Agenda Item F.1
Situation Summary
November 2014

NATIONAL MARINE FISHERIES SERVICE REPORT

National Marine Fisheries Service (NMFS) West Coast Regions and the Fisheries Science Centers will briefly report on recent developments relevant to salmon fisheries and issues of interest to the Pacific Fishery Management Council (Council).

Council Action:

Council Discussion and Guidance.

Reference Materials:

None.

Agenda Order:

a.	Agenda Item Overview	Mike Burner
b.	Regulatory Activities	Bob Turner
c.	Fisheries Science Center Activities	Michael O'Farrell
d.	Reports and Comments of Advisory Bodies and Management Entities	
e.	Public Comment	
f.	Council Discussion and Guidance	

PFMC
10/20/14


Agenda Item F.1.c
Supplemental SWFSC PowerPoint
(Electronic Only)
November 2014
Report on the September 2014 NMFS/CDFW California
coastal Chinook salmon fishery management workshop

Background

- CC-Chinook frequently constrain CA and OR fisheries under current PFMC process
- Interest in abundance-based management
- Work to date has been mostly retrospective
  - Exception: CDFW 2014 white paper
- NMFS/CDFW workshop intended to be prospective

CC-Chinook salmon fishery mgt: future prospects

- Workshop held Sept 3-4 at CDFW, Santa Rosa

- Goals:
    1. Identify level of information needed for an abundance-based mgt approach
    2. Evaluate the feasibility of obtaining that of information

- 14 participants, split between NMFS and CDFW

- Funding provided by NMFS West Coast Region

Workshop proceedings

- 10 presentations

- Discussions focused on:
  - Identifying data needed to implement abundance-based mgt
  - Technical impediments to collecting these data
  - Funding impediments to collecting these data

- A report describing the proceeding is under development

Main findings

- Data needs for fishery mgt go beyond what is described in the existing California Coastal Salmonid Monitoring Plan (CMP)

- Substantial technical difficulties exist
  - Watersheds tend to be flashy, turbid, remote, have difficult access
  - Chinook surveys particularly affected by these conditions
  - Lack of hatchery production complicates marking/tagging of outmigrants
  - However, strong interest in confronting these issues

- Lack of stable funding currently for the CMP
  - Needs for abundance-based mgt would require additional funding beyond full implementation of the CMP

Meeting participants:

CDFW

Kristine Atkinson
Sean Gallagher
Brett Kormos
Michael Lacy
Eric Larson
George Neillands
Seth Ricker

NMFS

Shanae Allen-Moran
Peter Dygert
Allen Grover
Michael Mohr
Michael O'Farrell
William Satterthwaite
Brian Spence

Agenda Item F.2
Situation Summary
November 2014

SALMON METHODOLOGY REVIEW

Each year, the Scientific and Statistical Committee (SSC) and Salmon Technical Team (STT) complete a methodology review to help assure new or significantly modified methodologies employed to estimate impacts of the Council's salmon management use the best available science. The Methodology Review is also used as a forum to review updated stock conservation objective proposals. This review is preparatory to the Council's adoption, at the November meeting, of all anticipated methodology and conservation objective changes to be implemented in the coming season, or in certain limited cases, of providing directions for handling any unresolved methodology problems prior to the formulation of salmon management alternatives in March. Because there is insufficient time to review new or modified methods at the March meeting, the Council may reject their use if they have not been approved the preceding November.

At its September 2014 meeting, the Council approved the items listed below for this year's methodology review. The methodology review meeting of the SSC Salmon Subcommittee, the STT, and the Model Evaluation Workgroup was held on October 21-23, 2014 where a detailed review of the following items occurred.

- Willapa Bay natural coho conservation objective, annual catch limit and status determination criteria, (Agenda Item F.2.a, Attachment 1).
- New conservation objective for Grays Harbor Chinook (Agenda Item F.2.a, Attachment 2).
- Standardized method for calculation of age-2 Fishery Regulation Assessment Model (FRAM) stock scalars (Agenda Item F.2.a, Attachment 3).
- Estimated non-local Chinook stock impacts in terminal fisheries (Agenda Item F.2.a, Attachment 4).
- Review of fishery impact estimation methodology relative to the Cape Flattery Control Zone (Agenda Item F.2.a, Attachment 5).
- Southern Oregon coastal Chinook conservation objective (Agenda Item F.2.a, Attachment 6).

The following two topics were presented as informational items that do not propose any methodology changes for 2015:

- Progress report on new Chinook Fishery Regulation Assessment Model (FRAM) base period.
- Coho FRAM and proposed revisions to Lower Columbia River coho harvest policy.

In a parallel process, the Economic Subcommittee of the SSC has been reviewing changes to salmon fishery economic impact estimation methodology in 2014, including a transition from Fishery Economic Assessment Model (FEAM)-based to IO-PAC (Input-Output Model for Pacific Coast Fisheries)-based models (Agenda Item F.2.a, Attachment 7). A presentation on the economic review was provided at the October salmon methodology review meeting.

The results of all of these methodology reviews will be presented to the full SSC and the Council at the November Council meeting where the Council is scheduled to approve new methodologies and conservation objectives.

Council Action:

1. **Approve new and modified methodologies and conservation objectives as appropriate.**
2. **Provide guidance, as needed, for any unresolved methodology issues.**

Reference Materials:

1. Agenda Item F.2.a, Attachment 1: Status Determination Criteria for Willapa Bay Natural Coho.
2. Agenda Item F.2.a, Attachment 2: Development of escapement goals for Grays Harbor fall Chinook using spawner-recruit models.
3. Agenda Item F.2.a, Attachment 3: Standardized Method to Calculate Chinook Age 2 FRAM Stock Recruit Scalars, Based Upon the Age 3 Forecast.
4. Agenda Item F.2.a, Attachment 4: A Method for Utilizing Recent Coded Wire Tag Recovery Data to Adjust FRAM Base Period Exploitation Rates.
5. Agenda Item F.2.a, Attachment 5: An evaluation of the effectiveness of the Cape Flattery Control Zone closure at reducing non-treaty troll fishery impacts on Puget Sound Chinook.
6. Agenda Item F.2.a, Attachment 6: Conservation Objective for Southern Oregon Coastal Chinook.
7. Agenda Item F.2.a, Attachment 7: Comparing Income Impact Estimates from IOPAC and FEAM (Salmon Review) Models.
8. Agenda Item F.2.b, Supplemental SSC Report.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt Final Methodology Changes and Conservation Objectives

PFMC
10/21/14

Status Determination Criteria for Willapa Bay Natural Coho

Salmon Technical Team
and
Washington Department of Fish and Wildlife

October 2, 2014

Prepared by:
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Introduction

When the Council took final action on Amendment 16 to the Salmon FMP at the June, 2011 meeting in Spokane, among other things, Willapa Bay natural coho were added to the FMP. Because this stock is not currently included in the Pacific Salmon Treaty, they are subject to the annual catch limit (ACL) requirement. In addition, regardless of whether or not they are subject to the ACL requirement, they require specification of S_{MSY}, and status determination criteria (SDC). We currently report on the escapement of this stock in our annual review of Ocean Salmon Fisheries, and list a WDFW escapement goal of 13,090, but there is no FMP goal. The WDFW goal is based on watershed area, so it could be argued that it is an estimate of S_{MSY}, but that has not been done; the goal has not been reviewed or adopted by the Council, and there is no estimate of F_{MSY}. We also have no F_{MSY} proxy for tier 2 coho stocks (stocks with no direct estimate of F_{MSY}), so we have no basis for developing SDC or an ACL control rule. Consequently, the status quo is that S_{MSY}, SDC (MSST, OFL, FMFT), as well as ACL are all undefined.

The purpose of this report is to develop SDC for Willapa Bay natural coho from evaluation of spawner-recruit data.

Background

Willapa Bay coho were historically managed for hatchery production. Hatcheries are located on Forks Creek (Willapa River), Nemah River, and Naselle River, but the hatchery program on the Nemah River was discontinued in 2009. In the mid-1990s WDFW began monitoring natural spawning escapement and established natural escapement goals based on available habitat, assuming that habitat in the Willapa Bay drainage was near the lower end of the range for smolt productivity observed in WDFW smolt trapping in other watersheds (Table 1).

In addition to ocean recreational and commercial fisheries, within Willapa Bay, there are commercial net fisheries, and recreational fisheries both in the bay itself, and freshwater fisheries in the tributaries.

Data and Methods

WDFW monitors spawning escapement and fisheries in Willapa Bay. The STT reports terminal catch data and spawning escapement in Appendix Table B-24 of our annual Review of Ocean Salmon Fisheries (STT 2013). Data in this table include natural spawners, hatchery spawners, terminal run, and terminal catches in gillnet and sport fisheries. However, WDFW maintains a more detailed dataset used for run reconstruction. The run reconstruction allocates catches to individual rivers and to hatchery and natural production on the basis of timing, location, and mark status. The run reconstruction backs natural and hatchery origin spawners out to terminal run size (Table 2). Spawner data used in this analysis were total natural are spawners regardless of origin, with no discounting for the effectiveness hatchery origin spawners in natural areas.

Recruits were calculated by expanding the terminal run of natural origin adults by the pre-terminal ocean exploitation rates for unmarked fish calculated using the fishery regulation assessment model (FRAM).

While CWT data are available for hatchery fish from Forks Creek, Naselle, and Nemah Hatcheries in Willapa Bay, natural production is unmarked. During the time period for which data are available, mark-selective ocean fisheries have been implemented. Because there have been mixtures of mark-selective and non-selective fisheries within fisheries in individual years, there is no easy way to infer exploitation rates on unmarked fish from CWT data. In order to infer incidental mortality on unmarked fish from CWT data, it would be necessary to examine the time and location of each tag recovery and determine whether or not the fishery in which it was recovered was mark-selective in that port on that date. Thus pre-terminal exploitation rates for unmarked fish from FRAM provide a more consistent and convenient framework for generating pre-harvest recruit estimates, and were used for this analysis (Table 3). This is consistent with the methods used for other Washington coast coho stocks.

A stochastic Ricker spawner-recruit relationship (SRR) was fitted to the data. The SRR was of the form:

(1) $$R_{t+3} = \alpha S_t e^{-\beta S_t + \varepsilon_t}$$

where *R* is natural origin pre-harvest recruits, *S* is natural area spawners, and ε assumed to be normally distributed independent errors with mean 0 and variance σ^2. The SRR was fitted by least squares regression after transforming it:

(2) $$\ln\left({R_{t+3}}/{S_t} \right) = \ln(\alpha) - \beta S_t + \varepsilon_t$$

Parameter estimates were corrected for process error, with estimation bias and measures of precision of parameter and reference point estimates derived by bootstrapping 100,000 samples using the methods described in STT (2005).

Results and Discussion

The bias corrected parameter estimates along with MSY reference points are presented in Table 4, along with bootstrapped estimates of bias and precision. The fit of the Ricker spawner-recruit relationship is shown in Figure 1. The estimated S_{MSY} of 17,200 natural area spawners is somewhat higher than the current WDFW escapement goal of 13,090 spawners for the aggregate of all subcomponents of the Willapa Bay coho stock based on habitat area (Table 1). However, the agency goal is for natural origin spawners, while the analysis presented here used all spawners in natural areas regardless of origin. Since 1996, natural origin spawners have accounted for approximately 79% of the total spawning escapement to natural areas. Applying this average percentage of natural origin spawners, the S_{MSY} value of 17,200 equates to 13,600 natural origin spawners. This is surprisingly similar to the current escapement goal.

The estimated F_{MSY} of 0.74 from this analysis is somewhat higher than values estimated for other Washington coastal coho stocks. Those ranged from 0.59 for the Quillayute River, to 0.69 for the Hoh River and Grays Harbor.

Recommendations

The STT currently reports spawning escapement for Willapa Bay coho in terms of natural origin and hatchery origin fish. Current agency goals are also expressed in these terms. From a pragmatic standpoint, it makes more sense to have an escapement goal (and SDC) based on the number of fish actually spawning, rather than on a portion of the natural spawning escapement. This is consistent with escapement goals on for other Washington coho stocks, and with the SDC the Council has adopted for Klamath River fall Chinook. The analysis presented here supports reference points of F_{MSY} = 0.74, and S_{MSY} = 17,200.

Based on these reference points the recommended SDC are:

MFMT = F_{MSY} = 0.74,

and

MSST = $0.5*S_{MSY}$ = 8,600.

While other Washington coastal coho and Puget Sound coho stocks are exempt from the ACL requirement by virtue of being managed under an international agreement, Willapa Bay coho are not. Under the FMP, as a tier 1 stock, Willapa Bay coho would thus have an ACL set by the $F_{ABC} = 0.95*F_{MSY}$ = 0.71.

References

STT. 2013. Review of 2012 Ocean Salmon Fisheries. Pacific Fishery Management Council. Portland, OR. February 2013. 364p.

STT 2005. Klamath River fall Chinook stock-recruitment analysis. Agenda Item G.1.b, Pacific Fishery Management Council. September, 2005. 31p.

Table 1. Current WDFW coho natural spawning escapement goals for Willapa Bay based on habitat area.

Watershed	Escapement Goal	Hatchery Program
North River/Smith Creek	5,286	No
Willapa River	4,030	Yes
Palix River	251	No
Nemah River	994	Yes[1]
Naselle River	2,091	Yes
Bear River	438	No
Total	13,090	

[1] The hatchery program was discontinued in 2009.

Table 2. Summary of the terminal run reconstruction. Spawning escapement is separated into natural spawning and hatchery spawning, and fish are identified as either natural origin (NOR), or hatchery origin (HOR). Numbers that fed into the spawner-recruit analysis are indicated in bold.

	Spawners					Terminal Catch				Terminal Run Size	
	Natural			Hatchery		Recreational		Commercial			
Year	NOR	HOR	total	HOR	NOR	NOR	HOR	NOR	HOR	NOR	HOR
1996	15,711	25,824	**41,535**	23,071	-	796	3,256	7,953	30,369	24,460	82,520
1997	4,934	2,879	**7,813**	3,520	-	360	446	504	1,022	5,799	7,866
1998	13,804	1,971	**15,775**	4,814	-	297	555	5,687	7,453	19,788	14,793
1999	9,628	4,404	**14,032**	18,307	-	331	2,505	3,866	1,601	**13,825**	26,817
2000	23,031	3,648	**26,679**	25,500	3	177	1,603	3,702	6,624	**26,913**	37,375
2001	48,404	7,752	**56,156**	46,607	-	2,082	3,607	6,350	25,562	**56,836**	83,528
2002	52,722	13,702	**66,424**	41,136	-	1,500	4,185	15,395	44,037	**69,616**	103,061
2003	46,469	9,474	**55,943**	59,323	235	1,639	4,087	16,926	49,541	**65,269**	122,425
2004	36,437	7,996	**44,433**	13,224	202	968	1,393	9,190	7,336	**46,797**	29,949
2005	21,904	10,654	**32,558**	34,511	103	977	2,915	42,509	6,492	**65,493**	54,572
2006	12,009	2,292	**14,301**	5,796	297	342	464	9,934	10,014	**22,583**	18,565
2007	18,022	2,502	**20,524**	6,741	180	412	543	5,167	3,051	**23,781**	12,837
2008	14,778	3,784	**18,561**	8,704	120	540	687	11,067	5,632	**26,505**	18,806
2009	45,354	5,296	**50,650**	17,517	301	2,999	3,462	38,792	36,625	**87,447**	62,899
2010	76,434	16,594	93,028	23,581	139	1,311	3,618	16,698	21,414	**94,582**	65,207
2011	30,523	5,415	35,938	17,360	216	2,092	3,726	18,488	29,685	**51,320**	56,185
2012	20,024	937	20,961	12,846	232	2,735	2,317	13,913	11,978	**36,904**	28,078

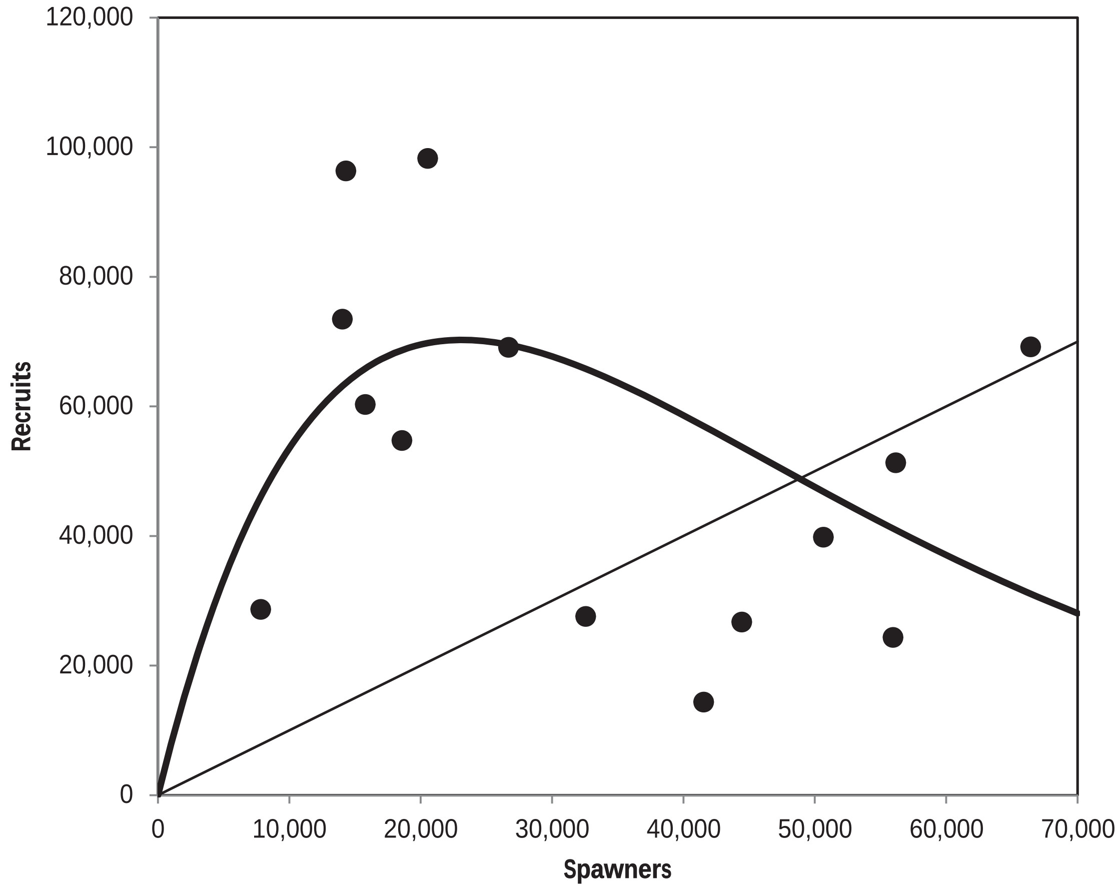
Table 3. Spawning escapement and recruitment data used for Willapa Bay coho. Spawners include both natural origin fish and hatchery origin fish that spawned in natural areas. Recruits include only natural origin fish. Data used in spawner-recruit analysis are in **bold**.

Return Year	Total ER	Ocean ER	Natural Esc (inc hatchery strays)	NOR Esc	NOR Terminal Run	NOR Adult Recruits (NOR TR/(1-OcnER))
1996	42%	14%	**41,535**	15,711	24,549	28,489
1997	22%	10%	**7,813**	4,934	5,823	6,432
1998	43%	5%	**15,775**	13,804	19,824	20,726
1999	21%	4%	**14,032**	9,628	14,061	**14,398**
2000	24%	6%	**26,679**	23,034	26,992	**28,672**
2001	30%	6%	**56,156**	48,404	56,959	**60,285**
2002	39%	5%	**66,424**	52,722	69,672	**73,441**
2003	40%	6%	**55,943**	46,704	65,408	**69,013**
2004	32%	9%	**44,433**	36,639	46,819	**51,132**
2005	45%	5%	**32,558**	22,007	65,594	**69,137**
2006	52%	7%	**14,301**	12,306	22,609	**24,343**
2007	34%	11%	**20,524**	18,202	23,805	**26,628**
2008	33%	4%	**18,561**	14,898	26,546	**27,608**
2009	59%	9%	**50,650**	45,655	87,732	**96,305**
2010	27%	4%	93,028	76,573	94,582	**98,269**
2011	45%	5%	35,983	30,739	51,320	**54,166**
2012	50%	7%	20,961	20,256	36,904	**39,836**

Table 4. Parameter estimates and reference points for Willapa Bay coho from fitting a Ricker spawner-recruit relationship to Willapa Bay coho data with correction for process error. Estimates of bias and precision based on 100,000 bootstrap replicates.

	Point estimate	Bootstrap mean	Bootstrap cv	90% lower bound	90% upper bound
α	8.23	8.39	30.4%	4.81	13.04
β	0.0000432	0.0000432	18.7%	0.0000300	0.0000565
S_{MSY}	17,200	17,400	12.7%	14,300	21,300
F_{MSY}	0.74	.73	8.8%	0.62	0.83

Figure 1. Fit of Ricker spawner-recruit relationship to Willapa Bay coho data including correction for process error. Spawners are in terms of total natural spawners, both hatchery and natural origin. Recruits are in terms of natural origin recruits.



Development of escapement goals for Grays Harbor fall Chinook using spawner-recruit models

May 2014
Quinault Department of Natural Resources (QDNR)
Washington Department of Fish and Wildlife (WDFW)

Abstract

Grays Harbor fall Chinook are currently managed for a system-total escapement goal of 14,600 naturally spawning adults (Chehalis: 12,364, Humptulips: 2,236), a goal established in 1979 based on estimates of total accessible spawning habitat and spawning habitat capacity for individual streams in the Grays Harbor Basin. Grays Harbor escapement goals have received additional attention since this capacity-based goal was developed, most recently by QDNR and WDFW in 2007 (a joint effort) and between 1999 and 2003 by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) and its Washington members. To develop an escapement goal for common use in the CTC's review of indicator stock performance and by the Grays Harbor co-managers (QDNR and WDFW) in management, QDNR and WDFW recently conducted stock-recruitment analyses for Grays Harbor fall Chinook using updated escapement, terminal run reconstruction, and ocean abundance datasets. Goals were developed separately for each main tributary (Chehalis, Humptulips) and summed to generate an aggregate goal for the CTC Grays Harbor fall Chinook escapement indicator stock. Of three spawner-recruit functions considered (Shepherd, Beverton-Holt, Ricker), the Ricker model was identified as being the most appropriate form for both the Chehalis and Humptulips datasets. Parameter estimates indicate that the adult spawning escapement needed to produce maximum sustained yield (mean S_{msy}) for the Grays Harbor fall Chinook indicator stock aggregate is 13,326 (age 3+ individuals); S_{msy} is 9,753 for the Chehalis River and 3,573 for the Humptulips River. Although there are uncertainties and limitations associated with these updated escapement goals (e.g., narrow range of parent-generation spawning escapement levels), they constitute the best estimates of sustainable management parameters available for Grays Harbor fall Chinook at this time.

Introduction

The abundance-based management regime for Chinook salmon established by the 2008 Pacific Salmon Commission (PSC) is intended to sustain production at levels associated with maximum sustained yield (MSY, measured in terms of adult equivalents) over the long term. For Grays Harbor fall Chinook, the present escapement goal of 14,600 (Chehalis: 12,364, Humptulips: 2,236) was established in 1979, based on spawning capacity estimates (adults / mile of spawning habitat) for individual streams in the Chehalis and Humptulips river basins and estimates of accessible spawning habitat in these basins (QDNR and WDFW, 2007). The escapement goals were most recently reviewed by QDNR and WDFW (a joint effort) in 2007 and Alexandersdottir in 2000 (personal communication).

The Chinook Technical Committee (CTC) is to review the biological basis for Chinook salmon management objectives under the Pacific Salmon Treaty (PSC, 2009), Chapter 3, Section 2. (b) (iv), The CTC shall "…evaluate and review existing escapement objectives that fishery management agencies have set for Chinook stocks subject to this Chapter for consistency with MSY or other agreed biologically-based escapement goals and, where needed, recommend goals for naturally spawning Chinook stocks that are consistent with the intent of this Chapter …".

The Grays Harbor fall Chinook stock is an aggregate of predominantly wild production with two major (Chehalis and Humptulips rivers, inclusive of tributaries) and multiple minor (Hoquiam and Wishkah rivers, South Bay tributaries) population segments. Grays Harbor Chinook spawn and rear in several tributaries in the basins draining the Black and Willapa hills, Olympic Mountains, Cascade foothills, and coastal Washington lowlands, the majority of which are characterized by a rain-dominated hydrology. The quality of Chinook spawning and rearing habitat varies widely across the Grays Harbor system. Many headwater reaches are affected by current and legacy logging impacts, whereas lowland river reaches are affected primarily by agricultural, residential, and industrial land uses. Although ongoing restoration activities aim to improve habitat conditions overall, there is great uncertainty about future conditions in the basin given the potential construction of new and major flood control projects in the upper Chehalis Basin (e.g., flood control dam, enhanced levee system, etc.).

The stock expresses a life history typical of Washington Coast fall Chinook, with adults returning to Grays Harbor from September through October and spawning from October to December. Juveniles typically emigrate as subyearling smolts the following spring and spend one to five years rearing off of the Alaska and British Columbia coasts. In addition to mixed-maturity ocean fishery exposure, Grays Harbor Chinook are subject to harvest in a combination of terminal estuarine and freshwater commercial (treaty and non-treaty), sport, and ceremonial and subsistence fisheries. In terms of stock size, the total natural-origin mature run (escapement + fishery landings) to the mouth of Grays Harbor has averaged *ca*. 25,000 fish during the period of record considered in this document (1986-2005 brood years).

This stock-recruitment analysis was performed using terminal run size estimates, expanded to pre-fishing recruits using results from the CTC's cohort reconstruction (i.e., '.OUT' files from the March 2012 CTC analysis) for the Washington Coastal fall Chinook coded-wire tag (CWT) indicator stock (Queets fall Chinook), for brood years 1986 to 2005[1]. Preterminal removals were estimated by multiplying Grays Harbor terminal run (inclusive of incidental mortality) by the ratio of Queets preterminal abundance (adult equivalent) / Queets terminal run. Terminal incidental mortality was also estimated using CWT data for the Queets indicator stock (i.e., ratios of total mortality to landed mortality for terminal fisheries) for corresponding brood years, ages, and fisheries. Although sizeable fall Chinook (*ca*. 200,000) CWT groups have been released from hatchery facilities within the Grays Harbor system in the past, release intermittency precludes the use of these data here. Where comparisons have been made, data indicate that the Queets indicator stock is a suitable surrogate for the present analysis (Appendix A). Spawning escapement estimates for the Grays Harbor system are based on a combination of extensive and intensive redd surveys and assume 2.5 fish (adults) / redd. Each of these data elements are described in detail below. Lastly, S_{msy} goals were estimated for the Humptulips and Chehalis rivers (Chehalis production includes all non-Humptulips production) separately, and S_{msy} for the indicator stock as a whole was taken as the sum of these estimates.

Methods

Data preparation

Terminal data

Grays Harbor production considered in this analysis is composed of Humptulips River and Chehalis River. Additional production from other Grays Harbor tributaries (South Bay: Elk and Johns, catch only[2]; Chehalis estuary: Hoquiam, and Wishkah rivers, catch and escapement) is included in Chehalis River production. Production is calculated as escapement + terminal catch (adjusted for incidental mortality) + pre-terminal catch (adjusted for incidental mortality and adult equivalence). Adult equivalence (AEQ) is the expected contribution to spawning escapement in the absence of fishing.

Hatchery escapement

The size of hatchery releases (Table 1) and hatchery rack returns (Tables 2) suggests that there is a high probability for stray hatchery contributions to natural escapement in portions of the Grays Harbor Basin. Off-station brood stock collection is common practice in the Chehalis Basin, particularly at Satsop Springs, which may also lead to straying. Table 1 shows releases

[1] The analysis was restricted to 1986+ to maintain consistency with the CWT time series associated with the Queets wild broodstock fall Chinook indicator stock program (Salmon River Fish Culture Center).
[2] Limited freshwater sport catch (<5 fish per stream per year) is occasionally reported on catch record cards for Elk, Johns, and misc. South Bay tributaries. Due to a general lack of production, Chinook escapement is not monitored in these streams.

in the Chehalis River from a variety of hatcheries and locations. As indicated in Table 1, the mark rate (% adipose clipped) of hatchery releases has increased to sufficiently high levels to allow for reliable identification of hatchery strays in natural spawning areas since return year 2010 in the Chehalis and 2011 in the Humptulips.

Table 2 shows Chehalis River returns to 4 hatcheries: Bingham Creek (weir and trap), Lake Aberdeen (Van Winkle Creek), Mayr Brothers (Wishkah River), and Satsop Springs. Some straying is expected for all of these facilities and particularly for Bingham Creek prior to 1993 when the height of its weir was raised (Jim Jorgensen, personal communication). Humptulips was the only hatchery releasing Chinook into the Humptulips River (Table 1). However this hatchery has high straying because, in the years covered in this analysis, the hatchery (and weir) were located on Stevens Creek but the hatchery (imprint) water source was the Humptulips River (HSRG, 2004).

Wild spawning escapement

Streams in the Grays Harbor basin are designated as index (weekly survey), extensive (annual survey), and un-surveyed. Index areas are surveyed for new redds weekly from approximately October 1st to December 30th. Extensive areas are sampled once per season as close to spawning peak as possible. Each index area is associated with one or more extensive areas.

Where i = survey wk. and n = total survey wks., the cumulative redds in index area j is

$$\sum_{i=1}^{n} new\ redds\ index\ area_{\,j}\ for\ week_{\,i}$$

and season total redd abundance for extensive area k associated with index area j is estimated by expansion.

Where p = week when spawning peak occurs in index area j and associated extensive area k, redd estimate for extensive area k =

$$\frac{\#\ redds\ in\ extensive\ area_{\,k}\ week_{\,p}}{\#\ redds\ in\ index\ area_{\,j}\ week_{\,p}} * season\ cumulative\ redds\ in\ index\ area_{\,j}$$

Un-surveyed areas are then estimated using redd densities (cumulative redds / river mile) from surveyed reaches with similar habitat-type. Additionally, given that high water events periodically interrupt weekly index area surveys, a variety of ad-hoc methods are occasionally used to estimate missing weeks in index area spawning. Although percentages vary from year to year (i.e., in response to weather, flows, staffing levels), index, extensive, and non-surveyed reaches comprise *ca*. 20%, 50%, and 30%, respectively, of the total stream length used by fall Chinook for spawning.

Final basin escapement is computed as the sum of cumulative redds in intensive, extensive, and un-surveyed reaches, multiplied by an assumed 2.5 fish (adults) / redd. The current survey design does not allow for the estimation of uncertainty associated with redd totals and/or the constant fish-per-redd multiplier. However, three years of mark-recapture studies conducted in the Little Hoquiam River (Chitwood 1987, 1988, 1989), a tributary of the Grays Harbor system, verify that this constant has local relevance is consistent across years (mean 2.50, CV(mean) = 7%).

WDFW estimated natural- and hatchery-origin components using two methods. When the majority of hatchery returns were from mass-marked (i.e., adipose fin-clipped) broods, the hatchery stray component of total escapement was estimated during carcass surveys. Resulting estimates of stray hatchery spawners were used in conjunction with hatchery rack observations to estimate an overall hatchery stray rate for each basin. Prior to complete mass marking, the stray hatchery component of natural spawning escapement was estimated by applying, retrospectively, the mean stray rate for recent mass-marked return years (2009+). See Appendix B for complete wild-origin estimation details.

Lastly, in all analyses, parent generation escapement (i.e., spawners) includes both natural- and hatchery-origin fish spawning naturally. No adjustments were made to account for the possibility of a reproductive fitness differential for hatchery- vs. natural-origin parents. On the recruitment side, only natural-origin escapement was included in production calculations.

Table 1. Releases of smolt stage fall Chinook into the Chehalis and Humptulips rivers (brood years 1986 – 2011) from 11/2013 RMIS query. AD = adipose clipped, UM = unclipped.

Brood Year	Chehalis[1]				Humptulips			
	AD (ALL)	UM	AD+CWT	% AD	AD (ALL)	UM	AD+CWT	% AD
1986	0	880,764	0	0%	201,993	81,327	201,468	71%
1987	72,710	2,310,675	71,919	3%	215,725	96,575	209,254	69%
1988	0	480,350	0	0%	208,403	283,747	206,735	42%
1989	44,998	299,970	44,667	13%	205,993	554,093	203,892	27%
1990	144,638	591,245	142,363	20%	212,156	1,952	207,589	99%
1991	169,022	490,348	164,363	26%	0	62,100	0	0%
1992	0	1,414,946	0	0%	0	402,700	0	0%
1993	0	752,763	0	0%	0	345,800	0	0%
1994	0	719,700	0	0%	0	467,800	0	0%
1995	0	562,342	0	0%	0	230,200	0	0%
1996	0	139,978	0	0%	0	237,435	0	0%
1997	0	269,932	0	0%	0	540,700	0	0%
1998	0	114,836	0	0%	0	437,000	0	0%
1999	0	409,000	0	0%	0	385,100	0	0%
2000	0	275,000	0	0%	0	259,425	0	0%
2001	0	103,300	0	0%	0	228,385	0	0%
2002	0	111,000	0	0%	0	535,750	0	0%
2003	211,302	274,726	136,663	43%	199,964	308,161	196,605	39%
2004	251,416	533,419	247,590	32%	185,982	297,538	180,029	38%
2005	144,365	36,835	143,995	80%	236,285	131,725	236,285	64%
2006	44,506	113,094	43,438	28%	198,689	324,411	198,689	38%
2007	238,950	4,430	0	98%	312,430	1,570	0	100%
2008	408,847	153	204,786	100%	270,710	3,790	0	99%
2009	116,749	526	0	100%	148,929	896	0	99%
2010	154,086	14	0	100%	567,997	4,217	0	99%
2011	621,978	12,656	0	98%	535,268	10,599	0	98%

[1]Includes releases into the mainstem Chehalis, Satsop, Hoquiam, Wishkah rivers, and Van Winkle Creek, as well as releases into the Wynoochee River for three broods (1992-94).

Table 2. Returns of fall Chinook to Chehalis River and Humptulips River hatcheries, return years 1989–2011 (source: WDFW Run Reconstruction, Dec. 2013).

Return Year	Satsop Springs/ Bingham	Lake Aberdeen	Mayr Bros (Wishkah)	Humptulips
1989	58	0	0	433
1990	30	0	0	169
1991	279	0	0	95
1992	431	0	0	190
1993	303	0	0	216
1994	292	0	0	236
1995	255	14	0	135
1996	343	86	0	150
1997	102	53	0	276
1998	100	67	0	298
1999	8	60	0	260
2000	3	55	0	169
2001	4	60	33	175
2002	0	291	80	405
2003	36	130	35	617
2004	314	84	0	474
2005	59	112	9	710
2006	73	342	41	1476
2007	132	74	7	363
2008	185	32	16	248
2009	94	91	13	467
2010	105	99	4	442
2011	330	130	51	852

Estimation of origin (hatchery or wild) and age in terminal fisheries

Sampling for CWTs and mark rates is done in Chehalis tribal net, Quinault Tribal net, and non-treaty fisheries by the Chehalis Tribe, the Quinault Indian Nation (QIN), and the Washington Department of Fish and Wildlife (WDFW), respectively. However, this sampling is considered unreliable for determination of hatchery / wild composition in most years (Jim Jorgenson, personal communication). Consequently, total hatchery return and wild spawning escapement are used to assign catch to production origin in terminal fisheries. The proportion wild Chehalis stock is estimated as Chehalis River wild-origin escapement / [total hatchery-origin escapement + Chehalis River wild-origin escapement]. The proportion wild Humptulips stock is estimated in a similar manner; for both rivers, hatchery-origin escapement includes hatchery fish homing to facilities as well as strays.

Scale samples obtained in the terminal fishery and in escapement sampling are used to determine age composition of returns. Scale samples are taken in treaty and non-treaty net fisheries and during Chehalis and Humptulips spawning ground surveys. No scale samples are taken in recreational sport fisheries. Scale samples from areas 2A, 2D, and the Chehalis River are used to estimate age proportions for Chehalis River stock (Figure 1). Scale samples from area 2C and the Humptulips River are used to proportion Humptulips River stock (Figure 1).

For return years during which raw data were available (2001-2011), the proportional abundance by age *a* (*a* = 3,4,..,6) in the terminal return was estimated for the Chehalis and Humptulips populations using a weighted average from samples collected in fisheries and escapements according to:

Notation	Definition
PR_a	Proportion age a
SC	Scale sample
CA	Catch
ESC	Escapement estimate
sp	Subscript for sample obtained in spawning survey
	Chehalis stock
2AD	Subscript for area 2A + area 2D
Cheh	Subscript for Chehalis River
tr	Subscript for treaty net fishery
nt	Subscript for non-treaty net fishery
	Humptulips stock
2C	Subscript for area 2C
Hump	Subscript for Humptulips River
tr	Subscript for treaty net fishery
nt	Subscript for non-treaty net fishery

For example, the weighed age 3 proportion for Chehalis stock is computed as

$$PR_3 = \frac{SC_{3,tr,2AD}}{\sum_{a=3}^{6} SC_{3,tr,2AD}} * CA_{tr,2AD} + \frac{SC_{3,nt,2AD}}{\sum_{a=3}^{6} SC_{3,nt,2AD}} * CA_{nt,2AD} + \frac{SC_{3,sp,Cheh}}{\sum_{a=3}^{6} SC_{3,sp,Cheh}} * ESC_{Cheh}$$

.

and the weighed age 3 proportion for Humptulips stock is computed as

$$PR_3 = \frac{SC_{3,tr,2C}}{\sum_{a=3}^{6} SC_{3,tr,2C}} * CA_{tr,2C} + \frac{SC_{3,nt,2C}}{\sum_{a=3}^{6} SC_{3,nt,2C}} * CA_{nt,2C} + \frac{SC_{3,sp,Hump}}{\sum_{a=3}^{6} SC_{3,sp,Hump}} * ESC_{Hump}$$

.

The relative abundance of returns for ages 4-6 is computed similarly. The weights used to estimate age composition for return years prior to 2001 are of undocumented origin.

Assignment of terminal marine catch to stock (Chehalis or Humptulips)

Net and sport catch in the Grays Harbor estuary (Marine Area 2.2, sub-areas 2A, 2B, 2C, and 2D; Figure 1) and its tributaries must be assigned to stock (Chehalis or Humptulips). Marine catch in Area 2.2 is composed of marine sport, non-Treaty net, and Quinault Treaty net (Table 3a). Freshwater catch includes freshwater sport, Quinault Treaty net, and Chehalis Tribal net (Table 3b). Stock assignment for freshwater net and sport fisheries is made on the basis of catch location, i.e., catches are assumed to be of 100% local origin stock. To assign catches in Grays Harbor's mixed-stock estuary areas (net fisheries in 2A-2D and sport fisheries in 2.2) rule- or CWT-based methods are used, and to account for spatial differences in treaty and non-treaty fisheries within catch areas (e.g., 2C) different methods are used to apportion their respective catches to the Chehalis and Humptulips population segments.

For treaty net fisheries, all catch occurring in areas 2A and 2D is assumed Chehalis stock and Area 2C treaty catch is assumed Humptulips stock. No treaty fisheries have occurred in Area 2B during the period covered in this analysis. Non-treaty net catch in Area 2A is apportioned in the same manner as treaty catch (i.e., 100% Chehalis), Areas 2B-2D non-treaty net and Area 2.2 non-treaty sport catches are apportioned to population segments based on historic CWT release–recovery data. Assignments are made based on the average probability of encountering fish from each stock in a particular catch area, given the run size of Chehalis wild- or hatchery-origin and Humptulips wild- or hatchery-origin fish in the return year of interest. Specifically, the catch (C_{SFY}) of stock *S* (Chehalis-wild, Chehalis-hatchery, Humptulips-wild, Humptulips-hatchery) in catch area *F* is computed for each return year (*Y*) as

$$P_{SFY} = \frac{P_{SFbase} * N_{SY}}{\sum_{S} P_{SFbase} * N_{SY}}$$

where,

C_{SFY} = catch of stock *S*, in fishery *F* (non-treaty net or sport), in return year *Y*,

C_{FY} = total catch in fishery *F* in return year *Y*,
P_{SFY} = is the catch probability of stock *S* in fishery *F* in return year *Y*,
P_{SFbase} = is the historic mean fraction of terminal CWT recoveries (i.e., of total CWT run entering, Grays Harbor) for stock *S* recovered in fishery *F* in base period years (1974 – 2010), and,
N_{SY} = the total terminal return of stock *S* in return year *Y*, and

$$C_{SFY} = P_{SFY} * C_{FY} .$$

Final non-treaty 2B-2D and 2.2 catch assignments must be determined through iteration, because P_{SFY} is a function of N_{SY}, which itself depends on C_{SFY}. This approach provides unbiased stock assignment if the distributions of Chehalis and Humptulips fish (within Grays Harbor) remain constant over time and if all stocks entering a particular area experience the same harvest rate.

Lastly, for both non-treaty and treaty fisheries, assignment of stock to production type (i.e., hatchery/wild) follows the method described above under '*Estimation of origin (hatchery or wild) and age in terminal fisheries*', and no discounts are made to estuarine catch to account for out-of-Grays-Harbor strays entering the system.

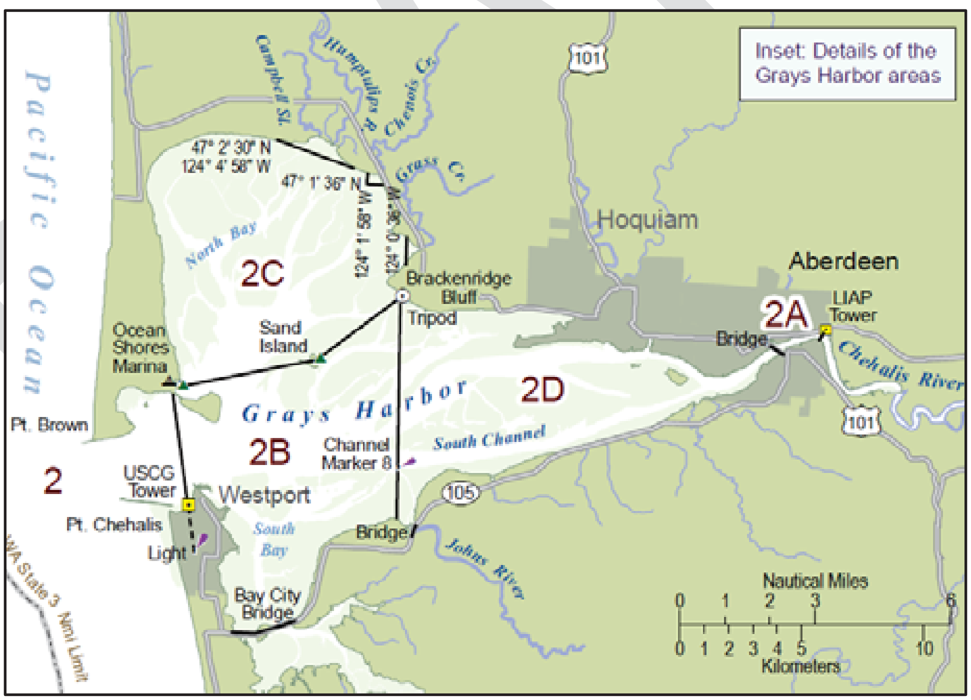


Figure 1. Grays Harbor Commercial Area Fishing Map.

Table 3a. Grays Harbor marine fisheries.

Grays Harbor	Subsets of 2.2	Fisheries		
Marine area 2.2	2A (subset of 2.2)	Marine sport	Quinault Indian Nation Treaty net	Non-Treaty net
	2B (subset of 2.2)	Marine sport		Non-Treaty net
	2C (subset of 2.2)	Marine sport	Quinault Indian Nation Treaty net	Non-Treaty net
	2D (subset of 2.2)	Marine sport	Quinault Indian Nation Treaty net	Non-Treaty net

Table 3b. Grays Harbor freshwater fisheries.

Grays Harbor Rivers	Tributaries	Fisheries		
Chehalis River	main stem	Freshwater sport	Chehalis Tribal Treaty net	Quinault Indian Nation Treaty net
	Van Winkle Creek	Freshwater sport		
	Wynoochee River	Freshwater sport		
	Satsop River	Freshwater sport		
	Cloquallum Creek	Freshwater sport		
	Black River	Freshwater sport		
	Skookumchuck River	Freshwater sport		
	Newaukum River	Freshwater sport		
Humptulips River	main stem	Freshwater sport		Quinault Indian Nation Treaty net
Elk River		Freshwater sport		
Johns River		Freshwater sport		
Hoquiam River		Freshwater sport		
Wishkah River		Freshwater sport		
Misc South Bay		Freshwater sport		

Queets River CWT Indicator Stock Data

Data for CTC exploitation rate analysis consist of CWT release, recovery, and catch sample data. The data are typically obtained from the Regional Mark Information System (RMIS) with supplementation (when necessary) from local management. Data are input into the Cohort Analysis System (CAS; Wostman and Associates) and stored in the CAS.mdb database. This analysis used Queets data in the CAS March 2012 database. The QIN commercial net, freshwater sport and escapement data in the CAS March 2012 database were removed and replaced with updated and corrected data from QDNR.

Commercial net fisheries in the Queets River are electronically sampled at ~25%. Freshwater sport is estimated using WDWF's catch record card (CRC) system. Queets spawning escapement is estimated using similar survey methods to those described above for the Grays Harbor system (i.e., redd counts). Returning CWT indicator stock adults do not return to the

Salmon River Fish Culture Center; thus, escapement recoveries occur on the spawning grounds. When spawning survey tag recoveries are available from all 3 tributaries (Queets River, Clearwater River, and Salmon River) the number of indicator CWTs in spawning escapement is estimated by tag expansion. When tag recoveries are insufficient for tag expansion, the total number of indicator stock CWTs in spawning escapement is derived using a ratio estimation approach based on a combination of data collected in terminal net fisheries and during spawning ground surveys, specifically the proportion indicator stock in commercial catch (indicator catch / total catch), age proportions (indicator $_{\text{age } i}$ / total indicator) of tags recovered in spawning surveys, and the total escapement to spawning beds in the Queets, Clearwater, and Salmon rivers:

Notation	Definition
$PRind^{net}$	Proportion CWT indicator in sampled commercial net fisheries
$PRind^{esc}{}_{a}$	Proportion CWT indicator age a, of total CWT indicator recovered in escapement surveys
ESC^{est}	Total estimated escapement to spawning beds in Salmon, Queets, and Clearwater rivers

Proportion indicator age *a*, in escapement =

$$PRind^{net} * PRind^{esc}{}_{a} * ESC^{est}$$

Queets River escapement estimates used in these calculations assume 2.5 fish / redd and all CWT calculations include fish of age 2 to 6.

After data are loaded into the CTC CAS database, the CAS maps the data to 85 fine-scale fisheries and generates one report (C-file) for each brood year. The C-files are inputs for the CTC's Coshak program. The Coshak program re-maps recoveries to 32 PSC fisheries (and escapement) and conducts a full cohort analysis, providing estimates of fishery-specific and total exploitation rates, maturation probabilities, release-to-age 2 survival rates, and adult equivalency (AEQ) factors (CTC 1988). The AEQ factors for each brood year and age are the proportion expected to return to spawn in the absence of a fishery (Table 4). The Coshak program calculates mortality estimates in terms of landed and incidental mortality due to undersized release in retention fisheries (shaker mortality), and incidental mortality in non-retention fisheries for legal- and sub-legal size encounters.

Table 4. Adult equivalent factors (AEQ; the proportion expected to return in the absence of fishery removal) is calculated by the COHSHK program.

Brood year	Age				
	2	3	4	5	6
1986	0.549	0.784	0.931	0.991	1.000
1987	0.546	0.779	0.911	0.987	1.000
1988	0.522	0.743	0.909	0.992	1.000
1989	0.514	0.733	0.909	0.982	1.000
1990	0.524	0.742	0.913	0.988	1.000
1991	0.515	0.732	0.910	0.985	1.000
1992	0.517	0.737	0.907	0.956	1.000
1993	0.531	0.758	0.922	0.982	1.000
1994	0.528	0.750	0.922	0.978	1.000
1995	0.524	0.746	0.914	0.996	1.000
1996	0.530	0.752	0.929	0.990	1.000
1997	0.534	0.762	0.923	0.984	1.000
1998	0.522	0.745	0.917	0.986	1.000
1999	0.516	0.737	0.904	0.968	1.000
2000	0.523	0.747	0.915	0.979	1.000
2001	0.549	0.784	0.953	0.995	1.000
2002	0.533	0.759	0.925	0.991	1.000
2003	0.523	0.746	0.921	0.990	1.000
2004	0.524	0.748	0.921	0.983	1.000
2005	0.530	0.757	0.927	0.993	1.000

Estimating Terminal Incidental Mortality and Pre-fishing Recruits from Queets CWT Data

Data for Grays Harbor fall Chinook are limited to estimates of landed catch in the terminal run and escapement. All pre-terminal mortality (landed + incidental) in Grays Harbor terminal fisheries was estimated using Queets River fall Chinook stock and methods devised by Morishima (personal communication [memo], 2011). Queets River was selected because of its proximity to Grays Harbor and because Queets River CWT indicator stock are used the CTC's annual exploitation rate analysis.

Incidental mortality

Estimates of Grays Harbor wild terminal catch (freshwater sport, terminal marine sport, and terminal net) were expanded to include incidental mortality using CTC estimates of incidental mortality for corresponding fisheries in the Queets River indicator stock CWT dataset.

Notation	**Definition**
GH_a	Grays Harbor stock age a
QTS_a	Queets stock age a
tn	Subscript for terminal net
tmfs	Subscript for terminal marine sport (inside Grays Harbor) + freshwater sport.
os	Subscript for ocean sport
landed	Superscript for landed mortality
total	Superscript for landed mortality + incidental mortality

Grays Harbor terminal net total mortality (landed catch + incidental mortality) for run year $_i$ =

$$\sum_{a=3}^{a=6} GH_{tn,a}^{landed} * \frac{Qts_{tn,a}^{total}}{Qts_{tn,a}^{landed}}$$

.

Grays Harbor terminal marine and freshwater sport total mortality (landed catch + incidental mortality) for run year $_i$ =

$$\sum_{a=3}^{a=6} GH_{tmfs,a}^{landed} * \frac{Qts_{tmfs,a}^{total}}{Qts_{tmfs,a}^{landed}}$$

.

Estimation of Pre-fishing AEQ Recruits

Estimating the total pre-fishing abundance (i.e., recruitment or production) additionally requires estimates of total (landed + incidental) ocean fishery mortality. These values were estimated using the gear-specific ratios (net and combined troll + sport) of preterminal mortality to terminal abundance estimated for the Queets River CWT indicator stock, adjusted for adult equivalency Pre-terminal fishery mortalities were converted to AEQ estimates because production is the expected spawning return in the absence of fishing (i.e., some portion of the catch would be reduced by natural mortality).

In this analysis preterminal-to-terminal ratios were applied to ages 2, 3, and 4 for all pre-terminal fisheries except ocean net. The ratios were applied to ocean net fisheries for ages 2, and 3 only. Grays Harbor pre-terminal fishery mortalities (ocean net, ocean troll, and ocean sport) were estimated for each brood year (1986 - 2005).

Total AEQ Grays Harbor (GH) ocean sport and ocean troll fishery mortality for brood year i and age a =

$$\sum_{a=3}^{a=6}(GH\ terminal\ catch_a + GH\ escapement_a) * \frac{Qts\ AEQ\ preterm\ troll\ \&\ sport\ total\ mortality\ _a}{Qts\ terminal\ mortality_a\ + Qts\ escapement_a}$$

,

and total AEQ Grays Harbor ocean net catch for brood year i and age a =

$$\sum_{a=3}^{a=6}(GH\ terminal\ catch_a + GH\ escapement_a) * \frac{Qts\ AEQ\ preterm\ net\ total\ mortality\ _a}{Qts\ terminal\ mortality_a\ + Qts\ escapement_a}$$

Given these estimates, Grays Harbor production for brood year *i* was computed as the sum of AEQ pre-terminal mortality (estimated above), terminal catch (with incidental mortality adjustment), and wild escapement (Table 5). Grays Harbor is composed of two separately managed stocks: Chehalis River and Humptulips River. Therefore the estimates of production described above were computed separately for each stock so that an independent spawner-recruit analysis could be conducted for each stock. All estimates of terminal incidental mortality and preterminal production were computed using programs and utilities developed by QDNR (R. Coshow) and executed using SAS (Copyright (c) 2002-2008 by SAS Institute Inc., Cary, NC, USA.).

Table 5. Brood year escapement and production for Grays fall Chinook Harbor. Preterminal production is adjusted for adult equivalent (AEQ) and incidental mortality. Terminal production includes incidental mortality. Brood escapement includes hatchery + natural spawners, production is natural only.

Sub-basin	Brood year	Brood year escapement	Pre-terminal production (AEQ)		Terminal production				
			Ocean troll & sport	Ocean net	Area 2.2 sport	Non-treaty net	Treaty net	Escape.	FW sport
Chehalis	1986	9,483	18,714	149	259	3,130	4,448	10,756	1,349
	1987	12,850	12,414	389	230	1,977	2,779	7,064	740
	1988	21,945	16,200	348	268	3,575	4,710	11,863	1,628
	1989	20,066	22,414	848	323	3,784	5,253	11,636	1,722
	1990	12,893	11,987	17	469	3,769	5,147	12,056	2,415
	1991	12,571	5,798	79	326	708	1,195	5,718	1,166
	1992	11,974	25,449	0	1,577	2,576	5,732	21,602	2,835
	1993	10,472	13,747	87	1,435	609	3,115	12,343	994
	1994	9,919	2,524	0	241	79	743	4,074	106
	1995	9,786	3,579	0	271	365	1,246	5,206	270
	1996	16,161	13,104	0	1,079	1,811	3,782	10,706	1,388
	1997	14,402	6,960	0	1,369	1,168	2,140	9,064	1,463
	1998	10,101	10,564	0	993	386	873	13,249	856
	1999	8,409	22,768	0	2,539	257	2,292	27,467	797
	2000	7,892	10,191	330	967	106	1,411	13,383	282
	2001	7,902	8,396	1	715	122	1,372	11,539	130
	2002	9,694	19,964	109	767	227	1,231	12,291	213
	2003	16,111	15,010	0	298	380	857	11,655	133
	2004	26,320	5,337	100	12	187	499	5,138	6
	2005	13,367	10,008	85	0	425	1,717	11,787	0
Humptulips	1986	4,325	10,879	63	29	2,453	3,302	2,591	1,150
	1987	6,163	4,616	177	21	1,290	1,332	1,921	577
	1988	6,213	7,717	133	30	2,287	1,882	3,901	1,423
	1989	5,611	9,019	339	28	1,429	2,190	4,069	1,692
	1990	4,102	4,597	11	40	1,052	2,461	3,494	2,206
	1991	1,821	2,694	38	33	442	1,114	1,722	1,062
	1992	4,618	6,178	0	93	914	2,360	4,703	1,998
	1993	2,877	4,757	40	95	403	1,683	3,471	975
	1994	4,401	1,240	0	20	51	683	1,644	112
	1995	2,941	573	0	11	17	273	877	40
	1996	4,066	1,749	0	38	64	412	2,007	127
	1997	3,766	1,155	0	43	24	277	1,573	49
	1998	2,428	2,010	0	32	18	261	2,393	334
	1999	1,954	4,714	0	98	38	615	5,316	1,193
	2000	1,493	5,132	120	80	69	736	5,300	692
	2001	1,590	3,110	0	53	62	920	3,920	259
	2002	2,147	7,380	33	54	171	1,348	3,179	431
	2003	3,760	4,196	0	17	261	963	2,340	206
	2004	5,453	2,769	67	3	282	575	1,478	220
	2005	6,328	6,296	44	0	882	1,560	5,115	1,229

Spawner –recruit modelling

Our spawner-recruit analysis largely follows the approach recommended by the CTC in the 1999 document 'Maximum Sustained Yield or Biologically Based Escapement Goals for Selected Chinook Salmon Stocks Used by the Pacific Salmon Commission's Chinook Technical Committee for Escapement Assessment' (CTC 1999) and reinforced in their recently published 'Bilateral Data Standards for Escapement Goals' (CTC 2013). The first step in the analysis was to determine the shape of the spawner-recruit function. The Shepherd model, written as,

$$\boldsymbol{R} = \frac{\boldsymbol{\alpha S}}{\boldsymbol{1+\beta S^{\gamma}}}, \qquad \text{Eq. 1}$$

can take the shape approximating a Ricker function when the parameter $\gamma > 1$, a Beverton-Holt function when $\gamma = 1$, or a strictly increasing function when $\gamma < 1$ (Figure 1). Thus, by first fitting the data to a Shepherd model, one can verify the underlying shape of spawner-recruit function empirically using a likelihood ratio test. Should test results reject that $\gamma \leq 1$, i.e., that the curve is more in the shape of a Ricker function, then that spawner-recruit model will be used, thereby reducing the number of estimated parameters.

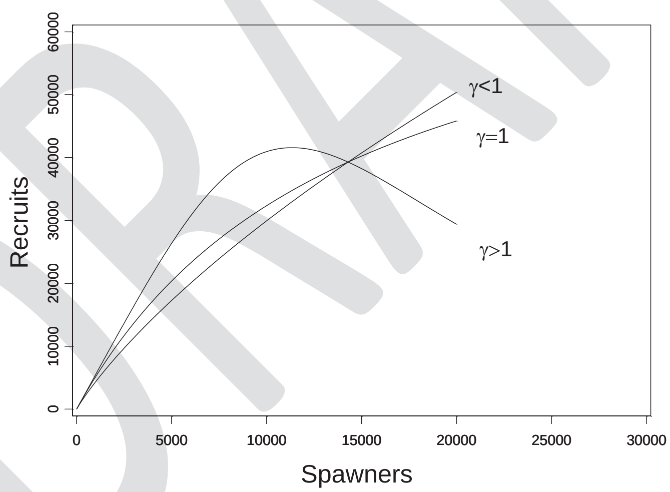


Figure 2. The functions of the Shepherd model for different values of the parameter.

