the basis of the proportion of IGH-origin fish that strayed into the respective watersheds, assuming that, for example, the high stray rate of IGH-origin fish to Bogus Creek would translate into the converse: a high stray rate of Bogus-origin fish into IGH.

River harvest in Yurok tribal fisheries and Klamath River recreational fisheries is of mixed stock. Natural-origin fish caught in these fisheries likely included contributions from the Trinity natural population, Scott River, Shasta River, and Bogus Creek. To estimate the composition of the natural-origin harvest in the Yurok tribal and lower Klamath River recreational fisheries, the harvest of natural-origin fish was apportioned to the Trinity, Scott, Shasta, and Bogus components on the basis of their relative escapement levels.

An estimate of Klamath River mouth return (N) for the Scott, Shasta, and Bogus components is thus the sum of escapement (both to the respective sector and IGH), harvest in Klamath River recreational fisheries, and the harvest in Yurok tribal fisheries. Pre-fishery ocean recruits are then estimated as $R = \frac{N}{(1-F)}$.

A similar procedure is used to reconstruct the natural-origin Trinity River component. To account for natural-origin Trinity River coho that strayed into TRH, we assume that all natural-origin fish that escaped to TRH were of Trinity River origin. To account for harvest in Hoopa tribal fisheries and Trinity River recreational fisheries, natural origin fish taken in those fisheries were all assumed to be of Trinity River origin. The estimate of N for the Trinity River natural component is therefore the sum of escapement (both to the Trinity River and TRH), natural-origin harvest in Hoopa tribal fisheries, natural-origin harvest in Trinity River recreational fisheries, harvest of natural-origin Trinity River coho in Yurok tribal fisheries, and harvest of natural-origin Trinity River coho in lower Klamath River recreational fisheries. Pre-fishery ocean recruits for natural-origin Trinity River coho are then estimated as $R = \frac{N}{(1-F)}$.