In the case where the Shepherd model could not be fit to the data (non-convergence of the optimizer), we fit the spawner-recruit data were the Beverton-Holt and Ricker spawner-recruit models, which are, respectively

$$R = \frac{\propto S}{1+\beta S},$$

and

$$\boldsymbol{R} = \propto \boldsymbol{S}\boldsymbol{e}^{-\boldsymbol{\beta S}}. \qquad \text{Eq. 2}$$

We used the non-linear least squares (nls) function in S-plus to fit the model Beverton-Holt model with additive errors,

$$\boldsymbol{R_i} = \frac{\propto \boldsymbol{S_i}}{1+\boldsymbol{\beta S_i}} + \boldsymbol{\varepsilon_i} \qquad \text{Eq. 3}$$

where ε_i, the error terms, are independent with mean 0 and constant variance, σ^2. A linear form of Eq. 3 that is can be fit to the data using least squares is,

$$\frac{\boldsymbol{S_i}}{\boldsymbol{R_i}} = \frac{1}{\boldsymbol{\alpha}} + \frac{\boldsymbol{\beta}}{\boldsymbol{\alpha}}\boldsymbol{S_i} + \boldsymbol{\varepsilon_i}.$$

More often, spawner-recruit data has a multiplicative error structure, where the Beverton-Holt model is

$$\boldsymbol{R_i} = \frac{\boldsymbol{\alpha S_i}}{1+\boldsymbol{\beta S_i}} * \boldsymbol{\varepsilon_i} \qquad \text{Eq. 4}$$

In this case, we fit the model using nonlinear least-squares (nls) as,

$$\boldsymbol{ln}\left(\frac{\boldsymbol{S_i}}{\boldsymbol{R_i}}\right) = \boldsymbol{ln}\left(\frac{1}{\boldsymbol{\alpha}}\right) + \frac{\boldsymbol{\beta}}{\boldsymbol{\alpha}}\boldsymbol{S_i} + \boldsymbol{ln}(\boldsymbol{\varepsilon_i})$$

where $ln(\varepsilon_i)$ are independent with mean 0 and constant variance, σ^2. We verified the appropriate choice of error structure through residual analysis. Linearizing the Ricker function to

$$\boldsymbol{ln}\left(\frac{\boldsymbol{R_i}}{\boldsymbol{S_i}}\right) = \ln(\boldsymbol{\alpha}) - \boldsymbol{\beta S_i} + \boldsymbol{ln}(\boldsymbol{\varepsilon_i}) \qquad \text{Eq. 5}$$

assumes a multiplicative error structure and is easily fit to the data using least squares methods.

Although the Shepherd model gives support to the underlying shape of the spawner-recruit function, we also assessed model fit by testing significance of estimates parameters. For both the Ricker and Beverton-Holt function, we tested the hypotheses H_o: $\alpha = 1$ and H_o: $\beta = 0$ against the one-tailed alternatives, H_a: $\alpha > 1$ and H_a: $\beta > 0$ at the α= 0.10 significance level using a t-distribution. When alpha and beta equal 1 and 0, respectively, the models reduce to R = S.

Further model refinement was done by checking the underlying assumptions of least squares regression, most notably the assumption of uncorrelated errors, by analyzing residual errors. The presence of serial correlation among the error terms was analyzed using autocorrelation function and partial autocorrelation plots and through a time series plot of residuals by brood year. Variances of model parameters will be underestimated if correlation between errors are not taken into account. In the presence of serial correlation between errors, we refit the model by differencing the predictor and dependent variables (Cochrane-Orcutt procedure; Neter et al. 1996, pg 509), spawners and recruits, respectively, as follows,

$$S_i' = S_i - rS_{i-t} \;;$$

$$R_i' = R_i - rR_{i-t}; \text{ and}$$

$$S_i' = \ln(\alpha)' + \beta' R_i'$$

where r = the correlation between error terms;

t = the lag of the significant correlation;

$\ln(\alpha)'$= the adjusted intercept;

β' = the adjusted slope.

Adjusted model parameters and standard errors are,

$$\ln(\alpha) = \frac{\ln(\alpha)'}{1-r};$$

$$SE(\ln(\alpha)) = \frac{SE(\ln(\alpha)')}{1-r} \text{ and;}$$

$$\beta = \beta'.$$

Calculations of escapement goals (S_{msy}) for the Beverton-Holt model were calculated as,

$$\hat{S}_{msy} = \frac{(\sqrt{\hat{\alpha}}-1)}{\hat{\beta}} \qquad \text{Eq. 6}$$

with variance approximated by the delta method,

$$\widehat{Var}(\hat{S}_{msy}) = \widehat{Var}(\hat{\alpha})\left(\frac{-1}{2\sqrt{\hat{\alpha}}\hat{\beta}}\right)^2 + \widehat{Var}(\hat{\beta})\left(\frac{(\sqrt{\hat{\alpha}}-1)}{\hat{\beta}^2}\right)^2 + 2\widehat{Cov}(\hat{\alpha},\hat{\beta})\left(\frac{-1}{2\sqrt{\hat{\alpha}}\hat{\beta}} \cdot \frac{(\sqrt{\hat{\alpha}}-1)}{\hat{\beta}^2}\right). \qquad \text{Eq. 7}$$

For the Ricker function, S_{msy} is calculated by the approximation of Hilborn and Walters (1992),

$$\hat{S}_{smy} = \left(\frac{ln(\hat{\alpha})+\frac{\hat{\sigma}^2}{2}}{\hat{\beta}}\right)\left[0.5 - 0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right], \qquad \text{Eq. 8}$$

The variance for Eq. 8 is approximated by the delta method as,

$$\widehat{Var}(\hat{S}_{smy}) = \widehat{Var}(ln(\hat{\alpha}))\left[\frac{1}{\hat{\beta}}\left(0.5 - 2*(0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right)\right]^2 + \widehat{Var}(\hat{\beta})\left[\frac{-ln(\hat{\alpha})+\frac{\hat{\sigma}^2}{2}}{\hat{\beta}^2}\left[0.5 - 0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right]\right]^2 + 2Cov(ln(\hat{\alpha}),\hat{\beta})\left[\frac{1}{\hat{\beta}}\left(0.5 - 2*(0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right)\right] \cdot \left[\frac{-ln(\hat{\alpha})+\frac{\hat{\sigma}^2}{2}}{\hat{\beta}^2}\left[0.5 - 0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right]\right] + \widehat{Var}(\hat{\sigma}^2)\left[\frac{1}{\hat{\beta}}\left(\frac{0.5}{2} - (0.07\left(ln(\hat{\alpha}) + \frac{\hat{\sigma}^2}{2}\right)\right)\right]^2. \qquad \text{Eq. 9}$$

Lastly, although not presented here, we evaluated the potential explanatory value of including marine survival covariates in spawner–recruit models during preliminary analysis stages. Specifically, we assessed correlations between residuals from Ricker models and estimates of early marine survival (release to age 2) for the Queets CWT indicator stock and found no association (Pearson correlation coefficient < 0.40). This finding combined with considerations of model parsimony led us to abandon further exploration of survival or environmental covariates.

Results

Grays Harbor Fall Chinook system-total Goal

Given that the PSC's Chinook Technical Committee recognizes only a single Grays Harbor fall Chinook escapement indicator stock, the separate estimates of S_{msy} for the Chehalis and Humptulips were combined to estimate an escapement goal for the Grays Harbor system as a whole. The system-total escapement goal, 13,326 adult spawners, is the sum of Ricker-based S_{msy} estimates for the Chehalis River (9,753; Hilborn and Walters [1992] approximation from Ricker model [Eq. 8] with a multiplicative error structure) and the Humptulips River (3,573 adults; Hilborn and Walters [1992] approximation from Ricker model [Eq. 8] with autocorrelated, multiplicative errors).

Chehalis Fall Chinook

We used the program R to fit the Shepherd model (Eq. 1) to the Chehalis fall Chinook spawner-recruit data. Results of the likelihood ratio test that $\gamma \leq 1$ were non-committal at a significance level of 0.10 (Table 6). Hence, both the Beverton-Holt and Ricker models were fit using these data.

Table 6. Stock, parameter estimates for the Shepard model.

Parameter	Value	Standard Error
$\hat{\alpha}$	2.431	0.315
$\hat{\beta}$	3.065×10^{-66}	3.72×10^{-64}
$\hat{\gamma}$	14.977	11.93
Likelihood Ratio Test	2.69	
$P(\gamma \leq 1)$	0.10	

Residual analysis of the Beverton-Holt function with additive errors (Eq. 3) showed this error structure to poorly represent these data, with a clear decreasing trend in residual plot where there should be none (Figure 3). A Beverton-Holt model fit with a multiplicative error structure (Eq. 4) eliminated this trend and better satisfied the error assumptions (i.e., mean 0, constant variance; Figure 4). Further, there was no evidence of serial correlation among the errors as verified by the ACF and PACF plots (Figure 5), and no clear temporal pattern in residuals (Figure 6). Estimates and associated variances for model parameters and the S_{msy}, and the mean squared error for the model are presented in Table 7.

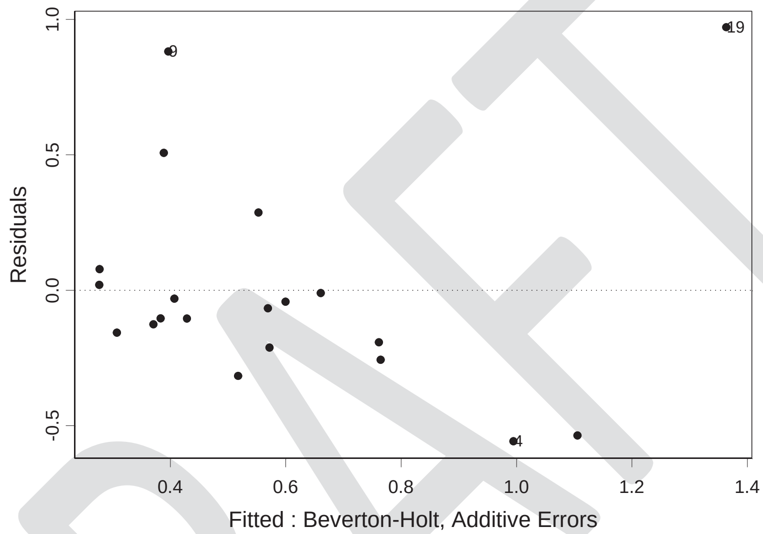


Figure 3. Residual plot from the fit of Beverton-Holt model with additive errors (Eq. 3) to the Chehalis fall Chinook data.

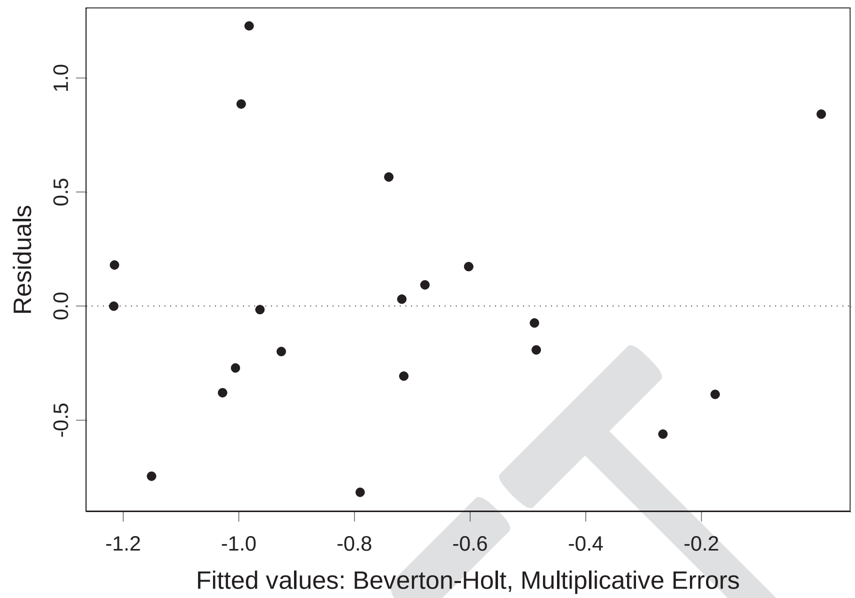


Figure 4. A plot of the residuals versus fitted values for the Beverton-Holt model with multiplicative errors (Eq. 4) for Chehalis Fall Chinook.

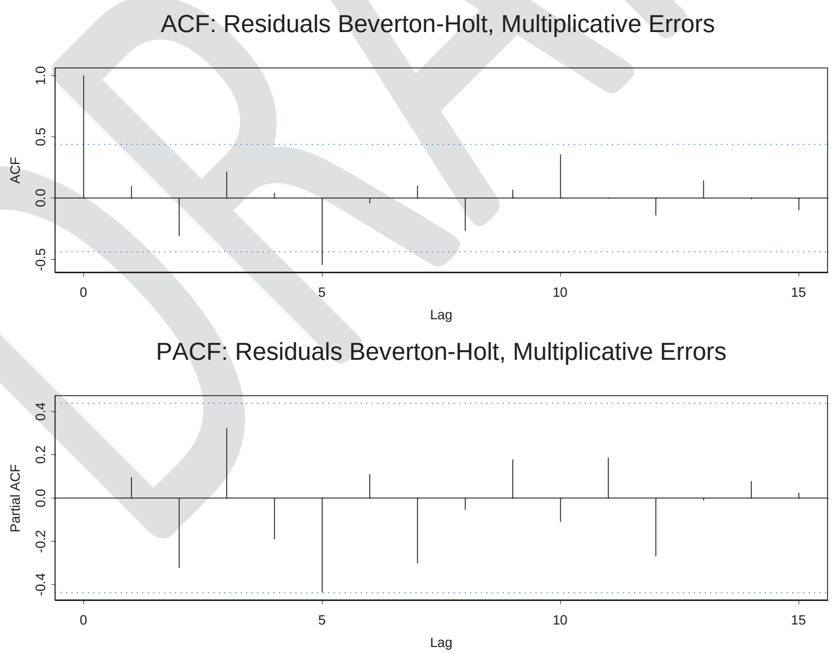


Figure 5. Autocorrelation and partial autocorrelation plots for the residuals from the Beverton-Holt model fit with multiplicative errors (Eq. 4) for the Chehalis fall Chinook data.

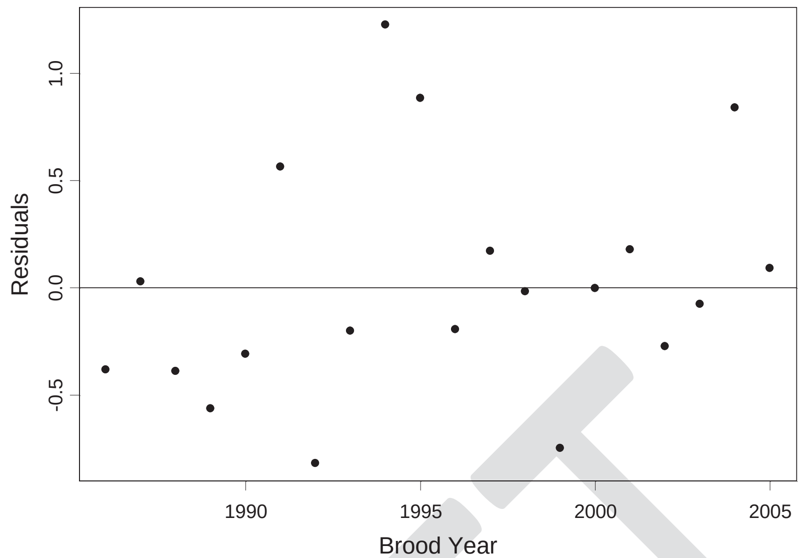


Figure 6. A time series plot of the residuals from the Beverton-Holt model fit with multiplicative errors for the Chehalis fall Chinook data.

Table 7. Estimates of the parameters for the Beverton-Holt spawner-recruit function for Chehalis Fall Chinook, assuming multiplicative errors (Eq. 4).

Parameter	Estimate	Standard Error	*t*-test results
α	315.55	18347.2	$P(\alpha \leq 1) = 0.493$
β	0.0012	0.680	$P(\beta \leq 0) = 0.493$
S_{msy}	1,443	122660.4	

The Ricker model with multiplicative errors was also fit to the Chehalis Chinook spawner-recruit data set (Eq. 5). A plot of residuals versus fitted values showed that multiplicative error was appropriate for these data (Figure 7). As with the Beverton-Holt model, there was no serial correlation among the error terms (Figures 8 and 9). These plots support the assumption that errors are independent with mean 0 and constant variance. Estimates of model parameters for the Ricker function in Eq. 2, their associated standard errors, and S_{msy} for the Chehalis fall Chinook data are in Table 8. The S_{msy} value for the Ricker model, estimated according to the Hilborn and Walters (1992) approximation (Eq. 8), is 9,357.

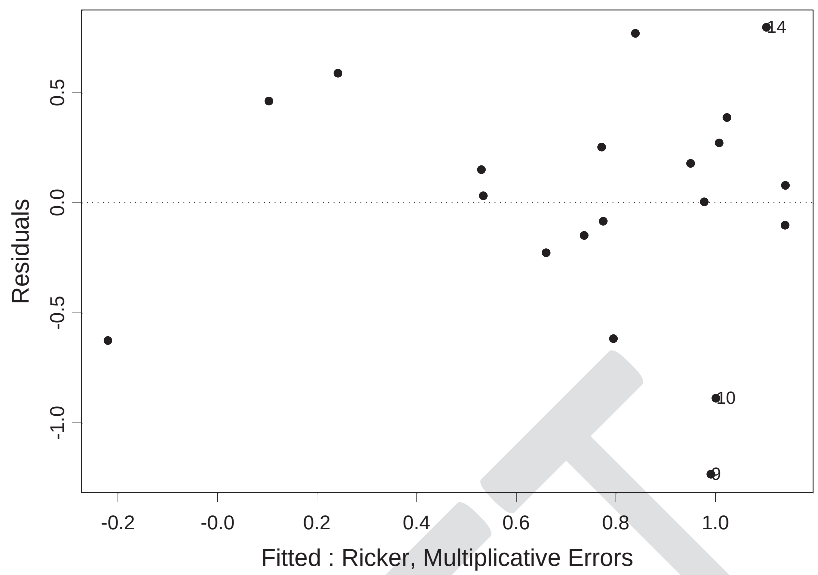


Figure 7. A plot of the residuals versus fitted values for the Ricker model with multiplicative errors (Eq. 5).

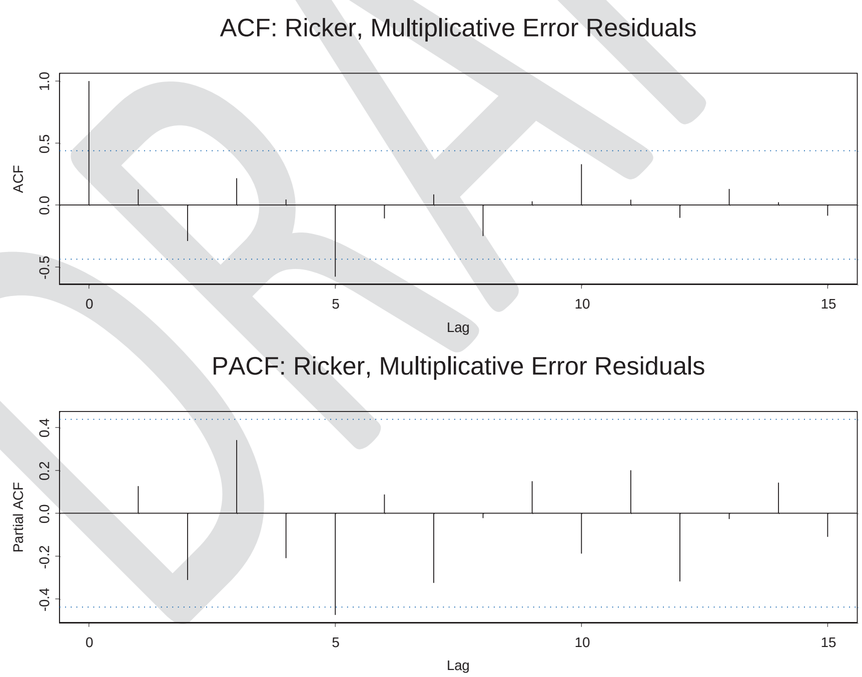


Figure 8. ACF and PACF for residuals from the fit of the Ricker model with multiplicative errors (Eq. 5) for the Chehalis fall Chinook data.

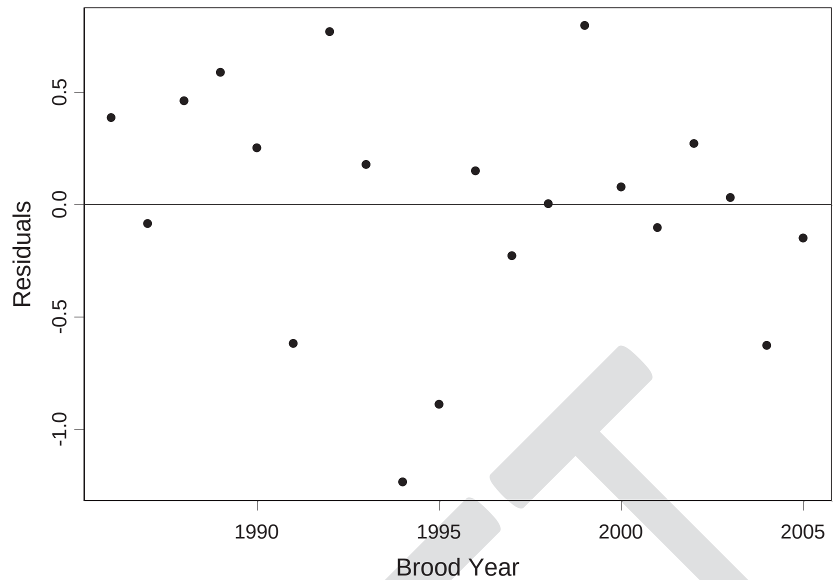


Figure 9. Time series plot of residuals from the fit of the Ricker model with multiplicative errors (Eq. 5) for the Chehalis fall Chinook data.

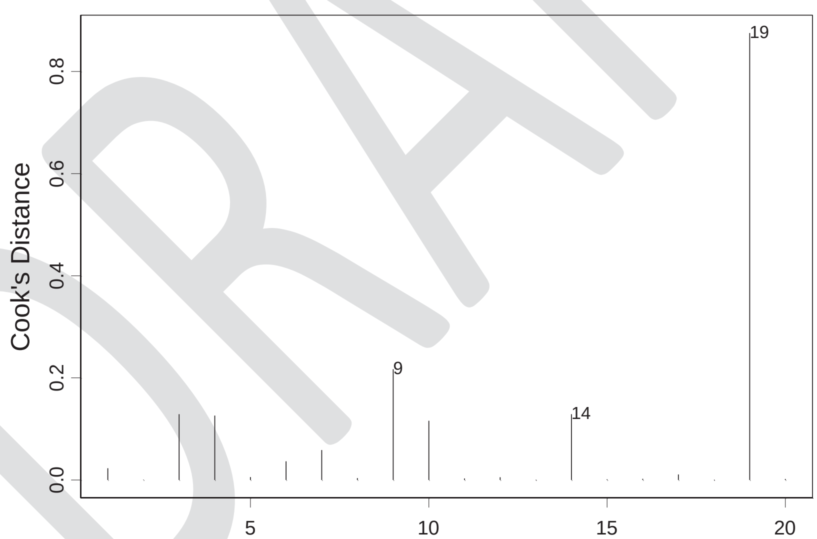


Figure 10. Plot of Cook's distances for the from the fit of the Ricker model with multiplicative errors (Eq. 5) for the Chehalis fall Chinook data showing that the 2004 had the highest influence on the model fit.

Table 8. Estimates and standard errors for parameters of the Ricker model (Eq. 2), and S_{msy}

Parameter	Estimate	Standard Error	*t*-test results
α	5.61	2.03	$P(\alpha \leq 1) = 0.016$
β	0.000074	0.000025	$P(\beta \leq 0) < 0.01$
S_{msy}	9,357	4329	

Of models considered, the information in the Chehalis spawner-recruit data supports the Ricker model (Figure 11). Evidence supporting the Beverton-Holt model is weak, or non-existent in these data. Parameter estimates do not differ significantly from zero (Table 7) and furthermore the S_{msy} value calculated from these estimates yields an escapement goal that falls well below the range of escapements seen in the observed data, i.e., S_{msy} = 1,443 vs. a series minimum of 7,892. In other words, S_{msy} computed from Beverton-Holt model parameters is based on an extrapolation of the curve beyond the range of the data. The Ricker model provided a better fit to the observed data and a Ricker-based S_{msy} is well within the range of historic escapements. Hence, S_{msy} for this stock should be based on the Ricker model.

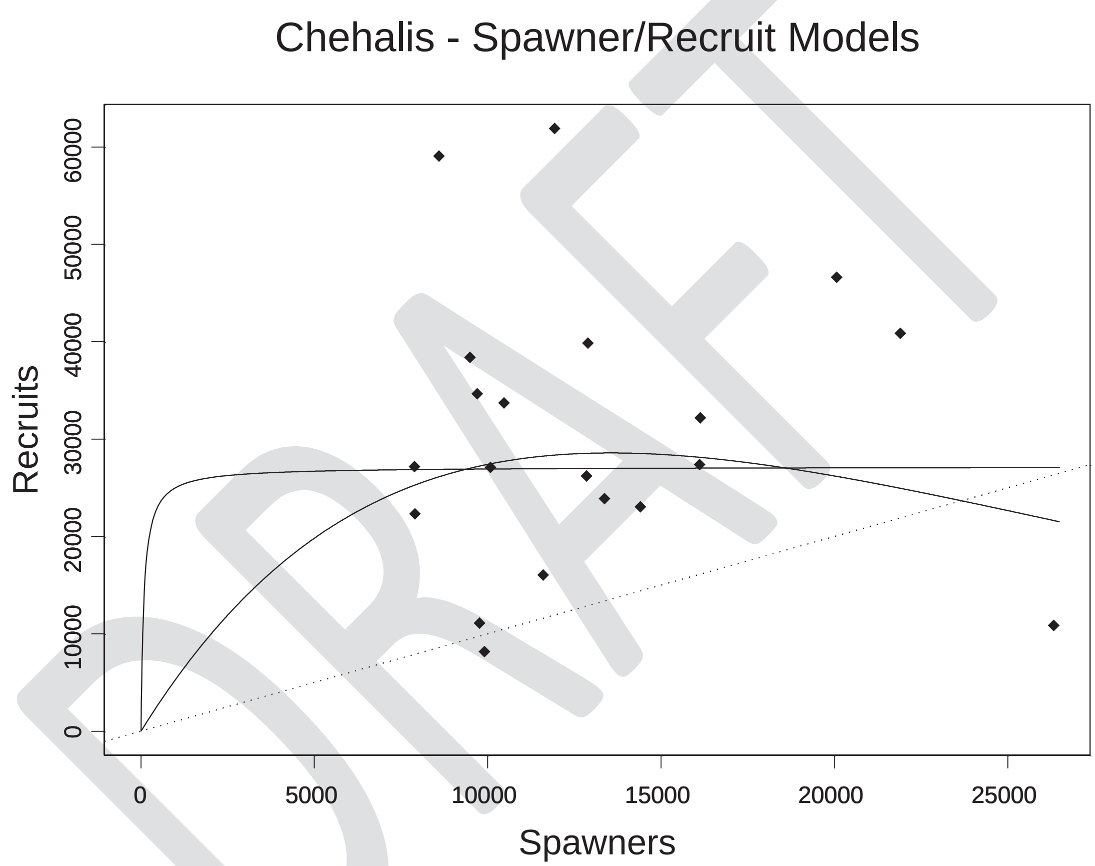


Figure 11. Beverton-Holt and Ricker spawner-recruit models fit to the Chehalis fall Chinook data. The dotted line in the line of equality between spawners and recruits.

We conducted additional analyses to assess the influence of a statistical outlier (2004 brood year; Figure 10) on Ricker α, β, and associated S_{msy} estimates. First, we fit the Ricker function of Eq. 5 using the bootstrap procedure of Efron and Tibshirani (1983). By resampling the data 1,000 times, with replacement, this procedure creates replicate data sets with varying degrees of outlier influence and allows for an assessment of bias in estimated S_{msy} relative to the unknown population parameter. Bootstrapped estimates of α and β differed slightly but not significantly (Table 9) from the point estimates summarized in Table 8, and produced a curve with higher fitted values than the original model did at high spawner levels (Figure 12). To further assess outlier influence, we computed point and bootstrapped estimates of α, β, and S_{msy} (Ricker) using a dataset that excluded the 2004 data point altogether (Table 9). In this case, point estimates from the fitted model were identical to their bootstrapped analogs, but Ricker parameters differed considerably from those based on the complete dataset. Excluding the 2004 point caused a decrease in estimates of Ricker productivity and capacity parameters and an increase in S_{msy} (9,357 to 14,007; Table 9). Despite this clear influence, available information suggests that the low level of recruitment associated with the 2004 brood is a biological reality and not an artifact of sampling. Thus, the bootstrapped S_{msy} value of 9,753 is recommended for adoption as the escapement goal for the Chehalis segment of the Grays Harbor fall Chinook indicator stock.

Table 9. Estimates and standard errors for parameters of the Ricker model (Eq. 2), and S_{msy} (Eq. 8), from an evaluation of the influence of the 2004 brood year (BY) data point.

Analysis	Parameter	Estimate	Standard Error	*t*-test results
Ricker (all BYs)	α	5.606	1.986	$P(\alpha \leq 1) = 0.016$
	β	0.000074	0.000025	$P(\beta \leq 0) < 0.010$
	S_{msy}	9,357	4296	
Bootstrap Ricker (all BYs)	α	5.29	2.10	$P(\alpha \leq 1) < 0.028$
	β	0.000068	0.000029	$P(\beta \leq 0) < 0.012$
	S_{msy}	9,753	2983	
Ricker (excl. 2004 BY)*	α	3.92	1.389	$P(\alpha \leq 1) < 0.025$
	β	0.000042	0.000031	$P(\beta \leq 0) < 0.096$
	S_{msy}	14,007	13,040	

* Bootstrapped estimates are equivalent and have SE = 0.0.

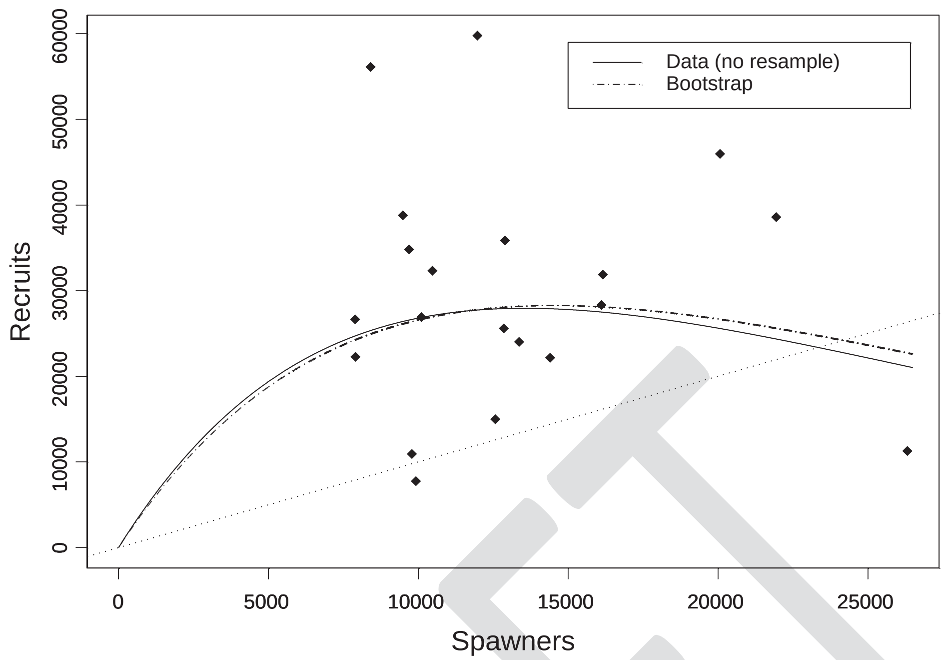


Figure 12. A comparison of the fit of the Ricker spawner-recruit model using the bootstrap procedure to the original fitted curve.

Humptulips Fall Chinook

Unlike the Chehalis analysis, we could not fit the Shepherd model to the Humptulips Chinook spawner-recruit data due to non-convergence of the nls function in both R and S-plus. This likely owes to the lack of definitive pattern in the spawner-recruit data when a three-parameter model is considered (Figure 13). Hence, we fit the two-parameter Beverton-Holt and Ricker models only to the Humptulips data set.

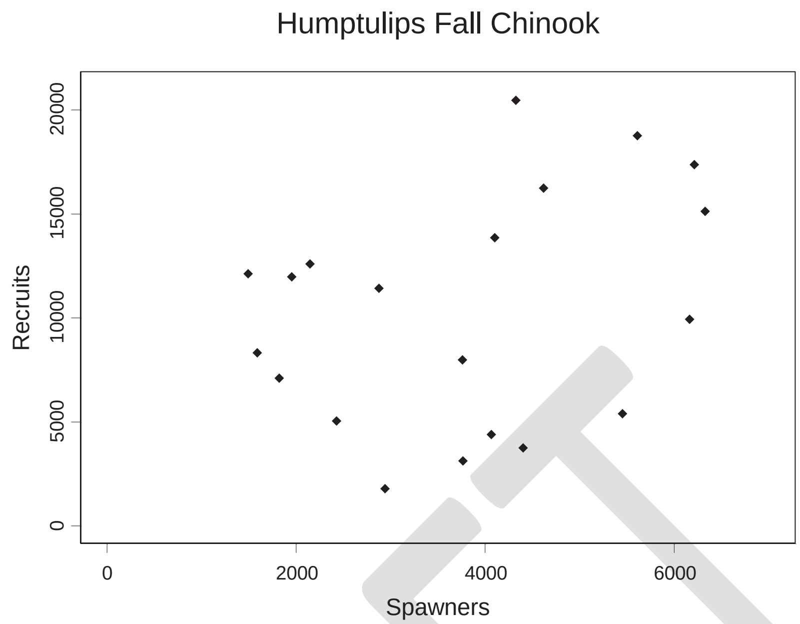


Figure 13. Scatter plot of the Humptulips fall Chinook spawner-recruit data.

We fit the Beverton-Holt model to the Humptulips spawner-recruit data first assuming additive (Eq. 3) then multiplicative (Eq. 4) errors. Although the residual plot for the model with additive error did not show any strong patterns (Figure 14), residuals for the model with multiplicative errors better approximate error assumptions (Figure 15). The assumption of uncorrelated errors, however, does not hold for this model, as both the ACF and PACF residual plots show a significant lag-1 correlation (Figure 16). Further, residuals show a discernable temporal trend, with estimated recruits being consistently underestimated in early and late years and overestimated in the middle of the series (Figure 17). Parameter estimates and unadjusted standard errors for this model are given in Table 10, as is the S_{msy}. To allow for comparisons to other models, the residual standard error in Table 10 is based on the difference between observed and predicted recruits on the original scale.

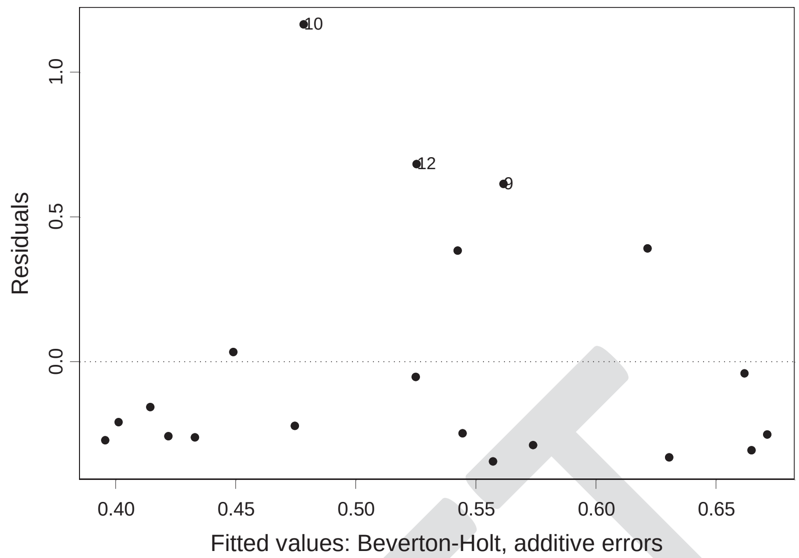


Figure 14. Residual plot from the fit of Beverton-Holt model with additive errors (Eq. 3) to the Humptulips fall Chinook data.

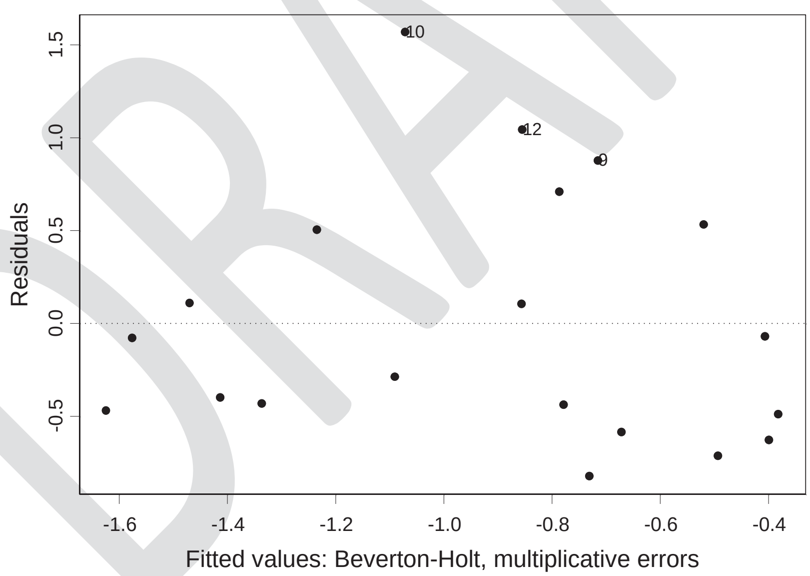


Figure 15. A plot of the residuals versus fitted values for the Beverton-Holt model with multiplicative errors (Eq. 4) for Humptulips Fall Chinook.

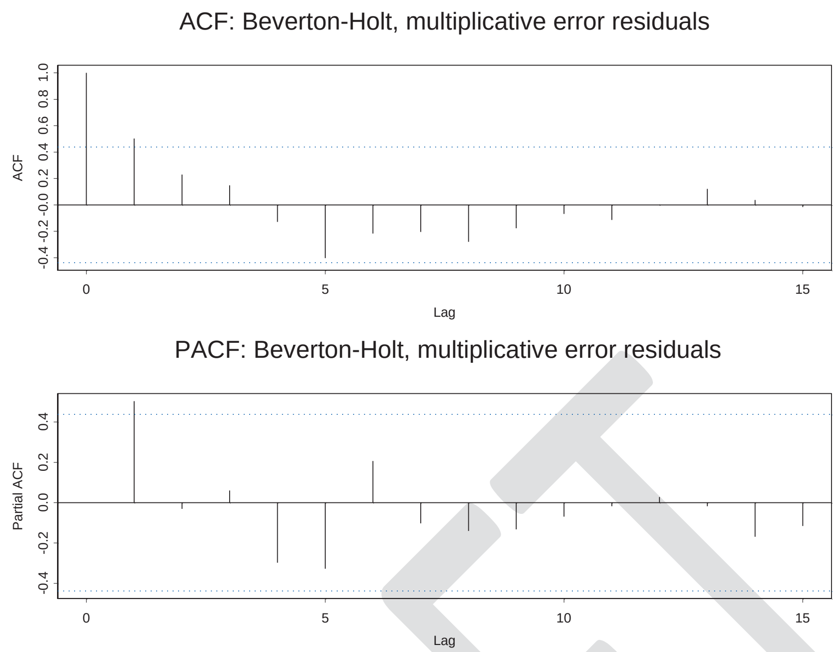


Figure 16. Autocorrelation and partial autocorrelation plots for the residuals from the Beverton-Holt model fit with multiplicative errors for the Humptulips fall Chinook data.

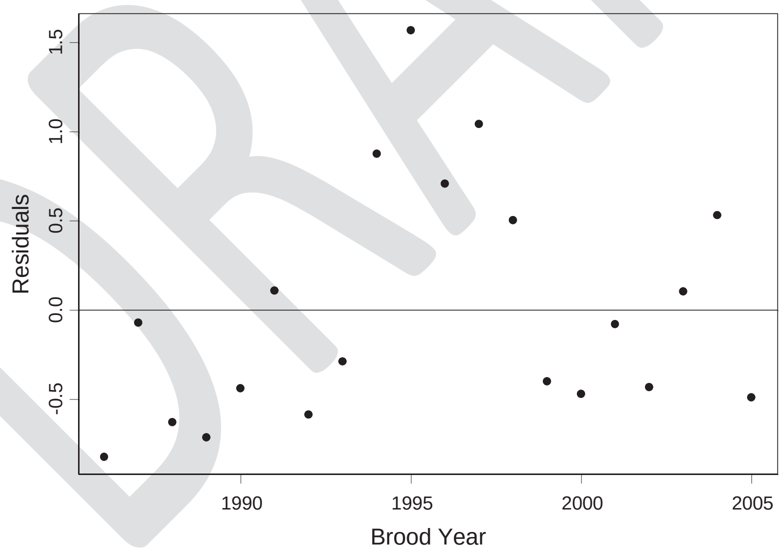


Figure 17. Time series plot of residuals from the fit of the Beverton-Holt model with multiplicative errors (Eq. 4) for the Humptulips fall Chinook data.

Table 10. Estimates of the Beverton-Holt for the spawner-recruit data for Humptulips Fall Chinook, assuming multiplicative (Eq. 5) errors.

Parameter	Estimate	Standard Error	*t*-test results
α	18.70	53.08	$P(\alpha \leq 1) = 0.63$
β	0.0018	0.0003	$P(\beta \leq 0) < 0.01$
S_{msy}	1,816	5417.4	

Similar to the Chehalis analysis, we fit the Ricker model with multiplicative errors (Eq. 5) to the Humptulips spawner-recruit data, as the Beverton-Holt analysis suggested this to be the most appropriate form and Ricker model residuals confirm (Figure 18). Ricker residuals also show a significant correlation among error variances at lag = 1 (Figure 19), indicating that an ARMA(1,1) error structure is needed to account for temporal dependence in the data. Residuals from the Ricker model also have a temporal trend, with periods of consistent over- or under estimation of recruits (Figure 20). In contrast to the Chehalis, there are no statistical outliers contained within the Humptulips data set (Figure 21). Estimates of model parameters, associated unadjusted standard errors, and S_{msy} for Ricker model are in Table 11. Note that the residual standard error in Table 11 is based on the difference between observed and predicted recruits on the original scale so that it could be compared to other models.

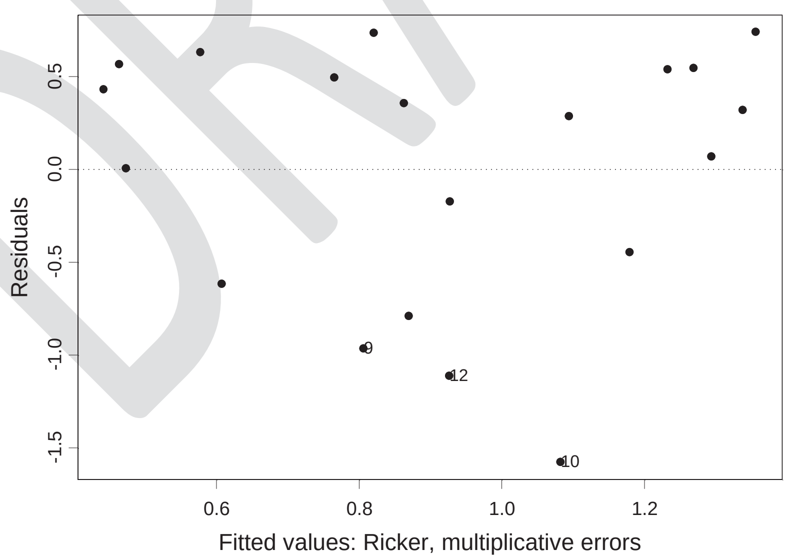


Figure 18. A plot of the residuals versus fitted values for the Ricker model with multiplicative errors for the Humptulips populations.

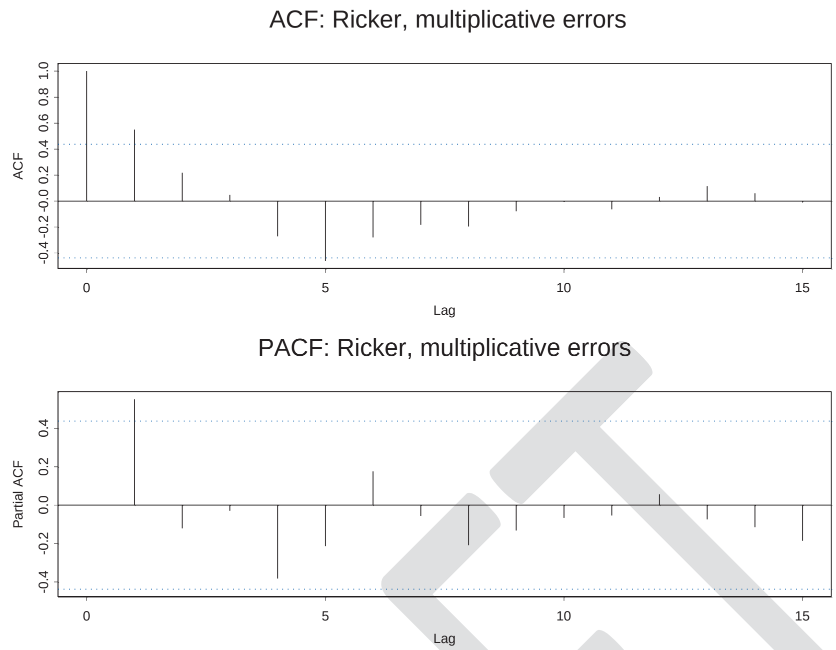


Figure 19. ACF and PACF for residuals from the fit of the Ricker model with multiplicative errors for the Humptulips fall Chinook data showing a significant correlation at lag 1 for both the ACF and PACF.

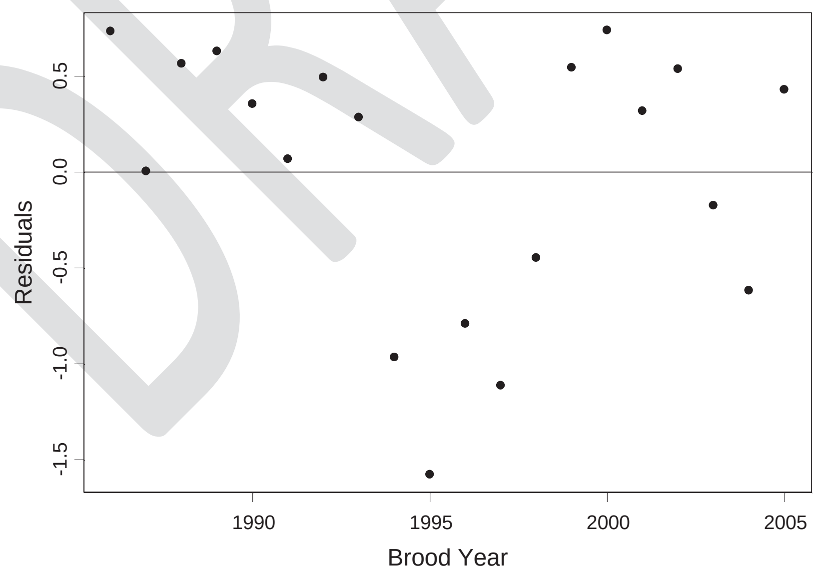


Figure 20. Time series plot of residuals from the fit of the Ricker model with multiplicative errors for the Humptulips fall Chinook data.

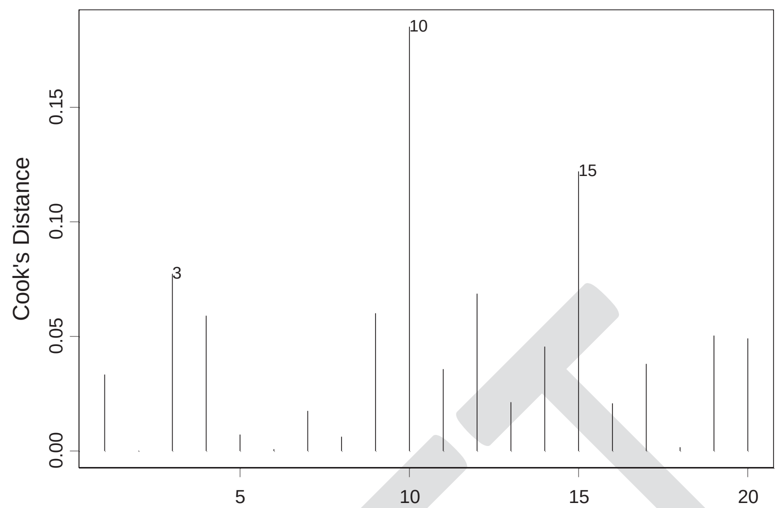


Figure 21. Plot of Cook's distances for the from the fit of the Ricker model with multiplicative errors for the Humptulips fall Chinook data showing that there was no data point having a clear influence on the model fit.

To address the lag-1 autocorrelation discussed above, we refit the Ricker model using the Cochrane-Orcutt procedure, which is equivalent to an ARMA(1,1) model. Changes in the estimate of α, its associated standard error, and the S_{msy} are in Table 11. Probabilities associated with the *t*-test for significance of the α parameter increase, as expected, but there was little change in estimates of β and S_{msy}. Analysis of the residuals from the adjusted model showed that the correlation between errors was eliminated (Figure 22). A comparison of the Ricker models between the original and adjusted model is shown graphically in Figure 23.

Table 11. Estimates and standard errors for parameters of the Ricker model, and S_{msy} for the Humptulips fall Chinook spawner-recruit data.

Model	Parameter	Estimate	Standard Error	*t*-test results
Original	α	5.14	2.16	$P(\alpha \leq 1) = 0.036$
	β	0.00019	0.0001	$P(\beta \leq 0) = 0.039$
	S_{msy}	3,676	2454	
Adjusted for autocorrelation	α	5.16	2.60	$P(\alpha \leq 1) = 0.064$
	β	0.0002	0.0001	$P(\beta \leq 0) = 0.031$
	S_{msy}	3,573	2177	

As was found in the Chehalis analysis, variation in Humptulips spawner-recruit data was better explained by the Ricker than the Beverton-Holt model (Table 10). Estimates of Beverton-Holt α and β did not differ from their null expectations (1 and 0, respectively) whereas Ricker estimates did (Table 11). Thus, the Ricker model, adjusted for autocorrelation, is considered to be the most appropriate for these data; S_{msy} for this model is 3,573.

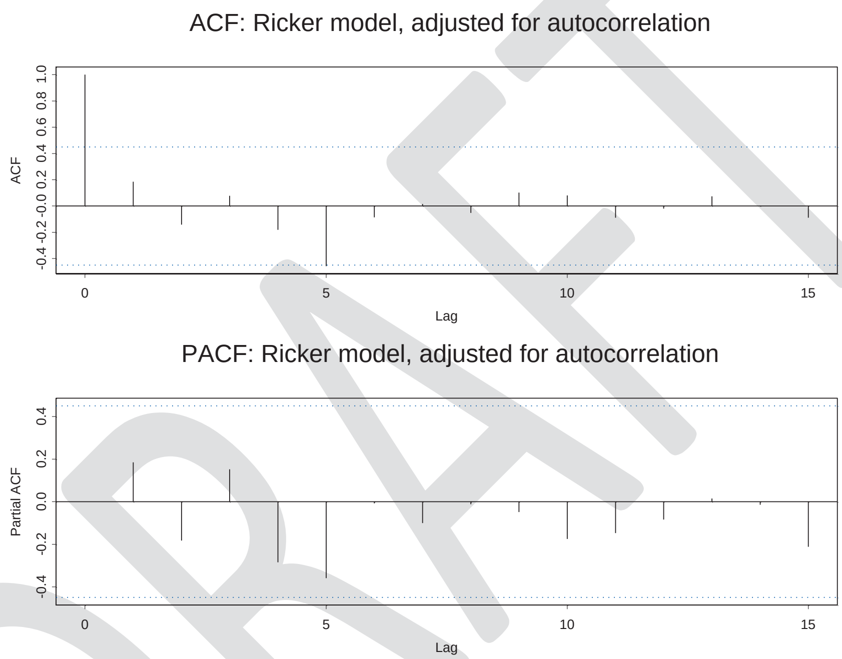


Figure 22. ACF and PACF plots of the residuals from the Ricker model after adjusting for autocorrelation.

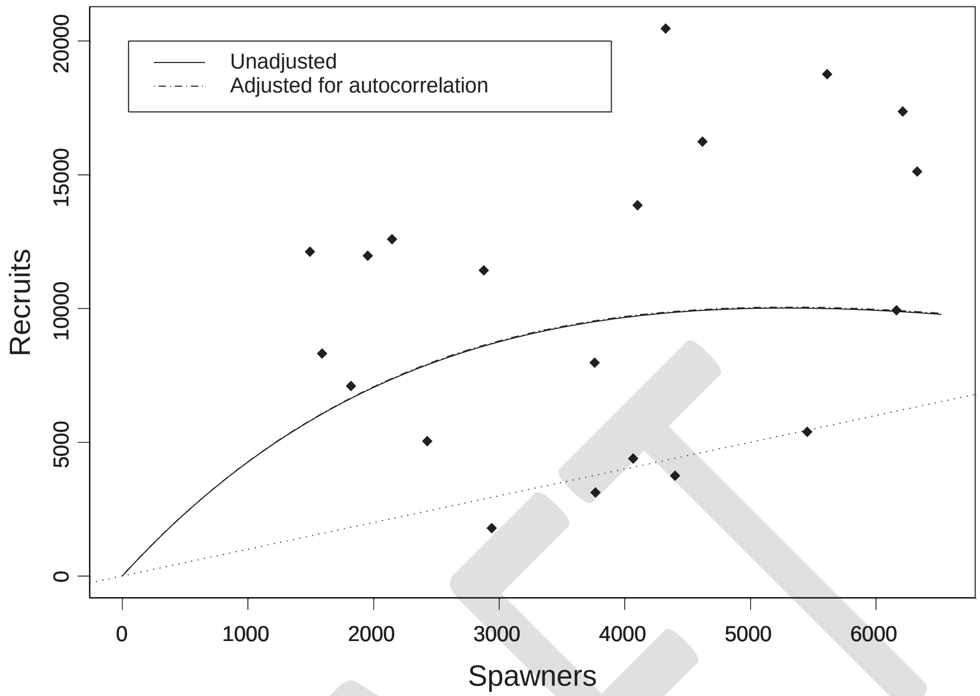


Figure 23. Comparison between the adjusted and unadjusted Ricker models for the Humptulips fall Chinook data.

Discussion

The lack of CTC-agreed escapement goals for several Washington escapement indicator stocks poses challenges to evaluations of the effectiveness of PSC management. This is particularly true for Puget Sound, but significant gaps also remain among coastal Washington indicator stocks. We propose to fill one major gap in coastal fall Chinook production, Grays Harbor, based on the spawner–recruit analysis reviewed here. Following a comprehensive review and compilation of escapement and production datasets for 20 brood years (1986-2005), the Grays Harbor co-managers (QDNR and WDFW) developed a biologically based escapement objective using methods consistent with those recommended by the CTC (CTC 1999; CTC 2013).

The improvements that the proposed goal offer to the management of Grays Harbor fall Chinook salmon are numerous. Most importantly, the S_{msy}-based goal provides a system-wide management objective that is firmly rooted in contemporary and basin-specific measures of stock productivity and capacity. In contrast, the current co-managers' management objective dates to the late 1970s, is largely undocumented, and is based on spawning habitat capacity assumptions of unknown origin. Secondly, the data review and documentation required for the analysis spurred several improvements to the base datasets (escapement and catch) underlying the analysis and used in ongoing terminal management (e.g., forecasting, fishery models). For example, an improved stray hatchery accounting method was developed and implemented, and several years of draft escapement estimates were also finalized. Additionally, as a joint QDNR-WDFW technical product, this effort fostered improved data exchange and collaboration among state–tribal parties. Lastly, by drawing upon CTC-created and -vetted datasets (i.e., the CTC's CWT cohort reconstruction for Queets), this effort syncs assumptions about Grays Harbor productivity and mortality with those embedded within the CTC models/algorithms, and emphasizes the utility of the coast-wide CWT indicator stock program. In sum, the data review and analysis required to estimate the escapement goal proposed here adds to the level of technical rigor with which Grays Harbor fall Chinook are managed.

The proposed goal is 13,326 adult spawners for the Grays Harbor aggregate, with system-specific S_{msy} values of 9,753 and 3,573 for the Chehalis and Humptulips sub-populations, respectively. Relative to the current Washington co-managers' capacity-based goal (14,600, basin total), this biologically based goal constitutes a *ca*. 10% decrease in escapement targets for the system as a whole. The new goal, however, is notably similar to estimates generated through prior (draft) spawner–recruit analyses conducted by the CTC and its Washington members, despite limited overlap in underlying datasets and differences in analytical approaches (Table 12). Using brood years 1976-1991 (vs. 1986-2005 here), for instance, the CTC estimated a system-total Grays Harbor goal of 13,024 (Table 12). Goodman (Table 12), whose estimate was based on separate Chehalis and Humptulips goals, arrived at 13,476 for a Grays Harbor goal and estimated sub-population goals comparable to ours. Among the three CTC-related efforts to estimate biologically based management objectives, Alexandersdottir's (Table 12) differed from ours—and the others—the most (12,444 vs. 13,326). However, much of this difference can be attributed to Alexandersdottir's use of a different analytical framework (i.e., inclusion of a marine survival covariate). Ultimately, the correspondence between our estimate of S_{msy} and those from past, somewhat independent efforts suggests that there is temporal stability in spawner–recruit parameters and strengthens the case for replacing the co-managers' current capacity-based goal with the proposed biologically based one.

Table 12. History of escapement goals in use or estimated through prior analysis efforts affiliated with the Chinook Technical Committee. CTC, Alexandersdottir, and Goodman are unpublished analyses reviewed in Clark (2003, unpublished memo) and years attached to names denote the year in which the analysis/review occurred.

Origin of goal	Broods included	Chehalis River	Humptulips River	Grays Harbor Total
WA Co-mgr goal (1979)	N/A	12,364	2,236	14,600
CTC (1999)	1976-1991	N/A	NA	13,024
Alexandersdottir (1999)	1976-1991	8,489	3,955	12,444
Goodman (2003)	1976-1991	10,084	3,392	13,476
Proposed goal (2014)	1986-2005	9,753	3,573	13,326

Although the goal proposed here improves the scientific basis for Grays Harbor fall Chinook salmon management, this advancement is not without weaknesses relative to the '*Bilateral Data Standards for MSY or Other Biologically-Based Escapement Goals*' that were adopted by the CTC in 2013 (CTC 2013). In particular, while our analysis conforms to CTC standards (CTC 1999, 2013) in most respects, it falls short in two key areas. First, our estimates of escapement lack a measure of uncertainty (Item 1 in CTC 2013 stock-recruit analysis data standards checklist). Second, the degree of contrast in spawning stock size (i.e., max escapement / min escapement, Item 7 of CTC 2013) is marginal for both the Chehalis (3.3) and Humptulips (4.0) population segments relative to the recommended minimum level of contrast (>4.0). Although we recognize these shortcomings, they are inherent features of the historic spawner–recruit data series. The first shortcoming illustrates a need for WDFW and QDNR to consider undertaking efforts to improve the escapement survey methods in use within the Grays Harbor basin, provided that any changes maintain consistency and compatibility with the proposed goal (e.g., calibrated to redd-based escapements). In contrast, the challenges introduced by narrow spread in parent escapements are an unavoidable reality in systems like Grays Harbor where escapement goal-based management has been in place for decades. In the absence of extreme overharvest (and/or stock collapse) or severely restricted fisheries (and/or record-high recruitment), escapements in such cases are effectively fated towards a narrow spread by management design. Taken together, both of these shortcomings demonstrate that periodic future comparisons of new—especially extreme—data points to fitted models will be necessary to maintain confidence in the proposed management objective. Similarly, future reviews should consider whether or not the stationarity assumptions inherent to spawner–recruit analysis remain valid, particularly if the flood control measures proposed for the Chehalis Basin move forward and impact the availability and/or productivity of spawning and rearing habitats.

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Appendix A
Validation of Queets CWT Indicator Stock As Surrogate For Grays Harbor

The development of an escapement goal for Grays Harbor fall Chinook requires the number of pre-fishing ocean recruits to be estimated using reliable methods. Working from the spawning grounds outwards, the ocean recruit estimates used in the spawner-recruit analysis were computed using a combination of (1) rule-based terminal run-reconstruction methods (i.e., to estimate the run entering Grays Harbor) and (2) CWT cohort analysis methods (i.e., to account for mortality in preterminal ocean fisheries). This appendix addresses the data choices associated with the latter estimation step and specifically validates the assumption that the Queets River fall Chinook CWT indicator stock is an appropriate surrogate for Grays Harbor fall Chinook.

Data Overview and Analysis

Although CWT'd Chinook have been released from various locations (Bingham Creek, Humptulips, Lake Aberdeen, and Satsop Springs hatcheries) in the Grays Harbor system for decades, the recovery data associated with these releases are considered inadequate for the type of cohort analysis required to estimate exploitation rates in preterminal fisheries. Firstly, CWT Chinook have only been released sporadically from Grays Harbor facilities over the period used for escapement goal development (1986-2005 brood years). Secondly, even for more recent years (2003 onward) when releases were more continuous, there are insufficient escapement recoveries to a complete cohort analysis. For these reasons it was necessary to estimate preterminal fishery mortality for Grays Harbor Chinook using the continuous time series of adult-equivalent (AEQ) exploitation rates (ERs) generated for the Queets River fall Chinook PSC-CTC indicator stock.

Given this surrogate data application, it is informative to determine whether or not Chinook salmon from a distant (i.e., ocean entry 50 miles up the coast) and somewhat different river (i.e., in terms of hydrologic and geomorphic setting) share a common ocean life history (i.e., in terms of survival, distribution, exploitation, propensity to mature at different ages, etc.) as is implicitly assumed in the current Grays Harbor escapement goal analysis. We evaluated the merits of this assumption by comparing patterns in pre-terminal ocean CWT recoveries, by age, for the three most recent completed broods (2003-2005) between Queets River and Humptulips Hatchery release groups (Table 1). Additionally, we assessed whether or not there might be other 'far-north migrating' CWT stocks that could be be equally appropriate for Grays Harbor ocean recruit estimation by considering similar data for Columbia Upriver Bright (URB, Priest Rapids and Ringold Springs hatcheries) and Willapa Bay (WPA, Forks Creek Hatchery) release groups. We did not consider other Washington Coast indicators (i.e., Sooes, Hoko) due to the lack of terminal harvest (necessary for terminal incidental mortality estimation) for these stocks. We conducted our analysis in two stages. Given the data deficiencies outlined above for Grays Harbor CWT groups, we first (Analysis 1) made comparisons between metrics computed from nominal fishery recoveries rather than for parameters estimated from a full cohort analysis. Thus, inferences regarding early marine survival (release-to-age 2) and maturation rates were made based on proxy values in our first set of analyses. To gain further confidence with the surrogate CWT indicator stock application—the magnitude of expansion for preterminal fishery impacts in particular (i.e., exploitation rates)—we conducted a second set of analyses (Analysis 2) involving only Queets vs. Grays Harbor comparisons for parameters estimated from a full cohort reconstruction. This required that gaps in freshwater terminal fishery and/or escapement

CWT recoveries be filled through ratio estimation methods (i.e., missing recoveries were ‘imputed’ based on expected recoveries per sampled fish, described below).

Analysis 1 Findings

Do Queets River and Grays Harbor Chinook have a similar ocean distribution?

There is clear evidence indicating that the Queets-as-surrogate application is reasonable from an ocean distribution perspective. Overall (all ages; $\chi^2 = 6.93$, df = 8, $P = 0.545$), age 4 ($\chi^2 = 1.55$, df = 7, $P = 0.981$), and age 5 ($\chi^2 = 1.55$, df = 7, $P = 0.981$) distributions were not significantly different. Ocean recovery distributions were centered primarily in Southeast Alaska troll, net, and sport fisheries (60-75% of all recoveries) with the bulk of remaining recoveries occurring in Northern BC troll and sport fisheries (Table 2; Figure 1, 2). Few recoveries were observed in Southern US (WA Coast sport and troll) and West Coast Vancouver Island fisheries for both stocks. Age 3 and age 6 recovery distributions appeared to differ to some extent, however, recovery distributions for these ages are based on few tags (Age 3, $n = 14$ and 8 for GHR and QUE, respectively; Age 6, $n = 3$ and 6, respectively). Taken together, these results combined with the heavy contribution of age 4 and 5 fish to the total Grays Harbor terminal run (85% of total on average) suggest that from a distribution perspective the Queets CWT data can serve as a suitable proxy in the absence of a continuous Grays Harbor-specific CWT time series. This, however, does not address the ‘gorilla assumption’ (i.e., that hatchery CWT groups are suitable indicators of natural fish), nor does it speak to the potential for subtle distributional differences (i.e., within spatiotemporal strata of CTC ERA fisheries).

Do Queets River and Grays Harbor Fall Chinook have a similar maturation schedule?

While estimated fishery recoveries alone cannot be used to estimate maturation probabilities, the adult equivalency factors applied to preterminal fishery mortalities are a function of maturation and natural mortality rates. Thus, whether or not both stocks have similar maturation schedules, in addition to the distributional assumptions discussed above, has implications for the suitability of Queets data for the Grays Harbor context. Although the comparison is somewhat circular due to the interdependency maturation and fishing mortality rates, maturation schedule differences can be inferred based on comparisons of the overall age composition of preterminal fishery recoveries. Specifically, if the two stocks experience similar preterminal fishing mortality rates, then the overall age composition of preterminal fishery recoveries should be comparable if both stocks have similar maturation schedules. Given the caveats outlined above, the average age composition of brood year 2003-2005 recoveries for Grays Harbor and Queets Chinook suggests these two stocks may behave slightly differently with respect to maturation (Table 3). The recovery distribution for Grays Harbor is skewed towards age 4s, whereas that for Queets is skewed towards age 5s. This suggests that Grays Harbor fish may have a higher propensity to mature at age 4 (i.e., fewer fish remaining in the ocean as age 5+ individuals) compared to Queets fish. A difference of this degree is likely inconsequential to the ocean recruit estimation context here, given that AEQ factors are relatively insensitive to modest changes in maturation probability.

Do Queets River and Grays Harbor fall Chinook experience similar early marine survival?

As with maturation, this question cannot be answered directly with the data in hand. However, if the assumptions described above for the maturation proxy comparison are made here, the estimated total number of recoveries per released Chinook may serve as a proxy of overall marine survival. Given that an overwhelming majority of natural mortality occurs prior to fish reaching age 2, this index will reflect early marine survival primarily. The mean estimated recoveries total per 1,000 fish released was virtually identical for the two stocks, at 2.6 (Grays Harbor) and 2.8 (Queets) (Table 1). Although this similarity provides further confidence in the Queets-as-surrogate application, equal early marine survival is not a necessary requirement to achieve unbiased estimates of Grays Harbor ocean recruits given that the analysis ultimately depends on rates computed from abundance after release-to-age 2 mortality has occurred.

Is there a better surrogate CWT indicator stock that could be used in place of Queets River?
The answer to this question appears to be no for at least three reasons: (1) The only stocks that might be appropriate are those with northerly centered (i.e., SEAK- and NBC-oriented) ocean distributions, which beyond the Queets include stocks like Oregon Coast fall Chinook, Columbia River upriver bright fall and summer Chinook, and Willapa fall Chinook. However, a comparison of average recovery distributions for brood year 2003-2005 between Grays Harbor and a subset of these stocks (Queets, Columbia URB, and Willapa; Figure 3) illustrates that the Queets selection is the most similar option. Whereas Grays Harbor and Queets have similar recovery distributions, the Willapa distribution is centered more in northern BC (i.e., 40-50% greater fraction of preterminal recoveries in NBC, Figure 3) than Southeast Alaska. Although Columbia River upriver brights have a similar Alaska recovery component, they also have a greater presence in southern fisheries (WCVI and Washington Coast). Age 6 fish are also less common (though present) for URBs (<1% of fish making it to terminal area for a given brood) than for either Grays Harbor or Queets (5-10%). (2) Geomorphic and hydrologic differences notwithstanding, the spatial proximity and genetic relatedness of Grays vs. Queets basins suggests the Queets to be a more logical choice. Had the recovery distribution for Willapa Bay Chinook been similar to that for Grays Harbor, and had its data series been continuous, perhaps the same argument could have been made in its favor. (3) Relative to the other possible options, the Queets River fall Chinook CWT dataset has been thoroughly reviewed and modified as needed (by US CTC-AWG members) to ensure its accuracy, and it extends further (and more continuously) into the past.

Analysis 2 Findings
Whereas Analysis 1 suggests that the Queets River CWT indicator stock is a suitable surrogate for Grays Harbor Chinook from a distribution/ life history parameter standpoint, it did not address the surrogate application in terms of ocean exploitation rates, despite the fact that ocean ER ultimately defines the expansion from terminal run to pre-fishing ocean abundance. Given this, we used a modified version of the Humptulips Hatchery CWT dataset (BY 2003-2005) to complete a full cohort analysis so that ocean ERs could be estimated and compared to analogous Queets values. In brief, we filled freshwater CWT recovery gaps for the 2003-2005 brood Humptulips Hatchery CWT releases using simple estimation methods. For each tag group *i*, basin-level escapement recoveries ($\widehat{CWT_{Esc\,i}}$) in a given run year were estimated based on the recovery rate ($\frac{\widehat{cwt_{net\,i}}}{C_{net}}$) of tag *i* in the combined freshwater net (Humptulips River, catch area 72F) and North Bay net (2C) catch (C_{net}) and basin-total escapement, according to:

$$(1)\quad \widehat{CWT_{Esc\,i}} = \frac{\widehat{cwt_{net\,i}}}{C_{net}}(\widehat{H_{Esc}} + \widehat{N_{Esc}})$$

where $\widehat{H_{Esc}}$ and $\widehat{N_{Esc}}$ are total Humptulips escapements of hatchery (to hatchery rack and strays to spawning grounds) and natural Chinook, respectively. Age-specific estimators were not needed given that the Grays Harbor Chinook run reconstruction assumes a similar age composition for net catches and escapements. This ratio estimation approach was also used to estimate expected CWT recoveries for the Humptulips freshwater sport fishery, with the quantity $\widehat{H_{Esc}} + \widehat{N_{Esc}}$ being replaced by Humptulips sport catch (from WDFW Catch Record Card) for that run year. This estimation approach is built on the following key assumptions:

(1) The 2C and 72F net fishery catches are perfectly known and have been sampled representatively for CWTs.
(2) Similar to (1), escapements have been accurately estimated.
(3) The 2C and 72F net fisheries exclusively catch fish that would otherwise contribute to Humptulips escapement had they not been caught (i.e., catches are 100% Humptulips-bound fish, regardless of whether they are homing correctly or strays from elsewhere).
(4) The age composition (age 3+) of fishery catches and spawning escapement are similar. In other words, all ages are similarly vulnerable to net and sport fisheries.

Although an improvement over using RMIS freshwater recovery data for Humptulips Hatchery Chinook CWT groups on an unmodified basis, this approach is not without its own shortcomings. For example, by assuming #2 above for catch area 2C, more tags become available for estimation. Yet, this condition is probably violated to some degree. Further, if a particular age class was not encountered (or sampled) in the net fishery, then by equation 1 it cannot be encountered in the escapement. This result is particularly nonsensical in cases where actual escapement CWT data illustrate that a particular tag group was present in a run year. In such cases, additional steps were taken to generate an estimate of total recoveries via alternative means. Issues such as these, combined with uncertainty regarding the validity of the assumptions outlined above, suggest that results from a cohort analysis built on these freshwater recoveries should not be over-interpreted or considered in high-precision quantitative terms. Rather, they are presented as an indicator regarding whether or not Grays Harbor ocean ERs are sufficiently similar to Queets ocean ERs to proceed with their use in escapement goal development.

Caveats notwithstanding, results from a full cohort analysis conducted using the modified CWT dataset described above, and other considerations, suggest that it is reasonable to proceed with Queets CWT data in the development of a Grays Harbor escapement goal. First, ocean ERs are similar for the two stocks, with the age class (age 4) most represented in ocean fisheries exhibiting an ER difference of only 5% (Grays > Queets) (Table 4, Figure 4). However, there is an overall tendency towards Grays Harbor having a higher exploitation rate, ~10-13% (relative difference) higher than Queets. Although sample sizes are low (n = 3 broods), none of these differences are statistically significant. Second, it is quite likely that further improvements in the accuracy of the modified freshwater Humptulips Hatchery CWT recovery dataset described here will translate into an increased terminal abundance of Humptulips CWTs and therefore reduced ocean ER, effectively reducing the gap in ERs for the two indicator stocks. For example, there are at least two years in the time series (2006, 2007) where the 2-2 sport fishery was open for Chinook retention but no Humptulips CWTs were recovered (due to sampling limitations). Given the mixed-stock status of that fishery, however, there was no attempt to estimate missing recoveries for this fishery in the modified CWT dataset described here.

Third, if the modest ER difference described here are an accurate reflection in stock differences, they will ultimately yield a slightly higher (i.e., more conservative) escapement goal. That is to say, expanding the Grays Harbor terminal run size to estimate pre-fishing ocean recruits using a lower Queets ocean ER will effectively make the stock appear less productive (e.g., lower Ricker α parameter) than it actually is. S_{msy} calculations made using a draft version of the S-R dataset suggest that consistent difference in ocean ERs on the order of 10-15% (relative difference, Grays > Queets) may yield a goal that is *ca*. 5% higher than it would be if Grays Harbor CWT data were available for the entire series. Lastly, other relevant exploitation rate analysis outputs, i.e., early marine survival rates (release to age 2, Table 5), maturation probabilities (Table 6), and AEQ factors (Table 6), illustrate that the life history parameters assessed using proxies in Analysis 1 are in fact similar for the two stocks. The only noteworthy difference is the tendency towards earlier maturation in Grays Harbor compared to Queets fish, as inferred above.

Table 1. Total releases, estimated preterminal (PT) fishery recoveries, and the ratio of recoveries:releases (Rec./Rel., 1,000s) for Grays Harbor (Humptulips Hatchery, codes: 632390, 633073, 633384) and Queets River (Salmon River Fish Culture Center, codes: 210545, 210593, 210679) brood years 2003-2005 release groups.

	Grays Harbor				Queets River			
Brood Year	Releases	Obs'd PT Rec's[1]	Est'd PT Rec's	Rec./ 1K Rel.	Releases	Obs'd PT Rec's[1]	Est'd PT Rec's	Rec./ 1K Rel.
2003	196,605	313	493	2.5	206,096	252	299	1.4
2004	180,029	161	255	1.4	170,652	100	552	3.2
2005	236,285	87	937	4.0	194,075	186	717	3.7
Mean	204,306	187	562	2.6	190,274	179	522	2.8
SD	28,908	115	346	1.3	18,025	76	211	1.2

[1]Approximated under the assumption that one estimated tags record equates to a single tag in hand.

Table 2. Average preterminal fishery CWT recovery distribution, by age, for Grays Harbor (Humptulips Hatchery) and Queets River (Salmon River Fish Culture Center) for brood year 2003-2005 releases.

		Est'd Recs	Southeast Alaska AABM			Northern BC AABM		WCVI AABM		Wash. Coast (ISBM)	
Origin	Age	(mean)	Troll	Net	Sport	Troll	Sport	Troll	Sport	Troll	Sport
Grays Hbr.	3	125	54.2	0.0	0.0	15.2	13.2	10.2	0.0	0.0	7.2
	4	975	52.9	1.0	3.5	24.4	13.0	0.6	4.0	0.0	0.6
	5	561	57.9	0.0	7.8	22.8	10.7	0.0	0.5	0.0	0.0
	6	23	73.4	0.0	0.0	0.0	26.6	0.0	0.0	0.0	0.0
	All	1685	54.9	0.6	4.6	22.9	12.5	1.1	2.5	0.1	0.9
Queets	3	87	34.8	0.0	1.2	16.4	11.2	11.4	8.0	17.0	0.0
	4	638	56.7	1.5	4.6	19.7	13.6	0.9	3.0	0.0	0.0
	5	789	58.3	1.4	10.9	17.1	10.9	0.0	0.8	0.0	0.2
	6	53	68.7	0.0	9.3	20.0	2.0	0.0	0.0	0.0	0.0
	All	1568	56.7	1.3	7.7	18.2	11.7	1.0	2.0	1.2	0.1

Table 3. Age composition of preterminal fishery recoveries for Grays Harbor (Humptulips Hatchery) and Queets River (Salmon River Fish Culture Center) brood year 2003-2005 CWT releases.

Age	Grays Harbor	Queets River
3	6%	6%
4	58%	43%

5	35%	48%
6	1%	3%

Table 4. Age-specific and overall ocean exploitation rates for Grays Harbor (Humptulips Hatchery, codes: 632390, 633073, 633384) and Queets River (Salmon River Fish Culture Center, codes: 210545, 210593, 210679) brood years 2003-2005 release groups.

		Ocean ER		
Age	Brood Year	Queets	Grays Harbor	Queets/ Grays
Age 3	2003	0.594	0.291	2.04
	2004	0.540	0.491	1.10
	2005	0.305	0.365	0.84
	mean	0.480	0.382	1.26
Age 4	2003	0.626	0.748	0.84
	2004	0.321	0.353	0.91
	2005	0.353	0.356	0.99
	mean	0.433	0.486	0.89
Age 5	2003	0.348	0.834	0.42
	2004	0.475	0.422	1.13
	2005	0.455	0.528	0.86
	mean	0.426	0.595	0.72
Age 6	2003	0.570	0.367	1.55
	2004	0.351	0.148	2.38
	2005	0.067	0.701	0.10
	mean	0.329	0.405	0.81
All ages	2003	0.504	0.651	0.77
	2004	0.429	0.397	1.08
	2005	0.340	0.424	0.80
	mean	0.424	0.491	0.87

Table 5. Release-to-age-2 survival for Grays Harbor (Humptulips Hatchery, codes: 632390, 633073, 633384) and Queets River (Salmon River Fish Culture Center, codes: 210545, 210593, 210679) brood years 2003-2005 release groups.

Brood Year	Queets	Grays Harbor
2003	1.0%	1.4%
2004	2.7%	1.4%
2005	4.2%	3.6%
mean	2.6%	2.1%
sd	1.6%	1.3%

Table 6. Maturation rates (Mat. Prob.) and adult equivalency factors (AEQ Factor) for Grays Harbor (Humptulips Hatchery, codes: 632390, 633073, 633384) and Queets River (Salmon River Fish Culture Center, codes: 210545, 210593, 210679) brood years 2003-2005 release groups.

		Queets River				Grays Harbor			
Metric	Age	2003	2004	2005	mean	2003	2004	2005	mean
Mat. Prob.	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.03	0.03	0.04	0.03	0.16	0.03	0.08	0.09
	4	0.22	0.31	0.25	0.26	0.44	0.37	0.54	0.45
	5	0.94	0.84	0.47	0.75	0.66	0.87	0.91	0.82
	6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AEQ Factor	2	0.52	0.52	0.51	0.52	0.55	0.53	0.55	0.54
	3	0.74	0.75	0.72	0.74	0.78	0.75	0.78	0.77
	4	0.92	0.92	0.89	0.91	0.93	0.93	0.95	0.94
	5	0.99	0.98	0.95	0.98	0.97	0.99	0.99	0.98
	6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

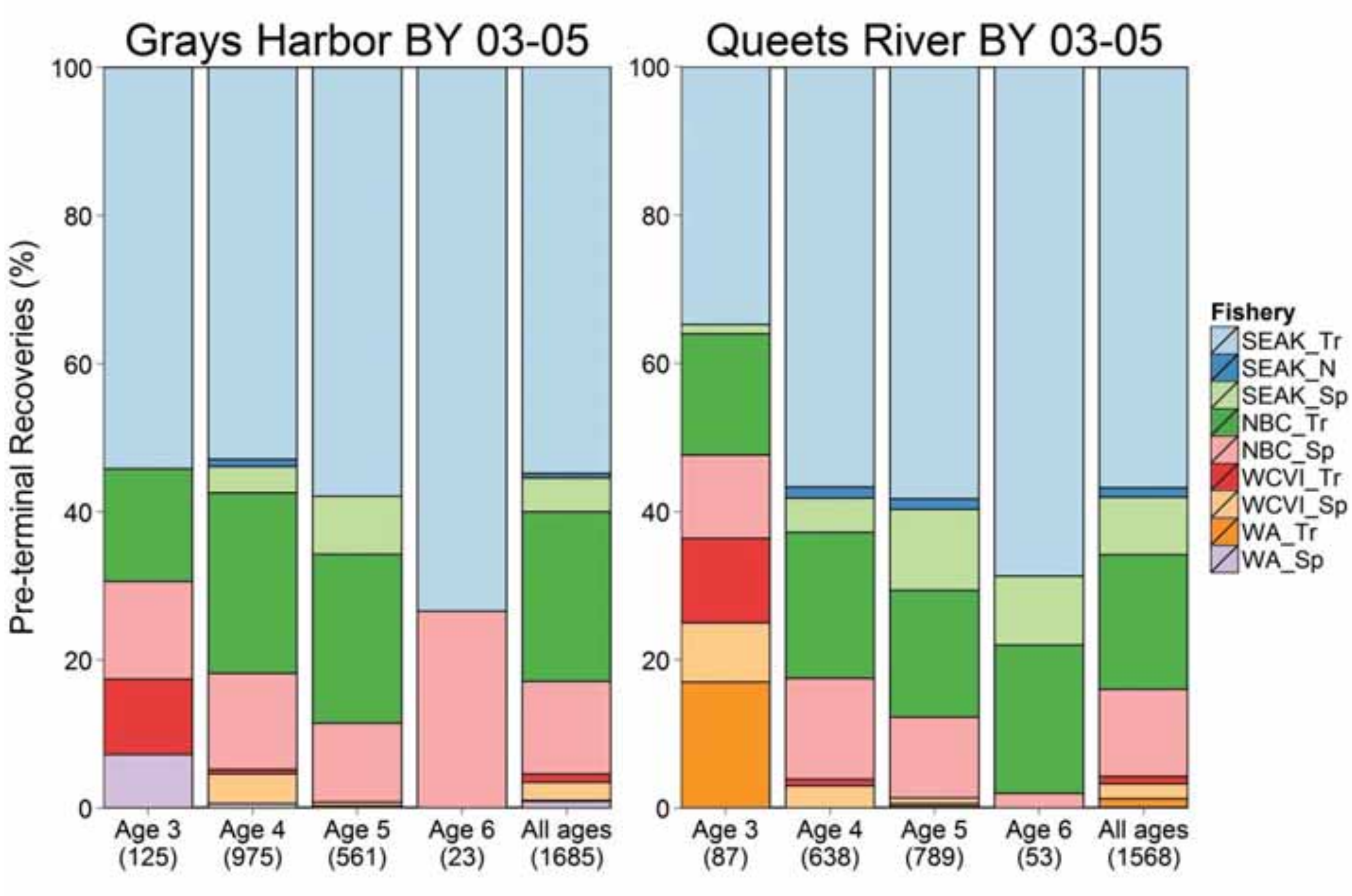


Figure 1. Age-specific preterminal fishery recovery distributions for Grays Harbor (Humptulips Hatchery) and Queets River (Salmon River Fish Culture Center) CWT release groups, brood years 2003-2005. Numbers below ages represent the average number of estimated recoveries per age class for the three brood years.

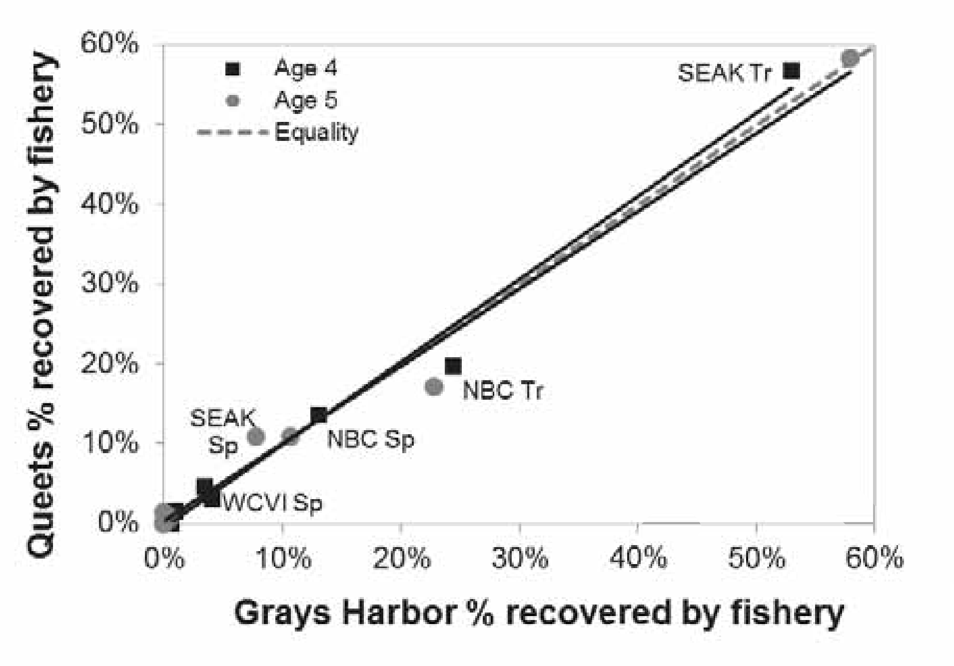


Figure 2. Comparison of preterminal fishery recovery distributions for age-4 and age-5 Chinook salmon from Grays Harbor (Humptulips Hatchery) and Queets River (Salmon River Fish Culture Center) across PSC AABM and Southern US/Canadian ISBM fisheries. The clustered points near the origin are for three fisheries comprising <1% each of the recovery distribution, SEAK Net, Washington Coast Sport, and Washington Coast Troll (See Table 3 for details). Solid lines are fitted regressions, by age.

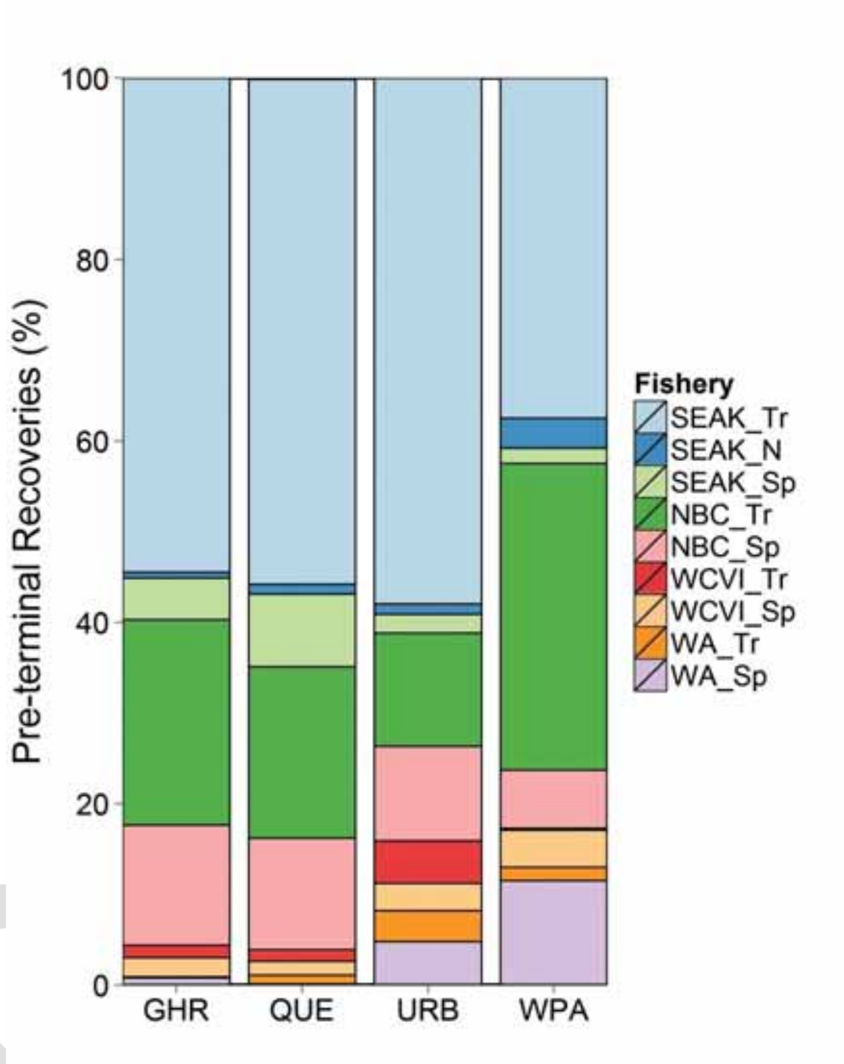


Figure 3. Distribution of pre-terminal fishery recoveries of coded wire tags for Grays Harbor (GHR, Humptulips Hatchery), Queets (QUE, Salmon River Fish Culture Center), Columbia Upriver Bright (URB, Priest Rapids and Ringold Springs hatcheries), and Willapa Bay (WPA, Forks Creek Hatchery) fall Chinook salmon, brood year 2003-2005 releases. Recoveries from terminal marine net and sport fisheries are excluded, consistent with the application of CWT data in the estimation of total ocean recruits.

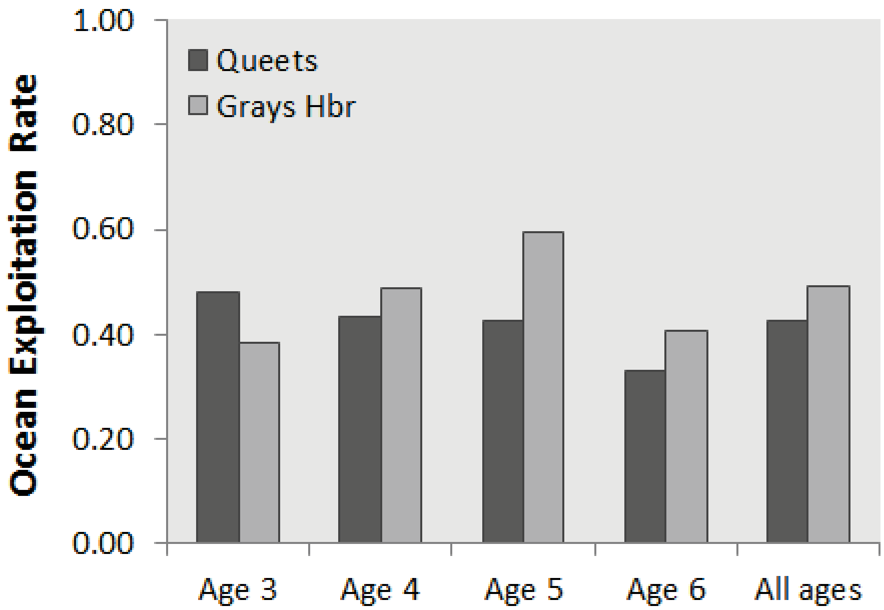


Figure 4. Age-specific and overall ocean exploitation rates for Grays Harbor (Humptulips Hatchery, codes: 632390, 633073, 633384) and Queets River (Salmon River Fish Culture Center, codes: 210545, 210593, 210679) brood years 2003-2005 release groups.

Appendix B
Estimating the Hatchery Component of Natural Escapement

Estimates of the hatchery- and natural-origin components of total escapement to the spawning grounds [i.e., $\widehat{S_{total}}$, hatchery- ($\widehat{S_{HOS}}$) plus natural-origin ($\widehat{S_{NOS}}$) fish spawning naturally] are needed to accurately account for brood year production by source. The accounting procedure is relatively straightforward for recent broods (2007+), due to the fact that ≥98% of all Grays Harbor hatchery Chinook releases have been adipose-fin clipped. For years prior to mass marking, however, alternative estimation procedures are needed. For each hatchery-affected river within the Grays Harbor system (i.e., Humptulips, Wishkah, Satsop, and Wynoochee), we retrospectively estimated $\widehat{S_{HOS}}$ as a function of the hatchery rack return (H_{rack}) in a given year and the recent (i.e., post-mass marking) average stray rate ($\bar{s}$) for that hatchery, and subsequently compute $\widehat{S_{NOS}}$ by subtraction.

Using this approach, $\widehat{S_{NOS}}$ was computed as

$$(1)\quad \widehat{S_{NOS}} = \widehat{S_{total}} - \widehat{S_{HOS}}$$

where $\widehat{S_{total}}$ is the redd-based estimate of total natural spawners for the tributary of interest and $\widehat{S_{HOS}}$ is the hatchery contribution to that total (i.e., strays). Accordingly, $\widehat{S_{HOS}}$ was estimated as

$$(2)\quad \widehat{S_{HOS}} = \widehat{H_{total}} - H_{rack}$$

where $\widehat{H_{total}}$ is the basin-level total escapement of hatchery-origin fish (i.e., strays, $\widehat{S_{HOS}}$, and fish returning to the facility, H_{rack}). Basin-level hatchery-origin escapement, $\widehat{H_{total}}$, was estimated by expanding the observed rack return (assumed to be perfectly known) to account for the fraction of fish expected to stray (stray rate, $\bar{s}$) on average,

$$(3)\quad \widehat{H_{total}} = \frac{H_{rack}}{1-\bar{s}}$$

Finally, the average stray rate was estimated as the mean of *i* yearly estimates ($\hat{s}_i$), which were computed as

$$(4)\quad \hat{s}_i = \frac{\widehat{S_{HOS}}_i}{H_{rack\,i} + \widehat{S_{HOS}}_i}$$

where $\widehat{S_{HOS}}_i$ was estimated directly from spawning ground survey data (i.e., the redd-based escapement estimate and carcass survey estimate of the hatchery fraction). Individual $\hat{s}_i$ were only computed for return years during which a sufficiently large number of carcasses were inspected for marks and hatchery returns were from adipose-clipped broods.

For run reconstruction purposes, we used the estimators described above to account for hatchery and natural-origin contributions to total natural spawning escapement for return years 1986 to 2010, thereafter we used year-specific estimates of strays ($\widehat{S_{HOS}}_i$). The mean stray rates that were applied retrospectively are presented in Table B.1 below. Although the reliability of this approach depends on the validity of a number of assumptions (described below), it has advantages over the approaches used in the past. Foremost, it ties the abundance of hatchery fish on the spawning grounds directly to a readily observable indicator of hatchery run strength (i.e., returns to the hatchery) and therefore decouples total hatchery- and natural-origin returns. Previous methods, in contrast, assumed that either a constant number of natural spawners were of hatchery origin (i.e., $\widehat{S_{HOS}} = \widehat{S_{total}} - k$, Chehalis basin) or that a constant fraction of total basin-level escapement was of hatchery origin [$\widehat{S_{HOS}} = k(\widehat{S_{total}} - H_{rack})$, Humptulips basin].

Table B.1. Estimates of stray rate used to retrospectively assign a fraction of total natural spawners to the hatchery origin category.

Population	Sub-basin	Hatcheries	Years	Mean	SD	CV
Chehalis	Satsop	Satsop/Bingham	2010-12	0.84	0.06	0.07
	Wynoochee	Lake Aberdeen	2009, 2011-12	0.62	0.09	0.15
Humptulips	All	Humptulips	2011-2012	0.44	0.01	0.03

The primary assumptions introduced into run reconstruction by using this estimation framework, and their plausibility, include the following:

(1) Stray rates are constant from year to year. The validity of this assumption depends on a number of factors, but is likely to be true on average in the absence of major changes to hatchery practices (rearing, release) or the configuration of hatchery facilities, or in the face of anomalous environmental conditions during the spawning migration.
(2) Escapement to the hatchery rack consists of hatchery origin fish only. If untrue, this natural production straying to the hatchery can be accounted for a manner similar to what has been outlined above for hatchery strays.
(3) Hatchery fish home accurately to their basin of origin (e.g., Humptulips River for Humptulips Hatchery) or to a known/assumed set of streams (e.g., Wynoochee River for Van Winkle/Lake Aberdeen releases).
(4) The number of fish spawning naturally has been estimated accurately. The validity of this assumption is unknown given the use of redd counts and a constant fish-per-redd multiplier (2.5). Further, the variance of $\widehat{S_{total}}$ (and associated quantities) cannot be estimated given the existing survey design.

Appendix C. Spawner–recruit time series used to estimate escapement goals for the Chehalis and Humptulips rivers, brood years 1986-2005.

Table C.1. Spawner and recruit data used in the analysis of biologically based escapement goals for the Grays Harbor Basin. Parent-generation spawners include age 3+ individuals of hatchery and natural origin. Recruits include natural origin (only) spawners, terminal catch and incidental mortalities, and adult equivalent ocean catch and incidental mortalities. See text for further details.

	Chehalis		Humptulips	
Brood	**Spawners**	**Recruits**	**Spawners**	**Recruits**
1986	9,483	38,805	4,325	20,467
1987	12,850	25,593	6,163	9,935
1988	21,945	38,592	6,213	17,372
1989	20,066	45,980	5,611	18,766
1990	12,893	35,859	4,102	13,861
1991	12,571	14,990	1,821	7,105
1992	11,974	59,771	4,618	16,246
1993	10,472	32,329	2,877	11,425
1994	9,919	7,767	4,401	3,749
1995	9,786	10,937	2,941	1,792
1996	16,161	31,869	4,066	4,398
1997	14,402	22,164	3,766	3,122
1998	10,101	26,921	2,428	5,046
1999	8,409	56,120	1,954	11,975
2000	7,892	26,671	1,493	12,128
2001	7,902	22,275	1,590	8,323
2002	9,694	34,801	2,147	12,596
2003	16,111	28,334	3,760	7,983
2004	26,320	11,281	5,453	5,394
2005	13,367	24,022	6,328	15,125

2014 Salmon Methodology Review

Standardized Method to Calculate Chinook Age 2 FRAM Stock Recruit Scalars, Based Upon the Age 3 Forecast

October 7, 2014

Prepared by Andy Rankis, MEW

BACKGROUND

Work on a new Chinook base period and prior of issues with FRAM age composition identified the need for a new way of forecasting the age 2 cohort. FRAM abundance inputs for Chinook at age 2 received extra focus when it was shown that for most sampled Puget Sound marine sport fisheries, FRAM estimated total encountered sublegal sized Chinook deviated significantly from observed total sublegals. The 2013 Methodology Report: 'Correction to FRAM Algorithms for Modeling Size Limit Changes' (Hagen-Breaux et al 2013) addresses only part of the problem.

Age 2 Chinook are the major component of FRAM estimated Sublegal Encounters. Annual forecasts of expected Chinook abundance, by stock, are perhaps the most important component of the pre-season Fishery Regulation Assessment Model (FRAM). Those forecasts are transformed into age specific FRAM 'cohort size', or 'recruit scalars' (ages 2 through 5) as used in the model algorithms, for model input (model input designated as: Age2, Age3, Age4, and Age5). Presently there is very little substance to most Age2 input forecasts. In Chinook FRAM, the Age2 cohort ages up to be the Age3 cohort in the final timestep, magnifying Exploitation Rate (ER) errors due to poor age 2 forecasts.

From California through British Columbia, a variety of forecasting methods are used. An increasing proportion of regional stock forecasts are by age class, but some continue to be in terms of Total Terminal Runsize (TRS) which needs to be portioned into age class prior to model input. Almost all forecasts are based upon data for age 3 through age 6 Chinook, which dominate the terminal (or mature) run reconstruction datasets and coded wire tag (CWT) recovery datasets. Age 2 Chinook contribute very few CWT recoveries and usually are a very small, often ignored, component of TRS. The regionally produced forecasts for many stocks don't include age 2 components; thus the required Age2 model input is creatively generated by staff assigned to pre-season model preparation.

Chinook FRAM is set up with four sequential timesteps (Table 1). For input into the model, the forecast of abundance for the terminal runsizes (mature fish in timestep 3 for summer/fall stocks) need to be expanded to 'ocean abundance' values at the beginning of the first timestep. A standard method is to produce a set of FRAM ocean abundance recruit scalars that, when modeled with a recent "average fishery regime," produce a set of output TRS values matching that year's TRS forecasts. Age 2 Chinook are again not part of this methodology.

So what does the FRAM model use for required Age2 abundance? When required input is missing, the modelers may resort to:

1. Using base period level abundance (FRAM recruit scalar of 1.0).
2. Apply an adjustment (perhaps for mark rate) to recruit scalar of 1.0.
3. Re-use the input recruit scalar from the preceding year.
4. Or apply an adjustment to previous year recruit scalar.

Appendix Table A presents the pre-season Age2 recruit scalarsused for PFMC pre-season modeling for 2004 through 2013. Some Age2 recruit scalars are seen to change year to year, some do not; none are based upon solid survival rate data. If we had a perfect model these Age2 recruit scalars would reflect changing smolt production levels as compared to the Age2 base period levels, with consideration to recent survival patterns. However, given the large uncertainty in estimating survival to age 2, it is more important to have model input Age2 forecasts that are compatible with model algorithms; i.e. Age2 values that are compatible with the exploitation rate denominators and aging in time step 4.

Model fishery-induced mortalities, primarily due to release mortality rates, of Age2 Chinook can be a significant component of ER calculations. Escapement is calculated in timestep 3 after pre-terminal fishery mortality, maturity of remaining cohorts, and terminal fishery mortality upon the mature cohort. At the beginning of timestep 4, all cohorts age. The Age2 Chinook become Age3, and the influence of poor Age2 forecasts amplifies as the higher Adult Equivalence (AEQ) mortality upon Age3 affects exploitation rate calculations. This timestep 4 Age3 fishery mortality may have no relationship to the stocks' escapements, especially so when the Age2 recruit scalar was not provided as part of (or consistent with) the regionally produced annual forecasts. For some stocks the difference in abundance of Age3 in timestep 1 and timestep 4 has surpassed an order of magnitude due only to the Age2 recruit scalar.

For timestep 4 FRAM will recycle the timestep 1 recruit scalars for Age2 fish, while Age3, Age4, and Age5 abundances are from the aging of the younger cohorts. Because of the potential importance of fishery mortalities of Age3 fish in timestep 4 for ER calculations, basing Age2 stock recruit scalars upon a more reliable forecast is desirable. Given that forecasts for age 3 Chinook are more reliable, **the presented method will calculate NewAge2 stock recruit scalars that will "age up" in timestep 4 to produce Age3 abundance that match the original Age3 timestep 1 stock abundances.** These Age2 recruit scalars will be used in timesteps 1 and 4, as FRAM presently does. There will be no change to present methodology to obtain values for Age3 through Age5 recruit scalars. Stock escapement (model output sum of mature fish for ages 3 through 5) values should not change, or change very little.

Table 1. Chinook FRAM timesteps, and which timesteps' fishery related mortality counts toward exploitation rate calculations and which determine escapement.

Timestep	Months	Fishing Mortality: Included in ER Calculations?	Fishing Mortality: Affects escapement?
Time 1	Preceding October-April	no	yes
Time 2	May-June (of management year)	yes	yes
Time 3	July-Sept (of management year)	yes	yes
Time 4	Octr-April (of management year)	yes	no

The structure of Chinook FRAM is such that Age2 abundance has almost no effect upon TRS or estimates of spawner escapement. The FRAM model is for a "fishing year", with mature runsize (ages 3 through 5) producing spawner escapement values. When management focus shifted from staying above minimum escapement values to staying below Exploitation Rate (ER) caps, then mortality of Age2 Chinook potentially became a significant factor. Age2 mortality is included in ER calculations but the minimal Age2 escapement is not. Almost all Age2 fishery related mortality is 'release mortality'. All fishery mortality is adjusted by stock specific Adult Equivalence Values (AEQ) that discount mortality of younger fish. In combination this greatly reduces the influence of Age2 mortalities in ER calculations. By FRAM stock:

$$ER = \frac{\sum_{t=2}^{4}(\mathbf{F_{a2}} + F_{a3} + F_{a4} + F_{a5})}{\sum_{t=2}^{4}(\mathbf{F_{a2}} + F_{a3} + F_{a4} + F_{a5}) + \sum_{t=1}^{3}\sum_{a=3}^{5} Esc}$$

Where: a = age
t = timestep
F = fishing related mortality
Esc = escapement

And where: $\sum F_{a3} = \sum(F_{a3,t2} + F_{a3,t3} + \mathbf{F_{a3,t4}})$

There are essentially two types of abundance inputs affecting ER calculations:

1. Values based upon TRS forecasts, and
2. Values based upon questionable Age2 forecasts (yellow highlighted bolded values)

Note that the Age2 forecast determines the abundance of Age3 Chinook in timestep 4, thus , initial Age2 recruit scalars can contribute to a big part of the fishery mortality in the numerator, especially in timestep 4 when they 'age-up' to Age3 (higher AEQ mortality and usually higher BasePeriodExploitationRates, BPER) but do not contribute to the escapement in the denominator. This can be problematic if Age3 timestep 1 and Age3 timestep 4 abundances are largely mismatched.

Basing Age2 abundance upon the Age3 forecast would add consistency to ER calculations.

METHODS

To explore and apply this alternative Age2 forecast method, the final pre-season 2008 and 2012 PFMC Chinook FRAM model runs were used. The purpose was not to re-evaluate the historic set of preseason model runs, but to check if this method was workable under the current base period and for future modeling. In 2008 a new Chinook FRAM calibration was implemented that included adding four new stocks to the base data, and sets (marked and unmarked) of stock Age2 recruit scalars were updated to values that for most stocks remained unchanged for several years (see Appendix Table A). By 2012 many of those Age2 recruit scalars had changed, and the overall fishery structure was more similar to future expectations.

The same versions of FRAM and supporting 'base data' were used for this exercise as were used in each of these two pre-season years. The forward moving calculation (for each stock) to produce Age3 abundance for timestep 4 starts with the Age2 forecast for timestep 1 and proceeds through timestep 3 (the 2 year olds age up to 3's for timestep 4). The FRAM calculations can be represented as:

(1) $$Cohort_{age3,time4} = Cohort_{age2,time1} \prod_{t=1}^{3} [(1-N_t) * (1-F_t) * (1-M_t)]$$

Where:

Cohort = stock cohort abundance (model input)
N = natural mortality rate (Base Period model constants)
F = fishery related mortality rate (resulting from model inputs)
M = maturation rate (Base Period stock constants)
t = timestep

The objective of the NewAge2 abundance is to produce an Age3 timestep 4 abundance equal to the forecasted Age3 timestep 1 value. Initially this was done by back-calculating through equation (1). Substituting the Age3 abundance from timestep 1 into Age3 abundance at timestep 4, and dividing by Age2 natural mortality, fishery mortality, and maturation rates (going backward by timestep) produced the NewAge2 timestep 1 abundance. Then moving forward through equation (1) the NewAge2 abundance produces a timestep 4 abundance of Age3 fish consistent with the pre-season forecast of Age3 fish for timestep 1, and therefore consistent with Age3 escapement in timestep 3.

If all variables, except the initial Age2 and Age3 forecasts, are constants then the process simplifies to:

(2) $$\frac{Age3,t1}{Age3,t4} * Age2,t1 = New\ Age2,t1$$

Per equation (1), Age3 abundance in timestep 4 is a function of initial Age2 timestep 1 input. Equation (2) will work with any initial Age2 forecast but may require a couple of FRAM iterations to stabilize.

However, the annual fishing mortality rates are not constants. To use equations (1) for pre-season planning an average (or expected) set of stock specific fishery mortality rates would be necessary. One source for these rates could be average fishery mortality rates from recent year Chinook Validation Runs, a post-season type of FRAM model run. Another source could be pre-season FRAM mortality from the previous year's planned fisheries.

Chinook FRAM Validation Runs have updated age 3 through age 5 abundances based upon observed Terminal Run Size for those age classes, but continue to use the Age2 recruit scalar from the original pre-season model runs. Applying equation (2) to Chinook FRAM Validation Runs (2003 through 2010 fishing years) produced annual sets of post-season NewAge2 stock abundances. It was seen that there existed a very stable stock specific relationship between the Age3 "forecast" and the NewAge2 "forecast". These constants could be used to calculate NewAge2 stock recruit scalars as:

(3) $$NewAge2Scalars, s, t1 = Age3Scalars, s, t1 * Ks$$

Where:

$$Ks = {}^{Validation\ Run\ NewAge2, s, t1}/_{Validation\ Run\ Age3, s, t1}$$

These calculated stock specific constants ranged from 0.79 to 1.0 (Appendix B). For pre-season application the Age3 recruit scalar at timestep 1 can simply be multiplied by the stock specific constant (k_s) to produce the NewAge2 recruit scalar at timestep 1.

Three variations of calculating a NewAge2 abundance based upon the Age3 abundance have been presented, with the purpose of improving pre-season Age2 abundance model input. For methods (1) and (2), the resulting NewAge2 abundance estimates are divided by Age2 base period abundance to obtain the NewAge2 recruit scalars:

(4) By stock: NewAge2 Recruit Scalars = NewAge2 forecasts/BasePeriod Age2 Abundance

Practical considerations in pre-season application of the three equations.

Equation (1) is applied within a complicated spreadsheet that requires model parameters (by timestep) for age 2 natural mortality rates, and stock specific fishery and maturation rates. The fishery mortality rates are dependent upon annual fishery inputs, either "adopted" from a particular pre-season model run or averaged from recent Validation Runs.

Equation (2) does not require the step by step calculations of equation (1). This condensed method does require a model run, as does equation (1), to obtain values for the variables.

Equation (3) would be the easiest to apply, or directly code into FRAM. A model run with assumed fishery mortality is not needed. The annual Age3 forecast is simply multiplied by stock specific constants (Ks), as derived from NewAge2 Validation Runs. This "short-cut" method of using a constant works because fishery mortality for age 2 Chinook is small and relatively constant from year to year.

The driving variable, in all three equations for the NewAge2 stock abundance estimates, is Age3 at timestep 1. For application of the NewAge2 methodology during pre-season modeling there are two potential sources for the needed Age3 timestep 1 seed abundance. The source of these Age3 abundances could be the annual forecasts. Or the value could be "observed" average Age3 abundance from recent Validation Runs. Neither source is without issue. While the pre-season forecast has inherent forecast error, the Validation Runs lag several years, i.e. for pre-season 2014 planning the most recent Validation year was 2010.

The lack of consistency between Age3 escapement and Age3 fishery mortality in timestep 4 has been identified as a weakness in Chinook FRAM modeling. Using an average Age3 abundance from Validation Runs would address some concerns about Age3 forecast errors, but would introduce error if smolt production and survival has varied since the last set of Validation Runs and the present fishery planning year. Adjustment for hatchery smolt production should be straight forward, but variation in natural production would be difficult to quantify. Differences in annual freshwater and marine survival rates, between the Validation Run years and the present, would need to be addressed.

The age 2 and age 3 cohorts are from different brood years and thus the argument might be made that Age2 abundance should not be expected to be consistent with Age3 input. However, neither should the abundance of the age 2 cohorts invalidate stock specific ER calculations. Possible adjustments for known differences between the Age2 and Age3 brood year smolts (hatchery release levels, marine survival conditions) could be considered on a case by case basis.

RESULTS

The calculated NewAge2 abundances, within the 2008 and 2012 Final PFMC Chinook model runs, increased the overall age 2 population in the model. Some stocks' NewAge2 abundances increased dramatically (greater than 2000% relative increase). A few stocks saw a decrease (as much as 100%). The NewAge2 recruit scalars from 2008 and 2012 FRAM model runs, back-calculated through Equation (1), are presented in Appendix Table A for easy comparison to the original recruit scalars used for those two years. Table 2 presents summary statistics for percent change in Age2 stock abundances, and percent change in total fishery mortality by age, over all stocks. Note that for Age2 cohorts, the percent change in fishery related mortality for each timestep corresponds to the change in Age2 abundance; this is also the case for Age3 fish in timestep 4 (Age2 “aging up”).

Graphic representation of the summary statistics for relative percent change in total fishery related mortality of individual stocks, at age and by timestep, is presented in Figures 1 through Figure 4 using box-and-whiskers plots. The box-and-whiskers plots encompass the central quartiles of the data (the central 50% of the data values) in the shaded box with the median value indicated by the heavy black line in the box. The box whiskers include all data values not considered outliers or extreme values. Outliers are marked with open circles and are values between 1.5 and 3 box lengths from the upper or lower edges of the box (Hoaglin et al. 1983). Extreme values are marked by asterisks and are more than three box lengths from the upper or lower edges of the box. Age2 and Age3 outliers, above 500% change in total mortality are not presented in the figures but are summarized in Table 3. The graphic representation of relative change in total fishery mortality for Age3 Chinook also illustrates the “aging-up” process in timestep 4.

Age4 and Age5 cohorts, as well as Age3 in timesteps 1 through 3, showed very little change in fishery mortality resulting from the incorporation of the NewAge2 abundances. However, progressing through the timesteps, an increasing effect is seen in timestep 4 (Figures 2 and 4). This may be attributed to the NewAge2 change in abundance affect upon how fishery quotas were filled. Even though very few age 2 fish are of legal size, there are a lot of them, and the significant increase in overall NewAge2 abundance did increase landed catch for that age class. This would function to allow more of the older fish to survive into the later timesteps and increase their catch, relative to their catch with original Age2 forecasts. Note that more timestep 3 and especially timestep 4 fisheries are modeled with fishery scalars, while earlier timesteps (1 and 2) have relatively more fishery inputs as fishery quota values. However, the scale of relative increase in timestep 4 of Age4 and Age5 mortality, (as high as 10% to 50% for a couple of stocks) is minor compared to the change in Age2 fishery mortality.

Puget Sound Chinook are presently managed with maximum ER caps upon natural stocks, with spawner escapement as another consideration. Re-running the 2008 and 2012 pre-season Chinook model runs with the respective sets of NewAge2 recruit scalars produced different exploitation rates for many stocks, but had little effect on estimates of spawner escapement. For the 2008 model run (Table 4) the effect upon exploitation rates was not as dramatic as seen for the 2012 model run (Table 5).

As an example of NewAge2 recruit scalar affect upon pre-season FRAM outputs we’ll look at adjacent Puget Sound fall Chinook stocks, the Unmarked and Marked stocks for Mid Puget Sound Fall Fingerlings (MidPS FF) and for South Puget Sound Fall Fingerling (SPSd FF). These are very large FRAM stocks, and are major contributors to Puget Sound marine sport catch. In both years there is an increase in ER for the component sub-stocks of FRAM's MidPS FF stock, while a sub-stock of FRAM's SPSd FF stock showed a relatively large drop in ER when modeled with NewAge2 recruit scalars. Specifically, total ER for Unmarked Puyallup Falls increased 1.9% in both years while the Unmarked Nisqually Falls showed a decrease of 0.7% and 2.7% for 2008 and 2012 respectively (Table 4 and Table 5). The very low pre-season Age2 recruit scalars for the MidPS FF stocks produced very few Age3 fish for timestep 4 fisheries, while the relatively high pre-season recruit scalars for the Age2 SPSd FF stocks produced an inflated abundance of Age3 in timestep 4. Appendix Table A presents bolded values for the pre-season recruit scalars (2004-2013) used for these stocks, and also shows the NewAge2 recruit scalars calculated for 2008 and 2012. With NewAge2 recruit scalars, the same direction of change in ER values for these stocks would be expected to occur over the last six years of pre-season modeling since neither of these stocks have changed their rather extreme Age2 recruit scalars since 2008.

The population age structures for these stocks, original pre-season compared to NewAge2, is informative. Table 6 presents 2012 age abundance by timestep for the MidPS FF stocks; note the low abundance of Age2 Chinook produced by the original Age2 recruit scalar. The original MidPS FF Age2 (47,249 Marked) is a fraction of its Age3 abundance (307,429 Marked). The original Age2 recruits then 'age up' in timestep 4 to an Age3 abundance (27,696 Marked). The 307,429 value (timestep 1) is based upon a TRS forecast of Age3 fish, while the 27,696 value (timestep 4) is based upon an Age2 recruit scalar unchanged since pre-season 2008. This is an extreme example. The opposite pattern exists for the SPSd FF stocks. Table 7 presents the population age structures for a stock (SPSd FF) that has been modeled with relatively high Age2 recruit scalar. For the Unmarked SPSd FF the original escapement of Age3 fish is from a timestep 3 cohort of 22,677, while the timestep 4 fishery mortality of Age3 fish was calculated from an abundance of 78,901 Age3; producing the inflated original pre-season ER for Nisqually Fall Chinook (Table 5).

Table 8 presents escapements for selected Columbia River Chinook stocks, before and after Age2 recruit scalars adjustments. Escapements should not change much, if any, because Age2 fish are not included in FRAM calculations of "mature terminal runsize". Note that escapement occurs in timestep 3 before the Age2 cohort "ages up". Exploitation rate calculated for Columbia Natural Tule stock uses a brood year approach and thus was not considered sensitive to the Age2 forecasts. The ER value for 2008 did not change but the 2012 ER went up 0.2% (Table 8). We speculate this is because of the overall changes in abundance of all stocks contributing to the major fisheries impacting Columbia River Natural Tule stocks.

Table 2. Summary statistics, over all stocks, of percent change in Age2 abundance and Total Mortality (by age and timestep) with NewAge2 recruit scalars. Ratios are from preseason 2008 and 2012 model runs, calculated as (NewAge2 – preseasonAge2)/preseasonAge2 values.

2008	Age2	Change in Age2 Total Mortality					Change in Age3 Total Mortality				
	Abundance	1	2	3	4	Total	1	2	3	4	Total
Average:	132.3%	**119.9%**	**134.8%**	**133.0%**	**122.3%**	137.7%	1.8%	0.2%	-0.3%	**141.3%**	-2.8%
Minimum:	-96.7%	-96.5%	-96.6%	-96.5%	-96.4%	-96.5%	0.0%	-0.1%	-4.4%	-96.6%	-83.7%
Maximum:	2993.5%	3194.0%	2993.4%	2986.6%	3225.2%	3061.3%	8.1%	4.2%	2.4%	3004.3%	23.6%
St Dev:	505.5%	535.1%	508.7%	507.7%	541.9%	520.6%	2.0%	0.8%	0.9%	519.1%	14.8%
# of Stocks:	64	56	64	64	56	64	66	66	66	64	66

2012	Age2	Change in Age2 Total Mortality					Change in Age3 Total Mortality				
	Abundance	1	2	3	4	Total	1	2	3	4	Total
Average:	101.6%	112.0%	101.9%	106.1%	116.4%	106.7%	1.0%	0.0%	0.8%	105.9%	-3.5%
Minimum:	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	0.0%	-0.9%	0.0%	-100.0%	-100.0%
Maximum:	2186.4%	2325.4%	2185.8%	2253.7%	2411.4%	2288.3%	6.1%	2.3%	3.9%	2215.3%	17.6%
St Dev:	360.8%	392.7%	361.1%	369.0%	403.5%	372.4%	1.2%	0.3%	0.7%	366.0%	19.1%
# of Stocks:	63	56	63	63	56	63	62	62	62	63	64

2008	Age2	Change in Age4 Total Mortality					Change in Age5 Total Mortality				
	Abundance	1	2	3	4	Total	1	2	3	4	Total
Average:	132.3%	0.0%	0.0%	-0.4%	1.8%	0.0%	0.0%	0.0%	-0.1%	2.1%	0.2%
Minimum:	-96.7%	0.0%	-0.1%	-6.6%	-1.0%	-5.1%	0.0%	-0.3%	-5.9%	-21.4%	-4.3%
Maximum:	2993.5%	0.1%	0.0%	0.7%	8.5%	2.2%	0.0%	0.0%	1.9%	48.9%	3.8%
St Dev:	505.5%	0.0%	0.0%	1.2%	2.0%	1.0%	0.0%	0.1%	1.2%	9.8%	1.1%
# of Stocks:	64	66	66	66	66	66	63	67	67	63	67

2012	Age2	Change in Age4 Total Mortality					Change in Age5 Total Mortality				
	Abundance	1	2	3	4	Total	1	2	3	4	Total
Average:	101.6%	0.0%	0.0%	0.6%	1.7%	0.5%	-0.1%	0.0%	0.8%	2.9%	1.0%
Minimum:	-100.0%	-0.4%	-0.4%	0.0%	-1.0%	0.0%	-9.1%	-5.8%	-5.8%	-0.4%	-1.3%
Maximum:	2186.4%	0.3%	0.3%	3.4%	5.0%	2.0%	7.7%	7.7%	8.0%	43.6%	9.1%
St Dev:	360.8%	0.1%	0.1%	0.7%	1.5%	0.5%	1.7%	1.2%	2.2%	7.9%	2.1%
# of Stocks:	63	67	67	67	62	67	63	65	65	65	67

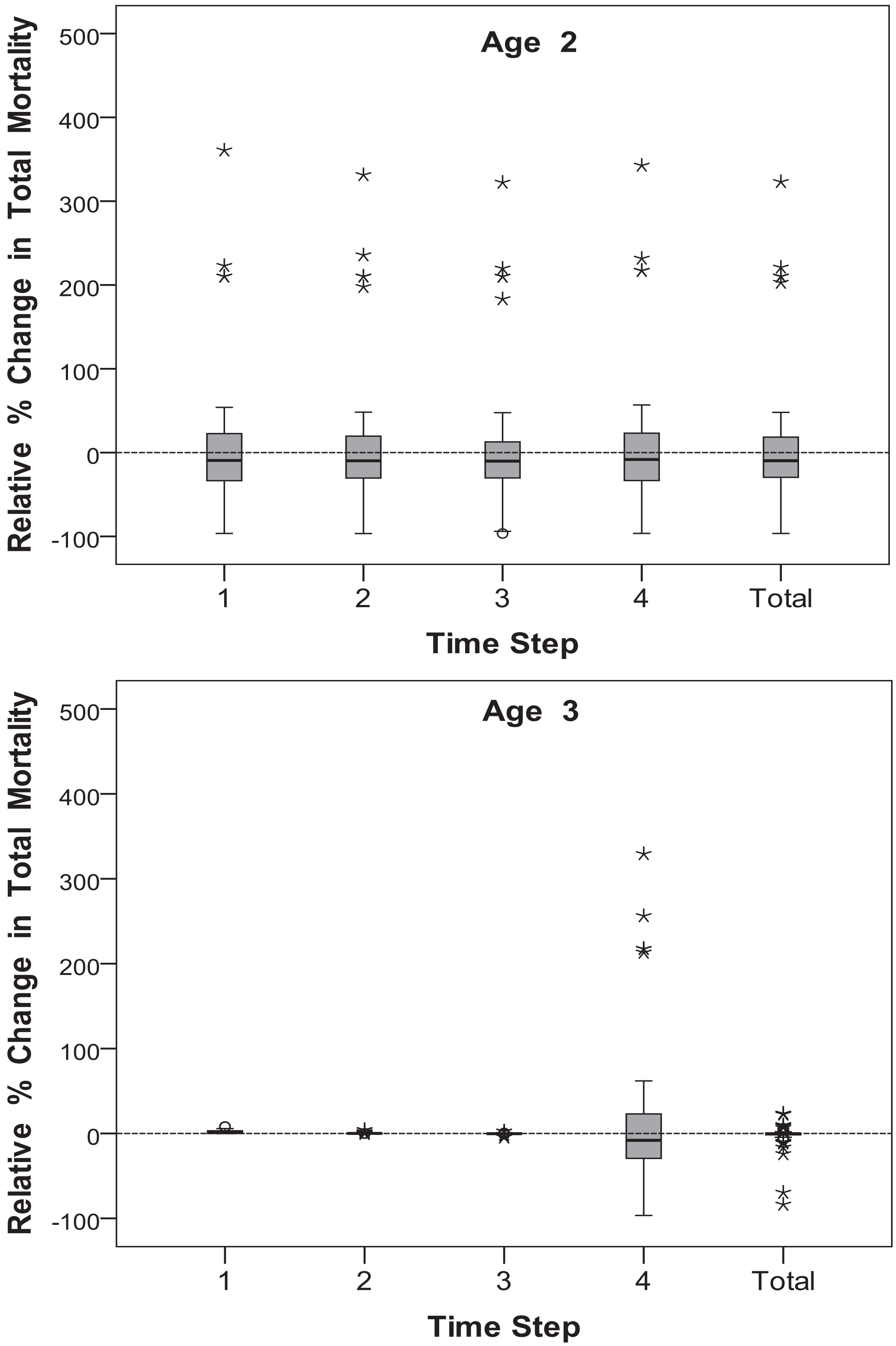


Figure 1. Box-and-whiskers plots of relative change for all stocks in Total Mortality of the Age2 and Age3 cohorts as NewAge2 forecasts were inserted into the 2008 final PFMC Chinook model run. Outliers above 500% removed from plot but are presented in Table 3. See text for quantile and outlier definitions for box-and-whiskers plots.

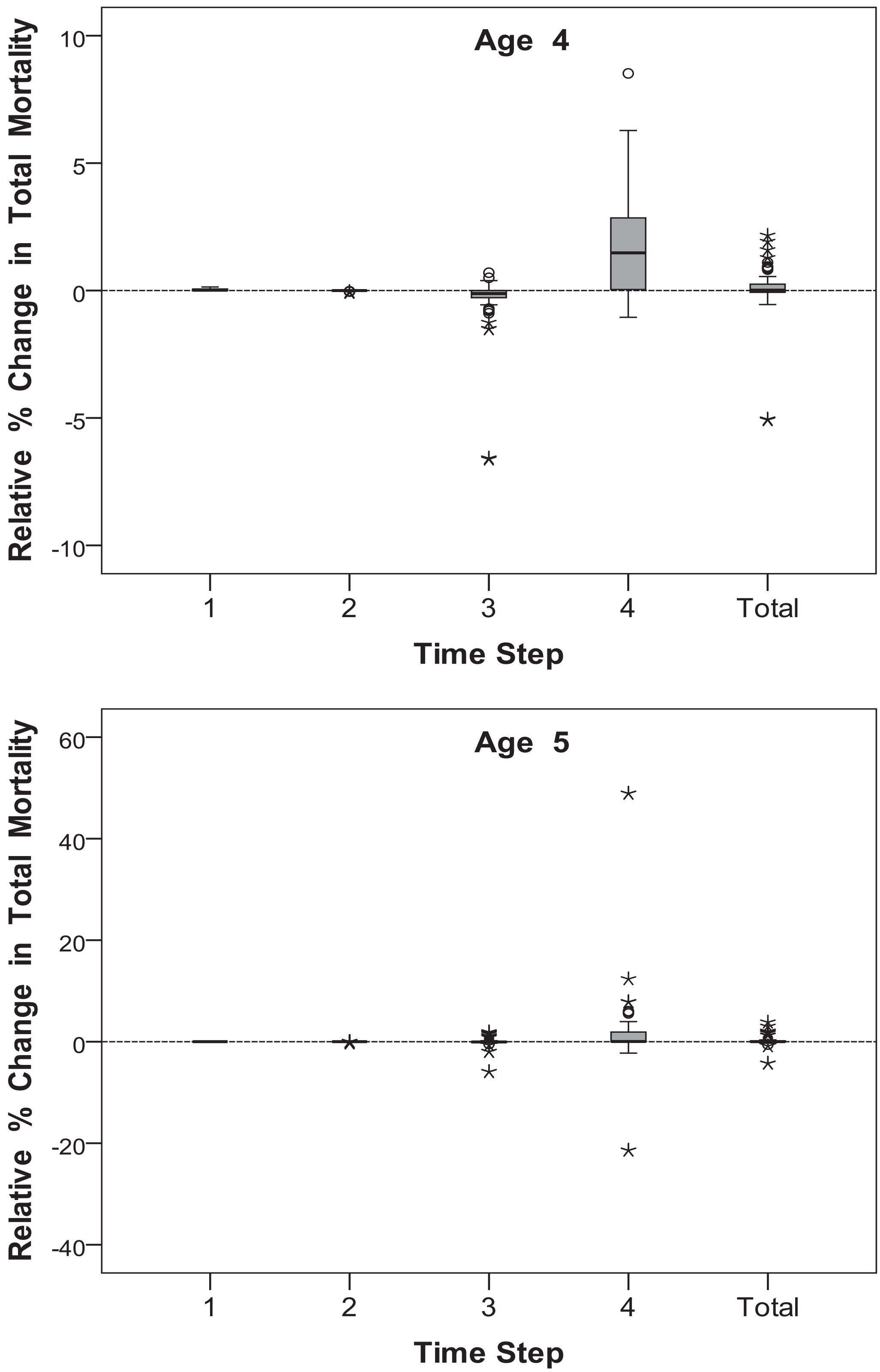


Figure 2. Box-and-whiskers plots of relative change for all stocks in Total Mortality of the Age4 and Age5 cohorts as NewAge2 forecasts were inserted into the 2008 final PFMC Chinook model run. All stocks included in figure.

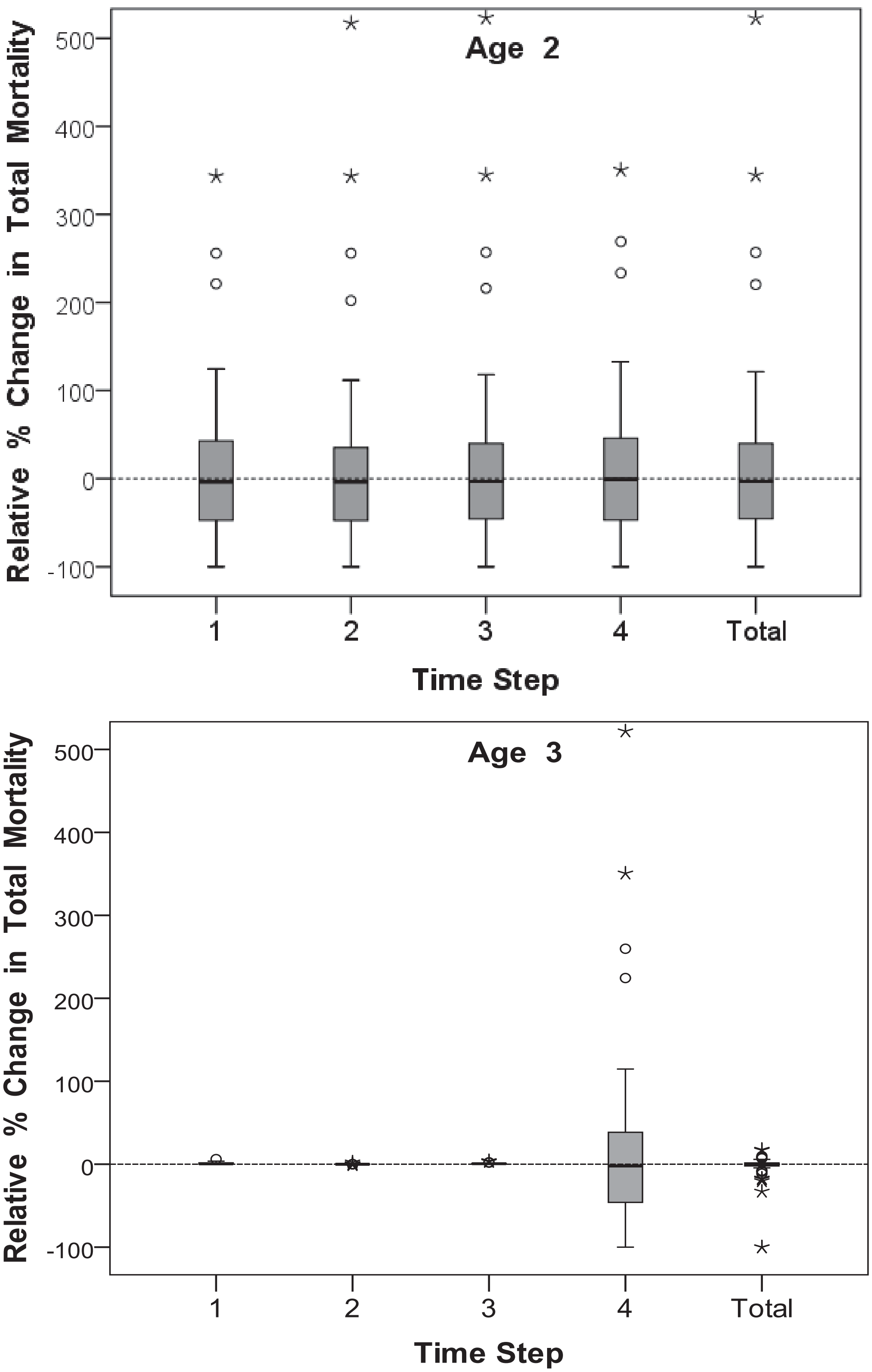
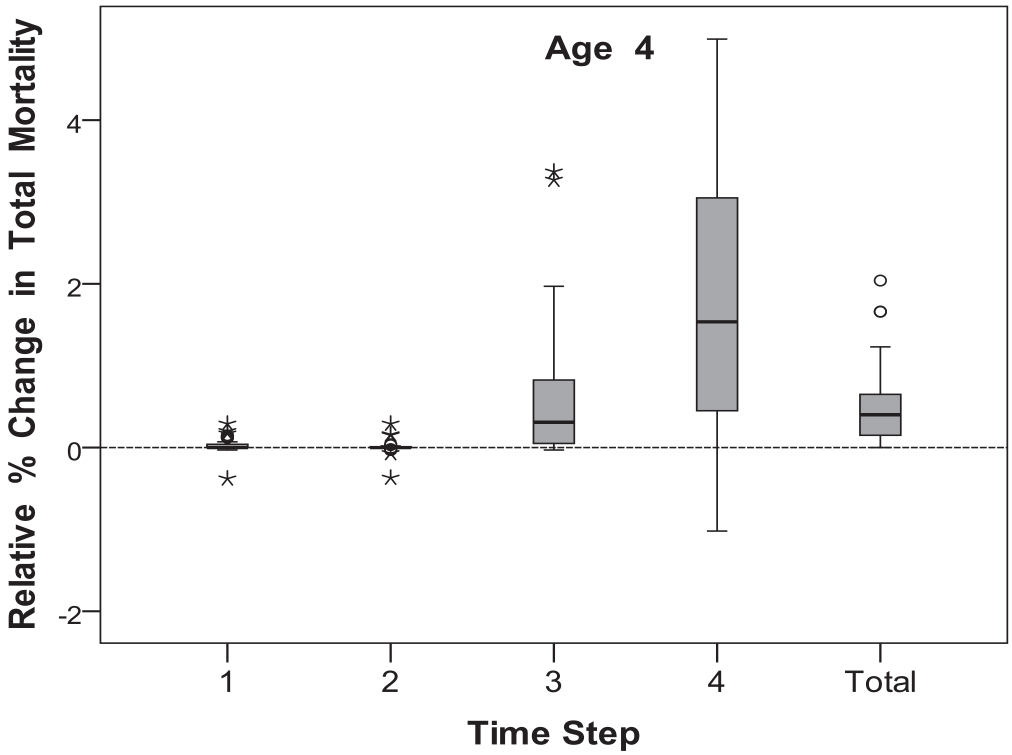


Figure 3. Box-and-whiskers plots of relative change for all stocks in Total Mortality of the Age2 and Age3 cohorts as NewAge2 forecasts were inserted into the 2012 final PFMC Chinook model run. Outliers above 500% removed from plot but are presented in Table 3.



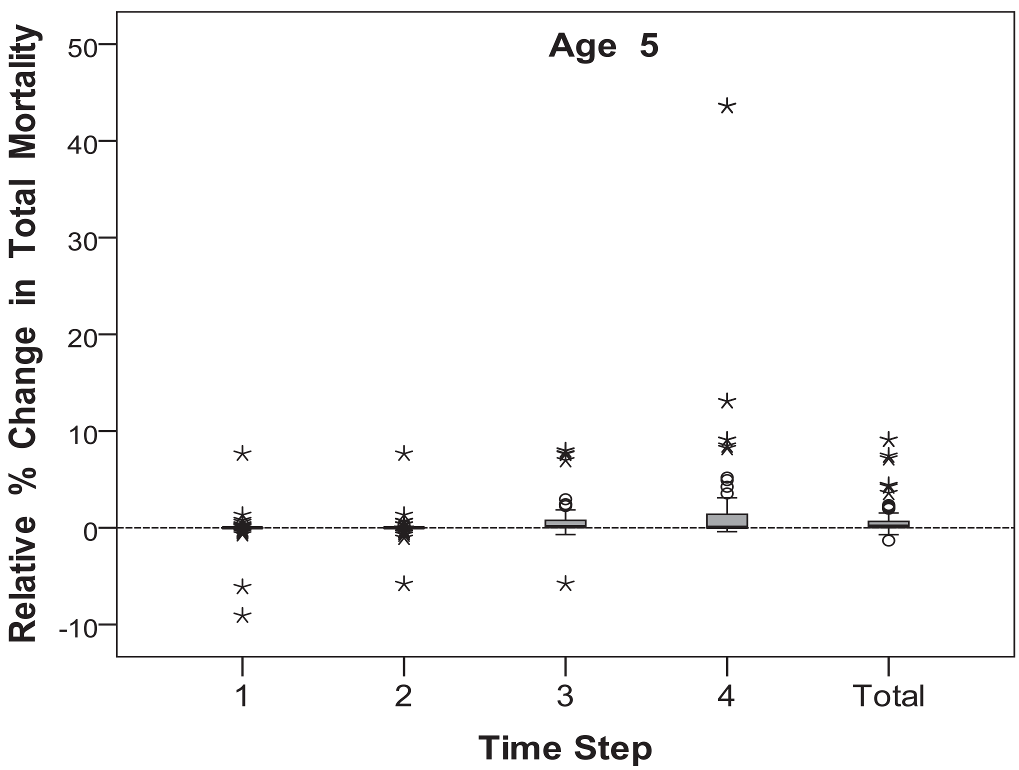


Figure 4. Box-and-whiskers plots of relative change for all stocks in Total Mortality of the Age4 and Age5 cohorts as NewAge2 forecasts were inserted into the 2012 final PFMC Chinook model run. All stocks included in figure.

Table 3. Stocks with greatest change in Age2 abundance for 2008 & 2012, and their recruit scalars for preseason 2004 – 2013.

Year	Stock	Age 2 Recruit Scalars			Range of pre-season Age 2 Recruit Scalars
		Original	Adjusted	Percent Change	
2008	U-Skag FF	0.1001	1.646	1544.36%	Ranged from .1488 to .8749 for 2004-2007, dropped to .1001 in 2008 and remained at that level through pre-season 2010. Value was .2886 for 2011 and 2012, and .0149 for 2013.
	M-Skag FF	0.0031	0.0959	2993.55%	Ranged from .0002 to .0234 for 2004-2007, went to .0031 in 2008 and remained at that level through pre-season 2010. Value was .0110 for 2011 and 2012, and .0003 for 2013.
2008	U-SkagFYr	0.1996	2.9937	1399.85%	Ranged from .0391 to .1989 for 2004-2007, went to .1996 for 2008 and 2010, dropped to .1174 for 2009. No Age 2 recruit scalars for 2011 and 2012, but for 2013 value was .0895.
	M-SkagFYr			no forecast for 2008	
2008	U-SnohFYr	0.0293	0.0961	227.99%	Age 2 recruit scalar ranged from .0185 to .1984 for 2004-2013.
	M-SnohFYr	0.0347	0.3681	960.81%	Age 2 recruit scalar ranged from .0347 to .0837 for 2004-2013.
2008	U-MidPSFF	0.0588	1.0096	1617.01%	Ranged from .2136 to .2927 for 2004-2007, but dropped to .0588 for 2008 through pre-season 2013.
	M-MidPSFF	0.2680	0.7787	190.56%	Ranged from .8742 to 1.085 for 2004-2007, dropped to .2680 in 2008 through pre-season 2013.
2008	U-Will Sp	0.1565	0.4856	210.29%	Was .3683 and .3975 for 2004 and 2005, then was .1565 for following years except 2009 when value was .4470.
	M-Will Sp	1.4093	4.3705	210.12%	3.3149 and 3.5771 for 2004 and 2005, then was 1.4089 for following years except 2009 when value was 1.1158.
2008	U-LwGeo S	0.7764	3.3488	331.32%	1.0885 for 2004 and 2005, then at 1.6723 for 2006 and 2007, 0.7764 for 2008-2010, and .7766 for 2011-2013.
	M-LwGeo S	0.0660	0.0496	-24.85%	Age 2 recruit scalar was .0454 for 2004 and 2005, then was .0697 for 2006 and 2007, then 0.0660 for 2008-2013.
2012	U-Skag FF	0.2886	0.6114	111.85%	Age 2 recruit scalar ranged from .1488 to .8749 for 2004-2007, dropped to .1001 in 2008 and remained at that level through pre-season 2010. Value was .2886 for 2011 and 2012, and .0149 for 2013.
	M-Skag FF	0.0110	0.2515	2186.36%	Age 2 recruit scalar ranged from .0002 to .0234 for 2004-2007, went to .0031 in 2008 and remained at that level through pre-season 2010. Value was .0110 for 2011 and 2012, and .0003 for 2013.
2012	U-Tula FF	0.3503	1.058	202.03%	Highly variable Age 2 recruit scalars ranged from 0.3503 (2012) to 24.1551 (2005).
	M-Tula FF	7.4467	3.9027	-47.59%	Highly variable Age 2 recruit scalars ranged from 0.4524 (2004) to 38.4530 (2006).
2012	U-MidPSFF	0.0588	0.4739	705.95%	Ranged from .2136 to .2927 for 2004-2007, but dropped to .0588 for 2008 through pre-season 2013.
	M-MidPSFF	0.2680	2.9749	1010.04%	Ranged from .8742 to 1.085 for 2004-2007, dropped to .2680 in 2008 through pre-season 2013.
2012	U-SPS Fyr	0.0112	0.0097	-13.39%	Ranged from .0196 to .1842 for 2004-2007, dropped to .0112 in 2008 through pre-season 2013.
	M-SPS Fyr	0.1984	1.2178	513.81%	Ranged from 3.3506 to 4.4900 2004-2007, dropped to .1985 in 2008 through pre-season 2013.
2012	U-WA Tule	0.0485	0.0451	-7.01%	Age 2 recruit scalar ranged from 1.7816 to 2.3268 2004-2007, but dropped to .2441 in 2008 and remained at that level through pre-season 2011. For 2012 and 2013 the value was .0485
	M-WA Tule	0.6305	2.2445	255.99%	Age 2 recruit scalar ranged from .0254 to .0331 2004-2007, but rose to .5695 in 2008 and remained at that level through pre-season 2011. For 2012 and 2013 the value was .6305
2012	U-Will Sp	0.1565	1.6976	984.73%	Was .3683 and .3975 for 2004 and 2005, at .1565 for all following years except 2009 when value was .4470.
	M-Will Sp	1.4089	6.2488	343.52%	Was 3.3149 and 3.5771 for 2004 and 2005, at 1.4089 for following years except 2009 when value was 1.1158.
2012	U-CentVal	2.9956	3.6837	22.97%	Stock added to FRAM in 2008. Ranged from .3060 to .3250 for 2009-2011, 2.6746 to 2.9956 for 2012 and 2013.
	M-CentVal	0.1789	1.7927	902.07%	Stock added to FRAM in 2008. Ranged from .0180 to .0194 for 2009-2011, at .1789 for both 2012 and 2013.

Table 4. Comparison of FRAM estimated pre-season 2008 exploitation rates and natural escapements of selected Puget Sound Chinook stocks (MSF compatible) to FRAM results modeling the NewAge2 recruit scalars.

	Model Prediction			
Stock	Total ER	SUS ER	SUS Preterm . ER	Natural Escapement
Spring/Early:				
Nooksack (n)	24.1%	5.1%	1.7%	375
Skagit (n)	32.3%	19.0%	7.7%	1446
White	15.9%	13.9%	1.6%	5585
Dungeness	37.3%	2.7%	2.5%	1033
Summer/Fall:				
Skagit	47.1%	15.8%	4.0%	20253
Stillaguamish (n)	33.0%	14.8%	13.8%	355
Snohomish (n)	25.4%	12.9%	11.7%	4401
Lake Wa. (Cedar R.) (n)	40.4%	20.0%	7.3%	678
Green	56.0%	35.7%	7.3%	9695
Puyallup	47.0%	26.6%	7.3%	1153
Nisqually	71.5%	53.4%	12.5%	1928
Western Strait-Hoko	19.4%	2.3%	2.3%	925
Elwha	38.6%	2.8%	2.6%	2222
Mid-Hood Canal tribs. (n)	30.4%	8.4%	8.3%	57
Skokomish	58.3%	36.8%	8.3%	1207

FRAM Version: **5.3**
FRAM Description: **2008 preseason Final PFMC**
FRAM Run Number: **2108**

	Model Prediction			
Age2 from Age3 forecasts!				
Stock	Total ER	SUS ER	SUS Preterm . ER	Natural Escapement
Spring/Early:				
Nooksack (n)	23.9%	5.1%	1.7%	375
Skagit (n)	32.0%	18.8%	7.4%	1446
White	15.9%	13.9%	1.6%	5585
Dungeness	37.1%	2.7%	2.5%	1033
Summer/Fall:				
Skagit	49.8%	15.9%	4.7%	20260
Stillaguamish (n)	30.7%	12.6%	11.5%	355
Snohomish (n)	20.1%	7.3%	6.1%	4401
Lake Wa. (Cedar R.) (n)	42.6%	22.3%	9.8%	678
Green	57.8%	37.5%	9.8%	9666
Puyallup	48.9%	28.6%	9.8%	1152
Nisqually	70.8%	52.6%	10.7%	1924
Western Strait-Hoko	18.4%	2.2%	2.2%	926
Elwha	38.4%	2.8%	2.6%	2223
Mid-Hood Canal tribs. (n)	30.8%	8.7%	8.6%	57
Skokomish	58.5%	37.0%	8.6%	1207

FRAM Version: **5.3**
FRAM Description: **2008 preseason with NewAge2**
FRAM Run Number: **NewAge2 from Age3; Chin2108**

Table 5. FRAM estimated pre-season 2012 exploitation rates and natural escapements of selected Puget Sound Chinook stocks (MSF compatible) compared to FRAM results with NewAge2 recruit scalars.

	Model Prediction pre-season Chin1512				Model Prediction Age2 from Age3 Chin1512			
					NewAge2 forecasts			
Stock	Total ER	SUS ER	SUS Preterm. ER	Natural Escapement	Total ER	SUS ER	SUS Preterm. ER	Natural Escapement
Spring/Early:								
Nooksack (n)	35.1%	7.0%	3.0%	309	35.4%	7.2%	3.2%	309
				236				236
				73				73
Skagit (n)	33.1%	18.8%	8.3%	942	33.7%	19.4%	8.9%	938
				468				467
				276				275
				197				197
White	19.2%	18.2%	3.6%	2141	20.2%	19.1%	4.7%	2,141
Dungeness	63.9%	3.4%	3.3%	656	64.6%	4.3%	4.2%	656
Summer/Fall:								
Skagit	40.4%	14.3%	4.9%	8,398	42.9%	14.8%	5.8%	8,390
				5,796				5,790
				288				287
				1,168				1,167
Stillaguamish (n)	23.4%	13.5%	8.2%	338	24.5%	14.7%	9.4%	337
				296				295
				43				43
Snohomish (n)	16.4%	9.1%	7.5%	2,301	15.6%	8.3%	6.6%	2,300
				1,453				1,452
				848				848
Lake Wa. (Cedar R.)	34.1%	17.8%	9.6%	994	36.5%	20.2%	12.2%	993
Green	31.0%	14.6%	9.6%	1,911	33.4%	17.1%	12.2%	1,910
Puyallup	**48.5%**	32.2%	9.6%	2,206	**50.4%**	34.1%	12.2%	2,202
Nisqually	**55.3%**	41.2%	20.7%	1,072	**52.6%**	38.3%	16.6%	1,069
Western Strait-Hoko	21.6%	2.8%	2.8%	2,118	21.5%	2.8%	2.8%	2,117
Elwha	63.2%	3.4%	3.3%	1,887	63.9%	4.2%	4.1%	1,886
Mid-Hood Canal tribs. (n)	25.9%	12.2%	12.0%	196	26.4%	12.7%	12.5%	196
Skokomish	47.9%	34.3%	12.6%	1,889	48.4%	34.8%	13.1%	1,885

FRAM Version:	**2.09**	**FRAM Version:**	**2.11**
FRAM Description:	**2012 preseason Final PFMC**	**FRAM Description:**	**2012 preseason with NewAge2**
FRAM Run Number:	**1512**	**FRAM Run Number:**	**NewAge2 from Age3; Chin1512**

Table 6. Original pre-season 2012 population age structure, for the Unmarked and Marked **Mid Puget Sound Fall Fingerling stocks**, compared to population age structure with NewAge2 abundances.

		2012 **original** abundance at start of Timestep					2012 **NewAge2** abundance at start of Timestep			
Stock	Age	T1	T2	T3	T4		T1	T2	T3	T4
U-MidPSFF	2	**10,366**	7,654	7,021	**10,366**		**83,549**	61,676	56,581	**83,549**
U-MidPSFF	3	**48,968**	39,358	36,755	**6,077**		**48,968**	39,353	36,751	**48,954**
U-MidPSFF	4	12,941	11,094	10,227	29,200		12,941	11,094	10,227	29,185
U-MidPSFF	5	1,232	1,082	985	2,058		1,232	1,082	985	2,058
M-MidPSFF	2	**47,249**	34,884	32,003	**47,249**		**524,476**	387,171	355,186	**524,476**
M-MidPSFF	3	**307,429**	246,289	229,737	**27,696**		**307,429**	246,257	229,707	**307,304**
M-MidPSFF	4	29,118	24,704	22,762	180,445		29,118	24,703	22,762	180,332
M-MidPSFF	5	777	679	618	4,369		777	678	617	4,365

Table 7. Original pre-season 2012 population age structure, for the Unmarked and Marked **South Puget Sound Fall Fingerling stocks**, compared to population age structure with NewAge2 abundances.

		2012 **original** abundance at start of Timestep					2012 **NewAge2** abundance at start of Timestep			
Stock	Age	T1	T2	T3	T4		T1	T2	T3	T4
U-SPSd FF	2	**133,927**	98,908	90,702	**133,927**		**51,078**	37,715	34,585	**51,078**
U-SPSd FF	3	**30,092**	24,145	22,677	**78,901**		**30,092**	24,141	22,673	**30,074**
U-SPSd FF	4	8,139	6,908	6,385	17,572		8,139	6,908	6,385	17,561
U-SPSd FF	5	292	269	259	2,615		292	269	259	2,614
M-SPSd FF	2	**1,575,763**	1,163,741	1,067,181	**1,575,763**		**703,625**	519,533	47,6424	**703,625**
M-SPSd FF	3	**414,536**	331,211	310,779	**928,342**		**414,536**	331,151	310,723	**414,285**
M-SPSd FF	4	84,368	71,036	65,657	236,122		84,368	71,035	65,656	235,958
M-SPSd FF	5	633	582	560	25,623		633	582	560	25,601

Table 8. FRAM estimated pre-season 2008 and pre-season 2012 ocean escapements, and brood year ER, of selected Columbia River Chinook stocks (MSF compatible) compared to results with NewAge2 recruit scalars.

Table 5 PFMC Preseason Report for 2008		
	Adult Ocean Escapement or Other Crit.	
	Chin2108	Chin2108 with NewAge2
Col Upriver Brt	175.9	175.9
Mid-Col Brt	45.2	45.2
Col Lower Hatch	60.4	60.4
Col Nat Tule Brood Year ER	35.9%	35.9%
Col LRW	3.8	3.8
Spring Creek	86.2	86.2

Table 5 PFMC Preseason Report for 2012		
	Adult Ocean Escapement or Other Crit.	
	Chin1512	Chin1512 with NewAge2
Col Upriver Brt	353.0	353.0
Mid-Col Brt	90.7	90.7
Col Lower Hatch	128.4	128.1
Col Nat Tule Brood Year ER	**40.9%**	**41.1%**
Col LRW	16.2	16.2
Spring Creek	60.0	59.9

DISCUSSION

When the initial structure of Chinook FRAM was conceived there was more of a focus on stock escapement (age 3 through 5). The present management focus has shifted to ER caps. The importance of accurate Age2 forecasts appears to have been lost during this transition. Age2 abundance is an important component of total fishery mortality.

The lack of data for age 2 survival rates (limited terminal return information, almost no CWT fishery recoveries), and subsequent poor quality of input Age2 Chinook forecasts has long been known, but ignored. The work toward an updated Chinook Base Period and the recent work to better model sublegal encounters motivated this effort to address the Age2 forecast dilemma. Although it was surprising to see how stagnant the modeled Age2 annual forecasts had become (Appendix Table A), choosing an alternative is difficult when the provided regionally produced forecasts are only for “total runsize” of combined ages 3 through 5, or at best by Age3, Age4, and Age5, with no Age2 forecast. What has not been investigated before is the potential effect of Age2 forecasts on stock specific exploitation rates.

Initially it was expected that the NewAge2 forecasts would raise the ER for some stocks and drop it for others. Since Age2 calculated fishery mortality is significantly reduced by the AEQ factor the changes to ER were not expected to be great (AEQ mortality is used for ER calculations). This was generally the case for 2008 (**Table 4**), while for 2012 (**Table 5**) all but three Puget Sound stocks showed an increase in ER. A couple of stocks had an absolute ER increase in the neighborhood of 2%; one stock saw a drop of nearly 3%. When we struggle during pre-season negotiations to stay below an ESA driven ER cap, often trying to find tenths of a percent reduction, changes of a full percent or more could be disruptive to the present annual fishery structure.

However, the results from re-running 2008 and 2012 with NewAge2 recruit scalars should not be taken as absolute. This present exercise took a narrow focus and only changed the one parameter of Age2 recruit scalars in these two pre-season model runs. With every pre-season there are potentially changes, with usually subtle effects, in the FRAM application and many input parameters. Some changes, or corrected “model glitches” aren’t so subtle. An example is the natural mortality rates used in the 2008 Outfile, or the base period calibration result that is input into FRAM (Table 9). After the 2008 pre-season, it was discovered that the Outfiles used up to that year were created with the wrong natural mortality rates for timestep 4. The 2008 model run with NewAge2 recruits would have produced a different result with the corrected Outfile, but wouldn’t have been directly comparable to the pre-season 2008 product.

Several types of annual input parameters are calculated/calibrated using the post-season Validation Runs. Validation Runs, a type of post-season FRAM run, incorporate observed fishery catch and observed Terminal Run Size of stocks’ Age3, 4, and 5 year old fish to back-calculate their initial recruit scalars. But this isn’t the case for the Age2 recruit scalar. Validation Runs have reused the annual pre-season Age2 recruit scalars. If realistic Age2 abundances are provided for Validation Runs then we can expect changes to parameters such as input ‘fishery scalars’ for Puget Sound marine sport retention and non-retention fisheries. The fishery scalar reflects an average effort that should produce a model estimated landed catch consistent with observed landed catch. Since, over all FRAM stocks, the NewAge2 recruits increase overall Chinook abundance then reduced ‘fishery scalars’ would be needed to keep model estimated landed catch consistent with observed levels. This applies particularly for timestep 4 fisheries when NewAge2 “age-up”. In general, this should somewhat reduce ERs produced in the NewAge2 versions of pre-season 2008 and 2012 model runs. The largest affect of using NewAge2 recruit methodology may be in the re-distribution of fishery impacts among FRAM stocks contributing to timestep 4 fisheries.

The calculations of, and/or acceptance of, several stocks’ ER caps are based upon FRAM Validation Run results. Validation Runs should be reproduced with realistic Age2 abundances.

The need to use realistic Age2 forecasts is a given, so the issue at hand is when to implement either the presented NewAge2 forecast methodology or alternative realistic methods. Some potential options:

1. Full implementation of a NewAge2 forecast methodology for pre-season 2015.
    a. Option 1: Direct calculation from annual Age3 forecasts.
        i. Model with average, or anticipated fishery mortality rates.
        ii. Apply average NewAge2/Age3 ratio from Validation Runs.
    b. Option 2: Calculation from average Age3 abundances from recent Validation Runs.
        i. Apply average NewAge2/Age3 ratio from Validation Runs.
        ii. Option to simply average NewAge2 abundances from same Validation Runs.

2. Implement a NewAge2 forecast methodology as part of the Chinook Base Period update, with potential corresponding adjustments to ESA stock ER caps, perhaps by 2016 pre-season.

3. Consult with regional biologists regarding limitations of current Age2 forecasts and discuss options for development of Age2 forecasts for preseason 2015.

Table 9. Time period and age-specific rates used by FRAM to simulate Chinook natural mortality

Chinook FRAM Natural Mortality Rates, by age and timestep:

Age	Timestep 1 Oct. to April	Timestep 2 May to June	Timestep 3 July to Sept.	**2008 Outfile** Timestep 4 Oct. to April	**2012 Outfile** Timestep 4 Oct. to April
2	0.2577	0.0816	0.1199	0.1878	0.2577
3	0.1878	0.0577	0.0853	0.1221	0.1878
4	0.1221	0.0365	0.0543	0.0596	0.1221
5	0.0596	0.0174	0.026	0.0596	0.0596

Supplementary Reference

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Appendix Table A. Age2 pre-season recruit scalars for Chinook FRAM stocks, 2004-2013, and recalculated NewAge2 scalars for 2008 and 2012.

StockName	Pre-season Age2 Recruit Scale Factors (2004 through 2013):										New Age2 from Age3	
	Chin1604	Chin2705	Chin3006	Chin3007	**Chin2108**	Chin2309	Chin1010	Chin1811	**Chin1512**	Chin1213	**Chin2108**	**Chin1512**
U-NkSm FF	0.0955	0.0277	0.0261	0.0261	0.0260	0.0260	0.0260	0.0421	0.0421	0.0421	0.0354	0.0394
M-NkSm FF	0.5858	0.3527	0.3039	0.3039	0.3025	0.3025	0.3025	0.7589	0.7589	0.7589	0.2516	0.7232
U-NFNK Sp	1.4734	1.5632	2.1621	1.3230	3.4646	3.4646	3.5330	2.7510	2.7510	0.3986	1.9597	3.8861
M-NFNK Sp	0.5266	0.4368	3.4182	2.0900	5.4732	5.4732	5.6968	6.4250	6.4250	1.0533	6.0060	8.6634
U-SFNK Sp	2.0000	2.0000	5.5803	3.4940	0.1397	0.1397	0.2757	0.2268	0.2268	0.1134	0.1257	0.0174
M-SFNK Sp												
U-Skag FF	0.6479	0.3917	0.8749	0.1488	0.1001	0.0938	0.1001	0.2886	0.2886	0.0149	1.6460	0.6114
M-Skag FF	0.0179	0.0129	0.0234	0.0002	0.0031	0.0030	0.0031	0.0110	0.0110	0.0003	0.0959	0.2515
U-SkagFYr	0.0785	0.0391	0.0929	0.1989	0.1996	0.1174	0.1996			0.0895	2.9937	
M-SkagFYr												
U-SkagSpY	2.1049	1.8550	1.6927	1.8606	1.6838	0.8460	0.8000	0.8001	0.8001	2.4051	1.0416	0.9571
M-SkagSpY	3.4599	1.6712	1.4137	3.1224	2.2491	2.2456	6.6700	10.2810	10.2810	3.5189	2.1238	2.4213
U-Snoh FF	1.1701	1.5732	1.2471	1.0967	1.7176	0.3749	0.7612	0.3794	0.1332	0.0492	0.0986	0.0735
M-Snoh FF	0.3650	0.8131	0.9496	0.6580	1.0262	0.1597	0.1964	0.0978	0.1264	0.1264	0.0338	0.1712
U-SnohFYr	0.1184	0.0903	0.0433	0.0399	0.0293	0.0532	0.1111	0.0687	0.0185		0.0961	0.0102
M-SnohFYr	0.0837	0.0580	0.0375	0.0377	0.0347	0.0831	0.0819	0.0506	0.0741	0.0741	0.3681	0.0747
U-Stil FF	1.8700	1.8235	1.6380	2.5140	1.2792	0.6803	0.5729	0.1718	0.3334	0.2811	0.8362	0.4077
M-Stil FF	0.1321	0.4830	0.5453	0.5594	1.1344	0.3886	0.0731	0.3670	0.8803	1.9448	0.5146	0.4120
U-Tula FF	3.0887	24.1551	16.8750	6.3756	6.7360	2.2918	0.9042	0.6018	0.3503	0.4312	1.1538	1.0580
M-Tula FF	0.4521	2.6244	38.4530	13.0623	24.0240	5.2121	1.8562	2.1398	7.4467	9.5998	2.3645	3.9027
U-MidPSFF	**0.2136**	**0.2145**	**0.2927**	**0.2560**	**0.0588**	**0.0588**	**0.0588**	**0.0588**	**0.0588**	**0.0588**	**1.0096**	**0.4739**
M-MidPSFF	**0.9027**	**1.0858**	**0.9996**	**0.8742**	**0.2680**	**0.2680**	**0.2680**	**0.2680**	**0.2680**	**0.2680**	**0.7787**	**2.9749**
U-UWAc FF	0.6556		0.0008	0.0008								
M-UWAc FF		0.6341	2.4837	2.4344	1.2879	1.2879	1.2879	1.2869	1.2869	1.2869	1.0656	0.2762
U-SPSd FF		**0.4137**	**0.4013**	**0.4575**	**0.6516**	**0.6516**	**0.6516**	**0.6513**	**0.6513**	**0.6513**	**0.2920**	**0.2484**
M-SPSd FF	**3.4844**	**3.6430**	**4.7382**	**5.4015**	**7.6665**	**7.6665**	**7.6665**	**7.6631**	**7.6631**	**7.6631**	**2.6208**	**3.4218**
U-SPS Fyr	0.1842	0.0493	0.0196	0.0223	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0096	0.0097
M-SPS Fyr	3.3506	3.8380	3.9386	4.4900	0.1985	0.1985	0.1985	0.1984	0.1984	0.1984	0.1700	1.2178
U-WhiteSp	15.2435	21.1897	21.1890	21.1890	14.2047	14.2047	14.2047	14.2040	14.2040	14.2040	12.5540	26.3841
M-WhiteSp												
U-HdCl FF	6.4769	6.0283	2.5444	3.8100	1.5058	1.5058	1.5058	0.6890	0.6890	0.5387	1.7813	0.7521
M-HdCl FF	0.3566	0.3339	2.5361	3.8000	2.6081	2.6081	2.6081	9.1590	9.1590	15.2650	3.3694	7.1247
U-HdCl FY	1.8433	2.0137										
M-HdCl FY			2.0000	2.0000	1.6479	1.6479	1.6479	4.4690	4.4690	4.4690	1.2457	5.8899
U-SJDF FF	1.7888	1.9014	2.2414	2.2414	3.9976	3.9976	3.9976	3.9994	3.9994	3.9994	3.1900	7.0841
M-SJDF FF	0.2351	0.2196	0.1709	0.1709								
U-OR Tule	0.8057	0.3130	0.1835	0.1743	0.4530	0.4530	0.4530	0.4507	0.1940	0.1940	0.1837	0.1632

StockName	Pre-season Age2 Recruit Scale Factors (2004 through 2013):										New Age2 from Age3	
	Chin1604	Chin2705	Chin3006	Chin3007	**Chin2108**	Chin2309	Chin1010	Chin1811	**Chin1512**	Chin1213	**Chin2108**	**Chin1512**
M-OR Tule	0.0114	0.0045	0.0026	0.0025	1.0670	1.0670	1.0670	1.0616	1.4550	1.4550	0.4288	0.8320
U-WA Tule	1.7816	2.3268	1.9039	1.8087	0.2441	0.2441	0.2441	0.2430	0.0485	0.0485	0.1012	0.0451
M-WA Tule	0.0254	0.0331	0.0271	0.0257	0.5695	0.5695	0.5695	0.5670	0.6305	0.6305	0.2361	2.2445
U-LCRWild	2.3620	1.9802	1.6926	1.6926	0.3362	0.3362	0.3362	0.3359	0.8250	0.8250	0.3990	0.9032
M-LCRWild	0.0311	0.0260	0.0222	0.0222	0.0083	0.0083	0.0083	0.0083			0.0123	
U-BPHTule	2.4238	1.9903	1.0386	1.0386	0.0503	0.1559	0.0503	0.0500	0.1200	0.1200	0.0684	0.0750
M-BPHTule	0.0296	0.0243	0.0127	0.0127	0.9553	0.8497	0.9553	0.9488	1.2000	1.2000	0.0120	0.8084
U-UpCR Su	7.1304	7.0677	7.8053	7.8053	3.8993	3.8993	3.8993	2.4542	2.4500		0.2310	
M-UpCR Su	1.2583	1.2478	1.3774	1.3774	0.7825	0.7825	0.7825	0.4925	0.4900		4.8400	
U-UpCR Br	8.6140	9.9402	7.9583	7.9583	4.8870	4.8870	4.8870	4.8887	6.2500	6.2500	0.9700	7.3104
M-UpCR Br	0.2600	0.3000	0.2402	0.2402	0.5430	0.5430	0.5430	0.5432	2.3200	2.3200	0.4841	2.7897
U-Cowl Sp												
M-Cowl Sp												
U-Will Sp	0.3683	0.3975	0.1565	0.1565	0.1565	0.4470	0.1565	0.1565	0.1565		0.4876	1.6976
M-Will Sp	3.3149	3.5771	1.4089	1.4089	1.4093	1.1158	1.4093	1.4089	1.4089		4.3889	6.2488
U-Snake F	0.7400	0.7382	0.7400	0.7400	0.7074	0.7074	0.7074	0.8700	0.8700	0.8700	0.6286	0.8394
M-Snake F	1.2600	1.2569	1.2600	1.2600	1.2046	1.2046	1.2046	1.1300	1.1300	1.1300	1.0707	1.0906
U-OR No F	1.9988	1.9988	1.9982	1.9982	0.7917	0.7917	0.7917	0.7918	0.7918	0.7918	0.7542	1.0457
M-OR No F												
U-WCVI Tl	1.2482	1.0617	2.9884	2.9884	0.3532	0.3532	0.3532	0.3532	0.3532	0.3532	0.3255	0.0618
M-WCVI Tl	0.0254	0.0254	0.0608	0.0608	0.0071	0.0071	0.0071	0.0071	0.0071	0.0071	0.0064	0.0013
U-FrasRLt	0.5102	0.8810	1.2068	1.2068	3.3900	3.3900	3.3900	3.3899	3.3899	3.3899	2.9662	1.3683
M-FrasRLt	0.0105	0.0187	0.0249	0.0249	0.0720	0.0720	0.0720	0.0720	0.0720	0.0720	0.0630	0.0608
U-FrasREr	5.3955	5.3955	4.0981	4.0981	3.2900	3.2900	3.2900	3.2903	3.2903	3.2903	3.0094	3.2574
M-FrasREr	0.1101	0.1101	0.0836	0.0836	0.0671	0.0671	0.0671	0.0671	0.0671	0.0671	0.0614	0.0663
U-LwGeo S	1.0885	1.0885	1.6723	1.6723	0.7764	0.7764	0.7764	0.7766	0.7766	0.7766	0.5835	0.4035
M-LwGeo S	0.0454	0.0454	0.0697	0.0697	0.0660	0.0660	0.0660	0.0660	0.0660	0.0660	0.0496	0.0345
U-WhtSpYr	3.5393	3.5393	4.0243	4.0243	8.5992	8.5992	8.5992	8.5865	8.5865	8.5865	7.5051	3.4586
M-WhtSpYr												
U-LColNat					0.7140	0.7140	0.7140	0.7113	2.0000	2.0000	0.5117	2.6912
M-LColNat												
U-CentVal					0.3250	0.3060	0.3250	2.6746	2.9956	2.9956	0.2985	3.6837
M-CentVal					0.0194	0.0180	0.0194	0.1597	0.1789	0.1789	0.0178	1.7927
U-WA NCst					0.2610	0.2610	0.2610	0.2610	0.1957	0.1957	0.2362	0.3959
M-WA NCst									0.0653	0.0653		0.1306
U-Willapa					3.4900	3.4900	3.4900	3.4902	0.7366	0.7366	3.1451	0.4875
M-Willapa					0.1930	0.1930	0.1930	0.1930	2.9466	2.9466	0.1739	1.5388
U-Hoko Rv					1.8272	1.8272	1.8272	3.1741	0.8119	6.0384	0.2591	0.4261
M-Hoko Rv					2.6294	2.6294	2.6294	4.6373	0.8192	3.4548	0.3577	0.4907

Appendix Table B. Summary statistics for FRAM stock specific initial Timestep 1 abundance ratios of NewAge2/Age3, as produced from Chinook FRAM Validation Runs (2003-2010)

	Stock specific 2:3 ratios from 2003-2010 Validation Runs.				
StockName	Mean	Median	Min	Max	SD
U-NkSm FF	0.96	0.96	0.96	0.97	0.00
M-NkSm FF	0.96	0.96	0.96	0.97	0.00
U-NFNK Sp	0.98	0.98	0.98	0.98	0.00
M-NFNK Sp	0.98	0.98	0.98	0.98	0.00
U-SFNK Sp	0.98	0.98	0.98	0.98	0.00
M-SFNK Sp					
U-Skag FF	0.93	0.92	0.92	0.97	0.02
M-Skag FF	0.93	0.92	0.92	0.97	0.02
U-SkagFYr	0.96	0.96	0.96	0.97	0.00
U-SkagSpY	0.98	0.98	0.98	0.98	0.00
M-SkagSpY	0.98	0.98	0.98	0.98	0.00
U-Snoh FF	0.93	0.93	0.93	0.95	0.01
M-Snoh FF	0.93	0.93	0.93	0.95	0.01
U-SnohFYr	0.95	0.95	0.95	0.95	0.00
M-SnohFYr	0.95	0.95	0.95	0.95	0.00
U-Stil FF	0.93	0.93	0.93	0.95	0.01
M-Stil FF	0.93	0.93	0.93	0.94	0.00
U-Tula FF	0.97	0.97	0.97	0.98	0.00
M-Tula FF	0.97	0.97	0.97	0.97	0.00
U-MidPSFF	0.95	0.95	0.95	0.96	0.00
M-MidPSFF	0.95	0.95	0.95	0.96	0.00
U-UWAc FF					
M-UWAc FF	0.88	0.87	0.86	0.89	0.01
U-SPSd FF	0.96	0.96	0.95	0.96	0.00
M-SPSd FF	0.96	0.96	0.95	0.96	0.00
U-SPS Fyr	0.92	0.92	0.92	0.93	0.00
M-SPS Fyr	0.92	0.92	0.92	0.93	0.00
U-WhiteSp	0.96	0.95	0.95	0.96	0.00
U-HdCl FF	0.94	0.94	0.93	0.94	0.00
M-HdCl FF	0.94	0.94	0.93	0.95	0.00
U-HdCl FY	0.95	0.95	0.95	0.96	0.00
M-HdCl FY	0.95	0.95	0.95	0.96	0.00
U-SJDF FF	0.96	0.96	0.95	0.97	0.00
M-SJDF FF	0.96	0.96	0.95	0.97	0.00
U-OR Tule	0.94	0.94	0.94	0.95	0.00
M-OR Tule	0.94	0.94	0.94	0.95	0.01
U-WA Tule	0.97	0.97	0.96	1.00	0.01
M-WA Tule	0.97	0.97	0.96	0.99	0.01
U-LCRWild	0.98	0.98	0.98	0.99	0.00
M-LCRWild	0.98	0.98	0.98	0.99	0.00
U-BPHTule	0.92	0.92	0.92	0.95	0.01
M-BPHTule	0.93	0.92	0.92	0.95	0.01
U-UpCR Su	0.98	0.98	0.97	0.99	0.01
M-UpCR Su	0.98	0.98	0.97	0.99	0.01

Stock specific 2:3 ratios from 2003-2010 Validation Runs.

StockName	Mean	Median	Min	Max	SD
U-UpCR Br	0.97	0.97	0.96	0.97	0.00
M-UpCR Br	0.97	0.97	0.96	0.98	0.00
U-Cowl Sp					
M-Cowl Sp					
U-Will Sp	0.99	0.98	0.98	0.99	0.00
M-Will Sp	0.99	0.98	0.98	0.99	0.00
U-Snake F	0.97	0.97	0.96	0.98	0.01
M-Snake F	0.97	0.96	0.96	0.98	0.01
U-OR No F	0.98	0.98	0.97	0.99	0.01
M-OR No F	0.98	0.98	0.96	1.00	0.01
U-WCVI Tl	0.98	0.98	0.97	0.98	0.00
M-WCVI Tl	0.98	0.98	0.97	1.00	0.01
U-FrasRLt	0.95	0.94	0.94	0.95	0.00
M-FrasRLt	0.95	0.94	0.94	0.95	0.00
U-FrasREr	0.99	0.99	0.98	0.99	0.00
M-FrasREr	0.99	0.99	0.98	0.99	0.00
U-LwGeo S	**0.81**	0.81	0.80	0.83	0.01
M-LwGeo S	**0.81**	0.81	0.79	0.83	0.01
U-WhtSpYr	0.97	0.97	0.97	0.98	0.00
M-WhtSpYr					
U-LColNat	0.96	0.96	0.95	0.96	0.01
U-CentVal	0.97	0.96	0.94	1.00	0.02
M-CentVal	0.97	0.96	0.94	1.00	0.02
U-WA NCst	0.98	0.98	0.98	0.98	0.00
M-WA NCst	0.98	0.98	0.98	0.99	0.00
U-Willapa	0.98	0.98	0.97	0.99	0.00
M-Willapa	0.98	0.98	0.97	0.99	0.00
U-Hoko Rv	0.98	0.98	0.98	0.98	0.00
M-Hoko Rv	0.98	0.98	0.98	0.98	0.00

Mean	0.96
Median	0.97
Min	0.81
Max	0.99
Count	68

A Method for Utilizing Recent Coded Wire Tag Recovery Data to Adjust FRAM Base Period Exploitation Rates

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6 October 2014

Introduction:

In the Chinook Fishery Regulation Assessment Model (FRAM), fisheries are either pre-terminal (fish on all fish alive during the time step) or terminal (fish on only mature fish in the time step). Even non-local fish caught in a terminal fishery are considered to be part of the mature run of the non-local stock, no matter the distance from the natal stream or the condition of the fish. FRAM does not differentiate between an immature, non-local fish caught in a terminal net fishery and a mature, non-local fish that has strayed to that terminal area and is caught in the net fishery; both are counted as a part of the non-local stock's terminal run (as a mature fish). This can cause numerous problems in accounting for fish mortality for management purposes and for forecasting; the problems tend to be fairly negligible when fisheries and/or mature run sizes are small, but when fisheries and/or mature run sizes are large the problems can impact effective management of the stock.

FRAM-estimated catch of non-local stocks in terminal net fisheries in Hood Canal has grown over the past few years from 661 non-local fish in 2009 to 1761 non-local fish in 2013 pre-season runs. Deep South Puget Sound Fall Fingerlings (SPS FF) make up the majority of the non-local catch in these fisheries in FRAM, and the large catch of mature SPS FF in a distant terminal fishery seemed suspect to managers of the stock. This prompted a comparison with coded wire tag (CWT) recoveries of non-local fish in Hood Canal; the disparity was quite large. Figure 1a shows the pre-season FRAM-estimated proportion of non-local catch for recent years compared to the proportion of non-local CWT recoveries for Hood Canal marine terminal net fisheries. Figure 1b shows the increase in total catch in Hood Canal terminal net fisheries estimated by pre-season runs of FRAM over recent years; although the FRAM-estimated proportion of non-local stock caught in these fisheries is declining, the increase in total fish means that the number of non-local fish caught is increasing.

At the same time, overall catch in Deep South Puget Sound net fisheries has decreased and the pre-season FRAM-estimated proportion of Hood Canal Fall Fingerlings (HC FF) in those fisheries has been changing in a pattern out of sync with the proportion of HC CWTs recovered in Deep South Puget Sound fisheries (Figures 2a and b). Because there are some ESA-listed stocks in the FRAM stock units for both SPS FF and HC FF, the disparity between FRAM-derived estimates of non-local catch in terminal fisheries and CWT-derived estimates is particularly problematic for fisheries managers. Some management goals are based on FRAM metrics, but changes in fisheries impacts might not be properly captured by these metrics when large terminal fisheries impacts are inaccurate. Also, fisheries managers interested in the conservation and rebuilding of the stocks would like to get the best possible information about how their stocks will be affected by fishing regulations, and FRAM is not providing that in these cases. Co-managers in Puget Sound have repeatedly expressed a desire to have FRAM estimate those impacts more accurately.

In FRAM, catch in each fishery (*f*) during each time step (*t*) is determined for each age (*a* = 2-5) of each stock (*s*) individually using the equation:

$$Catch_{s,a,f,t} = FishScalar_{f,t} * BPER_{s,a,f,t} * Cohort_{s,a,t} * PV_{s,a,f,t} \quad (1)$$

where

$FishScalar_{f,t}$ = the Fishery Scalar, the strength of this year's catch or effort in fishery *f* during time step *t* relative to the catch or effort in the base period,

$BPER_{s,a,f,t}$ = the base period exploitation rate, the number of fish of stock *s* age *a* caught in fishery *f* during time step *t* divided by the number of fish alive and of legal size in fishery *f* from age *a*, stock *s* during time step *t*,

$Cohort_{s,a,t}$ = the number of fish alive of age *a*, stock *s* in time step *t*, or the number of mature fish alive of age *a*, stock *s*, in time step *t* for terminal fisheries, and

$PV_{s,a,f,t}$ = is the proportion vulnerable, which is the proportion of fish of age *a*, stock *s* of legal size to be landed in fishery *f* during time step *t* (see Model Evaluation Workgroup, 2008a and b, for FRAM details.)

It appears that the large catch of SPS FF in Hood Canal and the large catch of HC FF in Deep South Puget Sound result from large base period exploitation rates (BPERs) in FRAM. If the Fishery Scalars (either input directly by the user or calculated from input fishery quotas) were causing the problem, the total catch in the terminal net fisheries would be too large, not just the catch of one portion of the catch. If the cohort sizes were causing the problem, there should also be large disparities between FRAM-estimated catch and reported catch in other terminal fisheries or between modeled and observed escapement. If the PV were causing the problem, there would also be problems in other pre-terminal and terminal fisheries for that stock. An error in the BPERs, however, could account for the problem being limited to just certain stocks in certain fisheries. In many cases for stocks that were present but rare in fisheries in the FRAM base period, there is low statistical confidence in the BPERs but managers were willing to accept the overall model because many of the big impacts for stocks were in fisheries with much greater tag recoveries. It was also believed that non-local impacts would balance out with non-local stocks caught in local terminal fisheries being roughly equivalent to local stocks caught in other terminal fisheries, but this assumption was never thoroughly tested. As stock abundances and fishery strengths have changed over time, the problems with FRAM estimates of non-local impacts have become larger for some stocks. For example, the fisheries managers of the Nisqually Indian Tribe are interested in fixing this error in FRAM-estimated impacts because the over-estimate of terminal fishery impacts in a distant net fishery lessens fishing opportunities for their Tribal fishers. Furthermore, FRAM does not include non-local terminal fishery impacts when expanding pre-season terminal run forecasts out to ocean cohort sizes, which means that terminal run size forecast methods for stocks with large non-local terminal impacts may be incompatible with FRAM.

It is possible to estimate more accurate impacts to the Hood Canal and Nisqually stocks external to FRAM, but that may create problems with evaluating ESA compliance and it means that impacts on other stocks in FRAM would still be in error (in quota fisheries, relative abundances of stocks matter in determining impacts). Thus, it seems preferable to find a method to estimate a more appropriate BPER for Deep South Puget Sound stocks in Hood Canal terminal net fisheries and vice versa, and to replace the current BPERs with the new ones.

Chinook FRAM BPERs are estimated in the base period calibration procedures using cohort analysis, which requires CWT recoveries in escapement and catch for complete brood years. Here, an alternative method is proposed for estimating a BPER for use in FRAM that uses more recent data. It is intended for use solely when large disparities are found between FRAM estimates and CWT-derived estimates of impacts. The method is stock-, age-, fishery- and time step-specific, and can be used for pre-terminal or terminal fisheries. Like the recent fixes that utilized more recent data on the ratio of legal:sub-legal encounters and patched a known problem with modeling size limit changes, using more recent CWT data to better estimate terminal fishery impacts can provide a short-term solution to known issues with FRAM modeling.

The Proposed Method:

The Base Period Exploitation Rate (BPER) is a stock-, age-, fishery- and time step-specific rate describing the proportion of fish alive during that time step in the base period that were landed by a fishery during the base period. In mathematical terms,

$$BPER_{s,a,f,t} = \frac{Catch_{s,a,f,t}}{Cohort_{s,a,t} * PV_{s,a,f,t,}} \qquad (2)$$

To improve a FRAM BPER that has been identified as problematic, stock-, age- and time step-specific estimates are needed of landed catch by fishery and of cohort size. Coded wire tag recoveries are currently the standard for deriving stock- and age-specific information about fishery impacts, with tagged fish used as an indicator for untagged fish. The sampling program in place for CWTs provides estimates of landed catch of tagged fish, but complete brood years are required to use CWT recoveries to estimate cohort sizes. There is not any other sampling program in place to provide estimates of cohort size, either. Here, the CWT landed catch estimate is used to estimate the numerator of the BPER, and the denominator is borrowed from FRAM. The denominator is less likely to be the problematic part of the BPER estimate anyway, since an error in cohort size would create problems in all terminal fisheries, not just one or two.

Since we want to use data from years other than the base period, the actual quantity that will be determined by the CWT recovery data is:

$$FishScalar_{f,t} * BPER_{s,a,f,t} = \frac{Catch_{s,a,f,t}}{Cohort_{s,a,t} * PV_{s,a,f,t,}} \qquad (3)$$

While catch is straightforward to estimate from CWT recoveries, CWT recoveries represent *tagged* fish and the FRAM stock of interest is *marked* (adipose fin-clipped) fish. The main novelty of this method is to use CWT-derived estimates of catch and release information for all tagged fish and all marked fish to come up with a FRAM-compatible substitute for the numerator in equation (3).

The following description of the method is for a single marked FRAM stock, Stock S, caught in a single FRAM fishery, Fishery F, during a single time step, Time Step T. The method can easily be adapted to more fisheries or time steps. In this description, "marked" is used in the sense it is used in FRAM and refers only to adipose fin-clipped fish.

(1) First, all CWT recoveries for components of Stock S in the region of Fishery F should be downloaded from the Regional Mark Information System (RMIS, database access provided at www.rmpc.org). The time span must be specified for the CWT recoveries, and will need to balance the desire for recent data with the scarcity of CWT recoveries of non-local stocks. These recoveries should then be sorted by fishery type and by time step, and the recoveries from Fishery F in Time Step T selected for further analysis. If data from certain years is going to be discarded due to insufficient sampling or tag recoveries within the fishery, that should be done at this point.

The release information for the tag codes for all CWT recoveries selected for further analysis should then be downloaded from RMIS, and the information used to separate recoveries by separated by mark status, age, and release stage (fingerling, yearling, etc.) Only fish from the release stage of Stock S should be retained (fingerlings and yearlings are separate stocks in FRAM). Only tag codes for marked and coded wire tagged fish should be used for further analysis. If BPERs for only certain ages of fish are being evaluated, unneeded ages can be discarded.

(2) The estimated number of CWT recoveries of Stock S fish in Fishery F during Time Step T should then be summed by age and year of recovery. For each year of analysis, there will be a sum of estimated recoveries of tagged fish by age.

(3) Next, the records of all marked releases for Stock S for the brood years represented in the coded wire tags in step 2 should be downloaded from RMIS. For each brood year, the number of coded wire tagged and marked fish should be summed, and the number of marked fish (tagged or untagged) should be summed. The former result (CWT & Mark) should be divided by the latter result (Mark) to get a proportion of the marked fish that had CWTs.

(4) Each estimate of the total tagged catch by year and age from step 2 should be divided by the final result for the appropriate brood year from step 3 (the proportion of tagged and marked releases to marked releases) to give an estimate of the marked fish of Stock S by age caught in Fishery F during Time Step T. This expands the estimate of CWT catch to an estimate of marked catch, which is what is used in FRAM.

(5) To estimate a new BPER using this estimate of marked catch, the estimate of marked catch is used as the numerator and the appropriate cohort size can be taken from the FRAM PopStat report for the appropriate stock, age, time step and maturation status. Cohort sizes can be taken from either pre- or post-season runs, depending on the goals of the analysis and availability (post-season runs may not be available for recent years).

(6) The result of step 5 is the equivalent of the Fishery Scalar * BPER from FRAM as shown in equation 3, so it must be divided by either a FisheryScalar or by an average of recent FisheryScalars to give a BPER replacement value. Again, the goals of the analysis must be considered in choosing whether to use one FisheryScalar or an average of FisheryScalars, the time period over which to average values, and whether to use pre- or -post-season FisheryScalars. The BPER derived from this method for the marked stock should then be inserted into the base period file for both the marked and unmarked portions of Stock S.

Testing the method:

An example was carried out using the catch of marked South Puget Sound Fall Fingerlings (FRAM stock 22) in Hood Canal terminal net fisheries (FRAM fisheries 65 and 66) in Time Step 3, July-September, when fish mature and terminal fisheries are executed (see Appendix 1). The methods given above were followed, using recoveries from 2003-2012. Using the last 10 years for which sampling was complete was an attempt to limit the analysis to recent recoveries while still capturing relatively rare events. The denominator of the estimated exploitation rate for each year was determined using the post-season cohort number for available years at the time of analysis (2003-2010) and the pre-season cohort number from the other years (2011, 2012). The CWT-derived exploitation rate was split between Treaty and non-Treaty fisheries based on the averages of the past 3 years, then converted to a BPER by dividing by the fishery scalars for the most recent three years of final PFMC pre-season models (2012 to 2014).

A similar analysis was carried out for marked Hood Canal Fall Fingerlings (FRAM stock 32) in South Puget Sound terminal net fisheries (FRAM fisheries 68-71) (Appendix 2).

The results for both stocks and the terminal net fisheries were then used to create a new base periods for the runs from 2012-2014, and the pre-season runs for 2012-2014 were performed using the unaltered and altered base periods. The impacts of the BPER changes on the metrics used for ESA decision-making are summarized in Table 1 (exploitation rates) and Table 2 (escapements). Because the impacts are only in terminal fisheries, only stocks that co-occur in those terminal net fisheries showed changes in exploitation rates (ERs) are output of FRAM, unlike the BPERs, and reflect the AEQ (adult equivalence) total fishing mortality for a stock over that total fishing mortality plus escapement. The biggest changes in ER were seen for Hood Canal and South Puget Sound stocks, with small (<0.04%) changes in ER for all other stocks. Catch of the two stocks was much smaller in the non-local marine terminal net fisheries (Figures 3 and 4), as expected, but with only small changes seen in the escapements (Table 2) those fish were caught mostly in local terminal fisheries. In the terminal net fisheries in both locations, the "lost" non-local catch is primarily made up by the local mature run, with tiny increases in the contribution of other non-local stocks. This resembles the catch composition seen in CWT recoveries.

Conclusion:

This methodology seeks to use the best available data of landed catch by stock and age to improve estimates of catch in Chinook FRAM. It is not the goal of this methodological description to provide guidelines on what FRAM estimates should be considered problematic and thus candidates for the method, but to provide a tool that can be used when managers deem it necessary to do so.

This method is meant to be a temporary fix between model calibrations. It does not account for the interactions between stocks or for coded wire tag recoveries not representing all stocks in a fishery at a given time, as a full calibration does. The method assumes that the error in the BPER comes only from the numerator (the catch), even though the methods for deriving cohort estimates from cohort analysis result in large confidence intervals. However, there is no sampling program that provides good cohort size estimates at this time, especially on the time-scale most managers will want to use. It is also difficult to capture very recent trends with this method when CWT recoveries are rare, since often 10 or more years might be needed to even detect presence of a stock in a fishery. Despite these potential drawbacks, this method provides a transparent means of temporarily fixing biases or inaccuracies that hopefully results in better FRAM metrics for management.

Works Cited.

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Model Evaluation Workgroup (MEW). 2008b. Fisheries Regulation Assessment Model (FRAM) Technical Documentation for Coho and Chinook v. 2.0. (Document Prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Table 1. Change in exploitation rates (ER) for ESA-listed stocks (New BPER FRAM Run - Original BPER FRAM Run), from the TAMM ER_ESC_Overview Spreadsheets, for the pre-season FRAM runs of 2012-2014. Total ER reflects all FRAM and TAMM fishing during the management year. SUS ER, or Southern U.S. ER, reflects all FRAM and TAMM fishing by the U.S., excluding Alaska. SUS PTER is the Southern U.S. ER for only pre-terminal fisheries. Results for stocks with changes to BPERs are shown in bold.

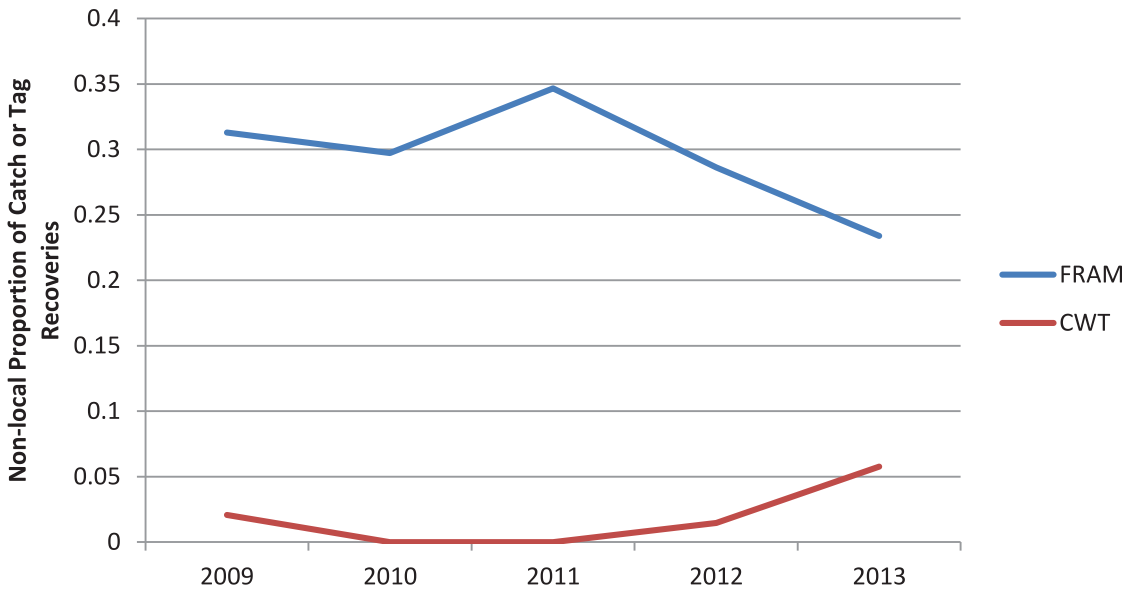
Stock	Total ER			SUS ER			SUS PTER		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Spring/Early:									
Nooksack (n) - Total	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Skagit (n) - Total	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dungeness	0.0%	-0.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Summer/Fall:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Skagit - Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Stillaguamish (n) - Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Snohomish (n) - Total	0.0%	0.3%	0.0%	0.0%	0.4%	0.0%	0.0%	0.4%	0.0%
Lake Wa. (Cedar R.)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Green	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Puyallup	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Nisqually	**-0.7%**	**-1.2%**	**-1.1%**	**-0.7%**	**-1.1%**	**-1.1%**	**-1.0%**	**-1.6%**	**-1.5%**
Western Strait-Hoko	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Elwha	0.0%	-0.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Mid-Hood Canal tribs. (n)	**-0.2%**	**-0.2%**	**-0.2%**	**-0.2%**	**-0.1%**	**-0.2%**	**-0.2%**	**-0.2%**	**-0.2%**
Skokomish	**1.0%**	**0.9%**	**0.6%**	**1.0%**	**1.0%**	**0.6%**	**-0.2%**	**-0.2%**	**-0.2%**

Table 2. Change in escapement for ESA-listed stocks (New BPER FRAM Run - Original BPER FRAM Run), from the TAMM ER_ESC_Overview Spreadsheets, for the pre-season FRAM runs of 2012-2014. Results for stocks with changes to BPERs are shown in bold.

Stock	2012	2013	2014
Spring/Early:			
Nooksack (n) - Total	0	0	0
North Fork	0	0	0
South Fork	0	0	0
Skagit (n) - Total	0	0	0
Upper Sauk	0	0	0
Upper Cascade	0	0	0
Suiattle	0	0	0
White	0	0	0
Dungeness	-1	0	0
Summer/Fall:	0	0	0
Skagit - Total	0	0	0
Upper Skagit	0	0	0
Sauk	0	0	0
Lower Skagit	0	0	0
Stillaguamish (n) - Total	0	0	0
North Fork Summer	0	0	0
South Fork Fall	0	0	0
Snohomish (n) - Total	0	0	0
Skykomish	0	0	0
Snoqualmie	0	0	0
Lake Wa. (Cedar R.)	0	0	0
Green	0	0	0
Puyallup	0	0	0
Nisqually	**16**	**23**	**86**
Western Strait-Hoko	0	0	0
Elwha	-2	-1	-2
Mid-Hood Canal tribs. (n)	**1**	**1**	**2**
Skokomish	**-34**	**-28**	**-15**

Figure 1: (a) The proportion of total FRAM catch that is non-local and the proportion of CWTs recovered that are non-local in Hood Canal marine terminal net fisheries from 2009 to 2013. FRAM predicts that >90% of non-local catch is from South Puget Sound. (b) Total number of fish in the landed catch of Hood Canal Terminal Net Fisheries from the FRAM Fishery Mortality Report.

a.



b.

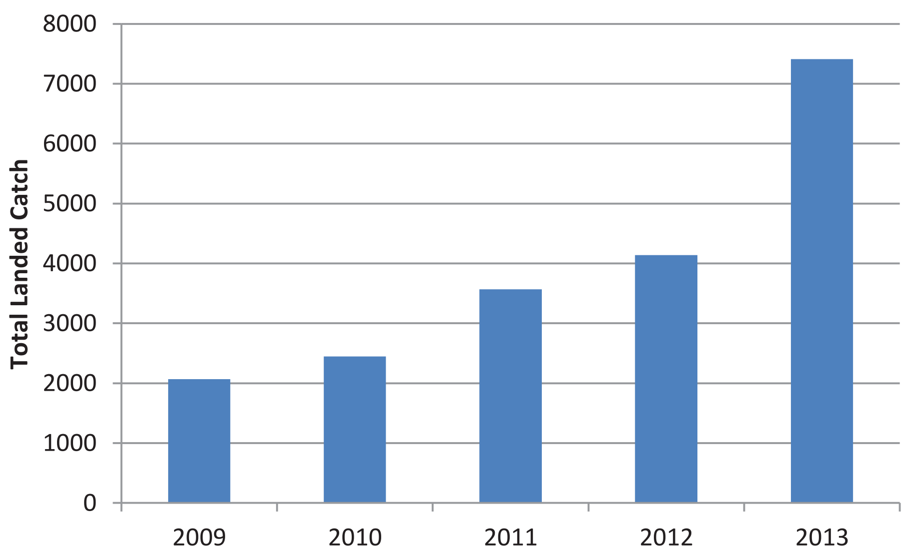
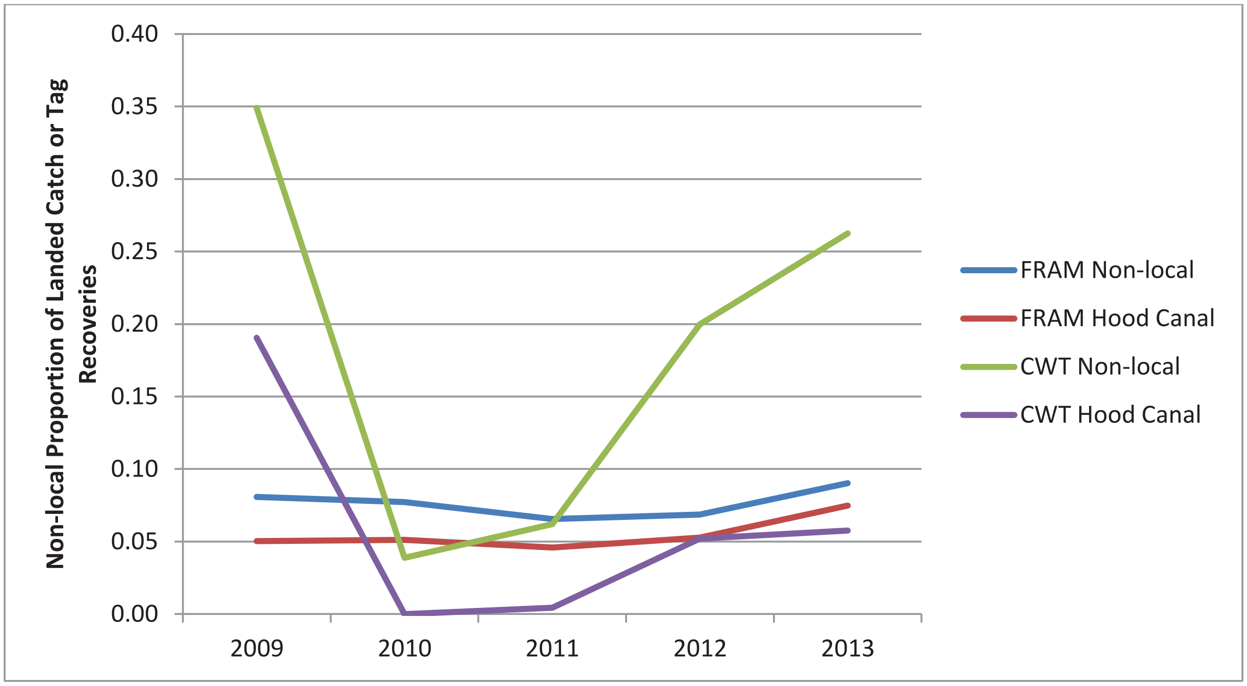


Figure 2: (a) The proportion of total FRAM catch that is non-local and from Hood Canal and the proportion of CWTs recovered that are non-local and from Hood Canal in South Puget Sound marine terminal net fisheries from 2009 to 2013. (b) Total number of fish in the landed catch of Hood Canal Terminal Net Fisheries from the FRAM Fishery Mortality Report.

a.



b.

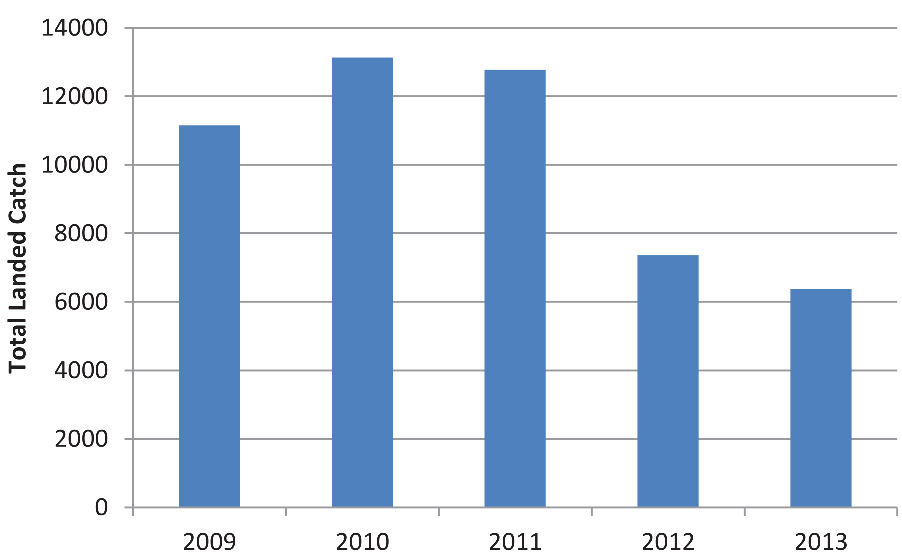


Figure 3: A comparison of AEQ Total Fishery Mortality for South Puget Sound Fall Fingerlings (SPS FF) in Hood Canal terminal marine net fisheries in the original FRAM pre-season runs and in the runs with new BPERs.

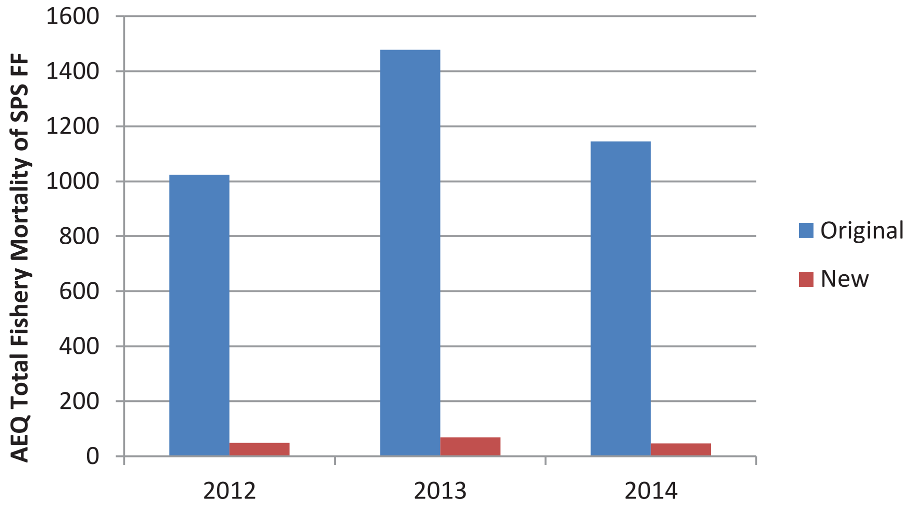
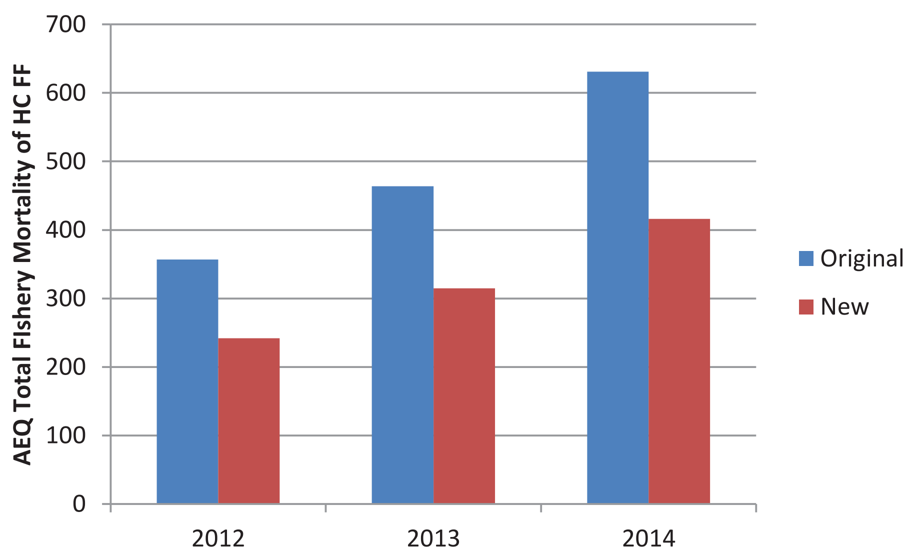


Figure 4: A comparison of AEQ Total Fishery Mortality for Hood Canal Fall Fingerlings (HC FF) in the South Puget Sound terminal marine net fisheries in the original FRAM pre-season runs and in the runs with new BPERs.



An evaluation of the effectiveness of the Cape Flattery Control Zone closure at reducing non-treaty troll fishery impacts on Puget Sound Chinook

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October 6, 2014

Background and Key Questions

In response to the declining status of Puget Sound Chinook salmon, the State of Washington closed nearly half of Marine Area 4 (MA4) to the non-treaty troll fleet prior to the 1999 fishing season. The closure area, hereafter referred to as the Cape Flattery Control Zone (CFCZ; Figure 1), was implemented without an empirical assessment of the conservation benefits of the proposed fishery restrictions, but instead based on general knowledge of Puget Sound Chinook's ocean distribution. The CFCZ restriction has now been applied to non-treaty (NT) trollers for more than 15 years (1999-2014); the Treaty Indian (TI) troll fleet has had unrestricted access to the CFCZ during this same period. Given that MA4 TI and NT Chinook troll fishery catches are sampled for coded-wire tags at a relatively high rate, this combination of circumstances presents a unique opportunity to evaluate the effectiveness of a sizeable area closure relative to its original intent. Accordingly, here we report on an analysis that aims to address two key questions: (1) did the closure of the CFCZ to the non-treaty troll fleet in 1999 result in a measurable reduction in fishery impacts for Puget Sound Chinook? (2) If the answer to (1) is yes, what magnitude of reduction should be incorporated into the Chinook Fishery Regulation Assessment Model (FRAM) to more accurately capture this fishing pattern in ongoing and future modeling activities?

Evaluation Framework

The effect of the CFCZ was evaluated based on patterns of coded-wire tag (CWT) recoveries in the MA4 troll fishery for three large and consistently tagged Puget Sound fall fingerling production groups using a simple before–after comparison approach, which proceeded in four steps. Firstly (Test 1), we compared the exploitation rates (ER; normalized to catch) of CWT stocks between before vs. after periods for the NT troll fleet alone. We then repeated the same analysis for the TI troll fishery alone (Test 2), to verify our treatment of it as an 'experimental control' (i.e., it was never excluded from the CFCZ). Thirdly (Test 3), we evaluated pre–post CWT recovery patterns for the NT troll fishery relative to those for the TI fleet. It is important to note that although the Treaty (57 cm FL) and Non-treaty (67 cm FL) troll fisheries have operated and continue to operate under different minimum size limits, they have remained consistent during the period under consideration here. Lastly, given results from tests 1-3, we estimated an impact savings for incorporation into fishery modeling based on the FRAM vs. CWT differential in projected impacts for the CFCZ-affected model fishery during the post-closure era.

Data Overview

Data Sources: This analysis was conducted using CWT data assembled by the Pacific Salmon Commission Chinook Technical Committee (CTC) for use in their annual (2014) exploitation rate analysis (i.e., the CTC Cohort Analysis System [CAS] database). Specifically, we used the tag data contained in the CAS database to compute total estimated recoveries per 10K landed Chinook (described below under 'Analysis Approach') as well as 'fishing year ERs' generated through the CTC's annual cohort analysis (Appendix C in CTC *In Prep.*). The fishery catches used in our analyses were assembled from Appendix A of PFMC (2014).

Stocks: In this analysis, we considered three of the CTC's hatchery CWT indicator stocks that are closely aligned with the natural-origin Hood Canal, Mid- and South Puget Sound fall fingerling type Chinook salmon expected to benefit from the CFCZ closure (i.e., the 'Green River derivatives'): (1) George Adams

Hatchery (GAD) in the Skokomish Basin of Hood Canal, (2) Nisqually Hatchery (NIS) in the Nisqually Basin of 'Deep South' Puget Sound, and (3) Mid-Puget Sound[1] (MPS; a CWT aggregate comprising Soos Creek [majority of CWT codes/releases], Issaquah, and Grovers hatcheries). These stocks correspond to FRAM's Hood Canal, Deep South Puget Sound, and Mid-Puget Sound fall fingerling model stocks, respectively. Other Puget Sound Chinook CWT indicator stocks were considered but were not included due to their limited presence in MA4 troll fishery catches (Skagit spring, summer/fall; Skykomish; Stillaguamish; Nooksack spring) or lack of affiliation to a natural stock (Samish fall).

Fishing Years: Data for fishing years 1984 to 2012 (up to 15 before years, 14 after years) were considered for inclusion in our analysis, with the lower limit set by the first year in which treaty and non-treaty CWT recoveries were consistently distinguished in the coastwide Regional Mark Information System database (by gear code) and the upper limit set by the last year included in the 2014 CTC cohort reconstruction for the stocks in question. The 1984-2012 data series was additionally filtered to remove years in which (1) the fishery was either completely closed or quotas were tightly restricted (before period: 1989, 1994-1996; after period: 2007-2008) and/or (2) CWT sampling was insufficient for conducting a reliable tag-based analysis (before period: 1984-1985, 1997; after period: 2011; Table 1). Filter criteria for CWT data adequacy were defined as a fishery sample rate of at least 20% and at least 20 observed tags (across all stocks) recovered from the fishery (PSC CWT Workgroup 2008). This yielded a total of up to 19 fishing years for use in comparisons (n = 8 before-closure, n = 11 after-closure) involving NT troll data, with additional exclusions determined programmatically by the CTC's fishing year ER calculation criteria (minimum of 3 tagged broods, ages 2-5, present in a calendar year). Due to the larger size of the TI troll fishery, Test 2 (TI-only pre- vs. post-CFCZ) included up to 27 years based on the same filter criteria.

Analysis Approach

Response Variables.—We computed two different response variables for each of the three CWT indicator stocks, one which relies on a full CWT cohort reconstruction (*Fishing Year ER*) and another which simply provides an index on the relative effectiveness of the CFCZ (*NT vs. TI CWT Recovery Differential*): (1) *Fishing Year ER*: We estimated this variable using data contained within the CTC's distribution tables as proxy. Fishing Year ER was computed as adult equivalent (AEQ) total mortality (landed and non-landed) for CWTed fish arising due to the NT or TI Area 4 troll fishery, divided by total AEQ mortality (i.e., across all fisheries plus escapement), within a fishing year for all ages/broods present. Although CWT-based exploitation rates are typically expressed in brood year terms, this metric is a suitable CWT analog to FRAM's fishing year ER. Also, we normalized ERs to landed catch given that changes in ER may have arisen due to either the implementation of the CFCZ or changes in catch. Thus, we divided annual ERs for the TI MA4 and NT MA4 fisheries by catch and additionally multiplied this catch-normalized ER index by 1M for presentation purposes (i.e., it is a very small number otherwise). (2) *NT vs. TI CWT Recovery Differential*: We computed the number of CWT recoveries per 10K fish landed for both NT and TI fleets, and then the within-year difference between fleets. These metrics were computed on a stock-specific (i.e., GAD, NIS, MPS) basis. See Appendix A for a complete table of the data used in the analysis.

Statistical Analysis Methods.—We tested for changes in response variables resulting from the implementation of the CFCZ using a before–after comparison approach using a mixed-effects modelling approach. Specifically, we modeled each response variable as a function of a fixed CFCZ effect (i.e.,

[1] To maintain consistency with FRAM, we refer to this group as Mid-Puget Sound (MPS) even though it is referred to as 'South Puget Sound' (SPS) by the CTC.

before/after implementation), the factor of primary interest, and included stock and year variables as random blocking effects. We subsequently assessed the significance of the CFCZ effect in each model using likelihood ratio tests computed relative to reduced models fitted with the same random structure but not the CFCZ effect. We analyzed the data in this way for two primary reasons. Firstly, we were mainly interested in evaluating the general effect of the CFCZ on the Puget Sound fall fingerling aggregate. In this vein, the levels of 'stock' and 'year' included in our analysis constitute a subset of the broader data universe of interest, but also possess within-group similarities (i.e., non-independence) that must be accounted for analytically. Secondarily, the maximum likelihood-based mixed-effects modeling framework is generally regarded as being more robust to 'treatment' imbalance issues, like those inherent to our dataset, relative to traditional before–after ANOVA comparison approaches (i.e., based on sums of squares). Lastly, it should be noted that although there is potential for serial correlation in time series data, we were unable to account for it in our analysis due to the presence of missing years in our data set.

Analysis Findings and Discussion

Test 1. NT troll Chinook catches varied widely during both pre- (*ca*. 7K mean) and post-CFCZ assessment periods (*ca*. 9K mean) and have not trended in any particular direction through time (Figure 2). Despite this, patterns in catch-standardized fishing year ERs for the NT MA4 troll fishery suggest that there was a CFCZ response consistent with the closure's original intent (Figure 3). While not statistically significant (likelihood ratio test results: $\chi^2 = 2.5$, $P = 0.115$), standardized ERs for the NT troll fishery decreased by 44% on average between the pre- and post-CFCZ period (i.e., based on mixed-effects model parameter estimates; Table 2). Further, the magnitude of decrease varied across the three CWT indicator stocks, as well as across years within individual stocks (Figure 3).

Test 2. In contrast to NT catches, TI troll catches in MA4 have increased progressively from 1984 to 2012 and have more than doubled between the pre- and post-CFCZ periods. Further, consistent with our treatment of the TI troll fishery as a 'control' due to their continued access to the CFCZ, catch-standardized fishing year ERs have remained remarkably stable for the fleet between periods (Figure 4; likelihood ratio test results: $\chi^2 = 0.1$, $P = 0.706$; Table 2).

Test 3. Consistent with the results of tests 1 and 2, which suggest that NT but not TI ERs decreased following the implementation of the CFCZ closure, we observed a shift in the CWT recovery differential for NT and TI fisheries following the implementation of the CFCZ closure (Figure 5; likelihood ratio test results: $\chi^2 = 2.6$, $P = 0.109$; Table 2). In particular, fitted parameter estimates indicate that the recoveries/10K differential shifted from being slightly negative and indistinguishable from zero (i.e., fish for fish, TI and NT fisheries impact Puget Sound Chinook similarly) to a six-fold larger negative number. Thus, given the assumption that the TI is an appropriate control, the impact of the MA4 NT troll fishery on Puget Sound Chinook appears to have been considerably reduced by the CFCZ.

The statistical tests described above provide two lines of evidence indicating that the CFCZ fishery restriction has led to some reduction in NT fleet impacts on Puget Sound fall fingerling Chinook in the MA4 troll fishery. If assessed purely in terms of pre-post differences in impacts for the NT fishery in isolation (i.e., ER comparisons), this decrease may be upwards of 40%. If viewed relative to the TI troll fleet control, the impact reduction resulting from the CFCZ restriction may be even greater. However, neither estimate of the CFCZ effect can be interpreted without qualification. In particular, although *P*-values for both statistical tests were within a neighborhood of probability suggesting that the observed patterns did not arise by chance alone, neither test was statistically significant. Similarly, whereas the CFCZ effect size in both the ER and CWT recovery differential models were of a magnitude of management relevance, neither parameter estimate was particularly precise. Considering this magnitude and uncertainty simultaneously, we believe that efforts to integrate a CFCZ savings into future Chinook FRAM modeling efforts err conservatively in application.

Proposed CFCZ Adjustment for Chinook FRAM Modelling

Given our findings, we compiled data to compute an adjustment factor to account for CFCZ-related reductions in fishery impacts on Puget Sound fall fingerling Chinook in future FRAM modelling activities. We approached the model adjustment derivation using a fairly simplistic approach given a need for a stopgap adjustment while the modern Chinook FRAM base period, which will implicitly include the CFCZ, is completed. In brief, we computed the ratio of model-projected to CWT-estimated marked landed Chinook mortalities (adult equivalent) for the relevant FRAM model fishery[2] using the CWT groups analyzed here and the results from post-CFCZ FRAM validation runs (Table 3). Note also that we restricted calculations to the subset of years within the most recent validation run series (2003-2012, August 2014 draft) that met the same CWT adequacy criteria outlined for NT MA4 analyses above.

This analysis revealed a pattern of deviation between FRAM and CWT projections of marked landed mortalities during the post-CFCZ era that was remarkably consistent with the NT pre- vs. post-CFCZ ER comparison (Test 1) summarized above. Namely, there was considerable variability in the CWT/FRAM ratio across years and stocks, but on average a clear tendency towards reduced impacts relative to a CFCZ-open baseline (in this case FRAM, which projects only pre-CFCZ information). More importantly, if the adjustment factor is estimated on an aggregate basis (i.e., across ages, stocks, and years), the magnitude of deviation between FRAM and CWT projections (CWT/FRAM ratio = 0.56, which corresponds to 44% differential) is identical to the level of reduction estimated in our Test 1 analysis (44%, Table 2). In addition to providing a basis for a model adjustment, this provides a compelling line of corroboratory evidence indicating that the CFCZ closure has lessened the impact of the MA4 troll fishery on Puget Sound Chinook.

An important question remains unanswered—precisely how should this information be integrated into current/future Chinook FRAM modelling efforts, both in terms of magnitude and model operations? Firstly, in light of the uncertainty mentioned above and the original conservation intent of the CFCZ, we recommend using an adjustment that poses little risk of over-correcting for model error. For the same reasons, we also believe that the adjustment should not be estimated on an overly resolved basis but instead in aggregate terms (i.e., compute and apply the same adjustment to the Hood Canal, Deep South Puget Sound, and Mid-Puget Sound FRAM model stocks). With these principles in mind, we propose adopting a 0.75 adjustment (i.e., a 25% reduction) for incorporation into future modeling as a 'Stock-Fishery Exploitation Rate Scalar'. This adjustment is at the conservative end of the distribution of plausible values (Table 2) and is also consistent with the draft value used during the 2014 preseason fishery planning process.

[2] The NT MA4 troll fishery is part of a combined NT MA3 and MA4 model fishery in FRAM. Thus, all CWT and FRAM calculations are based on this fishery aggregation.

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Table 1. Summary of CWT sample data and criteria for including or excluding specific years from the analysis.

Year	NT Obs'd tags	NT Sample Rate	NT MA4 Catch	TI Obs'd tags	TI Sample Rate	TI MA4 Catch	Include In NT?	Basis for NT omission
1984	16	31%	2,329	12	22%	2,081	no	too few tags
1985	0	0%	4,416	16	16%	6,759	no	too few tags (none)
1986	54	35%	4,656	47	26%	5,208	yes	
1987	159	43%	4,838	177	51%	9,480	yes	
1988	335	29%	21,941	102	19%	13,266	yes	
1989	6	25%	282	130	12%	15278	no	low catch, too few tags
1990	233	28%	16,286	240	35%	13,647	yes	
1991	200	32%	15,238	183	32%	16,169	yes	
1992	145	23%	17,076	182	25%	17,305	yes	
1993	106	21%	16,010	338	53%	19,872	yes	
1994	0	NA	0	52	58%	2045	no	low catch
1995	1	NA	3	42	17%	7506	no	low catch
1996	0	NA	0	114	43%	9654	no	low catch
1997	17	20%	3,785	147	52%	11,567	no	too few tags
1998	83	61%	4,160	174	39%	14,050	yes	
1999	195	41%	12,698	641	41%	26,468	yes	
2000	156	59%	7,548	183	52%	6,657	yes	
2001	344	73%	6,253	869	42%	21,236	yes	
2002	413	30%	18,708	519	22%	38,093	yes	
2003	665	35%	30,514	587	25%	34,742	yes	
2004	530	37%	19,084	1512	46%	42,277	yes	
2005	173	24%	11,991	1116	62%	33,815	yes	
2006	134	57%	4,211	507	28%	25,546	yes	
2007	27	69%	554	676	37%	19,585	no	low catch
2008	8	29%	499	556	47%	13,192	no	low catch, too few tags
2009	50	79%	1,201	299	52%	5,146	yes	
2010	235	61%	4,131	692	36%	22,813	yes	
2011	12	6%	2,934	788	39%	28,071	no	low sample rate, too few tags
2012	282	48%	6,102	1657	33%	48,746	yes	

Table 2. Estimates of fitted model parameters (fixed effects) and pre-post shifts from mixed-effects model analysis of CWT response variables.

	Fixed effect parameter estimates				Likelihood Ratio Test	
Response Variable	**Parameter**	**Est.**	**SE**	**t-value**	χ^2	***P***
NT Standard. ER	Pre CFCZ value (intercept)	0.867	0.220	3.94	2.5	0.115
	CFCZ effect	-0.383	0.238	-1.61		
	Post CFCZ value	0.485				
	% change	-44%				
TI Standard. ER	Pre CFCZ value (intercept)	0.959	0.155	6.17	0.1	0.706
	CFCZ effect	0.077	0.213	0.36		
	Post CFCZ value	1.036				
	% change	8%				
NT-TI Recs/10K	Pre CFCZ value (intercept)	-1.732	4.538	-0.38	2.6	0.109
	CFCZ effect	-8.635	5.464	-1.58		
	Post CFCZ value	-10.367				
	% change	499%				

Table 3. FRAM projections and CWT estimates (i.e., total estimated marked CWT recoveries / % of marked production that is CWTed) of adult-equivalent marked (i.e., adipose-clipped) landed mortality of age 3-5 Chinook salmon in the combined Marine Areas 3 and 4 model fishery. Note, grayed columns are years excluded from analyses based CWT filter criteria.

FRAM-projected Marked Landed Mortalities												
Stock	**Age**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**
George Adams	3	4	7	20	12	--	--	--	72	--	896	168
	4	15	7	9	11	--	--	--	41	--	136	36
	5	0	0	0	0	--	--	--	0	--	0	0
Nisqually	3	0	0	0	0	--	--	--	0	--	0	0
	4	418	179	308	355	--	--	--	144	--	398	300
	5	0	0	0	0	--	--	--	0	--	0	0
Mid-Puget Sound	3	29	25	57	90	--	--	--	19	--	175	66
	4	101	62	75	129	--	--	--	44	--	80	82
	5	23	11	19	37	--	--	--	5	--	27	20
CWT-expanded Marked Landed Mortalities												
Stock	**Age**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**
George Adams	3	0	5	0	1	--	--	--	11	--	123	23
	4	12	12	8	12	--	--	--	0	--	73	20
	5	0	0	6	0	--	--	--	0	--	0	1
Nisqually	3	0	26	0	117	--	--	--	47	--	102	49
	4	460	322	47	78	--	--	--	118	--	128	192
	5	0	24	35	0	--	--	--	0	--	0	10
Mid-Puget Sound	3	0	0	0	23	--	--	--	17	--	0	7
	4	200	56	20	74	--	--	--	51	--	30	72
	5	7	0	0	0	--	--	--	0	--	0	1
Ratio CWT/FRAM Marked Landed Mortalities												
Stock	**Age**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**
George Adams	3	0.00	0.67	0.00	0.08	--	--	--	0.15	--	0.14	0.17
	4	0.83	1.57	0.94	1.12	--	--	--	0.00	--	0.54	0.83
	5	--	--	--	--	--	--	--	--	--	--	--
Nisqually	3	--	--	--	--	--	--	--	--	--	--	--
	4	1.10	1.79	0.15	0.22	--	--	--	0.82	--	0.32	0.73
	5	--	--	--	--	--	--	--	--	--	--	--
Mid-Puget Sound	3	0.00	0.00	0.00	0.25	--	--	--	0.92	--	0.00	0.10
	4	1.98	0.91	0.26	0.58	--	--	--	1.16	--	0.38	0.88
	5	0.29	0.00	0.00	0.00	--	--	--	0.00	--	0.00	0.05
											Ratio of Means (R):	0.56
											Approx. 95% CI of R:	0.25-0.86

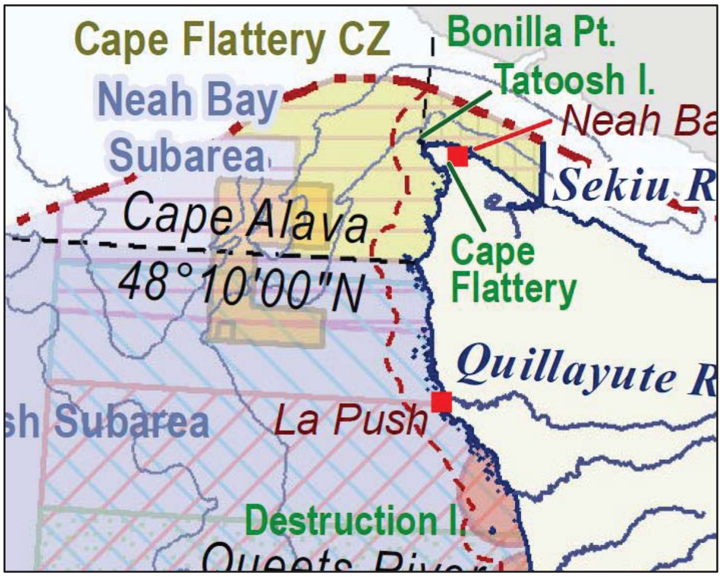

Figure 1. Map of the Cape Flattery Control Zone, denoted by the mushroom-shaped yellow shaded area.

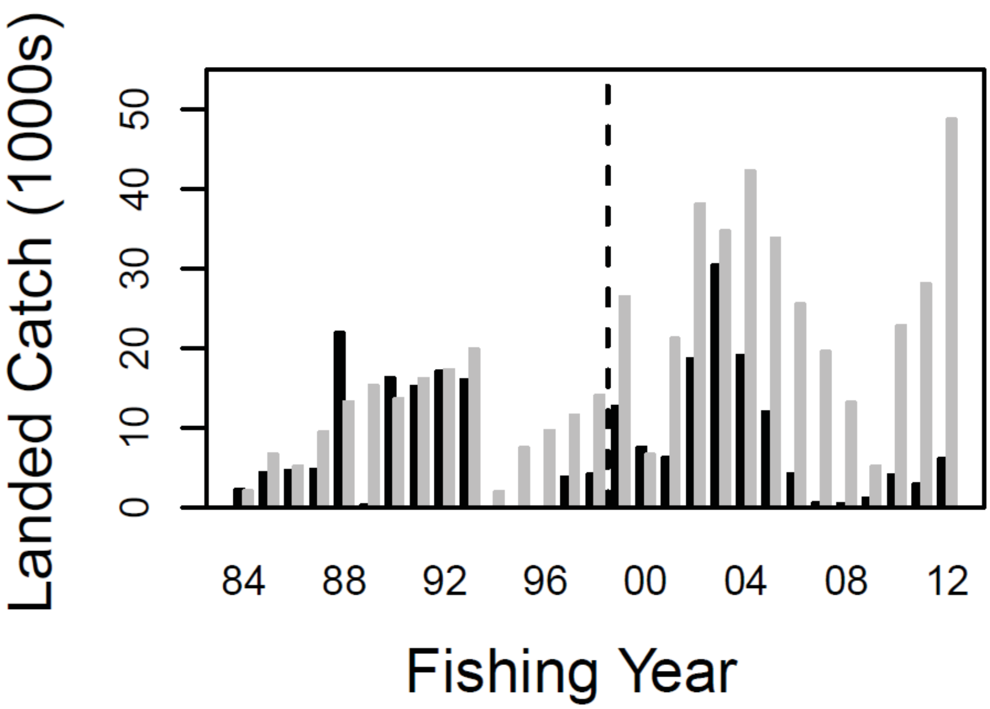

Figure 2. Non-treaty (black bars) and treaty (gray bars) Chinook catch (in thousands of fish) in the Area 4 troll fishery, 1984-2012. Note, the dashed vertical line denotes the break between the pre- and post-CFCZ restriction for the NT troll fleet.

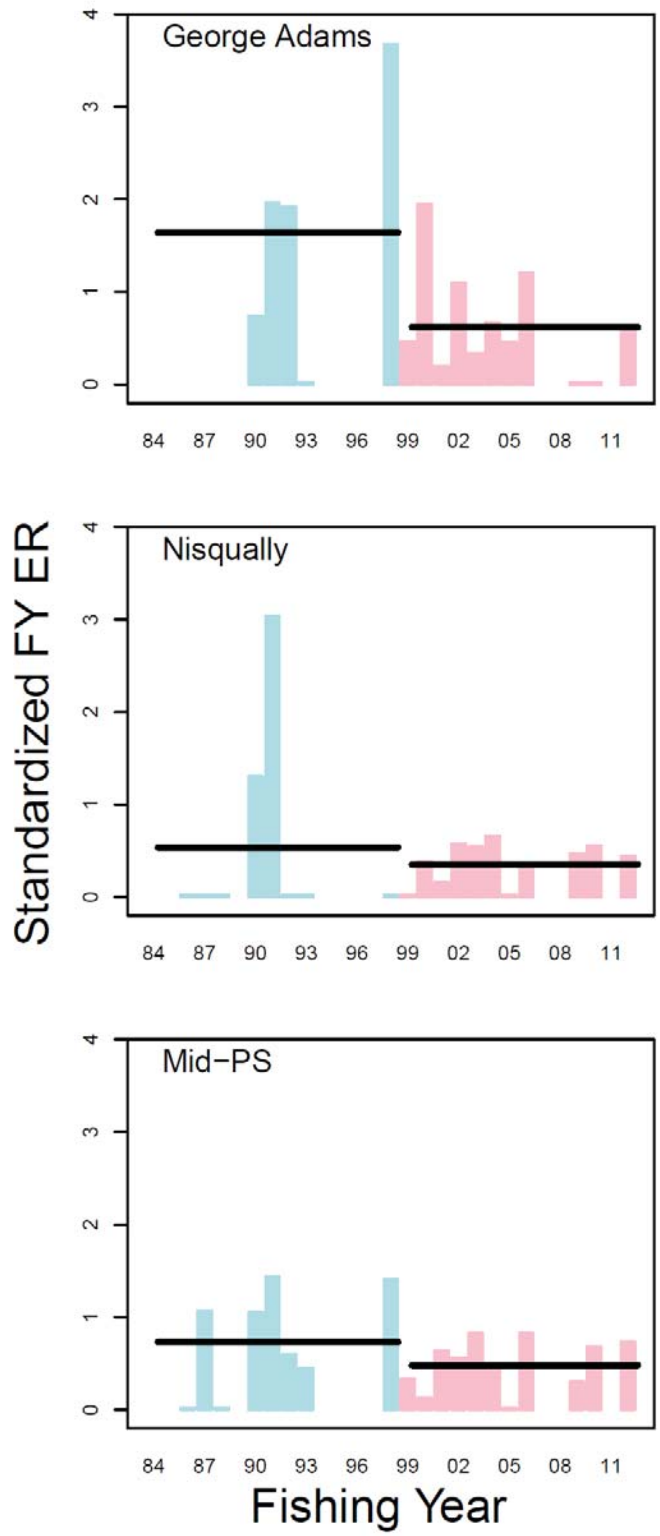

Figure 3. Fishing year exploitation rates (FY ER), standardized to Chinook catch, for the George Adams (Hood Canal), Nisqually, and Mid-Puget Sound (Mid-PS) CWT indicator stocks in the Area 4 Non-Treaty troll fishery, 1984-2012. Note, light blue bars denote the pre-CFCZ period whereas pink bars denote post-CFCZ years. The solid horizontal lines correspond to mean values during pre- and post-CFCZ closure periods.

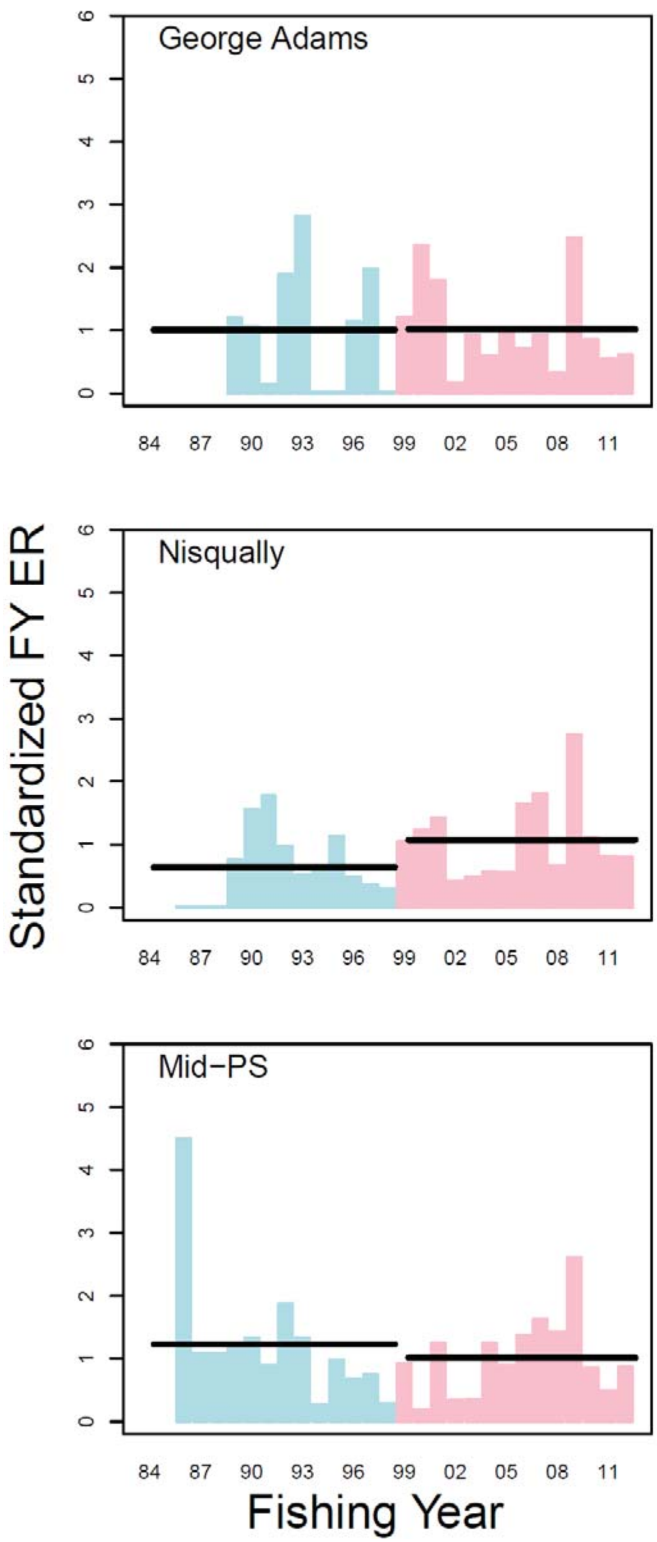

Figure 4. Fishing year exploitation rates (FY ER), standardized to Chinook catch, for the George Adams (Hood Canal), Nisqually, and Mid-Puget Sound (Mid-PS) CWT indicator stocks in the Area 4 Treaty Indian troll fishery, 1984-2012. Although the CFCZ restriction does not apply to the TI troll fleet, pre- and post-CFCZ periods are denoted by bar coloring (see Figure 3); the solid horizontal lines correspond to mean values during pre- and post-CFCZ closure periods.

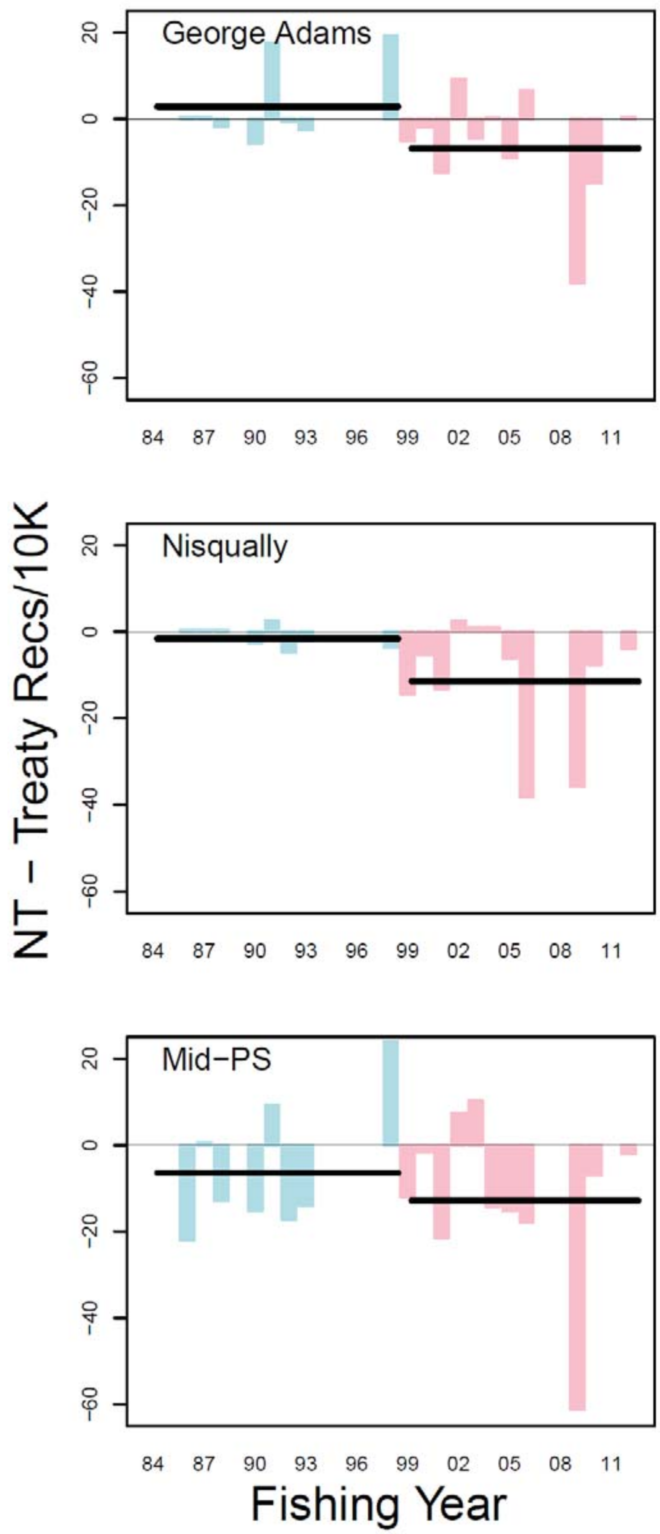

Figure 5. The differential (NT-TI MA4 troll fisheries) in recoveries of CWTs for every 10,000 landed Chinook, for the George Adams (Hood Canal), Nisqually, and Mid-Puget Sound (Mid-PS) CWT indicator stocks in Marine Area 4, 1984-2012. Note, light blue bars denote the pre-CFCZ period whereas pink bars denote post-CFCZ years. The solid horizontal lines correspond to mean values during pre- and post-CFCZ closure periods.

Appendix A. Data table used in CFCZ statistical tests. FY = Fishing Year; CFCZ = before (B) or after (A) Cape Flattery Control Zone closure; ER = fishing year ER; StdER = fishing year ER / landed catch in the fishery x 1M; Recs/10K = total estimated recoveries for the CWT indicator stock per 10,000 fish landed; NT-TI Rec Diff. = the differential between NT and TI in Rec/10K. Note, '--' denotes years excluded from analysis for a particular variable due to either CWT screening criteria (ER, Std ER, Recs/10K) or exclusion from the CTC fishing year ER calculation based on secondary criteria (min 3 BYs present in fishing year; affects ER, StdER).

			Non-treaty (NT)			Treaty Indian (TI)			
FY	**CFCZ?**	**Stock[3]**	**ER**	**Std ER**	**Recs/10K**	**ER**	**Std ER**	**Recs/10K**	**NT-TI Rec Diff.**
1984	B	MPS	--	--	--	--	--	--	--
1985	B	MPS	--	--	--	--	--	--	--
1986	B	MPS	0.00%	0.0000	0.0	2.33%	4.4734	22.4	-22.4
1987	B	MPS	0.51%	1.0439	4.6	1.01%	1.0673	4.4	0.2
1988	B	MPS	0.00%	0.0000	0.0	1.42%	1.0707	13.4	-13.4
1989	B	MPS	--	--	--	1.78%	1.1653	--	--
1990	B	MPS	1.68%	1.0320	56.4	1.80%	1.3175	72.2	-15.7
1991	B	MPS	2.15%	1.4132	24.3	1.42%	0.8770	15.6	8.7
1992	B	MPS	0.99%	0.5773	8.4	3.21%	1.8526	26.1	-17.7
1993	B	MPS	0.68%	0.4249	6.1	2.60%	1.3087	20.6	-14.5
1994	B	MPS	--	--	--	0.05%	0.2562	--	--
1995	B	MPS	--	--	--	0.72%	0.9630	--	--
1996	B	MPS	--	--	--	0.63%	0.6550	--	--
1997	B	MPS	--	--	--	0.84%	0.7270	--	--
1998	B	MPS	0.58%	1.3851	28.1	0.37%	0.2610	4.7	23.4
1999	A	MPS	0.39%	0.3094	5.6	2.40%	0.9074	18.2	-12.6
2000	A	MPS	0.08%	0.1039	2.2	0.12%	0.1767	4.4	-2.2
2001	A	MPS	0.38%	0.6148	24.5	2.62%	1.2333	46.5	-22.0
2002	A	MPS	1.01%	0.5414	17.4	1.20%	0.3162	10.6	6.8
2003	A	MPS	2.45%	0.8025	16.4	1.18%	0.3398	6.6	9.8
2004	A	MPS	0.91%	0.4774	7.7	5.20%	1.2296	22.4	-14.8
2005	A	MPS	0.00%	0.0000	1.5	2.95%	0.8737	17.4	-15.8
2006	A	MPS	0.34%	0.8025	25.4	3.46%	1.3548	43.8	-18.3
2007	A	MPS	--	--	--	3.14%	1.6055	--	--
2008	A	MPS	--	--	--	1.86%	1.4123	--	--
2009	A	MPS	0.03%	0.2775	8.3	1.33%	2.5901	70.0	-61.6
2010	A	MPS	0.27%	0.6589	14.7	1.91%	0.8352	22.2	-7.5
2011	A	MPS	--	--	--	1.33%	0.4752	--	--
2012	A	MPS	0.44%	0.7162	17.9	4.11%	0.8439	20.6	-2.6
1984	B	NIS	--	--	'--	--	--	--	--
1985	B	NIS	--	--	'--	--	--	--	--
1986	B	NIS	0.00%	0.0000	0.0	0.00%	0.0000	0.0	0.0
1987	B	NIS	0.00%	0.0000	0.0	0.00%	0.0000	0.0	0.0
1988	B	NIS	0.00%	0.0000	0.0	0.00%	0.0000	0.0	0.0
1989	B	NIS	--	--	--	1.13%	0.7367	--	--
1990	B	NIS	2.09%	1.2811	16.3	2.09%	1.5288	19.4	-3.1
1991	B	NIS	4.59%	3.0146	6.9	2.84%	1.7545	4.8	2.1
1992	B	NIS	0.00%	0.0000	0.0	1.65%	0.9543	5.3	-5.3
1993	B	NIS	0.00%	0.0000	0.0	0.98%	0.4947	2.7	-2.7
1994	B	NIS	--	--	--	0.13%	0.6346	--	--
1995	B	NIS	--	--	--	0.84%	1.1140	--	--
1996	B	NIS	--	--	--	0.46%	0.4747	--	--
1997	B	NIS	--	--	--	0.40%	0.3435	--	--
1998	B	NIS	0.00%	0.0000	0.0	0.39%	0.2762	4.1	-4.1

[3] Note 'MPS' corresponds to the CTC 'SPS' indicator stock.

FY	CFCZ?	Stock[3]	Non-treaty (NT) ER	Non-treaty (NT) Std ER	Non-treaty (NT) Recs/10K	Treaty Indian (TI) ER	Treaty Indian (TI) Std ER	Treaty Indian (TI) Recs/10K	NT-TI Rec Diff.
1999	A	NIS	0.00%	0.0000	0.0	2.73%	1.0326	14.9	-14.9
2000	A	NIS	0.27%	0.3590	2.2	0.81%	1.2196	8.1	-5.9
2001	A	NIS	0.08%	0.1333	2.1	3.00%	1.4115	15.7	-13.7
2002	A	NIS	1.03%	0.5496	7.6	1.54%	0.4049	5.5	2.1
2003	A	NIS	1.58%	0.5187	7.9	1.64%	0.4719	7.4	0.5
2004	A	NIS	1.21%	0.6353	9.8	2.32%	0.5486	9.2	0.5
2005	A	NIS	0.00%	0.0000	0.0	1.83%	0.5420	6.7	-6.7
2006	A	NIS	0.12%	0.2949	7.9	4.16%	1.6285	46.8	-38.9
2007	A	NIS	--	--	--	3.50%	1.7870	--	--
2008	A	NIS	--	--	--	0.86%	0.6501	--	--
2009	A	NIS	0.05%	0.4493	8.3	1.40%	2.7252	44.6	-36.3
2010	A	NIS	0.22%	0.5350	9.4	2.49%	1.0904	17.6	-8.2
2011	A	NIS	--	--	--	2.24%	0.7995	--	--
2012	A	NIS	0.25%	0.4175	6.2	3.82%	0.7845	10.7	-4.5
1984	B	GAD	--	--	--	--	--	--	--
1985	B	GAD	--	--	--	--	--	--	--
1986	B	GAD	--	--	0.0	--	--	0.0	0.0
1987	B	GAD	--	--	0.0	--	--	0.0	0.0
1988	B	GAD	--	--	0.0	--	--	2.3	-2.3
1989	B	GAD	--	--	--	1.79%	1.1741	--	--
1990	B	GAD	1.16%	0.7131	9.4	1.42%	1.0400	15.7	-6.3
1991	B	GAD	2.95%	1.9375	18.1	0.19%	0.1178	1.0	17.1
1992	B	GAD	3.23%	1.8891	3.3	3.23%	1.8641	4.5	-1.2
1993	B	GAD	0.00%	0.0000	0.0	5.56%	2.7957	3.2	-3.2
1994	B	GAD	--	--	--	0.00%	0.0000	--	--
1995	B	GAD	--	--	--	0.00%	0.0000	--	--
1996	B	GAD	--	--	--	1.08%	1.1198	--	--
1997	B	GAD	--	--	--	2.26%	1.9550	--	--
1998	B	GAD	1.52%	3.6483	18.8	0.00%	0.0000	0.0	18.8
1999	A	GAD	0.56%	0.4414	3.7	3.14%	1.1846	9.4	-5.7
2000	A	GAD	1.45%	1.9241	16.4	1.56%	2.3374	19.0	-2.6
2001	A	GAD	0.11%	0.1767	1.7	3.76%	1.7691	14.6	-12.9
2002	A	GAD	2.00%	1.0701	10.3	0.57%	0.1502	1.6	8.7
2003	A	GAD	0.95%	0.3112	2.7	3.13%	0.9021	7.9	-5.2
2004	A	GAD	1.23%	0.6438	7.6	2.46%	0.5816	7.8	-0.2
2005	A	GAD	0.51%	0.4282	5.7	3.42%	1.0128	15.3	-9.5
2006	A	GAD	0.50%	1.1844	13.7	1.75%	0.6833	7.6	6.0
2007	A	GAD	--	--	--	1.78%	0.9113	--	--
2008	A	GAD	--	--	--	0.40%	0.3042	--	--
2009	A	GAD	0.00%	0.0000	0.0	1.26%	2.4510	38.5	-38.5
2010	A	GAD	0.00%	0.0000	0.0	1.90%	0.8341	15.3	-15.3
2011	A	GAD	--	--	--	1.46%	0.5218	--	--
2012	A	GAD	0.37%	0.6132	16.8	2.87%	0.5887	16.7	0.1

Agenda Item F.2.a
Attachment 6
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Conservation Objective for Southern Oregon Coastal Chinook

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Oregon Department of Fish and Wildlife

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Introduction

The current conservation objective for Southern Oregon coastal Chinook (SOCC) in the Pacific Coast Salmon Fishery Management Plan was based on information and reports that are now outdated. SOCC stocks are included as an unspecified portion of an aggregate Oregon coast natural adult spawner goal of 60-90 spawners per mile. As a result of the Amendment 16 process SOCC were classified as a component stock of the Southern Oregon Northern California complex regulated by Annual Catch Limits that use Klamath River fall Chinook as the indicator stock. Oregon Department of Fish and Wildlife (ODFW) recently completed the *Conservation Plan for Fall Chinook Salmon in the Rogue Species Management Unit* (Rogue Plan) and it was adopted by the Oregon Fish and Wildlife Commission in January, 2013 (ODFW 2013). The Rogue Plan covers the geographic area and fall Chinook stocks that are defined as SOCC.

Analyses used in developing the Rogue Plan are described in detail in the plan itself and its appendices, which may be found at:

http://www.dfw.state.or.us/fish/CRP/rogue_fall_chinook_conservation_plan.asp

and

http://dfw.state.or.us/fish/CRP/docs/rogue_fall_chinook/Rogue_fall Chinook_Plan_Final_Appendixes_1-11-13.pdf

Development of new conservation objectives may be implemented without plan amendment upon approval by the Council. The Rogue Plan provides new information and data analyses for use in updating the current conservation objective for SOCC.

Methods and Results

Spawner and Freshwater Escapement Estimates For Rogue River Basin Fall Chinook

There are five populations of fall Chinook present in the Rogue River Basin. The populations are generally defined as Upper Rogue, Middle Rogue, Lower Rogue, Applegate, and Illinois. Availability of adult fall Chinook abundance data within these populations varies markedly. An overview of the sources of available data follows. Only those data sets which covered at least five consecutive years are described. Also described is the relevance of the data to the development of this conservation plan.

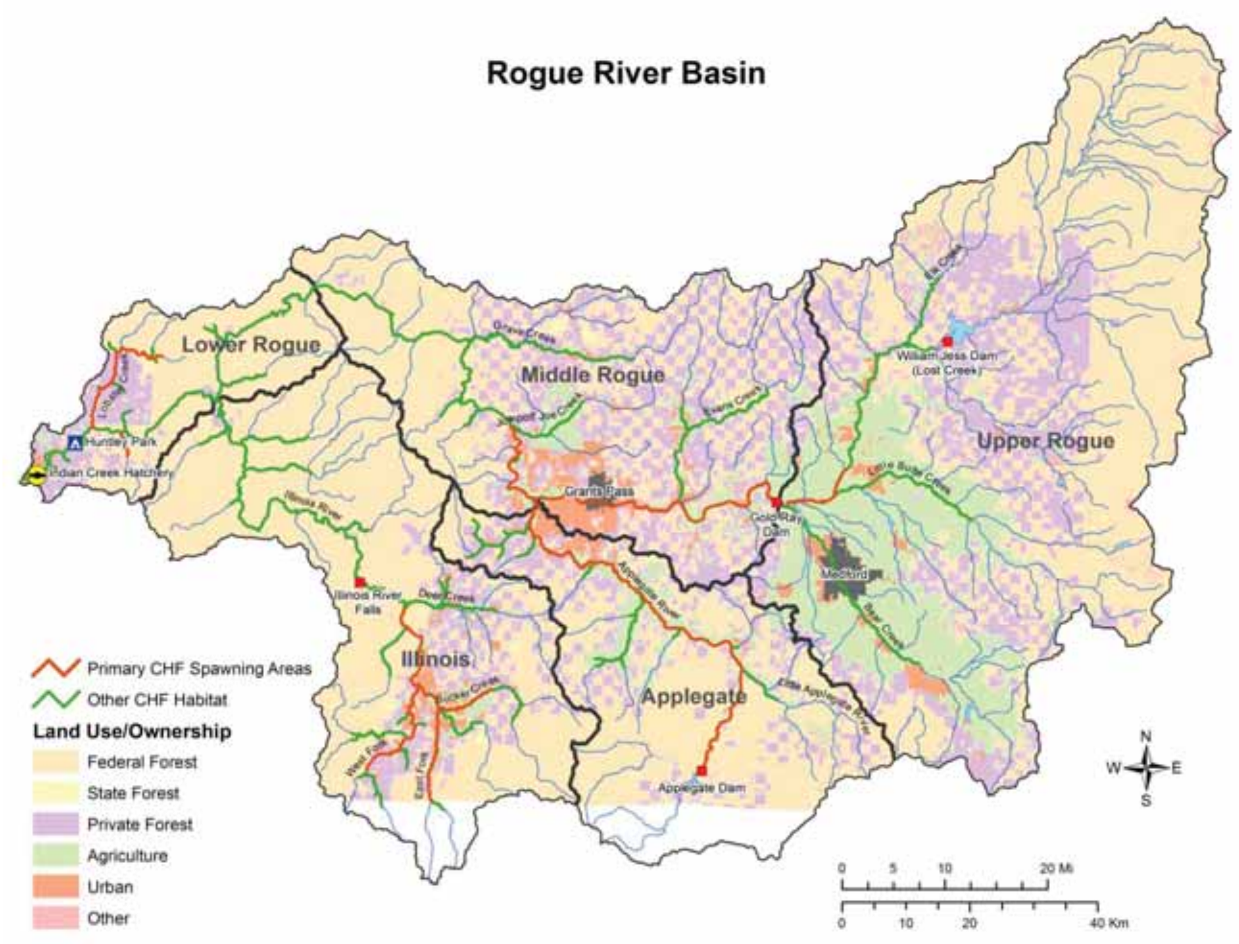

Figure 1. Spatial distribution of independent populations of fall Chinook salmon in the Rogue stratum of the Species Management Unit. The boundaries of the different population areas are shown as black lines.

Lower Rogue population:
Spawners (live and dead fall Chinook) were counted in portions of various tributary streams during 1986-2010. This database was directly relevant to the purpose of this conservation plan because spawner abundance could be estimated for the entire population, criteria could be

developed in relation to desired status and conservation status, and monitoring is ongoing and expected to continue for the foreseeable future.

Middle Rogue population:
Carcasses were counted within two survey areas located on the mainstem of the Rogue River during 1974-2004. The areas surveyed included Valley of the Rogue State Park - the city of Rogue River (RM 113-111) and Lathrop's Landing - Robertson Bridge (RM 97-87). This database was judged to not be directly relevant to the purpose of this conservation plan because the data could not be used to estimate spawner abundance for the entire population, and monitoring has been terminated and is not expected to be implemented again within the foreseeable future. As a result it was judged there was minimal value in trying to craft criteria for desired status or conservation status for this population.

Upper Rogue population:
Fish passage at Gold Ray Dam (RM 125) was estimated at a counting station during 1942-2009. In August 2010, the fish counting station became inoperable with the removal of Gold Ray Dam. Substitution of spawning surveys to estimate fall Chinook spawner abundance is not possible because of the spatial and temporal overlap in spring and fall Chinook spawning in this area (ODFW 1991). With the loss of the fish counting station, it was judged there was minimal value in trying to craft criteria for desired status or conservation status for this population.

Illinois population:
Spawners (live and dead fall Chinook) were counted within portions of three tributary streams (Mendenhall Creek, Elk Creek, and Sucker Creek) during 1996-2004. This database was judged to not be directly relevant to the purpose of this conservation plan because the data could not be used to estimate spawner abundance for the entire population, and monitoring has been terminated and is not expected to be implemented again within the foreseeable future. In addition, ODFW staff judged that fall Chinook spawn primarily in the mainstem, and in the East and West Forks. It is currently unknown whether spawner counts in the smaller tributaries may be representative of spawning escapement throughout the entire basin. As a result of these factors, it was judged there was minimal value in trying to craft criteria for desired status or conservation status for this population.

Applegate population:
Carcasses were counted within three survey areas located on the mainstem of the Applegate River, and in Slate Creek, during 1974-2004. The areas surveyed in the Applegate River included the town of Applegate - Williams Creek (RM 25-20), the town of Murphy - Hog Ranch (RM 13-11), and Highway 199 - the mouth (RM 4-0). The Slate Creek survey covered the lowest 5.0 miles of Slate Creek. This database was judged to not be directly relevant to the purpose of this conservation plan because the data could not be used to estimate spawner abundance for the entire population. Monitoring has been terminated and is not expected to be implemented again within the foreseeable future. As a result, it was judged there was minimal value in trying to craft criteria for desired status or conservation status for this population.

Aggregate populations

Migrating adults were captured during 1976-2010 with a 300' beach seine fished at Huntley Park (RM 8) three days weekly during July 15-October 28 (ODFW 1992). Each day, sampling began early in the morning and continued until the seine had been fished 15 times. This sampling effort was standardized in 1978 and tagging studies indicated that all of the fall Chinook populations in the Rogue River Basin are susceptible to capture (ODFW 1992).

The Oregon Game Commission (OGC, now ODFW) began beach seining near the mouth of the Rogue River in 1974 in order to capture adult salmonids that entered the Rogue River. Initially, the sampling was designed to collect fish in order to obtain life history information and to estimate freshwater escapement through the use of mark-recapture methods. Mark-recapture efforts were terminated after 1976 when it became apparent that mortality rates of tagged Chinook salmon resulted in biased estimates of freshwater escapement (Cramer 1979). Instead, catch per unit of seining effort was used as an index of abundance. This approach continued through the 1980s, although it became apparent that unusually high flows in 1983 and 1984 affected the efficacy of sampling with the beach seine at the Huntley Park site.

Establishment of a run of hatchery coho salmon in the early 1980s afforded an opportunity to generate annual estimates of seining efficiency. Available data indicated that few coho salmon died during upstream migration, few hatchery fish strayed to spawn naturally, and at the time, there was no directed freshwater fishery for coho salmon. Seining efficiency on coho salmon of hatchery origin was estimated, compared to flow at time of seine capture, and a catch efficiency model was developed (ODFW 1989). This flow-based model (Table 1) was subsequently used to estimate freshwater escapement for other runs of anadromous salmonids, including fall Chinook (ODFW 1989; ODFW 1992; ODFW 1994). Estimation of fall Chinook escapement comprises 3 steps. First, a standard weekly catch is calculated based on 45 seine sets weekly. Second, weekly estimates of seining efficiency are used to expand the standardized catches. Finally, weekly estimates of escapement are summed for calendar weeks 30-43.

Table 1. Estimated efficiency of weekly seining at Huntley Park.

Range of flow (cfs)[1]	Predictor of seining efficiency (%)
800 – 1,700	2.80
1,700 – 3,000	$2.6X10\text{-}3(\text{flow}) – 7.952X10\text{-}7(\text{flow}^2) + 0.7068$
3,000 – 4,500	16.939 – 1.9454(ln flow)

[1] Average weekly flow measured at USGS Gage #14372300 Rogue River near Agness, OR

In 1992, ODFW determined that the flow-based model significantly underestimated the number of fall Chinook that returned to the Rogue River. During some years, known numbers of fall Chinook exceeded the estimate produced by the flow-based model. Known numbers of fall Chinook included: (1) those that passed the fish counting station at Gold Ray Dam, (2) those recovered as carcasses during spawning surveys, and (3) those estimated to be harvested by anglers based on returns of salmon-steelhead cards. In light of these results, ODFW subsequently termed estimates derived from the flow-based model as the “Huntley Park Index” of fall Chinook freshwater escapement, to differentiate it from a formal abundance estimate.

Estimating fall Chinook Passage at Huntley Park

ODFW has developed two methods to estimate the number of fall Chinook that passed Huntley Park. Both methods entail expansion of the Huntley Park Index. The first method uses the results of mark-recapture efforts during 2000-2002 to calibrate the passage index. The second method uses historic fall Chinook passage estimates at Gold Ray Dam to calibrate the passage index. Both methods resulted in similar passage estimates at Huntley Park and a description of each method follows.

Calibration of Huntley Park Index with mark-recapture estimates:
ODFW has tried twice (once during 1975-76 and once during 2000-2002) to estimate fall Chinook escapement in the Rogue River using mark-recapture methods. Freshwater returns were estimated to be about 63,000 fish in 1975 and about 93,000 fish in 1976 (Table 2). However, these estimates were judged to be inflated by disproportionately high mortality of tagged fish (Smith et al. 1978).

Instances of significant prespawning mortality decreased markedly after the mid-1980s as water release strategies at Lost Creek Dam were modified to increase flow during critical periods of fall Chinook migration (ODFW 1992). The only instance of significant prespawning mortality occurred during the drought year of 2001 (Satterthwaite 2002). The decrease in fall Chinook prespawning mortality led ODFW to attempt another series of mark-recapture efforts with fall Chinook during 2000-2002. Resultant mark-recapture estimates of the number of fall Chinook that passed Huntley Park during these years ranged between 126,000 and 405,000 fish (Table 2).

Table 2. Petersen mark-recapture estimates of the number of fall Chinook salmon that entered the Rogue River, 1975-2002 and associated data relevant to the calibration of the Huntley Park Index of freshwater escapement. River physical factors are reported as mean daily maximum values during August at Agness (RM 30).

Year	Mark-recapture estimate	(95% CI)	Huntley Index	River physical factors: Flow (cfs)	River physical factors: Temperature (F)
1975	63,235	(47,160-87,655)	37,175	1,716	--
1976	92,977	(61,807-147,043)	23,469	2,149	71
2000	126,085	(88,540-208,919)	40,047	2,317	73
2001	404,660	(192,880-616,440)	42,577	1,762	74
2002	203,267	(150,057-290,622)	80,545	2,027	72

All of the mark-recapture estimates listed in Table 2 are believed to be inflated to some degree because of delayed mortality among tagged fish. Bias related to tagging mortality was judged to be differentially high in 2001 because of low flow and extensive prespawning mortality (Satterthwaite 2002). Consequently, the 2001 estimate was excluded from further consideration. Tagging related mortality was assumed to be 10% in the other years, resulting in adjusted mark-recapture estimates of 113,476 in 2000 and 182,940 in 2002. The escapement estimates exceeded the Huntley Passage Indexes by 2.70-fold in 2000 and 2.27- fold in 2002. The average (2.485) of these values was used to expand the Huntley Passage Index for the period of record. Expanded values were then used as estimates of the total number of fall Chinook that passed Huntley Park. Resultant estimates are shown as “Method 1” in Table 3.

Calibration of Huntley Park Index with Gold Ray Dam counts:
ODFW has estimated fish passage at Gold Ray Dam since 1942. All passing fish were counted during 1942-1947. During 1948-92, fish were counted eight hours daily, five days weekly. Partial count sampling designs were intended to estimate biweekly passage with an average error of less than 10% (Li 1948). Since 1993, passage has been estimated with 24-hour, seven day per week video recordings; a procedure which is assumed to have minimal uncertainty. Chinook salmon that pass the counting station by August 15 are classified as spring Chinook, while later migrants are classified as fall Chinook (ODFW 2000).

ODFW tagged numerous fall Chinook in the lower Rogue during 1974-78 and looked for tags on carcasses found during spawning surveys. Most tags were recovered in the Middle Rogue, Applegate, and Lower Rogue population areas. However, five tags were recovered upstream of Gold Ray Dam (Upper Rogue population area). All of these fish had been captured and tagged at Huntley Park between July 15 and August 4 and were considered early-run fall Chinook. Remaining tag recoveries indicated that later migrating fall Chinook eventually spawned in population areas farther downstream in the Rogue River Basin (ODFW 1992). Early-run fish are therefore defined as those fall Chinook that pass Huntley Park before August 4.

Application of radio-tags to a few fall Chinook caught at Huntley Park in 2008 (ODFW 2009) afforded the opportunity to examine the assumption that early-run fall Chinook migrate upstream to spawning areas above Gold Ray Dam. There were three early-run fall Chinook tagged at Huntley Park that passed Gold Ray Dam. One passed on August 11 and was therefore classified as a spring Chinook. The other two passed after August 5 and were thus classified as fall Chinook. Another three fall Chinook were tagged at Huntley Park after August 4 and were subsequently detected on spawning grounds downstream of Gold Ray Dam.

The OGC tagged large numbers of fall Chinook near the mouth of the Rogue River in 1970 and in 1971 during a summer steelhead research project (Everest 1973). Efforts to recover tagged fall Chinook were limited to a few spawning surveys, but 36 tagged fall Chinook were trapped at Gold Ray Dam. The mean date of tagging at the river's mouth was August 11 (95% CI = ±4 days). These results, coupled with the 1974-78 tag recoveries, confirmed that early-run fall Chinook primarily spawn upstream of Gold Ray Dam. Assuming that all early-run fish pass the Gold Ray Dam counting station, an appropriate expansion factor could be developed for the Huntley Park Index.

The early-run component of the Huntley Passage Index accounted for an average of 40% (95% CI for arc-sine transformed data = 17-64%) of the early-run fall Chinook that subsequently reached Gold Ray Dam during 1992-2008. Data from years prior to 1992 were not included because of concern that the population of fall Chinook in the upper Rogue was still increasing during that time relative to fall Chinook in the remainder of the basin (ODFW 2000). Because 17 years (1992-2008) of data are available, it was judged that effects due to variations in fall Chinook migration timing would likely be mostly cancelled provided that annual variations in fall Chinook migration timing were random in nature. Assuming that 40% of fish passing

Huntley Park are reflected in the Huntley Park Index, an expansion factor of 2.5 (1/40%) was used to produce the Huntley Park estimates referred to as "Method 2" in Table 3.

Table 3. Four abundance metrics for abundance of fall Chinook salmon in the Rogue River Basin, 1974-2010.

Year	Total known[a]	Huntley Index[b]	Passage at Huntley Park: Method 1[c]	Passage at Huntley Park: Method 2[d]
1974	--	42,656	106,021	106,660
1975	--	37,175	92,383	92,940
1976	--	23,469	58,329	58,680
1977	12,697	32,038	79,615	80,095
1978	18,501	74,575	185,321	186,438
1979	13,239	69,730	173,281	174,325
1980	6,497	33,478	83,194	83,695
1981	13,552	41,420	102,942	103,563
1982	10,568	55,735	138,506	139,340
1983	9,314	21,464	53,336	53,658
1984	8,336	18,212	45,257	45,530
1985	20,282	36,109	89,722	90,263
1986	39,760	98,314	244,291	245,763
1987	51,204	65,133	161,857	162,833
1988	61,078	33,930	84,319	85,423
1989	24,787	38,767	96,337	96,918
1990	9,472	10,187	25,315	25,468
1991	10,749	7,544	18,747	18,860
1992	13,403	31,288	77,751	78,220
1993	22,515	19,002	47,220	47,505
1994	30,740	33,114	82,290	82,786
1995	28,580	35,444	88,079	88,610
1996	20,283	27,004	67,105	67,509
1997	10,056	24,625	61,193	61,562
1998	12,435	19,967	49,618	49,917
1999	9,500	23,710	58,920	59,275
2000	21,624	42,047	104,489	105,118
2001	29,095	42,577	105,805	106,442
2002	42,491	80,545	200,157	201,363
2003	57,760	94,231	234,167	235,577
2004	--	63,561	157,950	158,902
2005	--	25,821	64,167	64,553
2006	--	17,972	44,660	44,929
2007	--	20,540	51,041	51,350
2008	--	17,403	43,246	43,508
2009	--	30,685	76,252	76,713
2010	--	26,633	66,184	66,582

a *Carcasses were not surveyed after 2003 and only three areas were surveyed during 1974-76.*
b *Index values for 1974-77 were adjusted for non-standardized sampling (ODFW 1992).*

[c] *Huntley Park Index calibrated with mark-recapture estimates from 2000 and 2002.*
[d] *Huntley Park Index calibrated with 1992-2009 passage estimates at Gold Ray Dam.*

In summary, the Gold Ray Dam counts provide an accurate abundance estimate of the Upper Rogue population and tag recoveries indicate that this population passes Huntley Park by August 5. A comparison of the Huntley Park Index, calculated only for the period July 15-August 5, with the Gold Ray dam counts resulted in the conclusion that fall Chinook passage at Huntley Park is best estimated with the application of a 2.5X expansion factor (0.40/Huntley Park Index).

Estimation of Life History Parameters

Aggregate populations:
Scale interpretations were used to estimate the origin and age composition of fall Chinook that entered the Rogue River during 1974-1988 (ODFW 1992). Scales were also used to estimate fall Chinook age composition for the 2007-2011 returns. The age composition of the 1989-2006 returns was estimated based on length-at-age criteria developed from scale samples obtained from the 2007-2011 returns. Annual proportions of hatchery fish within the 1989-2011 returns were estimated by expanding the number of fin-clipped fish caught at Huntley Park by the mark rates among cohorts released from hatcheries in the Rogue River Basin. Fin-clipped fish were assigned to specific brood years based on their length. Final estimates of fall Chinook passage at Huntley Park can be found in Table 4.

All spawners were assumed to be naturally produced fish. During 1991-2004, ODFW recovered about 80,000 fall Chinook carcasses during spawner surveys conducted throughout the Rogue River Basin. Only 54 of those fish were marked with adipose fin clips and expansions for the proportions of smolts indicated that hatchery fish composed about 0.2% of the spawners, which was judged to be insignificant.

Table 4. Estimated number of adult fall Chinook salmon that passed Huntley Park and the estimated age composition of naturally produced fish, 1974-2011.

Return	Passage Estimate			Proportion by Age				
Year	Natural	Hatchery	Total[1]	Age 2	Age 3	Age 4	Age 5	Age 6
1974	106,021	0	106,021	0.189	0.271	0.461	0.070	0.009
1975	92,383	0	92,383	0.118	0.195	0.567	0.113	0.008
1976	58,329	0	58,329	0.414	0.174	0.343	0.069	0.000
1977	79,615	0	79,615	0.676	0.167	0.129	0.028	0.000
1978	185,321	0	185,321	0.162	0.377	0.405	0.056	0.000
1979	173,281	0	173,281	0.054	0.101	0.802	0.044	0.000
1980	83,010	184	83,194	0.343	0.110	0.284	0.262	0.000
1981	101,429	1,513	102,942	0.258	0.486	0.175	0.073	0.010
1982	134,684	3,822	138,506	0.274	0.266	0.432	0.027	0.001
1983	45,441	7,895	53,336	0.148	0.487	0.336	0.030	0.000
1984	42,255	3,002	45,257	0.231	0.374	0.360	0.029	0.005
1985	84,141	5,582	89,722	0.581	0.110	0.261	0.048	0.000
1986	229,858	14,433	244,291	0.373	0.497	0.113	0.016	0.001
1987	147,944	13,914	161,857	0.210	0.398	0.364	0.028	0.000
1988	79,078	5,241	84,319	0.144	0.198	0.606	0.052	0.000
1989	89,144	7,193	96,337	0.170	0.323	0.421	0.070	0.016
1990	23,915	1,400	25,315	0.183	0.370	0.395	0.051	0.000
1991	18,364	383	18,747	0.184	0.476	0.309	0.031	0.000
1992	76,456	1,295	77,751	0.415	0.232	0.277	0.069	0.008
1993	46,668	552	47,220	0.228	0.598	0.128	0.040	0.006
1994	80,707	1,584	82,290	0.164	0.435	0.357	0.043	0.001
1995	82,745	5,334	88,079	0.224	0.510	0.215	0.046	0.005
1996	64,445	2,660	67,105	0.243	0.380	0.338	0.036	0.003
1997	58,860	2,333	61,193	0.302	0.386	0.241	0.061	0.010
1998	47,732	1,886	49,618	0.142	0.577	0.257	0.024	0.000
1999	56,350	2,570	58,920	0.333	0.264	0.287	0.093	0.023
2000	100,701	3,787	104,489	0.128	0.581	0.216	0.070	0.004
2001	103,026	2,778	105,805	0.259	0.274	0.314	0.134	0.020
2002	196,948	3,209	200,157	0.217	0.318	0.313	0.119	0.033
2003	224,139	10,027	234,167	0.086	0.287	0.425	0.173	0.029
2004	152,081	5,869	157,950	0.130	0.197	0.446	0.188	0.040
2005	61,323	2,843	64,167	0.079	0.281	0.455	0.158	0.026
2006	41,845	2,815	44,660	0.162	0.254	0.428	0.134	0.023
2007	46,778	4,264	51,041	0.070	0.326	0.343	0.256	0.005
2008	39,495	3,751	43,246	0.384	0.181	0.336	0.099	0.000
2009	73,883	2,369	76,252	0.185	0.419	0.342	0.055	0.000
2010	63,849	2,335	66,184	0.223	0.348	0.390	0.038	0.002
2011	97,875	3,044	109,919	0.308	0.242	0.397	0.052	0.001

[1] Total is from Method 1, Table 3.

Fisheries

A primary impact exerted on salmon populations is mortality that results from fishing activities. Wading and boating may have some impact on production (Roberts and White 1992; Horton 1994), but the greatest impact almost certainly originates from the directed fishing on salmon by recreational and commercial fisheries. Mortality rates associated with fishing can vary widely for Pacific salmon, especially for Chinook salmon that mature at multiple ages.

Harvest rates, unless otherwise stated, are defined as that percentage of recruits which were taken by fishers, for the brood years in question.

Estimation of Ocean Fishery Impacts

Ocean harvest rates of NP CHF produced in the Rogue River Basin have decreased since the 1970s (Table 6). The decline in ocean harvest rates coincided with decreases in ocean harvest for CHF in the Klamath River Basin of northern California, beginning in 1988 (PFMC 1988). Resultant harvest restrictions to the ocean fisheries caused NP CHF of Rogue River Basin origin to be harvested at lower rates because both groups of fish tend to be caught in the same general area of the ocean.

Annual exploitation rates on age 3 and age 4 fish in the ocean fisheries were assumed to equal those estimated for fall Chinook salmon of Klamath River Basin origin, as reported by the Pacific Fishery Management Council (PFMC 2010). Ocean exploitation rates on age 5 and age 6 fish were assumed to equal those on age 4 fish. These assumptions had to be made because there were no consistent releases of CWT marked fall Chinook from hatcheries within the Rogue River Basin that would allow for direct estimation of exploitation rates in the ocean fisheries.

The assumption of equal ocean exploitation rates on age 3 and age 4 fish of Rogue and Klamath origin appeared reasonable because (1) Rogue and Klamath fall Chinook exhibit indistinguishable catch distribution patterns in the ocean fisheries (Table 5) and (2) freshwater returns of fall Chinook in the Rogue and Klamath rivers are positively correlated to each other (*see* Comparisons to Other Populations in the conservation plan). Weitkamp (2010) also documented very similar ocean landing distributions of Chinook salmon released from hatcheries in the Southern Oregon - Northern California ecoregion.

Table 5. Comparisons of landing distributions of CWT-marked fall Chinook salmon released from hatcheries in the Rogue and Klamath River basins, 1987-2003 brood years. Data incorporated in the analyses include only those CWT groups released after the month of August. Comparisons were made with paired t-tests of arcsine transformed data. Data from Iron Gate and Trinity River hatcheries in the Klamath River Basin were pooled because no difference in landing distributions could be detected (paired t-test $P = 0.52$).

	Mean by Stock		P for
	Rogue	Klamath	difference
Proportion landed in California and Oregon	0.99	0.99	0.76
Proportion landed in Oregon only	0.43	0.45	0.38

Estimation of Freshwater Harvest

In contrast to ocean harvest rates, brood harvest rates in the river fishery (includes estuary) increased during the 1980s (Table 6).

Freshwater harvest (includes the estuary) was estimated from salmon-steelhead cards (punchcards) returned to ODFW by anglers. ODFW (1992) reported estimates of total harvest for 1956-1984. Estimates for later years were obtained from ODFW records. Harvest estimates from salmon-steelhead cards do not include jacks; which are almost all age 2 fish (ODFW 1992). Harvest of jacks was estimated based on their proportion among fall Chinook captured at Huntley Park (i.e., it was assumed that the freshwater fishery did not selectively harvest fall Chinook of different ages).

Estimates of fall Chinook harvest were segregated into areas upstream and downstream of Huntley Park (Table 6). Angler harvest downstream of Huntley Park was assumed to equal the salmon-steelhead card estimates applicable to the Rogue River downstream of Elephant Rock (RM 3). Estimates for this area were only available for 1993 and later years. During this period, the area downstream of Elephant Rock accounted for an average of 53% (95% CI = 48-58% as estimated from arcsine transformed data). The mean estimate of harvest distribution was applied to years prior to 1993 in order to estimate angler harvest downstream of Elephant Rock.

Estimation of Ocean Abundance

Cohort reconstructions (Ricker 1975) were employed to estimate the number of naturally-produced fall Chinook that resided in the ocean during the spring prior to onset of any fishing mortality. Estimation procedures began with age 6 fish and ended with age 3 fish and were analogous to those employed by Hankin and Healy (1986) and Mohr (2006). Estimates of cohort abundance began with age 6 fish because all naturally-produced fall Chinook of Rogue River Basin origin mature at ages 2-6. The abundance of younger cohorts were estimated as the sum of (1) the number of fish that resided in the ocean during the succeeding year, (2) natural mortality, (3) harvest in the ocean fisheries, and (4) the number of fish that returned to the river.

For each cohort, we used the equation:

$$N_i = \frac{\dfrac{N_{i+1}}{1-A_i} + E_i}{1-u_i}$$

where

N_i = number of age i fish resident in the ocean prior to fishing during year t,
N_{i+1} = number of age i+1 fish resident in the ocean during the next year,
A_i = rate of natural mortality for age i cohorts resident in the ocean between years t and t+1,
u_i = exploitation rate of age i fish in the ocean during year t, and
E_i = freshwater return of age i fish during year t.

Table 6. Estimates of population and harvest metrics for aggregated populations of naturally produced fall Chinook salmon in the Rogue River Basin, 1972-2006 brood years.

Brood year	Ocean harvest	Total river harvest	River Harvest[a] Below Huntley	Above Huntley	Adult equivalent recruits	Parent spawners[b]	Brood harvest rate	Brood h. rate ocean	Brood h. rate river
1972	64,832	2,115	1,125	989	100,232	--	0.668	0.647	0.021
1973	98,268	2,341	1,246	1,095	114,121	--	0.882	0.861	0.021
1974	212,244	3,218	1,712	1,505	289,621	82,518	0.744	0.733	0.011
1975	479,073	2,954	1,572	1,382	658,090	78,840	0.732	0.728	0.004
1976	105,752	834	444	390	141,072	32,474	0.756	0.750	0.006
1977	60,128	813	433	380	84,397	23,486	0.722	0.712	0.010
1978	176,491	3,086	1,642	1,444	285,148	134,691	0.630	0.619	0.011
1979	182,635	1,769	942	828	377,237	29,875	0.489	0.484	0.005
1980	73,955	2,252	1,198	1,053	238,336	23,206	0.320	0.310	0.009
1981	19,258	2,954	1,572	1,382	60,935	65,448	0.365	0.316	0.048
1982	45,547	2,173	1,157	1,017	82,591	92,768	0.578	0.551	0.026
1983	120,683	10,163	5,409	4,754	290,726	37,696	0.450	0.415	0.035
1984	84,580	17,968	9,563	8,406	201,344	31,683	0.509	0.420	0.089
1985	51,980	8,674	4,616	4,058	107,284	33,414	0.565	0.485	0.081
1986	27,551	5,601	2,981	2,620	68,221	140,969	0.486	0.404	0.082
1987	17,434	3,902	2,071	1,831	37,061	109,293	0.576	0.470	0.105
1988	3,721	4,915	2,578	2,337	37,919	58,733	0.228	0.098	0.130
1989	3,751	3,775	1,892	1,883	32,910	68,177	0.229	0.114	0.115
1990	8,882	13,122	6,456	6,666	75,470	17,403	0.292	0.118	0.174
1991	6,890	8,725	4,884	3,841	67,192	12,581	0.232	0.103	0.130
1992	9,291	9,207	5,536	3,671	82,007	42,112	0.226	0.113	0.112
1993	4,353	4,448	2,429	2,019	47,566	29,866	0.185	0.092	0.094
1994	3,294	3,327	1,909	1,418	45,622	60,887	0.145	0.072	0.073
1995	4,810	4,472	2,598	1,874	59,722	59,464	0.155	0.081	0.075
1996	11,699	5,054	2,623	2,430	69,616	44,949	0.241	0.168	0.073
1997	27,674	10,662	5,523	5,139	150,542	38,785	0.255	0.184	0.071
1998	50,222	10,455	4,503	5,952	183,635	38,864	0.330	0.273	0.057
1999	65,609	13,688	6,007	7,682	254,879	35,293	0.311	0.257	0.054
2000	68,144	10,302	4,559	5,743	210,998	82,935	0.372	0.323	0.049
2001	22,469	4,514	2,066	2,448	86,379	63,555	0.312	0.260	0.052
2002	9,134	4,279	2,629	1,650	58,211	144,954	0.230	0.157	0.074
2003	6,902	2,819	1,864	955	38,938	191,999	0.250	0.177	0.072
2004	5,004	3,017	1,917	1,101	39,173	124,571	0.205	0.128	0.077
2005	124	4,783	3,400	1,383	38,442	53,208	0.128	0.003	0.124
2006	1,987	7,656	5,301	2,355	68,654	32,873	0.140	0.029	0.112

[a] *Includes estuary.*

[b] *Age 3-6; includes hatchery fish.*

Estimation of Spawning Escapement

Aggregate populations:
Spawning escapement in the Rogue River Basin (Table 6 Parent Spawners) was estimated as:

Passage estimates at Huntley Park - (prespawning mortality + angler harvest)

Fall Chinook in the Rogue River are susceptible to high rates of prespawning mortality during years of low flow and warm water temperatures. Rates of prespawning mortality were estimated during 1978-1986 (ODFW 1992) and during 2001 (Satterthwaite 2002). Prespawning mortality rates in all other years were assumed to equal 2% because there were no anecdotal reports of significant prespawning mortality in years after 1986 (2001 excepted).

Estimation of Recruitment

For each cohort (brood year), recruitment was estimated as the sum of the estimated freshwater returns of age 3-6 fall Chinook under a scenario of no ocean fishing mortality (as termed “adult equivalents” by Mohr (2006)) (Table 6 Adult Equivalent Recruits).

Population Models

For each population, we assessed the relationship between the abundance of spawners on a given year and the resulting number of adult progeny (recruits) produced by those spawners. Estimates of parent spawners and adult equivalent recruits for the aggregated Rogue populations are included in Table 6. This spawner-recruit analysis yields information about trans-generational population dynamics that is subsequently used to assess extinction risk in a population viability analysis (PVA). This appendix begins by describing spawner-recruit analysis and then goes on to describe how results from this analysis are used in a PVA.

Spawner-Recruit Relationships

Annual estimates of spawner abundance and recruits produced for each population were used to assess the shape and strength of relationship between estimates of spawners and recruits. A simple straight linear relationship between spawners and recruits is biologically unrealistic because, among other reasons, it suggests that there is no upper limit to the number of recruits that can be produced. Thus, a nonlinear relationship between spawners and recruits is more appropriate. We considered the two most common relationships commonly used by fish scientists; the Ricker (1954) and Beverton-Holt (1957) curves.

The Ricker curve (Ricker, 1954):

$$R = \alpha S e^{-\beta_{RK} S} \qquad \textit{Eq. 1}$$

and the Beverton-Holt function (Beverton and Holt, 1957):

$$R = \frac{\alpha S}{1 + \frac{\alpha}{\beta_{BH}} S} \qquad \textit{Eq. 2}$$

Both functions model recruit abundance (*R*) as a two-parameter function of spawner abundance (*S*). In both equations, α represents "intrinsic productivity," which is the number of recruits produced per spawner as spawner abundance approaches zero. This value therefore represent the reproductive output when animals are uninhibited by density-dependent effects, and is an important component of population resiliency. The meaning of the β parameter is different in the two functions, and so we denote this difference by using subscripts RK and BH in equations 1 and 2 above. In a Ricker function, β_{RK} indicates the rate of decline in recruit abundance (*R*) as spawner abundance (*S*) increases. There are different algebraic ways of writing the Beverton-Holt function (*see* Equations 7-9 below), but as it is written in Equation 2, the β_{BH} parameter represents the asymptote of recruit abundances as *S* increases. Example Ricker and Beverton-Holt functions are plotted in Figure 2. The Ricker function (red) assumes that recruitment drops at very high spawner abundances while the Beverton-Holt function (blue) assumes that recruitment asymptotes as spawner abundance increases. The maximum sustained yield occurs at the spawner abundance (S_{MSY}) with the maximum vertical distance (dotted) between the model (colored) and population replacement (black). In the absence of fishing mortality, spawner abundance will reach equilibrium at N_{eq}.

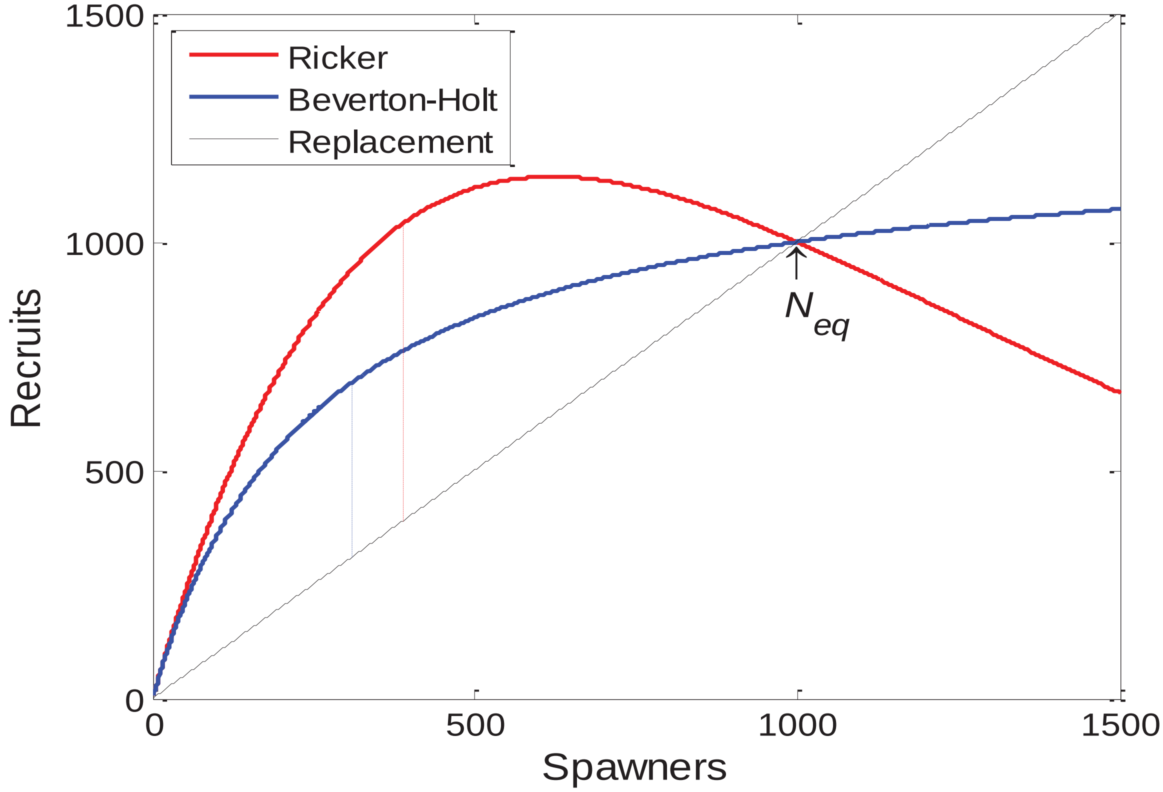

Figure 2. Example Ricker and Beverton-Holt functions.

Both functions in Figure 2 assume $\alpha = 5$. Values of β were selected for each function so that they cross the replacement line (spawners = recruits) at a point corresponding to 1000 spawners and recruits•. The point where the function crosses the replacement line is denoted N_{eq}. If there was no harvest, then all recruits would become spawners, and abundance of spawners would be in equilibrium at N_{eq}.

Maximum sustained yield is a mathematical concept that can be derived from spawner-recruit relationships. It is the maximum number of animals that can be harvested such that the abundance of animals escaping harvest should produce an equally harvestable surplus of recruits. Graphically, the number of spawners that produces MSY (S_{MSY}) is the point on the x-axis of a spawner-recruit plot where there is maximum vertical distance between recruits and the replacement line (Figure 2). S_{MSY} is computed because we define critical conservation abundance as 50% of the 75^{th} percentile of our estimate of S_{MSY} (*see* next section).

For the Ricker and Beverton-Holt functions, S_{MSY} is, respectively:

• Solve Equation 1 and Equation 2 for R=S, call the result Neq, then rearrange for β to obtain:

$$\beta_{RK} = \frac{\log(\alpha)}{N_{eq}}, \beta_{BH} = \frac{N_{eq}\alpha}{\alpha - 1}$$

$$S_{MSY} = \frac{\ln(\alpha)}{\beta_{RK}}\left(0.5 - 0.07\ln(\alpha)\right) \qquad \textit{Eq. 3}$$

$$S_{MSY} = \beta_{BH}\sqrt{\frac{1}{\alpha} - \frac{\beta_{BH}}{\alpha}}\ , \qquad \textit{Eq. 4}$$

Statistical Fits of Spawner-Recruit Relationships:

We used Bayesian methods to fit spawner-recruit functions for two reasons. First, as noted above, the spawner-recruit relationship is used to drive trans-generational population dynamics in the PVAs. An important aspect of any PVA is incorporation of statistical uncertainty in underlying parameters. Bayesian methods yield probability densities for the parameters of the spawner-recruit functions whereas non-Bayesian (i.e. “frequentist”) methods yield point estimates. Thus, Bayes’ method provides results that can be directly used to simulate parameter uncertainty in a PVA, which is one reason why Bayesian methods are appealing to conservation biologists (Wade 2002).

The second reason we used Bayesian methods to fit spawner-recruit relationships derives from our desire to characterize uncertainty in our estimate of S_{MSY}. Fifty percent of S_{MSY} has been used as a critically low abundance for triggering conservation action (AHSAC 2011). However, since S_{MSY} is never known perfectly, we define critically low abundance as 50% of the 75th percentile of the estimate of S_{MSY}. This definition of a critically low abundance explicitly acknowledges uncertainty in S_{MSY}, and in response reduces the conservation risk associated with overestimating the true value of S_{MSY}. Stated another way, when ambiguity in the data increases, fish managers should respond more conservatively. Since S_{MSY} is computed from α and β parameters (*see* Equations 3 and 4), our assessment of statistical uncertainty in S_{MSY} depends on uncertainty in both of those parameters as well as their covariance. Quantifying uncertainty in S_{MSY} is therefore a very complex problem. Indeed, an exact analytical solution is not known to science. However, the Bayesian statistical paradigm offers a method for numerically estimating uncertainty in S_{MSY}. S_{MSY} can be computed as Markov Chain Monte Carlo (MCMC) methods sample from parameter posterior distributions (Haddon 2011). This yields a probability density of S_{MSY}, which, unlike results of frequentist methods, can be used to make probability statements about the value of S_{MSY}.

We modeled recruits as a log-normally distributed random variable. Specifically, we let

$\log(R) \sim \text{Normal}(\mu,\tau)$ *Distribution 1*

and, for the Ricker function, we get

$\mu = \log(\alpha)+\log(S) - \beta_{RK} * S$. *Eq. 5*

If environmental covariates are included in the Ricker function, then we have:

$\mu = \log(\alpha)+\log(S) - \beta_{RK}*S + \gamma_1 \text{Env}_1 + \gamma_2 \text{Env}_2.$ *Eq. 6*

We had difficulty getting Beverton-Holt models to converge, so we tried several parameterizations of the Beverton-Holt function. Specifically, we explored three:

$\mu = \log(\alpha)+\log(S) - \log(1+ \alpha / \beta_{BH}*S)$ {logarithmic version of Equation 2} *Eq. 7*

$\mu = \log(S) - \log(1/\exp(\alpha) + S/\exp(\beta_{BH}))$ *Eq. 8*

$\mu = \log(a)+\log(S) - \log(b + S).$ *Eq. 9*

As in Equation 6, we included environmental covariates to the Beverton-Holt function by simply including them as additive terms.

We used WinBUGS to carry out MCMC fitting of our spawner-recruit functions. Here, we follow WinBUGS distributional notation and note that τ in Distribution 1 is the precision of the normal distribution, where $\tau = 1/\sigma^2$. We first transform τ to the more familiar standard deviation, σ, and then let

$\sigma \sim \text{Uniform}(0,6)$ *Distribution 2*

We also tried the more common:

$\tau \sim \text{Gamma}(0.005, 0.005)$ *Distribution 3*

and found that the choice of prior parameterizations had little effect of our posterior results. For the intrinsic productivity parameter of both Ricker and Beverton-Holt functions, we specified noninformative priors with:

$\alpha \sim \text{Uniform}(0,10).$ *Distribution 4*

The prior distribution we used for β_{RK} is

$\beta_{RK} \sim \text{Normal}(\mu = 0.0000001, \tau = 0.005),$ *Distribution 5*

but we also explored the effects of assuming

$\beta_{RK} \sim \text{Uniform}(0.00001, 0.005).$ *Distribution 6*

We tried a host of different prior distributions for Beverton-Holt functions given in equations 7-9 because of the difficulty we experienced getting good convergence. Specifically, we tried normal, lognormal, and uniform priors in conjunction with several different non-informative parameterizations of these distributions. We did not obtain satisfactory fits and good evidence to support the use of Beverton-Holt functions for any of the populations we modeled. Thus, all of the spawner-recruit models presented in this conservation plan were derived from the Ricker function.

We always ran two Markov chains, and typically allowed them "burn-in" for 5,000 iterations. We obtained a total of 3,500 samples from each chain, after thinning the chains out to every 31st iteration. We plotted the "trace" of the resulting samples and computed Gelman-Rubin statistics to verify that the chains had properly mixed. For many models, including all those assuming a Beverton-Holt function, we did not obtain good evidence of convergence. If we were not able to remedy the convergence problem by adjusting the length of the burn-in and making minor adjustments to the prior distribution values and/or starting values, we concluded that the model was not well suited to the data and abandoned further attempts to fit the model.

We looked at the resulting parameter estimates to ensure that there were not any biologically unrealistic values. For example, if non-informative normal priors are used for the parameters in *Equation 9* (a Beverton-Holt function), then we frequently obtained huge uncertainty intervals that include negative values. Since the parameters of *Equation 9* represent non-negative entities, we did not entertain results with negative estimates. Using such the results of such models in our PVA would have carried absurd assumptions into our estimates of extinction risk. As noted above, we were unable to obtain satisfactory results for any population using the Beverton-Holt function.

We included environmental covariates (Tables 8 and 9) in the spawner-recruit modeling for two reasons. First, it provides an opportunity to possibly better quantify, the effects of primary factors that have been previously shown to limit recruitment within fall Chinook populations of the Rogue SMU. Second, scatterplots of our spawner and recruit data look nothing like the recruitment functions we attempted to fit. Including environmental covariates provides a means of getting better parameter estimates if the covariates can significantly account for some of the apparent randomness in the spawner-recruit data. Covariates were z-transformed so that values approximately come from a standard normal distribution in order to improve convergence performance. Descriptions of the chosen covariates, and the rationale associated with those choices, can be found in the conservation plan (*see* Spawner Abundance in the conservation plan).

We computed a Deviance Information Criterion (DIC) for each model. DIC is a Bayesian analogue of Akaike Information Criterion (AIC), which represents the tradeoff between model fit and complexity (Spiegelhalter et al. 2002). Much like AIC, a practical rule of thumb is that models receiving DIC scores within 1-2 of the "best" (i.e. smallest DIC) deserve consideration, whereas scores 2-7 greater than the "best" have considerably less support (Table 7). The fitted model parameters for the three best models, determined by DIC, are provided in Table 10.

Table 7. Deviance Information Criterion scores for Ricker spawner-recruit models fitted to the populations of naturally produced Rogue fall Chinook salmon. The model with the lowest DIC is marked with an asterisk, along with models with similar (<2 difference) DICs.

Model Covariate(s)	Deviance Information Criterion score
Survival rate to age 2 for CWT-marked CHS (Table 8)	45.0*
Survival rate and Jul-Aug flow (Tables 8 and 9)	45.6*
Survival rate and peak flow (Tables 8 and 9)	46.4*
Jul-Aug rearing flow (Table 9)	51.7
None	53.9
Oct-Nov spawning flow (Table 9)	55.3
Peak flow during incubation (Table 9)	55.8

Table 8. Estimated mean annual survival rates of coded-wire tagged juvenile spring Chinook salmon released at Cole M. Rivers Hatchery during September and October, 1980-2004 brood years.

Brood Year	Ocean Survival Rate[a]	Normalized Survival Rate
1980	0.0824	0.6143
1981	0.0646	0.1623
1982	0.0930	0.8837
1983	0.1449	2.2027
1984	0.0597	0.0369
1985	0.1144	1.4275
1986	0.0283	-0.7619
1987	0.0179	-1.0257
1988	0.0237	-0.8771
1989	0.0272	-0.7885
1990	0.0374	-0.5291
1991	0.1062	1.2174
1992	0.0859	0.7032
1993	0.0623	0.1039
1994	0.0107	-1.2084
1995	0.0544	-0.0986
1996	0.0104	-1.2169
1997	0.0914	0.8434
1998	0.1155	1.455
1999	0.0778	0.4972
2000	0.0735	0.3869
2001	0.0400	-0.4638
2002	0.0095	-1.2391
2003	0.0142	-1.1188
2004	0.0108	-1.2063

[a] *Estimated survival to age 2 in the ocean before the onset of any fishing mortality.*

Table 9. Indicators of freshwater environmental conditions experienced by naturally produced fall Chinook salmon in the Rogue River Basin, 1969-2009.

	July-Aug flow[a]		Peak flow[b]		Oct-Nov[c]	
Year	Mean	Normalized	Mean	Normalized	Mean	Normalized
1969/70	1,404	-1.309	59,200	0.931	107	-1.100
1970/71	1,130	-1.765	87,100	1.994	409	0.392
1971/72	2,191	0.004	82,500	1.818	253	-0.378
1972/73	1,799	-0.650	13,400	-0.814	96	-1.153
1973/74	932	-2.094	96,400	2.348	992	3.276
1974/75	2,045	-0.240	56,000	0.809	80	-1.231
1975/76	2,149	-0.068	26,800	-0.303	273	-0.278
1976/77	1,985	-0.341	1,950	-1.250	53	-1.367
1977/78	916	-2.121	44,600	0.375	363	0.165
1978/79	2,216	0.044	18,600	-0.616	76	-1.253
1979/80	2,130	-0.099	38,400	0.138	283	-0.231
1980/81	2,069	-0.200	16,100	-0.711	75	-1.259
1981/82	1,970	-0.365	78,700	1.674	612	1.396
1982/83	2,621	0.720	73,300	1.468	521	0.947
1983/84	2,966	1.294	32,500	-0.086	767	2.162
1984/85	3,409	2.031	19,000	-0.601	806	2.358
1985/86	2,405	0.359	32,400	-0.090	268	-0.303
1986/87	2,328	0.231	22,600	-0.463	307	-0.112
1987/88	2,282	0.155	16,400	-0.700	249	-0.397
1988/89	1,844	-0.575	25,300	-0.361	393	0.317
1989/90	2,464	0.458	13,700	-0.803	312	-0.084
1990/91	1,983	-0.344	18,300	-0.627	291	-0.189
1991/92	2,166	-0.039	7,590	-1.035	279	-0.247
1992/93	1,534	-1.092	20,800	-0.532	234	-0.472
1993/94	2,895	1.175	4,950	-1.136	306	-0.113
1994/95	1,441	-1.246	16,800	-0.684	237	-0.458
1995/96	2,767	0.963	28,700	-0.231	314	-0.077
1996/97	2,528	0.564	90,800	2.135	485	0.771
1997/98	2,707	0.862	39,000	0.161	369	0.194
1998/99	3,157	1.612	43,400	0.329	638	1.524
1999/00	3,419	2.048	21,200	-0.517	265	-0.320
2000/01	2,376	0.312	3,010	-1.210	272	-0.286
2001/02	1,434	-1.258	13,000	-0.829	94	-1.162
2002/03	1,911	-0.463	34,800	0.001	305	-0.118
2003/04	2,042	-0.245	20,770	-0.533	266	-0.312
2004/05	2,040	-0.248	24,600	-0.387	308	-0.106
2005/06	2,273	0.140	78,200	1.655	333	0.019
2006/07	2,627	0.729	29,400	-0.204	282	-0.236
2007/08	2,029	-0.267	22,400	-0.471	328	-0.006
2008/09	2,988	1.331	18,000	-0.639	274	-0.273

[a] *Mean flow (cfs) at Agness when juveniles reared in freshwater.*

[b] *Greatest mean daily flow (cfs) at Grants Pass when eggs and alevins incubated in the gravel.*

[c] *Mean flow (cfs) at Applegate town when adults migrated and spawned in the Applegate River.*

Table 10. Parameter values of the best fit Ricker stock-recruitment models built for the aggregated populations of naturally produced fall Chinook salmon in the Rogue River Basin, 1980-2004 brood years.

Model 1: lnRecruits = lnα + lnSpawners - β*Spawners + e1*survival rate

Parameter	Coefficient	95%CI
Ricker α	4.07	2.11 – 6.28
Ricker β	1.57x10-5	9.76x10-6 – 2.24x10-5
e1[a]	0.37	0.14 – 0.61

Model 2: lnRecruits = lnα + lnSpawners - β*Spawners + e1*survival rate + e2*peak flow

Parameter	Coefficient	95%CI
Ricker α	3.92	2.03 – 6.16
Ricker β	1.56x10-5	0.88x10-5 – 2.17x10-5
e1[a]	0.38	0.15 – 0.61
e2[b]	-0.10	-0.38 – -0.17

Model 3: lnRecruits = lnα + lnSpawners - β*Spawners + e1*survival rate + e2*summer flow

Parameter	Coefficient	95%CI
Ricker α	3.93	2.03 – 6.01
Ricker β	1.56x10-5	0.95x10-5 – 2.20x10-5
e1[a]	0.32	0.08 – 0.57
e2[c]	0.16	-0.12 – 0.43

[a] *Survival rate (p) to age 2 for CWT-marked spring Chinook salmon cohorts of hatchery origin.*
[b] *Mean flow (cfs) at Grants Pass during July-August of juvenile rearing in freshwater.*

Parameter coefficients in the models suggested that the number of recruits produced per spawner changed in response to changes in environmental conditions and that these changes can be substantial. The models indicated that NP CHF recruitment was positively related to two factors: (1) survival rates of young hatchery fish in the ocean and (2) flow of the Rogue River during the period of peak water temperatures when juvenile NP CHF are resident in freshwater; and was negatively related to the intensity of peak flow when eggs and alevins of NP CHF are incubating in the gravel. These environmental effects can be marked, as conveyed in model 3 shown in Figure 3.

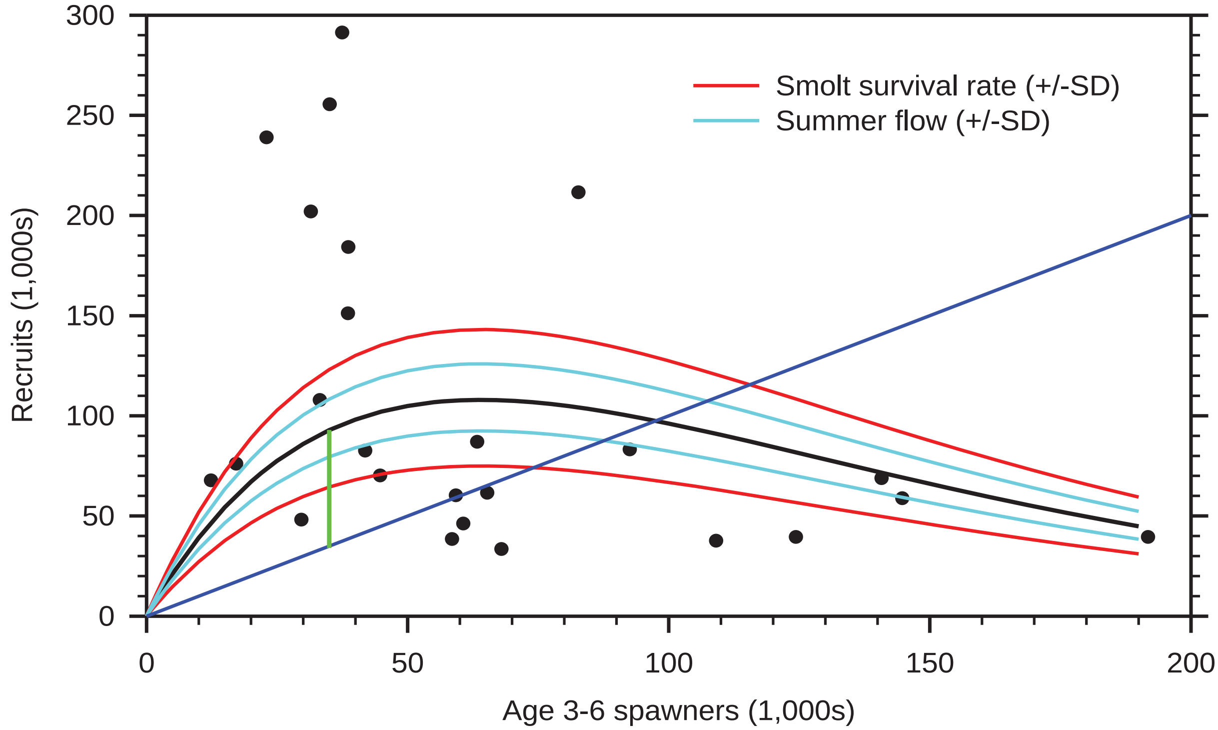

Figure 3. Ricker stock-recruitment model 3. One of three models that best fit spawner and recruit estimates for the Rogue aggregate populations of naturally produced fall Chinook salmon, 1980-2004 brood years. The solid black line represents the estimated relationship between recruits and spawners under average environmental conditions. The colored curved lines represent the estimated spawner-recruit relationship with each mean covariate value varied by +/- one standard deviation. The dark blue line represents replacement (recruits = spawners) and the green line represents the model estimate of maximum sustained yield.

Model Parameters and Diagnostics

Information that describes models generated for NP CHF populations in the SMU are presented in the Table 11 and Figures 4 - 6.

Table 11. Parameter values of the best fit stock-recruitment model (model 3) built for the aggregated populations of naturally produced fall Chinook salmon in the Rogue River Basin, 1980-2004 brood years.

RICKER MODEL EQUATION

lnRecruits = lnα + lnSpawners - β*Spawners + e1*survival rate + e2*summer flow

Parameter	Coefficient	95% confidence interval
Ricker α	3.93	2.03 – 6.01
Ricker β	1.56x10-5	0.95x10-5 – 2.20x10-5
e1[a]	0.32	0.08 – 0.57
e2[c]	0.16	-0.12 – 0.43

[a] *Survival rate (p) to age 2 for CWT-marked spring Chinook salmon cohorts of hatchery origin.*
[b] *Mean flow (cfs) at Grants Pass during July-August of juvenile rearing in freshwater.*

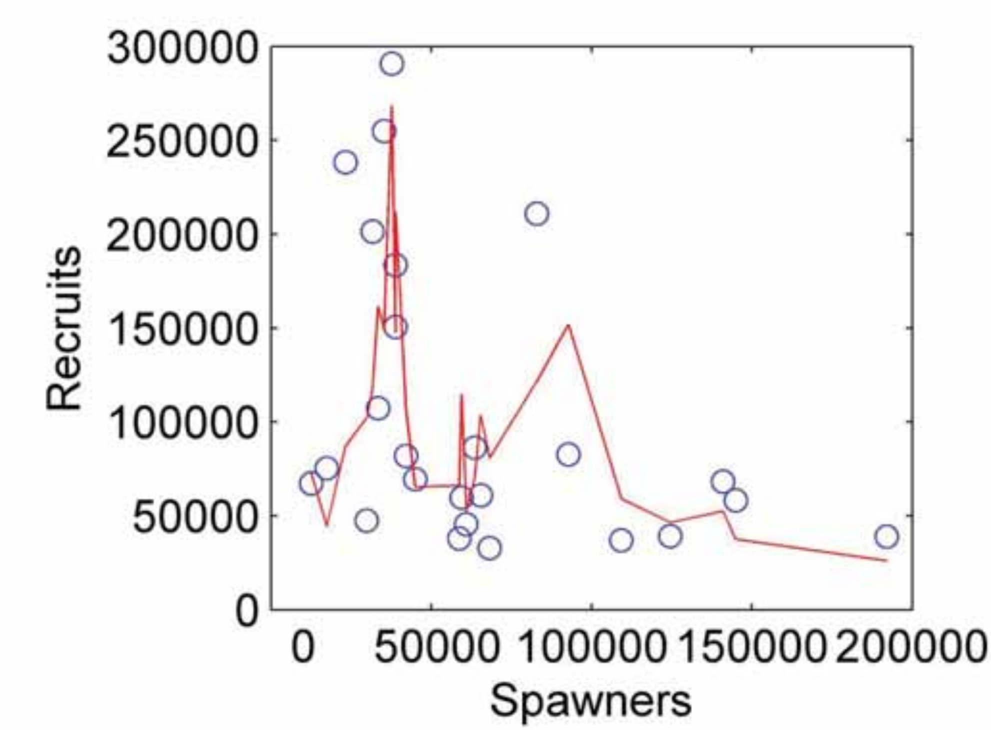

Figure 4. Model 3, recruitment with observed environmental variables.

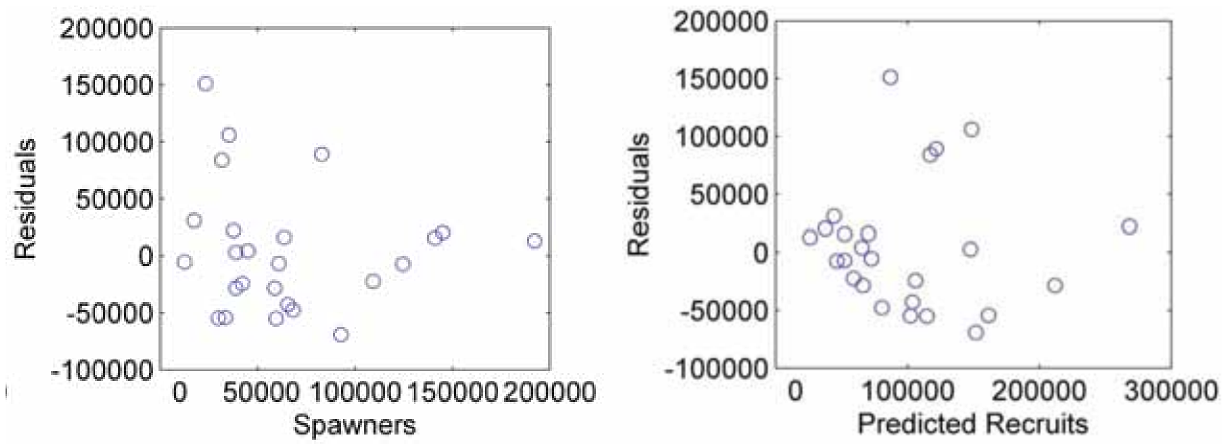

Figure 5. Model 3, residuals plotted against spawners and predicted recruits.

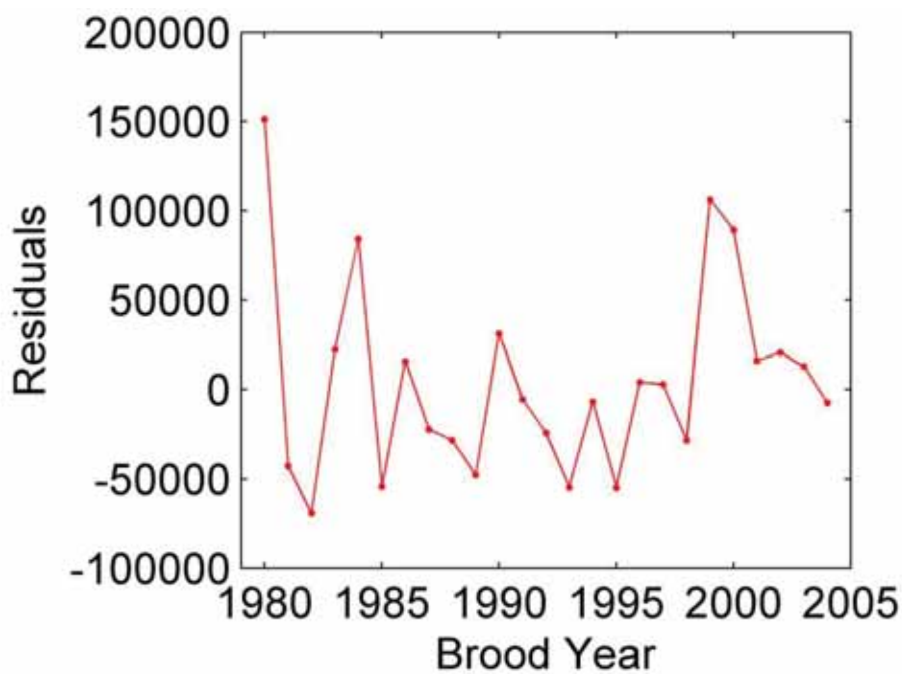

Figure 6. Model 3, residuals plotted against brood year.

Estimated S_{MSY}:

Ricker stock-recruitment model 3 developed for the Rogue aggregate populations was used to generate estimates of S_{MSY}. Ricker stock-recruitment model 3 was selected as the best fit model because it describes the effect of flow on recruitment. Uncertainty in S_{MSY} was evaluated with MCMC methods. S_{MSY} is a derived parameter (Eq. 3), so a posterior distribution of S_{MSY} was easily obtained. 50% of the upper 75th percentile of the S_{MSY} was selected as a conservation criterion.

Model point estimates, and estimates of the 75th percentile, for the number of spawners estimated for maximum sustained yield within independent populations of naturally produced Rogue fall

Chinook salmon. The table also conveys a rounded value proposed for the MSST conservation criteria (50% of the 75th percentile of S_{MSY}). Values included in the table below reflect estimates generated from Ricker stock-recruitment model 3 that included smolt survival rates and summer flow as environmental covariates.

Stock	S_{MSY} estimate Point Estimate	75th Percentile	Proposed Conservation Criteria (MSST)	Harvest rate for MSY (F_{MSY})
Rogue Aggregate	34,992	36,880	18,440	0.54

Discussion

Subpart D of the federal Magnuson-Stevens Act includes National Standard 1 (§600.310). This standard describes conservation and management measures designed to prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery managed by the federal government. Status determination criteria to determine overfished stocks are to be based on minimum stock size thresholds and must be expressed in terms of spawning biomass or other measure of reproductive potential, and should equal whichever of the following is greater: one-half (50%) of the spawning stock needed to maintain MSY, or the minimum stock size at which rebuilding to attain MSY would be expected to occur within ten years.

In 2011, the Pacific Fisheries Management Council (PFMC) adopted Amendment 16 to the Pacific Coast Salmon Plan. Included in Amendment 16 are status determination criteria related to minimum stock size thresholds (MSST) and these criteria options (Ad Hoc Salmon Amendment Committee 2011) functionally serve the same purpose as conservation criteria included in the Rogue Plan. ODFW agrees with the Ad Hoc Salmon Amendment Committee (2011) conclusion that a definition of MSST as 0.5* S_{MSY} is appropriate because salmon populations are relatively productive compared to other managed fish species. Consequently, this guidance was used to identify appropriate conservation criteria for fall Chinook spawning escapements in the Rogue SMU.

Table 12. Current conservation objective and reference points governing harvest control rules and status determination criteria for SOCC.

Stocks in Fishery	Conservation Objective	S_{MSY}	MSST	MFMT (F_{MSY})	ACL
Southern Oregon	Unspecified portion of an aggregate 150,000 to 200,000 natural adult spawners for Oregon coast streams measured by 60-90 fish per mile in index streams (Thompson 1977 and McGie 1982). ODFW developing specific conservation objectives for spring and fall stocks that may be implemented without plan amendment upon approval by the Council.	60 fish per mile in index streams	30 fish per mile in index streams	78% Proxy (SAC 2011a)	Component stock of SONC complex; ACL indicator stock is KRFC

Recommendations

ODFW proposes that the current conservation objective and reference points shown in Table 12 be replaced with those shown in Table 13.

Table 13. Proposed conservation objective and reference points governing harvest control rules and status determination criteria for SOCC.

Stocks in Fishery	Conservation Objective	S_{MSY}	MSST	MFMT (F_{MSY})	ACL
Southern Oregon	At least 41,000 naturally produced adults passing Huntley Park in the Rogue River annually to meet S_{MSY}. MSST would be reached at 20,500 measured at Huntley Park (average loss of 10% between Huntley Park and spawning, ODFW 2013).	36,880	18,440	78% Proxy (SAC 2011a)	Component stock of SONC complex; ACL indicator stock is KRFC

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Comparing Income Impact Estimates from IOPAC and FEAM (Salmon Review) Models

Prepared for the:

Joint Methodology Review Meeting of the Salmon Subcommittee of the Scientific and Statistical Committee (SSC), the Salmon Technical Team (STT), and Model Evaluation Workgroup (MEW)

October 21-23, 2014

Sheraton Airport Hotel
Portland, OR

The PFMC is in the process of transitioning its fisheries economic impact estimation method from models developed based on key informant interview data and the Fisheries Economic Impact Model (FEAM) to a structure based on more systematic data collections and the NWFSC's IOPAC model. In April 2014 the SSC Economics Subcommittee heard presentations on alternative model configurations for estimating income impacts of West Coast commercial salmon fisheries. The main issue was whether the cost of non-fish processing inputs such as labor and packaging should be treated as proportional to the weight (weight-based approach) or the ex-vessel value (cost-based approach) of fish purchased. The FEAM economic impact model assumes the former while the IOPAC model is based on the latter. The Subcommittee recommended the issue be subjected to further analysis using available data to determine whether there was justification for altering the current cost-based approach used in IOPAC.

In response the results of a statistical analysis of processor cost data collected by the West Coast Economic Data Collection (EDC) program were presented to the Economics Subcommittee at its September 2014 meeting. Linear regressions were performed using several years of available EDC data to test alternative hypotheses that in a given year processors' revenues were proportional to either (1) the weight or (2) the cost of salmon purchased by processors. Results of the analysis showed that while the weight-based hypothesis showed stronger results in certain years, the regression results lacked consistency over time. Subsequently the SSC Economics Subcommittee recommended that the cost-based approach for calculating salmon processing costs in IOPAC be used.

Table 1 compares commercial troll salmon fisheries income impact estimates calculated using IOPAC and the FEAM-based model that was used to produce the results shown in the *Review of 2013 Ocean Salmon Fisheries*. Income impact estimates are displayed in terms of thousands of inflation-adjusted 2013 dollars by year and port group. The table also shows for each port the "Processed Share", or the proportion of salmon revenue landed that is assumed to be processed in the port. In the FEAM-based model this was assumed to be 100% in all cases. This discrepancy accounts for at least some of the difference in estimated impacts for ports where the IOPAC processed share parameter is less than 100%.

Results of a more "apples-to-apples" comparison with 100% local processing shares assumed for all ports are shown in Table 2. For the two ports where IOPAC assumes zero processing, and thus no processor impact coefficients, processor impact components were “borrowed” from adjacent ports: Coos Bay was used to represent Brookings, and Eureka's processor impact measure was substituted for Crescent City.

In general, even assuming 100% local processing shares, IOPAC local-level impacts shown in Table 2 are still lower than FEAM for many ports, but by a smaller margin than in Table 1. However IOPAC state-level impact estimates shown in Table 2 are now all larger than the corresponding FEAM estimates, and often so by a wide margin (>20%). The reason for this result is not immediately clear. But it is useful to keep in mind that the multipliers used in the FEAM salmon impact model were calibrated from a 1998 IMPLAN model and year 2000 PacFIN landings, whereas the IOPAC model uses much more current data.

Table 1. Comparison of Income Impact Estimates from IOPAC and FEAM (Salmon Review) Models of Non-Tribal Salmon Fisheries [In thousands of inflation-adjusted, 2013 dollars]

	State-Level Impacts (Ocean Troll Fisheries Only)			Local Model Impacts (Ocean Troll Fisheries)												Local Model Impacts (CR Net Fisheries)	
	Washington	Oregon	California	North Washington Coast	South & Central WA Coast	Astoria	Tillamook	Newport	Coos Bay	Brookings	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	WA Col. River	OR Col. River
2010																	
IOPAC	4,708.6	4,543.2	2,140.9	539.8	3,234.7	826.5	137.5	1,069.1	947.2	172.7	0.0	28.4	1,286.2	136.4	90.3	2,182.3	5,489.3
Salmon Review	5,244.1	4,181.5	2,198.7	863.6	4,077.3	945.1	274.5	1,371.9	931.1	367.3	0.0	35.3	1,779.8	140.4	160.9	2,735.1	7,340.6
% diff (IOPAC-Review)	-10.2%	+8.7%	-2.6%	-37.5%	-20.7%	-12.5%	-49.9%	-22.1%	+1.7%	-53.0%		-19.6%	-27.7%	-2.8%	-43.8%	-20.2%	-25.2%
2011																	
IOPAC	2,560.5	3,922.1	8,775.7	657.2	1,219.0	207.1	50.1	437.5	1,970.2	237.3	30.1	364.0	3,612.1	2,272.3	576.5	2,118.5	5,085.7
Salmon Review	2,873.4	3,502.1	8,943.0	1,069.9	1,518.3	235.1	99.4	546.2	1,871.9	504.2	67.9	437.4	4,952.4	2,225.3	978.7	2,647.9	6,707.2
% diff (IOPAC-Review)	-10.9%	+12.0%	-1.9%	-38.6%	-19.7%	-11.9%	-49.6%	-19.9%	+5.3%	-52.9%	-55.7%	-16.8%	-27.1%	+2.1%	-41.1%	-20.0%	-24.2%
2012																	
IOPAC	3,620.5	7,033.6	22,372.8	1,126.6	1,422.8	626.2	248.4	1,668.5	1,962.9	322.9	17.3	597.3	3,562.3	11,107.3	3,413.0	1,793.6	3,241.9
Salmon Review	3,927.3	6,140.8	22,371.7	1,804.3	1,664.4	681.9	479.2	2,048.5	1,795.9	697.6	39.0	686.4	4,705.9	10,652.7	5,759.3	2,145.0	4,230.2
% diff (IOPAC-Review)	-7.8%	+14.5%	+0.0%	-37.6%	-14.5%	-8.2%	-48.2%	-18.6%	+9.3%	-53.7%	-55.5%	-13.0%	-24.3%	+4.3%	-40.7%	-16.4%	-23.4%
2013 (prelim)																	
IOPAC	4,362.0	12,354.8	39,857.8	880.0	2,452.5	267.0	308.1	1,549.4	6,497.1	583.4	100.6	1,690.6	9,972.5	20,431.7	2,429.1	2,786.9	5,268.1
Salmon Review	4,606.4	10,740.8	39,121.0	1,360.5	2,866.2	287.0	585.9	1,882.3	5,974.3	1,251.7	223.2	1,923.1	12,909.1	19,180.9	4,010.5	3,351.2	6,746.7
% diff (IOPAC-Review)	-5.3%	+15.0%	+1.9%	-35.3%	-14.4%	-7.0%	-47.4%	-17.7%	+8.8%	-53.4%	-54.9%	-12.1%	-22.7%	+6.5%	-39.4%	-16.8%	-21.9%
Processed Share	Assumed Percent Locally Processed																
IOPAC	55%	64%	44%	25%	90%	44%	19%	52%	100%	0%	0%	100%	100%	100%	38%	90%	44%
Salmon Review	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 2. Comparison of Income Impact Estimates from IOPAC and FEAM (Salmon Review) Models of Non-Tribal Salmon Fisheries Assuming 100% Local Processed Share [In thousands of inflation-adjusted, 2013 dollars]

	State-Level Impacts (Ocean Troll Fisheries Only)			Local Model Impacts (Ocean Troll Fisheries)												Local Model Impacts (CR Net Fisheries)	
	Washington	Oregon	California	North Washington Coast	South & Central WA Coast	Astoria	Tillamook	Newport	Coos Bay	Brookings	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	WA Col. River	OR Col. River
2010																	
IOPAC	5,598.4	5,216.9	2,669.7	747.5	3,354.8	1,038.6	206.7	1,300.1	947.2	309.9	0.0	28.4	1,286.2	136.4	121.0	2,250.6	6,698.3
Salmon Review	5,244.1	4,181.5	2,198.7	863.6	4,077.3	945.1	274.5	1,371.9	931.1	367.3	0.0	35.3	1,779.8	140.4	160.9	2,735.1	7,340.6
% diff (IOPAC-Review)	+6.8%	+24.8%	+21.4%	-13.4%	-17.7%	+9.9%	-24.7%	-5.2%	+1.7%	-15.6%		-19.6%	-27.7%	-2.8%	-24.8%	-17.7%	-8.8%
2011																	
IOPAC	3,070.0	4,533.3	11,064.5	925.4	1,266.3	263.2	76.8	537.0	1,970.2	439.2	52.2	364.0	3,612.1	2,272.3	782.7	2,188.0	6,270.3
Salmon Review	2,873.4	3,502.1	8,943.0	1,069.9	1,518.3	235.1	99.4	546.2	1,871.9	504.2	67.9	437.4	4,952.4	2,225.3	978.7	2,647.9	6,707.2
% diff (IOPAC-Review)	+6.8%	+29.4%	+23.7%	-13.5%	-16.6%	+12.0%	-22.7%	-1.7%	+5.3%	-12.9%	-23.1%	-16.8%	-27.1%	+2.1%	-20.0%	-17.4%	-6.5%
2012																	
IOPAC	4,391.3	8,203.0	28,640.0	1,623.6	1,481.1	808.3	392.0	2,074.4	1,962.9	623.6	31.3	597.3	3,562.3	11,107.3	4,721.8	1,856.2	4,054.7
Salmon Review	3,927.3	6,140.8	22,371.7	1,804.3	1,664.4	681.9	479.2	2,048.5	1,795.9	697.6	39.0	686.4	4,705.9	10,652.7	5,759.3	2,145.0	4,230.2
% diff (IOPAC-Review)	+11.8%	+33.6%	+28.0%	-10.0%	-11.0%	+18.5%	-18.2%	+1.3%	+9.3%	-10.6%	-19.7%	-13.0%	-24.3%	+4.3%	-18.0%	-13.5%	-4.1%
2013 (prelim)																	
IOPAC	5,290.6	14,408.9	51,023.1	1,268.3	2,553.1	344.6	486.1	1,926.4	6,497.1	1,126.7	181.4	1,690.6	9,972.5	20,431.7	3,360.6	2,884.2	6,588.9
Salmon Review	4,606.4	10,740.8	39,121.0	1,360.5	2,866.2	287.0	585.9	1,882.3	5,974.3	1,251.7	223.2	1,923.1	12,909.1	19,180.9	4,010.5	3,351.2	6,746.7
% diff (IOPAC-Review)	+14.9%	+34.2%	+30.4%	-6.8%	-10.9%	+20.1%	-17.0%	+2.3%	+8.8%	-10.0%	-18.7%	-12.1%	-22.7%	+6.5%	-16.2%	-13.9%	-2.3%
Processed Share	Assumed Percent Locally Processed																
IOPAC	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Salmon Review	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

MODEL EVALUATION WORKGROUP REPORT ON SALMON METHODOLOGY REVIEW

The Model Evaluation Workgroup (MEW) is not attending the November Council Meeting, but offers the following comments on the topics presented for review at the Salmon Methodology Review Meeting. There were three presentations regarding potential conservation objectives: Willapa Bay coho (Robert Kope, STT/NMFS), Grays Harbor Chinook (QDNR and WDFW), and Southern Oregon Coastal Chinook (Todd Confer and Matt Falcy, ODFW). For all of these stocks, the MEW commends the effort of the authors to pull together the necessary data and produce reasonable stock/recruit relationships. We will not comment upon Conservation Objectives but note that the exploitation rates in Council area fisheries for Willapa Bay coho and Grays Harbor Chinook are minor (<5 percent). The Southern Oregon Coastal Chinook represented by Rogue River has an ocean distribution that is indistinguishable from Klamath River stock

The MEW reviewed and has comments for the three presentations on FRAM modeling methodology. Two presentations compared Coded Wire Tag (CWT) based estimates of specific fishery impacts upon specific Chinook stocks against corresponding FRAM based estimates, and provided adjustments for FRAM modeling. These adjustments are meant to be short term, and in the cases presented will not be needed when the new Chinook base period is implemented (planned for 2016). The other presentation was of a methodology to generate model input of Age 2 Chinook abundance, based upon forecast of Age 3 cohort, potentially applicable to all FRAM stocks.

1) An Evaluation of the Effectiveness of the Cape Flattery Control Zone Closure at Reducing Non-treaty Troll Fishery Impacts on Puget Sound Chinook. Presented by Pete McHugh (WDFW)
2) Standardized Method to Calculate Chinook Age 2 FRAM Recruit Scalars, Based Upon the Age 3 Forecast. Presented by Andy Rankis (MEW/NWIFC)
3) A Method for Utilizing Recent Coded Wire Tag Recovery Data to Adjust FRAM Base Period Exploitation Rates. Presented by Galen Johnson (MEW/SSC/NWIFC)

1). Due to the Cape Flattery Control Zone closure the structure of the Area 4 (Neah Bay) troll fishery has changed since the Chinook base period was created. This closure has excluded the non-treaty fleet from nearly half of Area 4 since 1999. The presented CWT analysis supports reduced non-treaty troll impacts for three Puget Sound Chinook stocks, corresponding to a point estimate adjustment factor of 0.56 (a 44 percent reduction in impact). During the 2014 preseason process an adjustment factor of 0.75, informed by a preliminary analysis of CWT data, was applied to three Puget Sound fall fingerling FRAM stocks (Hood Canal, Deep South Sound, and Mid-Puget Sound). Given the amount of uncertainty in the data, the MEW supports WDFW's risk-averse proposal to keep the adjustment at 0.75 for each of the three Chinook stocks in the FRAM fishery strata for this area (non-treaty Area 3 and 4).

2). FRAM Chinook modeling results are highly sensitive to age specific ocean recruit inputs, by age and stock. Obtaining reliable and FRAM compatible estimates of age 2 ocean recruits has been especially difficult. Previously, model inputs for age 2 have been developed ad-hoc using inconsistent methods in preseason model runs. Thus, a method was developed to generate model input for age 2 ocean abundance from the stock's age 3 ocean abundance that provides a consistent method across all stocks and years for preseason model runs. This methodology can be applied to individual stocks or to all Chinook FRAM stocks. The MEW believes the application of this method to all stocks is preferable to partial implementation and recommends doing so for the 2015 preseason modeling.

3). The methodology for utilizing recent CWT recovery data to adjust FRAM Chinook base period exploitation rates profiled two examples from Puget Sound net fisheries directed on mature returns of local stocks. An examination of South Puget Sound stock impacts in the Hood Canal net fishery using CWT recoveries indicated that FRAM is overestimating the impacts to this non-local stock in this fishery. The other example identified an overestimate of FRAM catch of Hood Canal stock in the net fishery in south Puget Sound compared to CWT catch. The FRAM overestimates of South Puget Sound stock impacts are substantial. The methodology report stated: "It is not the goal of this methodology description to provide guidelines on what FRAM estimates would be considered problematic and, thus, candidates for the method but to provide a tool when managers deem it necessary to do so". The presented methodology uses recent year CWT recoveries to adjust FRAM's stock/age/fishery/time step-specific base period exploitation rates (BPER). The MEW agrees that the method provides a tool for adjusting FRAM estimates of stock impacts in terminal fisheries using CWT recoveries.

The MEW would also like to comment on two of the progress update reports presented at the Methodology Review meeting. 1) Work on the new FRAM Chinook base period is progressing. Testing has commenced, data gaps still need to be addressed, but the MEW anticipates a product will be ready for review at the 2015 Salmon Methodology Review Meeting. 2) A new Lower Columbia Natural Coho (LCRN) matrix for annual harvest guideline is being finalized. The potential configurations of the modified matrix are not expected to require any change to either FRAM modeling or to the calculations of total exploitation rate for the LCRN aggregate.

PFMC
11/04/2014

Agenda item F.2.b
Supplemental SAS Report
November 2014

SALMON ADVISORY SUBPANEL REPORT ON SALMON METHODOLOGY REVIEW

The Salmon Advisory Subpanel (SAS) reviewed the results of this year's salmon methodology review. The SAS appreciates the considerable efforts made in 2014 to evaluate the fishery impact evaluation methods relative to the Cape Flattery Control Zone. The report (Agenda Item F.2.a, Attachment 5) estimates that impacts in the non-treaty commercial troll salmon fishery to three Puget Sound Chinook stocks have been reduced by 44 percent as a result of this area closure. The SAS recognizes the uncertainty in this estimate and is supportive of a reductions in estimated impacts between 25 and 44 percent a risk-averse approach. The SAS is also supportive of future work to improve fishery impact estimation methods including ongoing work to implement a new base period for the Chinook Fishery Regulation Assessment Model (FRAM) in 2016 that is anticipated to represent years in which the Cape Flattery Control Zone was in place. The SAS recommends that if there are delays in implementation of the new FRAM base period that this issue be revisited.

Regard in the conservation objectives for Southern Oregon Chinook, the SAS supports the recommendations of the Salmon Technical Team.

PFMC
11/15/14

Agenda Item F.2.b
Supplemental SSC Report
November 2014

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON SALMON METHOOLOGY REVIEW

The Scientific and Statistical Committee (SSC) discussed the topics reviewed at a joint meeting of the Salmon Subcommittee of the Scientific and Statistical Committee, Salmon Technical Team (STT), and the Model Evaluation Workgroup (MEW) in Portland, Oregon on October 21-23, 2014. At that meeting proposed changes to salmon methodologies were reviewed for use in 2015 management.

Status Determination Criteria for Willapa Bay Natural Coho

Dr. Robert Kope (STT) gave a presentation on status determination criteria (SDC) for Willapa Bay natural coho (Agenda Item F.2.a. Attachment 1).

F_{MSY} and S_{MSY} were estimated based on a Ricker stock-recruit function fit to log-transformed data on recruits per spawner from 1996-2012, with appropriate back transformation. Spawner counts included both natural- and hatchery-origin fish, and recruits were reconstructed from spawners using run reconstruction based on terminal catch data and pre-terminal ocean exploitation rates of unmarked fish calculated using the fishery regulation assessment model (FRAM). The analyses are appropriate and the data used are the best available. Therefore the SSC supports F_{MSY}=0.74 and S_{MSY}=17,200 natural-area spawners.

Development of Escapement Goals for Grays Harbor fall Chinook Using Spawner-recruit Models

Dr. Pete McHugh and Dr. Kris Ryding presented the results of their recent stock-recruitment analyses for Grays Harbor fall Chinook, which produced a biologically-based spawner escapement goal to replace the current capacity-based escapement goal (Agenda Item F.2.a. Attachment 2). Escapement, terminal run reconstruction, and ocean abundance datasets were updated for this analysis. The two major populations of Grays Harbor fall Chinook, and Chehalis and Humptulips, were analyzed separately. This river system has been successfully managed to achieve an escapement goal, so there has been a narrow range of escapements over the 20 years of data and no observations of the very high or low escapements that would help define a spawner-recruit relationship. Although there was little evidence for a link between spawners and recruits over the observed range, the recommended S_{MSY} of 13,326 (S_{MSY} = 9,753 for the Chehalis and 3,573 for the Humptulips) is based on the best available science.

Standardized Method to Calculate Chinook Age 2 FRAM Stock Recruit Scalars, Based Upon the Age 3 Forecasts

Mr. Andy Rankis (MEW) gave a presentation on a new method of developing age-2 abundance inputs for Chinook FRAM (Agenda Item F.2.a. Attachment 3). Ms. Angelika Hagen-Breaux (MEW), Mr. Larrie LaVoy (MEW, STT), and Dr. Pete McHugh (WDFW) were also available to answer questions.

Currently, true age-2 forecasts based on full life cycle models or information specific to the cohort that will constitute age-2 fish in the upcoming year are not made for most stocks in Chinook

FRAM. Instead, age-2 inputs for Chinook FRAM are generated using different methods for different stocks, with a variety of assumptions.

Chinook FRAM has four model time steps, with time periods 1 and 4 spanning the same set of months in consecutive years, and assumes that fish "age up" between time steps 3 and 4. This means that the age 2 abundance in period 3 becomes the age 3 abundance (minus mortalities) in period 4. In Chinook FRAM's calculation of exploitation rates, fishing mortality is summed over time periods 2-4 while escapement is summed over time periods 1-3. Thus, the calculated exploitation rate is sensitive to the modeled number of age 3 fish in time step 4, which is driven not by the age-3 forecast inputs (which determines age-3 abundance at the start of time steps 1) but by the age-2 input.

The proposed method (specifically, equation 3 of F.2.a. Attachment 3) derives initial age-2 abundance in time period 1 such that it will project forward to an age-3 abundance in period 4 that matches the forecast abundance of age-3 in period 1. Using the current system of ad hoc age-2 inputs, modeled age-3 abundances in time periods 1 and 4 could be very different. In reality, age-3 fish in time period 1 and age-3 fish in time period 4 come from different cohorts (they were born one year apart) so the two abundances need not be equal. However, cohort strength tends to be autocorrelated: on average the two values should be close.

The SSC supports using this approach to generate age-2 inputs in Chinook FRAM in 2015. Exceptions should be stocks with age-2 forecasts shown to predict better than this default method. This will increase the accuracy of FRAM exploitation rate calculations but will not provide any new information on the strength of the actual age-2 cohort in the upcoming year.

A Method for Utilizing Recent Coded Wire Tag Recovery Data to Adjust FRAM Base Period Exploitation Rates

Dr. Galen Johnson gave a presentation on a method to adjust FRAM base period exploitation rates (BPERs) using recent coded wire tag (CWT) recoveries (Agenda Item F.2.a. Attachment 4). The recent FRAM-modeled Deep South Puget Sound Fall Fingerlings (SPS FF) catch in Hood Canal is much higher than the proportion of SPS FF CWT recoveries in the Hood Canal fishery. Adjusting BPERs using estimates from recent CWT recoveries was proposed as a short term solution specifically to reduce the modeled non-local catch of SPS FF in the Hood Canal fishery, however, it was noted that any stock in FRAM could be adjusted using this method.

The SSC agreed that a problem was identified; FRAM substantially over-estimates SPS FF catch in Hood Canal. The overestimate was quantified, and a sound solution proposed. If this adjustment is implemented, the FRAM output of SPS FF catch in Hood Canal would be reduced, and likely more realistic. However, concerns were voiced by several of the FRAM modelers about changing BPERs because reducing one BPER technically requires increasing all others slightly to maintain the model calibration. The larger problem is that arriving at a set of BPERs is a delicate balancing act. After a base period has been developed we inevitably identify areas where adjustments need to be made. The SSC recommends the development of standard procedures for identifying when adjustments are necessary and how the adjustments are implemented.

An Evaluation of the Effectiveness of the Cape Flattery Control Zone Closure at Reducing Non-treaty Troll Fishery Impacts on Puget Sound Chinook

Dr. Pete McHugh (WDFW) presented a series of analyses of the effectiveness of the Cape Flattery Control Zone closure in reducing impacts of the non-treaty troll fishery on three hatchery coded-wire tagged (CWT) indicator stocks that are believed to be closely aligned with the natural-origin Hood Canal, Mid- and South Puget Sound fall fingerling type Chinook salmon (Agenda Item F.2.a. Attachment 5).

The Cape Flattery Control Zone was closed to non-treaty trollers (NT) in 1999 but remained open to the Treaty Indian troll fleet (TI).

The analyses presented used CWT recovery data to estimate and quantify the statistical significance of:

1) The difference in exploitation rates (ER), normalized to catch in the NT fishery before and after the closure, to test whether the NT closure coincided with a reduction in ER,

2) The difference in ER in the TI fishery before and after the closure, to serve as a control, testing whether ER changed between the two time periods in a fishery expected to be largely unaffected by the NT closure, and

3) The difference in the ratio between ER of the NT and TI fisheries before and after the closure, with the expectation that NT ER would be reduced relative to TI if the closure reduced impacts of the NT.

Additionally, fishing mortalities estimated from CWT recovery data were compared to those calculated by Chinook FRAM, to determine an appropriate multiplier to apply to the Chinook FRAM-calculated NT fishing mortalities, which are driven by a base period prior to the closure.

The SSC finds the analyses technically sound and an appropriate use of the available data. The analyses show that ER in the NT fishery was lower, after the closure, although the difference is of marginal statistical significance, while ER in the TI fishery was very similar before and after the closure. Similarly, the NT:TI ER ratio became lower after the closure, but again statistical significance was marginal. Taken together, these results suggest that the closure was likely effective in reducing NT ER, although the magnitude of the reduction is uncertain. In addition, the size of reduction in ER may vary among individual stocks and across years.

The analysis found that the point estimate for the ratio of CWT-derived mortality estimates to FRAM mortality calculations was 0.56 (95% confidence interval of 0.25-0.86), or a 44% reduction. The SSC agrees that this is the best available point estimate. Using a value of 0.75, which was used last year, would be a precautionary policy decision. There was no risk assessment presented.

Conservation Objective for Southern Oregon Coastal Chinook

Todd Confer and Matt Falcy (ODFW) presented Conservation Objective for Southern Oregon Coastal Chinook (Agenda item F.2.a. Attachment 6). This document is based on the "Conservation Plan for Fall Chinook Salmon in the Rogue Species Management Unit" that was adopted by the Oregon Fish and Wildlife Commission in 2013. A version of this document submitted for methodology review in 2013 was not reviewed. The present document addresses most of the major concerns from 2013.

The analysts objective was to update the current Status Determination Criteria (SDC) to measures compatible with the Salmon Fishery Management Plan (FMP) Amendment 16, and for the FMP SDCs and Oregon conservation objectives to be compatible. Rogue River fall Chinook are the escapement indicator stock for Southern Oregon Coastal Chinook (SOCC) which, in turn, are part of the Southern Oregon Northern California Chinook (SONCC) complex. Klamath fall Chinook are the ocean exploitation rate indicator stock for the SONCC. Ocean exploitation rates are not assessed for Rogue River fall Chinook.

Rogue escapements are calibrated to seine samples at one station (Huntley Park) and summer flows. Ocean exploitation rates are from Klamath fall Chinook as reported in Preseason Report I. A Ricker stock-recruitment function was fit to data from brood years 1972 through 2006. Point estimates from the analysis were: S_{MSY} = 34,992 and F_{MSY} = 0.54. Oregon chose to use the 75th percentile estimate of S_{MSY} as a conservation buffer, resulting in S_{MSY} = 36,880. MSST was calculated as 50% of the buffered S_{MSY}, or 18,440. Oregon also adopted an F_{MSY} of 0.78; the proxy for stocks without estimates of F_{MSY}, even though there is now an estimate (0.54) for this population.

The SSC found the point estimates to be the best available science and recommends that the Council adopt S_{MSY} = 34,992 and F_{MSY} = 0.54 for Rogue River fall Chinook. The choice of MSST is a policy decision as long as it is at least 50% of S_{MSY}.

Economic Impacts of Processing in Commercial Fisheries

The SSC Economics Subcommittee reported to the full SSC on their meeting in Spokane, Washington on September 10, 2014 where they compared the Fishery Economic Assessment Model (FEAM) and the Input-Output Model for Pacific Coast Fisheries (IO-PAC) models for analyzing economic impacts of processing in commercial salmon fisheries (subcommittee report attached). The SSC endorses the recommendations of the Economics Subcommittee.

The SSC recommends that IO-PAC apply its current dollar mark-up approach to estimate economic impacts for the 2015 Salmon SAFE. The 2015 Salmon SAFE should document the change from FEAM to IO-PAC and include a comparison of the economic impacts for the past few years using both models. The SSC supports supplementing the EDC with a salmon processor survey and shares the concern that a voluntary survey often has a low response rate.

SCIENTIFIC AND STATISTICAL COMMITTEE'S ECONOMICS SUBCOMMITTEE REPORT ON THE COMPARISON OF FEAM AND IO-PAC-TYPE MODELS FOR ANALYZING ECONOMIC IMPACTS OF PROCESSING IN COMMERCIAL SALMON FISHERIES

September 10, 2014
Spokane, Washington

IO-PAC, a model developed by the Northwest Fisheries Science Center (NWFSC) to estimate regional economic impacts, was reviewed by the SSC (most recently in April 2013) and determined to be the best available method of estimating economic impacts for the groundfish fishery. IO-PAC has gradually replaced the Fishery Economic Assessment Model (FEAM) as the source of economic impact estimates for groundfish regulatory analyses and Stock Assessment and Fishery Evaluation (SAFE) documents. Council staff is now working with the NWFSC on transitioning from FEAM to IO-PAC to estimate economic impacts that are routinely reported in the Salmon SAFE (the annual *Review of Ocean Salmon Fisheries*).

In April 2014, the SSC became aware of a difference between FEAM and IO-PAC that has implications for how economic impacts for the commercial salmon fishery are estimated from the two models. FEAM estimates non-fish input purchases by processors on the basis of weight of landings, while IO-PAC estimates these purchases on the basis of ex-vessel value. More specifically, FEAM relies on multiple processor production functions that vary by species (Chinook, coho, chum, sockeye) and gear type (troll, net, other), on the basis that different species and gears yield distinguishable products that require different combinations of non-fish processor inputs. IO-PAC estimates salmon processing costs by applying a markup to the processor cost of acquiring salmon (i.e., the ex-vessel value of salmon) that is the same for all salmon species. Because of this difference between the two models, IO-PAC yields higher estimates of processor impacts than FEAM at higher ex-vessel prices and lower estimates at lower ex-vessel prices.

The SSC Economics Subcommittee met on September 10, 2014 in Spokane, Washington to consider the extent to which existing processor data could be used to resolve the differences between FEAM and IO-PAC identified at the April 2014 meeting. The discussion focused largely on a document prepared for the meeting by Jerry Leonard (NWFSC), Marie Guldin (NWFSC) and Ed Waters (PFMC contractor) dated August 20, 2014 and entitled *Comparison of Weight-based and Cost-based Methods for Estimating processing Costs and Economic Impacts*. Mr. Leonard presented the co-authors' findings to the Subcommittee.

IO-PAC estimates of processor impacts for the salmon fishery are based on processor data collected in the Economic Data Collection (EDC) program – a mandatory economic data collection program that includes processors who have first-receiver site licenses to purchase IFQ groundfish. EDC includes not only groundfish processing data but also data for all other species (including salmon) processed by EDC respondents. Processors covered by the EDC program account for about 20% of Pacific coast salmon landings.

Regression methods were used to determine whether non-fish processor purchases are better explained by the weight-based approach (FEAM) or the dollar markup approach (IO-PAC), and also whether processor operational costs vary by species. Because EDC processor data does not distinguish among individual salmon species, EDC data was combined with PacFIN landings receipt data to estimate the species composition of salmon processed by EDC respondents. Regression results from the merged 2012 EDC-PacFIN data are as follows:

- A statistically significant relationship was found between salmon processing costs and the weight of salmon landings, and the null hypothesis of equal coefficients for Chinook and other salmon landings was rejected – lending support to the weight-based (FEAM) approach.
- A statistically significant relationship was found between salmon processing costs and the ex-vessel value of salmon, and the null hypothesis of equal coefficients for Chinook and other salmon could not be rejected – lending support to the dollar markup (IO-PAC) approach.

Based on the r-squared, the weight-based approach appeared to fit the 2012 data better than the dollar markup approach and also supported differential treatment for Chinook versus other salmon species. However, similar regressions run with 2011 data yielded implausible results for the weight-based approach but plausible results for the dollar markup approach. *Although there appears to be merit to both approaches, based on the lack of consistency in regression results for the weight-based approach, the Economics Subcommittee recommends that IO-PAC apply its current dollar markup approach to estimate impacts for the Salmon SAFE.*

A comparison of income impacts of salmon processing using the weight-based and dollar markup approaches was provided for 14 port complexes on the Pacific coast, based on 2010 data. The two approaches yielded similar impact estimates except in ports where salmon prices paid by EDC processors differed substantially from the prices prevailing in that port. Price differences were most pronounced for Columbia River ports, which have an active salmon gillnet fishery. For these latter ports, the dollar markup approach (IO-PAC) yielded much lower impacts than the weight-based (FEAM) approach.

Given that the EDC program is constrained to collecting salmon data only from IFQ groundfish processors, it is not clear how well the EDC data represents salmon processing. One way to improve salmon coverage (particularly for under-represented ports or gillnet-caught salmon) would be to supplement the EDC with a voluntary salmon processor survey. However, it is not clear whether this would be feasible, given the typically low response rates to voluntary processor surveys.

Mr. Jim Seger indicated that an appendix will be added to the next Salmon SAFE that documents the change from FEAM to IO-PAC and includes tables that compare impact estimates for the past few years based on the two approaches. The Subcommittee agreed that this would be a useful way to alert managers and other users to the model change. These new comparisons will differ from the comparisons done for this Subcommittee review, as they will focus more broadly on how total income impacts (associated with both salmon harvesting and processing) would be represented in the SAFE using the two models.

The SSC Economics Subcommittee thanks the individuals who provided the analyses that clarified how the differences between FEAM and IO-PAC and how they affect the estimation of salmon processor impacts. The SSC also thanks Council staff for their involvement in planning this review.

SALMON TECHNICAL TEAM REPORT ON SALMON METHODOLOGY REVIEW

The Salmon Technical Team (STT), the Salmon Subcommittee of the Scientific and Statistical Committee, and the Model Evaluation Workgroup met on October 21-23, 2014, in Portland to conduct the annual Methodology Review. Nine topics were discussed at the meeting.

Willapa Bay natural coho status determination criteria – Robert Kope of the National Marine Fisheries Service presented a spawner-recruit analysis of Willapa Bay natural coho salmon. This stock was added to the Fishery Management Plan (FMP) by the adoption of Amendment 16, yet has no FMP-defined management objective. It also has no identified S_{MSY}, specified ACL, or status determination criteria (SDC), though the State of Washington has a habitat-based escapement goal of 13,090 natural-origin fish. The spawner-recruit analysis produced an estimated S_{MSY} of 17,200 natural-area spawners, and a F_{MSY} of 74 percent. The STT recommends that the Pacific Fishery Management Council (Council) adopt reference points for this stock based on this analysis. These would include a MFMT (maximum fishing mortality threshold) of 74 percent, a MSST (minimum stock size threshold) of 8,600 natural-area spawners (MSST = 0.5 * S_{MSY}), and annual catch limit calculated on the basis of F_{ACL} = 0.95*F_{MSY} = 71 percent.

Grays Harbor fall Chinook escapement goal – Pete McHugh and Kristin Ryding of Washington Department of Fish and Wildlife presented a spawner-recruit analysis for Grays Harbor fall Chinook. The analysis produced an estimated S_{MSY} of 13,326 for the Chehalis and Humptulips Rivers combined. This estimate is slightly lower than the current management objective of 14,600 natural-area spawners, which was adopted in 1979 and was based on available spawning habitat. The S_{MSY} estimate of 13,326 was accepted as an escapement goal by the Pacific Salmon Commission and adoption by the Council would provide consistency between the FMP and the Pacific Salmon Treaty. The data set used in the spawner-recruit analysis had relatively low contrast in spawner abundance resulting in large variance in the estimate of S_{MSY}. Despite this consideration, the STT believes the estimate of S_{MSY} is the best available science, and recommends adoption of this estimate of S_{MSY}, and associated reference points, for the salmon FMP.

Chinook FRAM base period – Larrie LaVoy of the National Marine Fisheries Service presented an update on the development of a new FRAM base-period. Work is progressing, but the new base-period will not be developed in time for the 2015 management cycle.

Coho FRAM and proposed revisions to Lower Columbia River coho harvest policy—Larrie LaVoy provided an update on the relationship between estimated exploitation rates produced from coho FRAM (Fishery Regulation Assessment Model) and the exploitation rate ceilings that are being developed for the Lower Columbia River natural (LCN) coho harvest matrix. The STT notes that with a simple weighting system the coho FRAM has the ability to produce exploitation rates estimates that are consistent with those that will be developed from the harvest policy matrix.

Method for generating age 2 abundance in Chinook FRAM - Andy Rankis of the Northwest Indian Fisheries Commission presented a method for calculating age-2 initial abundance, a necessary input for the FRAM model, based on the forecast abundance of age-3 fish. The proposed new method assumes that the age-2 year class has the same cohort strength as the age-3 cohort derived from cohort reconstruction. The method appears to be an improvement over the current mix of ad hoc age-2 forecasts for many FRAM stocks by providing consistency in methodology. An alternative to the proposed method discussed at the methodology review entails simply using the long-term average age-2 cohort abundance. The STT notes that the proposed method, and the alternative method of using the long-term average age-2 abundance, both provide some internal consistency in the FRAM model but do not produce age-2 forecasts based on any new knowledge of cohort strength. Nevertheless, the STT recommends adoption of the proposed age-2 abundance method for stocks in cases where formal age-2 abundance forecasts are not made. The STT would however like to see further consideration given to the use of long-term average age-2 abundance as an alternative approach.

<u>Method to use recent CWT data to adjust base period Chinook FRAM exploitation rates in terminal net fisheries</u> – Recent coded-wire tag data indicate that the contemporary distribution of impacts on non-local stocks in Puget Sound terminal fisheries differs from the patterns reflected in the FRAM base period which spans late 1970’s through early 1980’s. Galen Johnson of the Northwest Indian Fisheries Commission presented a method to adjust impacts in the FRAM base period data to be more consistent with recent impact distribution patterns. The STT notes that development of a new, more contemporary FRAM base-period should eliminate this problem, as the contemporary base period will reflect recent year fishing conditions and stock impacts. The STT approves of this method with the following caveat: if this or any alternative system is used to adjust FRAM base period exploitation rates for one stock (for example, by the use of the Stock Specific Scale Factor option in FRAM), then the same adjustments must apply to all stocks in the fishery such that the total observed landed catch is accounted for after summing the individual catches by stock.

<u>Cape Flattery Control Zone</u> – In April of 2014, the STT applied a 25 percent reduction to the impacts on fall Chinook stocks from mid- and south Puget Sound in the non-treaty troll fishery in Areas 3 and 4 (La Push and Neah Bay). The reduction attempted to account for the change in impacts to these stocks from the closure of Chinook salmon fishing in the Cape Flattery Control Zone (CFCZ) relative to the impacts that are estimated from FRAM under base period conditions when the area was open to fishing. To further evaluate this reduction in non-treaty troll impacts owing to the closure, Pete McHugh presented a comparison of CWT recoveries for Puget Sound Chinook stocks (George Adams, Nisqually, and mid Puget Sound) between the non-treaty troll fishery and the treaty troll fishery before and after the CFCZ was implemented. Differences in impacts between the two fisheries were substantial after the CFCZ was implemented, but were small prior to the closure, suggesting that closure had a measurable reduction in impacts for these Puget Sound Chinook stocks. The average ratio of marked landed mortalities based on CWT recoveries from the non-treaty fishery (under conditions of the CFCZ closure) to FRAM predictions of this quantity (that do not account for this closure) was 0.56, though there was substantial uncertainty in this estimate. This result suggests that including an adjustment factor in FRAM that reduces non-treaty troll impacts to these stocks by 44 percent (1 - 56 percent = 44 percent) is justified. The 25 percent adjustment factor applied in 2014 and recommended in the WDFW report is a risk-averse approach that could also be considered as an interim adjustment until the new FRAM base period is implemented. The development of a new, more contemporary FRAM base-period will eliminate the need explicitly account for changes in impacts due to the CFCZ because the contemporary base period will reflect recent year impacts estimated with the CFCZ in place.

Conservation objective for southern Oregon coastal Chinook – The current conservation objective for southern Oregon coastal Chinook is 60-90 fish per mile in three standard index areas. Todd Confer of the Oregon Department of Fish and Wildlife presented an analysis aimed at updating this conservation objective and providing SDC reference points. The focus of this analysis was the estimation of a Ricker spawner-recruit relationship for Rogue River fall Chinook that included smolt survival and mean summer flow covariates. On the basis of this analysis, Oregon has adopted new management objectives for Rogue River fall Chinook, and proposes that the Council adopt their conservation objective and reference points for the Southern Oregon coastal Chinook stock in the FMP, while keeping this stock as a component of the Southern Oregon Northern California stock complex (where Klamath River fall Chinook is the indicator stock). The stock-recruit analysis resulted in a S_{MSY} point estimate of 34,992 and F_{MSY} of 54 percent. Oregon has adopted the 75th percentile of the S_{MSY} posterior distribution (36,880 natural-area spawners) as a buffered estimate of S_{MSY}, with a corresponding MSST of 18,440 natural-origin spawners (MSST = 0.5 * 36,880). Furthermore, Oregon recommends using the 78 percent F_{MSY} proxy for tier II stocks (stocks for which no direct estimate of F_{MSY} exists) as the MFMT. The proposed stock conservation objective is a minimum of 41,000 naturally-produced adults passing Huntley Park in the Rogue River.

Based on the analysis presented and conventions currently used in the salmon FMP, the STT recommends adoption of the following reference points for southern Oregon coastal Chinook: a S_{MSY} of 34,992 and a MFMT of 54 percent. The Oregon-proposed MSST of 18,440 is 53 percent of the S_{MSY} point estimate, which is greater than the default MSST of 50 percent of S_{MSY}, though this is not inconsistent with other stocks in the FMP. The STT also sees no issues with adopting the Oregon-proposed conservation objective.

Salmon Fishery Economic Assessment - Ed Waters presented an update on plans to replace the model currently used to calculate economic impacts of commercial ocean salmon fisheries reported in the Salmon SAFE document (FEAM), with a new model that has more current estimates of economic impacts (IOPAC). The estimates coming from IOPAC are probably a better reflection of recent economic impacts, but there will be a discontinuity in the estimates of economic impacts when the model transitions from FEAM to IOPAC.

PFMC
11/04/2014

Agenda Item F.3
Situation Summary
November 2014

PRESEASON SALMON MANAGEMENT SCHEDULE FOR 2015

To plan, announce, and meet *Federal Register* deadlines for public hearing sites and the entire preseason salmon management process, staff needs to confirm details of the process prior to the end of November 2014. The proposed 2015 process and schedule are contained in Agenda Item F.3.a, Attachment 1.

For 2015, Council staff recommends one salmon management option hearing per coastal state. The hearings would be:

March 30, 2015 Westport, Washington and Coos Bay, Oregon
March 31, 2015 Eureka, California

In 2015, the March Council meeting will occur in Vancouver, Washington and the April Council meeting in Rohnert Park, California. Therefore, the public comment period regarding the tentative adoption of management measures for analysis at the April meeting in Rohnert Park also serves as a public comment opportunity. If the states desire to have additional hearings, we suggest they organize and staff them as was done in past years. The table below provides the public attendance at the hearing sites since 2000, for Council reference.

Hearing Site Location[1/]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Westport	24	30	11	16	16	25	26	34	20	27	21	54	25	36	26
Astoria															
Tillamook	13	16 [2/]	18 [2/]												
Coos Bay	36	18	40	26	26	105	146	43	60	108	60	19	29	25	14
Eureka	37	12	25	46					167	65	34	41	42	28	
Ft. Bragg					27	38									
Santa Rosa	4						500	35							5
Moss Landing[2/]	50	33	14												

1/ Sites in bold are proposed for Council staffing in 2015.
2/ Hearing staffed by state personnel.

Council Action:

1. **Confirm Council-staffed hearing sites and state intentions for additional hearings.**
2. **Approve staff's overall proposed schedule and process for developing 2015 ocean salmon management measures.**

Reference Materials:

1. Agenda Item F.3.a, Attachment 1: Pacific Fishery Management Council Schedule and Process for Developing 2015 Ocean Salmon Fishery Management Measures.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt a 2015 Preseason Management Schedule

PFMC
10/21/14

PACIFIC FISHERY MANAGEMENT COUNCIL PROPOSED SCHEDULE AND PROCESS FOR DEVELOPING 2015 OCEAN SALMON FISHERY MANAGEMENT MEASURES

Nov. 14-19, 2014	The Council and advisory entities meet at the Hilton Orange County, Costa Mesa, California, to consider any changes to methodologies used in the development of abundance projections or regulatory alternatives.
Jan. 20-23, 2015	The Salmon Technical Team (STT) meet in Portland, Oregon to draft The Stock Assessment and Fishery Evaluation (SAFE) document *Review of 2014 Ocean Salmon Fisheries*. This report summarizes seasons, quotas, harvest, escapement, socioeconomic statistics, achievement of management goals, and impacts on species listed under the Endangered Species Act. (Available early February.)
Feb. 17-20	STT meets in Portland, Oregon to complete *Preseason Report I Stock Abundance Analysis and Environmental Assessment Part 1 for 2015 Ocean Salmon Fishery Regulations*. This report provides key salmon stock abundance estimates and level of precision, harvest, and escapement estimates when recent regulatory regimes are projected on 2015 abundance, and other pertinent information to aid development of management options. (Available early March.)
Feb. 23 through Mar. 7	State and tribal agencies hold constituent meetings to review preseason abundance projections and range of probable fishery options.
Mar. 7-12	Council and advisory entities meet at the Hilton Hotel in downtown Vancouver, Washington to adopt 2015 regulatory alternatives for public review. The Council addresses inseason action for fisheries opening prior to May 1 and adopts tentative alternatives for STT analysis on March 9 and final alternatives for public review on March 12.
Mar. 13-19	The STT completes *Preseason Report II: Proposed Alternatives and Environmental Assessment Part 2 for 2015 Ocean Salmon Fishery Regulations.* (Available March 20.)
Mar. 17-31	Management agencies, tribes, and public develop their final recommendations for the regulatory alternatives. North of Cape Falcon Forum meetings are *tentatively* scheduled for March 16-18 and March 31-April 2.
Mar. 20	Council staff distributes *Preseason Report II: Proposed Alternatives and Environmental Assessment Part 2 for 2015 Ocean Salmon Fishery Regulations* to the public. The report includes the public hearing schedule, comment instructions, alternative highlights, and tables summarizing the biological and economic impacts of the proposed management alternatives.

Mar. 30-31	Tentative sites and dates of public hearings to review the Council's proposed regulatory options are: Westport, Washington (March 30); Coos Bay, Oregon (March 30); and Eureka, California (March 31). Comments on the alternatives will also be taken during the April Council meeting in Rohnert Park, California.
Apr. 11-16	Council and advisory entities meet to adopt final regulatory measures at the DoubleTree by Hilton Sonoma in Rohnert Park, California. *Preseason Report II: Proposed Alternatives and Environmental Assessment Part 2 for 2015 Ocean Salmon Fishery Regulations*, results from the public hearings, and information developed at the Council meeting are considered during the course of the week. The Council will tentatively adopt final regulatory measures for analysis by the STT on April 11. Final adoption of recommendations to National Marine Fisheries Service (NMFS) is tentatively scheduled to be completed on April 15.
Apr. 17-24	The STT and Council staff complete *Preseason Report III: Analysis of Council-Adopted Management Measures and Environmental Assessment Part 3 for 2015 Ocean Salmon Fishery Regulations* (Available April 24). Council and NMFS staff completes required National Environmental Policy Act documents for submission.
Apr. 24	Council staff distributes adopted ocean salmon fishing management recommendations, and *Preseason Report III* is available to the public.
May 1	NMFS implements Federal ocean salmon fishing regulations.

PFMC
10/21/14

Agenda Item F.4
Situation Summary
November 2014

LOWER COLUMBIA COHO HARVEST MATRIX

Lower Columbia natural (LCN) coho stocks in the Lower Columbia River evolutionarily significant unit (ESU) were listed as threatened under the Endangered Species Act (ESA) in 2005, and efforts to recover these populations often have a constraining effect on ocean and inriver salmon fisheries. Additionally, stocks on the Oregon side of the river have been listed under the Oregon ESA since 1999. Current and Federal ESA implementation has relied on a matrix approach that considers parental spawner escapement and marine survival as a harvest control rule to determine allowable fishery impacts. New information is available regarding the status of the populations since development of the current matrix control rule; thus, the Council has scheduled a review and possible revision of the matrix in current use.

At its September meeting, the Council reviewed preliminary analyses of a suite of alternatives and provided guidance on a focused set of recommendations and future work. The Council also adopted the following purpose statement for this effort:

> *Council intent is to incorporate new information on Lower Columbia River natural coho populations and stock status, evaluate the risk of various harvest strategies on populations across the Evolutionarily Significant Unit (ESU), and determine if a revised harvest policy can be developed that simplifies existing harvest rules and optimizes fishing strategies consistent with acceptable conservation risk tolerances in coordination with the applicable state and federal recovery plans.*

The Lower Columbia River Natural Coho Workgroup (LRC Workgroup) and the Salmon Advisory Subpanel (SAS) met in a joint session on October 15, 2015 to review Council guidance and to work towards final recommendations to the Council on potentially revising LCN coho harvest policy. The LRC Workgroup has completed a report that provides an overview of the history and status of LCN coho as well as a review of the existing harvest matrix and an assessment of risk associated with a suite of alternative harvest policies (Agenda Item F.4.a, LRC Workgroup Report 1). The LRC Workgroup has also prepared a summary report providing their perspectives and recommendations (Agenda Item F.4.b, LRC Workgroup Report 2). The SAS will be at the November Council meeting and will be developing recommendations to the Council at that time.

Council Action:

1. Adopt final recommendations to NMFS on any changes to the LCN coho harvest matrix.

Reference Materials:

1. Agenda Item F.4.b, LRC Workgroup Report 1: Allowable Fishery Impacts to Lower Columbia River Natural Coho: A Review of the 2006 Harvest Control Rule for Possible Policy Reconsideration.
2. Agenda Item F.4.b, LRC Workgroup Report 2.
3. Agenda Item F.4.c, Supplemental SAS Report.

Agenda Order:

a. Agenda Item Overview — Mike Burner
b. Lower Columbia River Natural Coho Workgroup Report — Stuart Ellis
c. Reports and Comments of Advisory Bodies and Management Entities
d. Public Comment
e. **Council Action**: Adopt Final Recommendations for any Changes to the Lower Columbia River Natural Coho Harvest Matrix

PFMC
10/21/14

ALLOWABLE FISHERY IMPACTS TO LOWER COLUMBIA RIVER NATURAL COHO

A Review of the 2006 Harvest Control Rule for Possible Policy Reconsideration

Pacific Fishery Management Council
Lower Columbia River Natural Coho Workgroup

Ray Beamesderfer, R2 Resource Consultants
Stuart Ellis, Columbia River Inter-Tribal Fish Commission
Jeromy Jording, National Marine Fisheries Service
Chris Kern, Oregon Department of Fish & Wildlife
Cindy LeFleur, Washington Department of Fish & Wildlife
Doug Milward, Washington Department of Fish & Wildlife
Enrique Patiño, National Marine Fisheries Service
Andy Rankis, Northwest Indian Fisheries Commission
Jeff Whisler, Oregon Department of Fish & Wildlife

October 20, 2014

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1 SUMMARY

1. Alternative harvest strategies were evaluated based on a risk analysis which considered exploitation rates in marine and Columbia River mainstem fisheries. Minor impacts of fisheries in lower Columbia River tributaries are subject to a separate consultation process.
2. ESA guidance for coho harvest management, including weak population protection, was effectively addressed by: a) basing the fishery management strategy on a conservation risk assessment which identifies the relative probability of critical low escapements, b) including representative populations of coho in Oregon and Washington identified by the State and Federal Recovery plans as primary populations with a priority for conservation and recovery effort; and c) focusing the assessment on the weakest of the primary populations.
3. The risk analysis was informative in helping to understand the relative effects of fishery alternatives on LCN status.
4. At current fishing levels, it is clear that small changes in effective average annual exploitation rates have a very small impact on LCN conservation risks. Further reductions in fishing rate from the current level do not provide large risk reductions.
5. Small increases in exploitation rates and an abundance-based fishery strategy have a negligible effect on conservation risks with very significant fishery benefits.
6. A simplified matrix structure substantially enhances the ability for stakeholders to understand and weigh fishery implications of various alternatives. Comparable levels of risk may be produced by a variety of more or less complicated harvest control rules. Schemes are not inherently more conservative by virtue of design.
7. A simple matrix structure including a marine survival index can effectively meet objective risk criteria for the weak primary LCN populations. At most abundances, coho returns are driven predominately by marine survival; however, incorporation of seeding level in the control rule provides protection at very low seeding levels when it is most needed.
8. Some consideration should be given to including a condition for very low seeding as a contingency for very low abundances.
9. Annual exploitation rates of 10% to 30% are appropriate for consideration in fishery alternatives. A rate of 10% is necessary to conduct Chinook-only PFMC fisheries, particularly in years of high abundance. A rate of 30% on the high end is appropriate for accessing large returns of Columbia River hatchery coho in years of good marine survival. Rates in the current matrix range from 8% to 45%.
10. Fishing strategies should provide for meaningful fishing rates in the middle range of marine survival where we will be operating most of the time, while maintaining protections when marine survival is poor.

2 INTRODUCTION

Lower Columbia natural (LCN) coho were listed as threatened under the Endangered Species Act (ESA) in 2005 (70 FR 37160). Ocean and Columbia River salmon fisheries are regulated in part to limit exploitation rates on this stock. Harvest control rules are based on an abundance-based matrix approach which identifies allowable fishery impacts based on parental spawner escapement and marine survival. The current LCN harvest matrix has been in place since 2006, with NMFS last completing a biological consultation for fisheries adopted by the PFMC affecting this ESU in 2008. Current fishing levels were effectively established in 2006 and 2007 when NMFS implemented further reductions under federal rules relative to those in place since 2001 under state rules. A more conservative strategy was adopted, in part due to the limited amount of data on status of LCN natural coho populations incorporated into the previous strategy. Since that time, formal recovery plans including LCN coho have been adopted (LCFRB 2010; ODFW 2010; NMFS 2013) and new information on stock status has also been collected.

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

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

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

At its March 2014 meeting, the Council appointed LRC Workgroup members representing primarily technical and policy staff from State, Federal, and Tribal agencies. The work group was directed to review the 2013 information and provide guidance on the development of alternative harvest control rules. The LRC Workgroup was expected to work closely with the SAS. This report summarizes new information and technical analyses developed by the LCN Work Group.

At its September 2014, the Council adopted the following purpose statement for the work group:

> *Council intent is to incorporate new information on Lower Columbia River natural coho populations and stock status, evaluate the risk of various harvest strategies on populations across the Evolutionarily Significant Unit (ESU), and determine if a revised harvest policy can be developed that simplifies existing harvest rules and optimizes fishing strategies consistent with acceptable conservation risk tolerances in coordination with the applicable state and federal recovery plans.*

3 Background

3.1 History of Listing

In 2001, NMFS reviewed the status of this ESU and concluded that the Clackamas and Sandy were believed to be the only populations to have, albeit very little, if any, natural production. The majority of the other populations were thought to be extirpated or the result of hatchery strays. In 2006, the NMFS concluded that "the naturally spawned component of the Lower Columbia River coho ESU is 'in danger of extinction.'" and that "the scale of artificial propagation poses genetic and ecological threats to the two extant natural populations in the ESU." NMFS concluded that the "ESU in-total is likely to become endangered within the foreseeable future throughout all or a significant portion of its range, and determine[d] that Lower Columbia River coho ESU warrants listing under the ESA as a threatened species." (70FR3793)

3.2 Washington Recovery Plan Guidance

The Washington Lower Columbia River Salmon Recovery Plan includes three measures that apply to discussions regarding the coho matrix:

F.M21 – The measure talks about the range harvest rates that the Recovery Plan uses to track progress with respect to implementation of the Recovery Plan. This section identifies an 8%-25% exploitation rate range for reference as an interim benchmark.

F.M22 – This is the measure that calls for a sliding scale harvest strategy for coho. In the title of the measure it calls for protection of weak stocks, but it does not specify that it must be managed to the weakest stocks annually. In the explanation of the measure it talks about the need to represent the status of populations for recovery including both weak and strong populations.

F.M25 – This measure discusses the need to review the current management strategy that uses Clackamas late coho as surrogate to protect Washington natural stocks.

Options for the coho matrix that are being considered effectively address all three of these measures. The current options address F.M22 by developing a matrix. Risk analyses described later in this report demonstrate that the range of exploitation rates being considered is low enough to protect weaker stocks. The risk assessment considers both weak and strong populations as called for by this measure and expands the number of populations to include several Washington stocks, which addresses the concern presented in F.M25.

While exploitation rates of 30% being considered exceed the 25% top end of the interim benchmark range, they are reserved for relatives few years where high marine survival is observed. Higher exploitation rates are identified as appropriate in the recovery plan when recovery trajectories are ahead of schedule and higher exploitation rates in years of high marine survival have a greater potential for reducing the number of hatchery origin spawners among natural Washington coho populations.

3.3 Oregon Recovery Plan Guidance

Oregon's Recovery Plan strategies and measures for coho harvest management include continued use of an abundance-based, sliding scale harvest matrix. The plan allows for modifications of this management approach to be made based on new information on the wild LCR coho populations. The threat scenarios developed for Oregon's LCR coho populations in the Recovery Plan included an average future harvest impact rate of 25 percent for each population.

The Plan noted that the current harvest matrix is based only on the Clackamas and Sandy coho which were historically believed to be the strongest extant populations in the ESU. The plan notes that the current harvest management does not consider how the weaker populations are faring and whether they could maintain their existence, or rebuild to recovery levels under the impact rates called for in the harvest matrix.

Oregon's recovery plan proposed to work with Washington and other harvest managers to review the harvest matrix and revise it based on "weak stock management" – protecting a weak grouping of populations in the ESU (within the Cascade and Coast strata considering the uncertainty of the appropriateness of a Gorge stratum with independent populations). This would base allowable harvest rates on the status of weak groupings of populations and ensure that those populations can rebuild to levels consistent with recovery and maintain those levels once they are reached.

The coho harvest matrix review by the Council's LCR Workgroup is consistent with coho harvest management strategies and measures identified in the Oregon Recovery Plan. Weak coho population protection was effectively achieved by: a) basing the fishery management strategy on a conservation risk assessment which identifies the relative probability of critical low escapements for all populations, b) including additional representative populations of coho in Oregon and Washington identified by the State and Federal Recovery plans as primary populations with a priority for conservation and recovery effort; and c) focusing the assessment of relative risk changes on the weakest of the primary populations.

3.4 NMFS Recovery Plan Guidance

Working with its federal, state, tribal, and local partners, NOAA Fisheries published a recovery plan for lower Columbia River salmon and steelhead in July 2013. The plan provides a road map to recover four salmon and steelhead species that spawn and rear in the lower Columbia River or its tributaries in Oregon and Washington. The Lower Columbia Recovery Plan is based on three locally developed plans, each of which covers a different portion of the species' range: Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead prepared by the Oregon Department of Fish and Wildlife (2010), NOAA Fisheries' ESA Salmon Recovery Plan for the White Salmon River Watershed (2013), and the Lower Columbia Fish Recovery Board's Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (2010). Two additional documents informed the development of this plan, The Columbia River Estuary ESA Recovery Plan Module for Salmon & Steelhead, and The Recovery Plan Module: Mainstem Columbia River Hydropower Projects. These two documents were prepared by NOAA Fisheries.

The NMFS Recovery plan is founded on strategies and measures identified by the management unit plans. For coho salmon, NMFS identified near-term priorities for implementing a harvest strategy consistent with recovery including:

- Obtaining better information on natural-origin and hatchery-origin spawner escapement and better estimates of natural population productivity
- Obtaining a better estimate of harvest impact rates for natural-origin Lower Columbia River coho salmon in ocean and Columbia River mainstem fisheries (and, in particular, addressing uncertainties related to harvest impacts in mainstem fisheries)
- Evaluating and refining harvest strategies for periods of poor ocean conditions and for years when returns are strong.
- Incorporating into the matrix a method of managing for weaker stocks that would benefit from harvest reductions
- Developing mark-selective fishing methods that can be used in the commercial mainstem fisheries

4 Lower Columbia Coho Status

4.1 Columbia River Run

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

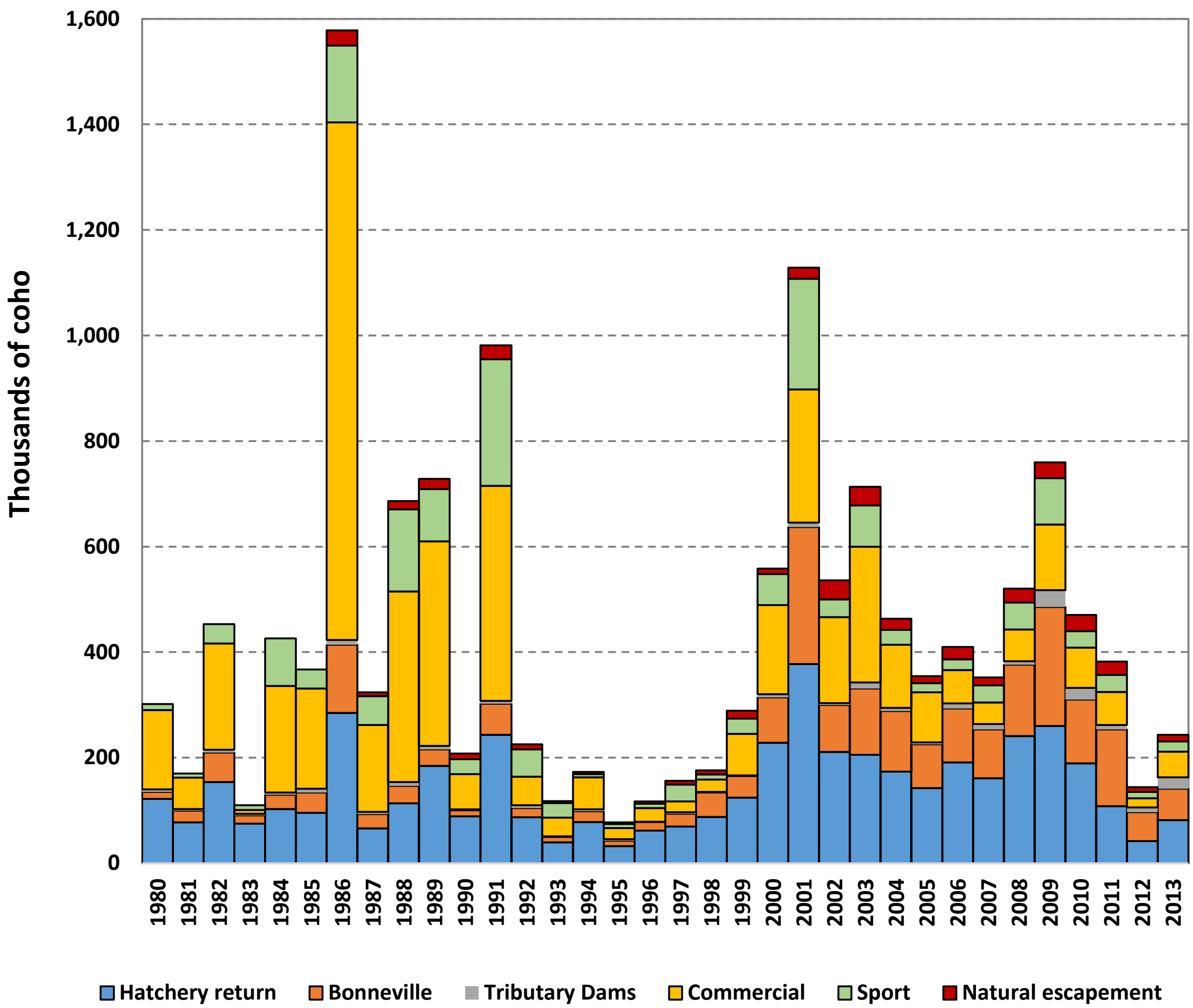


Figure 1. Columbia River return of coho, 1980-2013.

4.2 Lower Columbia River Natural

Salmon recovery plans adopted by Washington, Oregon, and NMFS, identify recovery objectives for LCN coho that designate a subset of all populations as primary targets for restoration to high levels of viability based on abundance, productivity spatial structure and diversity. A total of 16 of the 24 lower Columbia populations were identified in recovery plans as primary populations (Figure 2). The remainder were identified as contributing populations where recovery measures are expected to result in some improvement, or as stabilizing populations where measures are expected to prevent further declines. Of the primary populations, at least three were identified in each of the three spatial strata within the ESU. Some primary populations of coho will require some of the most significant improvements in status, hence, will be most constraining to a viable recovery fishing strategy.

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

The majority of this report deals with the effects of fishery exploitation rates on individual populations within the ESU. However, information on the status of the ESU as a whole may be useful to Council Members making a decision about a possible different fishery control rule, in terms of whether the ESU as a whole is considered to now be better, the same, or worse than what was thought to be the case at the onset of 2006 fisheries when the current control rule first became effective. It is beyond the scope of this report to assess the full "health" of the ESU in this context, as a truly comprehensive assessment of ESU health would include such parameters as the condition of the habitat coho are dependent upon, the genetic constitution of individual populations, the genetic diversity of populations comprising the ESU, hatchery reform, effects of mark-selective fishing, population reintroduction programs, etc.

Absent such a comprehensive assessment, this section presents escapement data for several Columbia River tributaries to provide a context for both the relative abundance of some of the primary populations, but also to illustrate the substantial increase in our understanding of the status of natural spawning in basins where, until recently, little information was available. This is largely due to greatly expanded sampling efforts by ODFW and WDFW since ESA-listing. The inclusion of this new sampling information indicates that several naturally spawning coho populations outside the Sandy and Clackamas River basins are more abundant than previously assumed, and modeling results indicate that some populations (Scappoose Creek, Clatskanie River, Lower Cowlitz River, Toutle River) are relatively productive and thereby more resilient (see Section 7.2.1).

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

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

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

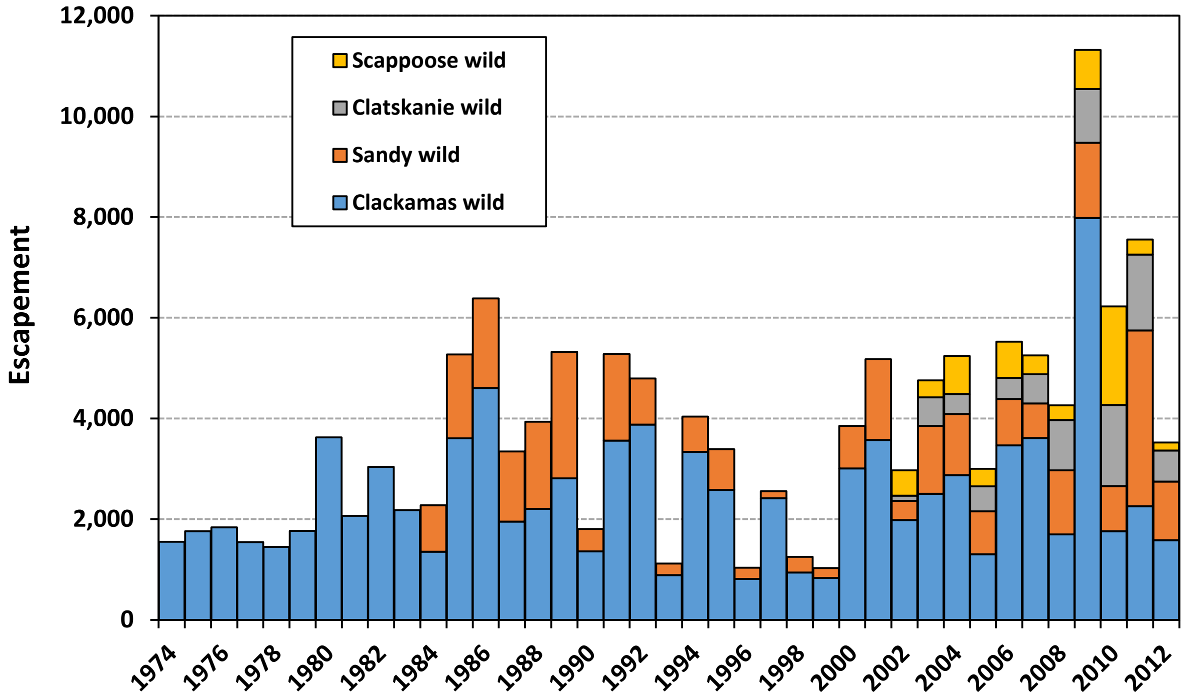


Figure 3. Escapement of LCN coho in selected Oregon tributaries. (Not all populations were surveyed in every year.)

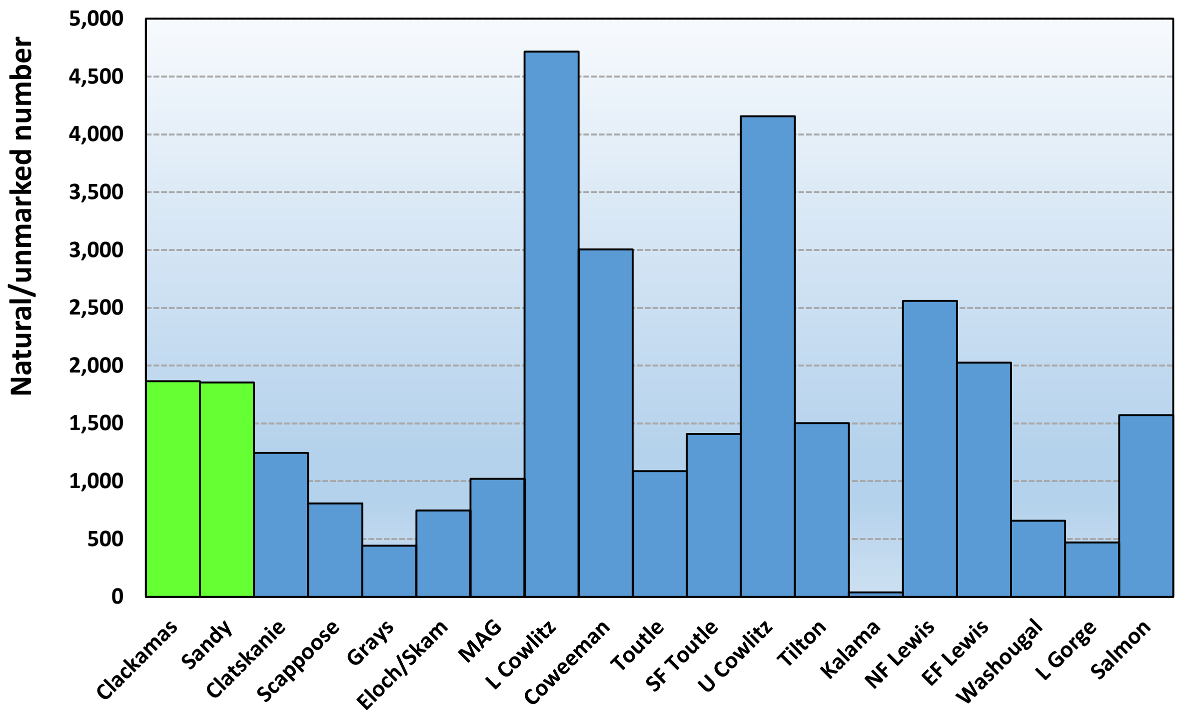


Figure 4. LCN coho abundance data by population for 2011.

Table 3. Recent adult coho spawning escapement data for Oregon lower Columbia River streams (ODFW unpublished).

	Clackamas				Sandy					Clatskanie				Scappoose			
	Total	Wild	Hat.	Hat (%)	Total	Wild	Hat.	Plants	Hat (%)	Total	Wild	Hat.	Hat (%)	Total	Wild	Hat.	Hat (%)
1974	2083	1551	532	26%													
1975	2692	1761	931	35%													
1976	3509	1835	1674	48%													
1977	1829	1544	286	16%													
1978	2645	1450	1195	45%													
1979	4310	1765	2545	59%													
1980	8156	3624	4532	56%													
1981	2896	2065	832	29%													
1982	6700	3037	3663	55%													
1983	2888	2183	705	24%													
1984	2136	1353	783	37%	1884	925	159	800	51%								
1985	5216	3604	1612	31%	2405	1665	140	600	31%								
1986	9443	4603	4841	51%	3001	1780	221	1000	41%								
1987	2715	1954	761	28%	1518	1390	128		8%								
1988	3340	2203	1137	34%	1893	1735	158		8%								
1989	6243	2811	3432	55%	2730	2508	222		8%								
1990	1854	1361	493	27%	617	443	174		28%								
1991	5631	3562	2069	37%	1889	1718	171		9%								
1992	5123	3881	1241	24%	1105	916	189		17%								
1993	1095	887	208	19%	391	233	157		40%								
1994	4346	3336	1010	23%	873	700	173		20%								
1995	3597	2578	1019	28%	956	810	146		15%								
1996	1360	813	547	40%	237	220	18		8%								
1997	2864	2413	450	16%	268	145	123		46%								
1998	5499	941	4558	83%	429	311	118		28%								
1999	5090	833	4257	84%	243	198	45		19%								
2000	15342	3006	12335	80%	993	847	145		15%								
2001	15613	3575	12039	77%	1730	1600	130		8%								
2002	4683	1981	2702	58%	897	382	515		57%	229	104	125	55%	502	502	0	0%
2003	2801	2507	294	10%	1348	1348	0		0%	563	563	0	0%	373	336	37	10%
2004	3411	2874	537	16%	1340	1213	127		9%	398	398	0	0%	822	755	67	8%
2005	1805	1301	504	28%	856	856	0		0%	501	494	7	1%	348	348	0	0%
2006	14335	3464	10871	76%	923	923	0		0%	467	421	46	10%	758	719	39	5%
2007	4190	3608	582	14%	753	687	66		9%	1126	583	543	48%	375	375	0	0%
2008	3104	1694	1410	45%	1277	1277	0		0%	995	995	0	0%	292	292	0	0%
2009	10960	7982	2978	27%	1667	1493	174		10%	1256	1070	186	15%	778	778	0	0%
2010	4040	1757	2283	57%	1029	901	128		12%	1774	1609	165	9%	1960	1960	0	0%
2011	2498	2254	244	10%	3813	3494	319		8%	1553	1506	47	3%	298	298	0	0%
2012	1755	1580	175	10%	1198	1165	33		3%	688	619	69	10%	210	161	49	23%

Table 4. Recent adult coho spawning escapement data for Washington lower Columbia River streams (WDFW unpublished).

	2010				2011				2012			
Population	Total	Marked	Unmarked	p marked ***	Total	Marked	Unmarked	p marked ***	Total	Marked	Unmarked	p marked ***
Grays/Chinook	1968	1587	381	0.81	4771	4620	152	0.97	1023	228	795	0.22
Eloch. /Skam.	3272	2393	880	0.73	1946	1095	851	0.57	708	202	505	0.29
MAG	1903	232	1671	0.12	1022	215	807	0.21	595	11	585	0.02
L. Cowlitz tribs.	7106	1069	6038	0.15	3706	312	3394	0.08	NA	NA	NA	NA
Coweeman	4006	393	3613	0.10	2582	146	2436	0.06	3105	141	2964	0.05
Toutle/Green	3686	2216	1469	0.60	526	160	365	0.27	1877	452	1425	0.24
SF Toutle	2118	442	1675	0.21	631	141	490	0.22	2409	346	2063	0.14
U. Cowlitz/Cispus	21746	18840	2906	0.87	20745	12870	7875	0.62	6832	5143	1689	0.75
Tilton	3501	2523	978	0.72	8090	6002	2088	0.74	6636	5192	1444	0.78
Kalama	521	516	5	0.99	311	NA*	NA*	NA*	320	251	69	0.79
NF Lewis	4338**	260**	4078**	0.06**	5804	3265	2538	0.56	2976	397	2579	0.13
EF Lewis	2022	655	1367	0.32	1091	65	1025	0.06	4060	379	3681	0.09
Salmon Creek	NA	NA	NA	NA	1562	314	1248	0.20	2434	537	1897	0.22
Washougal	1582	702	879	0.44	609	48	562	0.08	612	81	531	0.13
Lower Gorge	542	160	382	0.29	577	72	504	0.12	654	130	524	0.20

* *No carcass recoveries to determine proportion marked.*

** *does not include mainstem NF Lewis; only tributaries.*

*** *Proportion marked is equivalent to pHOS but does not include substantial numbers of unmarked adults from RSI programs in the Lower Cowlitz, NF Lewis, and Salmon Creek populations.*

4.3 Willamette coho

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

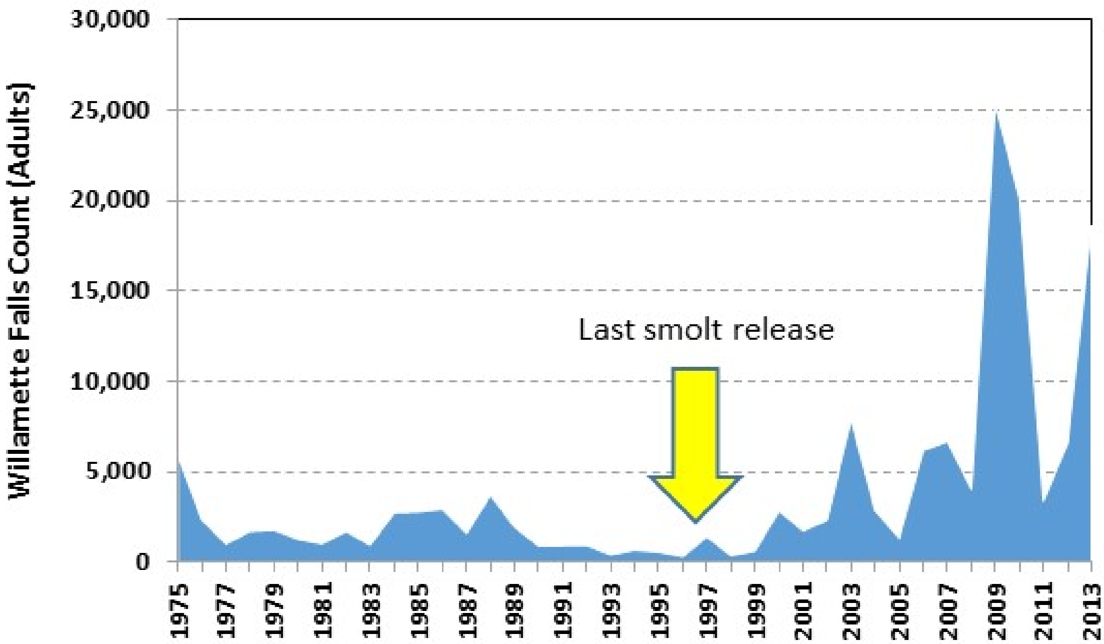


Figure 5. Willamette Falls coho counts.

The appropriate status of Willamette coho relative to the listed ESU and coho recovery goals has been debated. On the one hand, this population is not part of the ESU because it has colonized streams where it was not native prior to the construction of a fish ladder in 1882. On the other hand, it appears to be a viable naturally-producing population originating largely from Lower Columbia River hatchery sources.

The work group suggests that status of Willamette coho might inform our understanding of population dynamics and response to recent fishing patterns but does not change the need to develop effective fishing alternatives for management of listed coho populations throughout the designated ESU. The degree to which the Willamette population might be considered representative of other coho populations in the ESU warrants investigation. NMFS will review the classification of Willamette coho as part of the next formal 5-year status review scheduled for 2016.

5 LCN Exploitation Rates

5.1 Ocean & Mainstem Columbia River

Annual exploitation rates of LCN coho have been substantially reduced from very high historical levels as management has shifted from maximizing harvest of hatchery fish to protecting natural populations. LCN coho are harvested in a wide range of marine and freshwater fisheries in Washington and Oregon as well as Canada. For the purposes of this report, exploitation rates refer to ocean mainstem fishery impacts below Bonneville Dam.

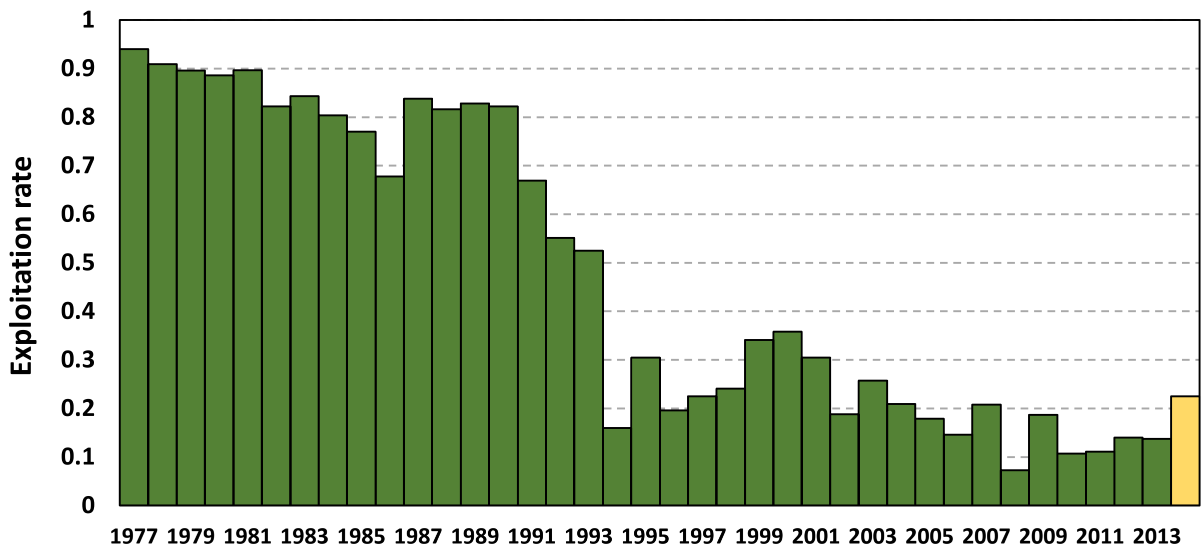


Figure 6. Annual exploitation rates of lower Columbia River natural coho, 1977-2013. The 2014 value is the preseason number.

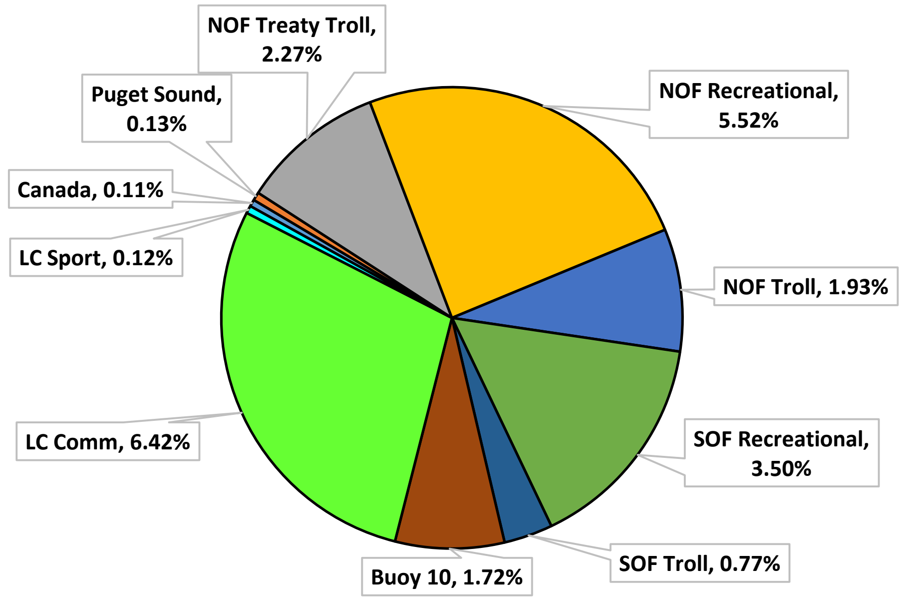


Figure 7. Distribution of expected 2014 fishery impacts on lower Columbia River natural coho salmon.

During recent years, exploitation rates have been limited from 8% to 22.5% (Table 5, Table 6). Exploitation rate has been limited to 15% in six of the last ten years. The weighted average exploitation rate during this period was 16%. Post-season rates have averaged approximately 1% less than allowable limits during this period (Table 5).

Table 5. Lower Columbia Natural adult coho allowable ocean and mainstem Columbia River fishery rates and actual fishery impacts.[a]

Year	Allowable	Pre-season	Post- season
2006	≤0.15	0.10	0.146
2007	≤0.20	0.13	0.208
2008	≤0.08	0.08	0.073
2009	≤0.20	0.20	0.187
2010	≤0.15	0.15	0.107
2011	≤0.15	0.15	0.111
2012	≤0.15	0.15	0.14
2013	≤0.15	0.15	0.137
2014	≤0.225		
Avg.		*0.139*	*0.139*

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

Table 6. Frequency occurrence of specific conservation objectives for LCN coho, 2005-2013.

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

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

The workgroup has estimated that a rate of 10% would often be necessary to conduct Chinook-only PFMC fisheries. The current LCN coho matrix includes rates as low as 8% but this rate is not expected to be sufficient to conduct future Chinook fisheries, particularly in years of high Chinook abundance. The fishery was managed under an 8% rate once (2008) but the fishery was very limited south of Falcon due to poor stock status of California Chinook stocks. The risk analysis showed that managing for 10% rather than 8% at the low end had a negligible effect on risk. At very poor coho stock status the PFMC should examine whether further reductions below 10% can be achieved while allowing access to Chinook stocks.

A rate of 30% on the high end would allow access to large returns of Columbia River hatchery coho in years of good marine survival. This opportunity is particularly important to Columbia River target coho fisheries – these years are very important in the long-term economic viability of these fisheries and to reducing hatchery coho natural spawning.

Table 7. Fishery implications of conservation objectives.

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

5.2 Mainstem Upstream from Bonneville

Coho salmon are harvested in tribal commercial and subsistence, and non-tribal sport fisheries upstream from Bonneville Dam. The coho Run at Bonneville is assumed to be comprised almost entirely of non-ESA listed coho originating from hatchery and natural production upstream of the LCR ESU. An unknown but probably small proportion of the Listed ESU passes Bonneville. Fishery impacts in the Columbia River mainstem will be considered separately in ESA consultations by NMFS from those of mainstem and ocean fisheries addressed by the harvest matrix.

Table 8 describes coho harvest rates in Bonneville Reservoir by treaty Indian fisheries. Actual exploitation rates on LCR coho would be less than the reservoir-wide estimates. The Bonneville Pool coho catch includes harvest upstream of the Hood River which is upstream of the LCR ESU boundary. Presumably the catch of LCR ESU coho upstream of the Hood River either does not occur or does not significantly impact listed LCR coho if it does occur.

5.3 Columbia River Tributaries

Mark-selective sport fisheries occur in some lower Columbia River tributaries to harvest hatchery-origin coho. Corresponding impact rates on wild coho are quite low, typically on the order of 2% or less. Tributary sport fishery impacts will be considered separately in ESA consultations by NMFS from those of mainstem and ocean fisheries addressed by the harvest matrix.

Table 8. Treaty Indian coho harvest rates in Bonneville Reservoir.

Year	Bonneville Dam Count	Bonneville Pool Catch	Harvest Rate
2001	259,553	3,566	1.37%
2002	88,084	672	0.76%
2003	125,747	744	0.59%
2004	114,940	2,720	2.37%
2005	83,305	1,796	2.16%
2006	102,111	3,047	2.98%
2007	96,378	3,211	3.33%
2008	135,536	10,508	7.75%
2009	224,897	6,663	2.96%
2010	120,928	5,648	4.67%
2011	145,299	12,889	8.87%
2012	54,968	2,060	3.75%
2013	59,610	3,086	5.18%
2001-2007 Avg			1.94%
2008-2013 Avg			5.53%
2001-2013 Avg			3.60%

6 Analysis of Current Matrix Efficacy

The current harvest control rule is based on a matrix approach that determines allowable fishery impacts based on many combinations of parental spawner escapement and marine survival. This matrix is complex, resulting in 20 combinations from five escapement and four survival index categories, though many of the combinations result in identical exploitation rates. The current matrix includes combinations that are not represented in the historical record, and are therefore unlikely to occur in the near future. This complexity makes it difficult for managers and fishers to understand and evaluate the implications of different alternatives. As an example, the current matrix contains a maximum harvest rate of 45% that is based on conditions that have not been observed since the early 1970s, and then only rarely. The matrix also currently includes a minimum harvest rate for very low fractions of full-seeding (<10% for Clackamas and Sandy) which have never been observed.

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

6.1 Marine Survival Index

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

Higher MSI values occurred from 1968-1974 prior to a change in ocean regime. However, the risk analysis modeling is based on the period since 1974 most representative of current conditions. It is entirely possible that marine survival patterns could one day return to a higher level. The high correlation between Columbia River hatchery jacks and adults holds when data are limited to the interval since 1974.

Note that the SSC commented on the time period used in population model parameterization in the Oct 2013 methodology review. The relationship between recruits and survival rates changed after 1992 – current risk analyses are based on stock-recruitment relationships during this period. Also note that all model runs are parameterized similarly. Hence, relative changes in risk among fishery alternatives are likely to remain comparable under a variety of alternative parameterization assumptions.

Figure 11 describes the relationship between marine survival index and Columbia River coho run size under recent hatchery production levels. This information is useful for placing marine survival indices and frequencies of occurrence of various fishing rates described by alternatives in context of how many coho were available for harvest at various fishing levels.

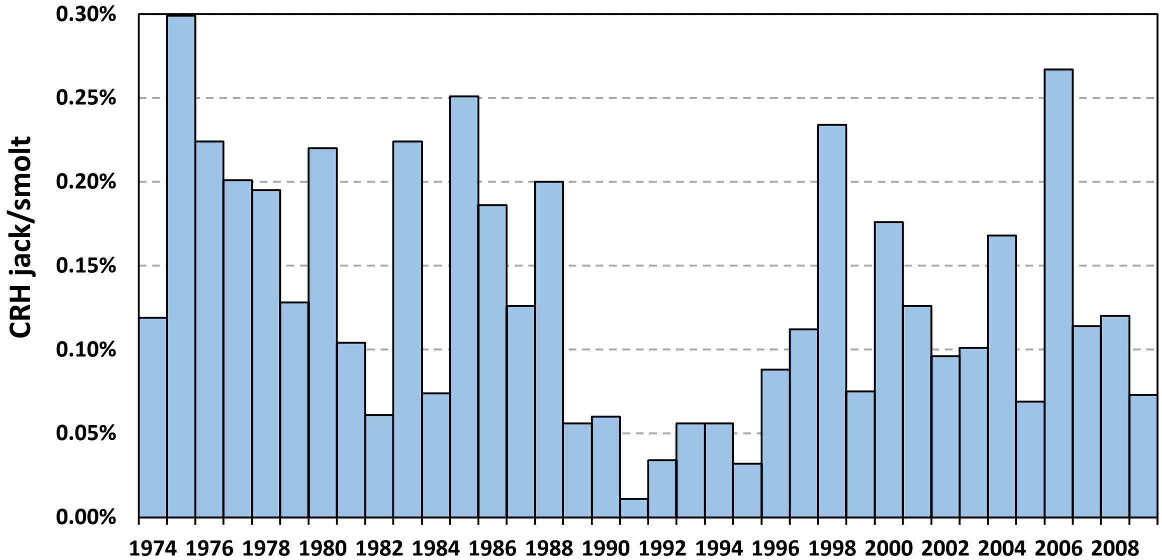


Figure 8. Marine survival index based on the percentage return of hatchery smolts returning after one year in the ocean as jacks, 1974-2009.

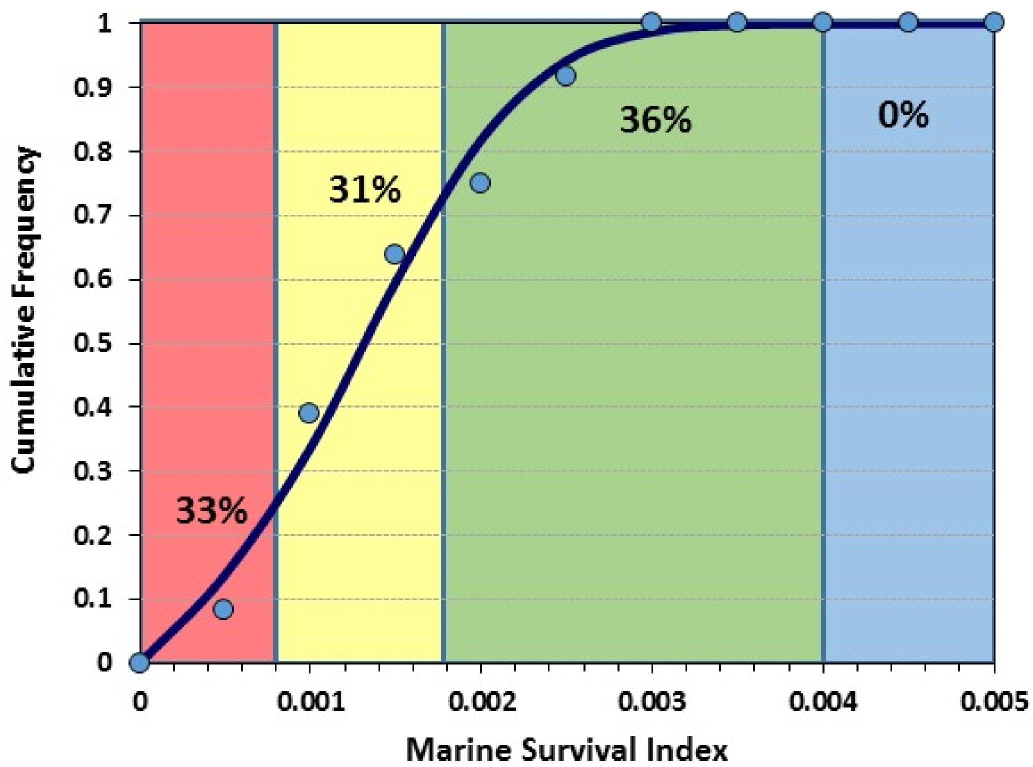


Figure 9. Cumulative frequency distribution of Columbia River hatchery coho marine survival index, 1974-2009. Categories identified in the LCN coho harvest matrix are identified along with observed frequencies for each category.

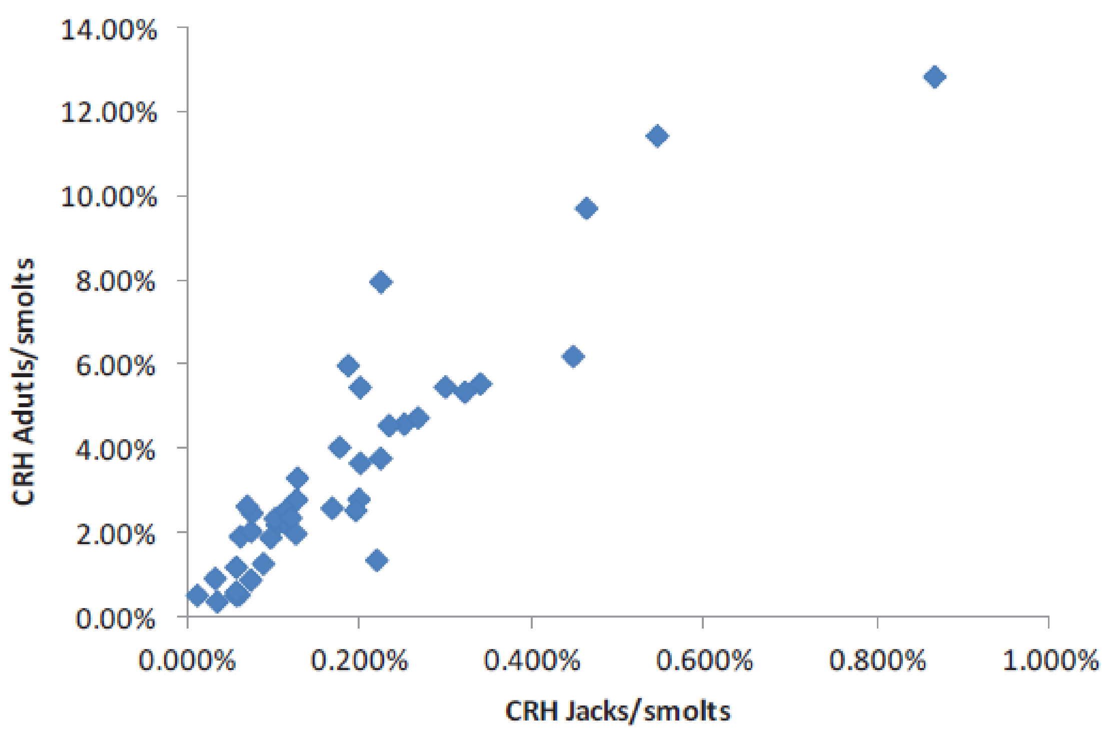


Figure 10. Relationship between survival rates of Columbia River hatchery jacks and survival rates for adults in the following year, 1968-2009. Note that CRH jack/smolt values exceeding 0.3% occurred prior to 1968, hence, are not included in the risk analysis.

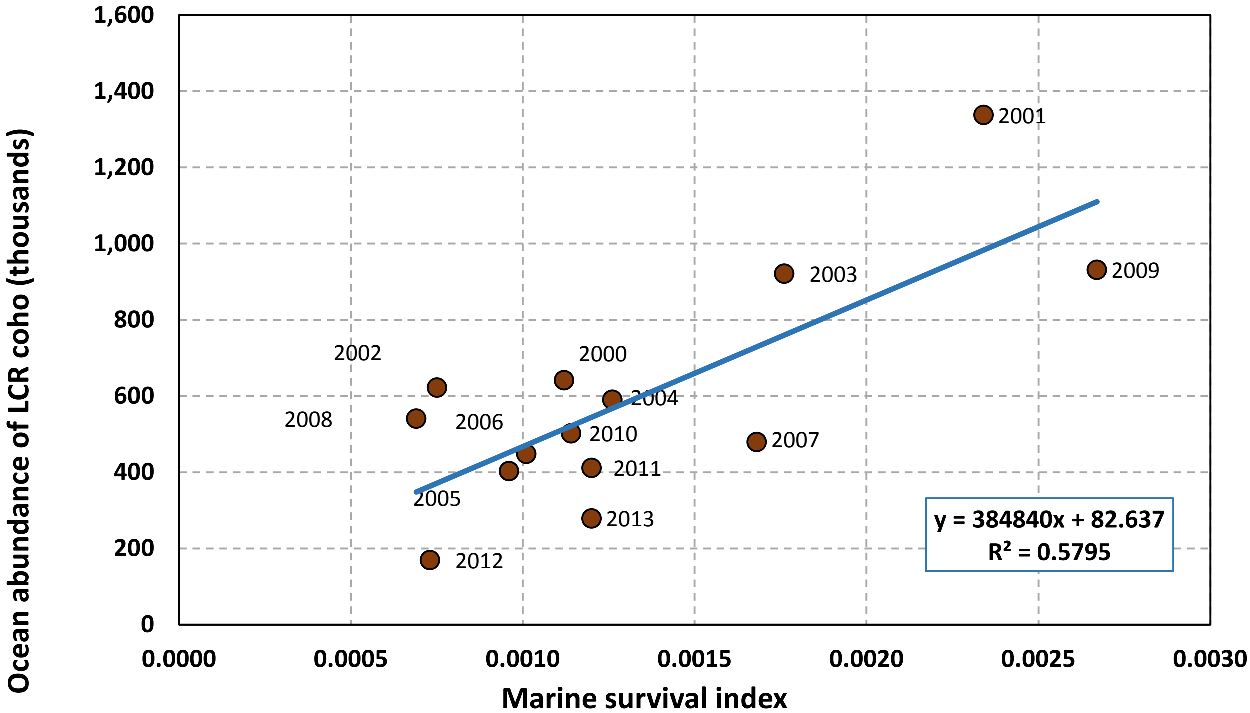
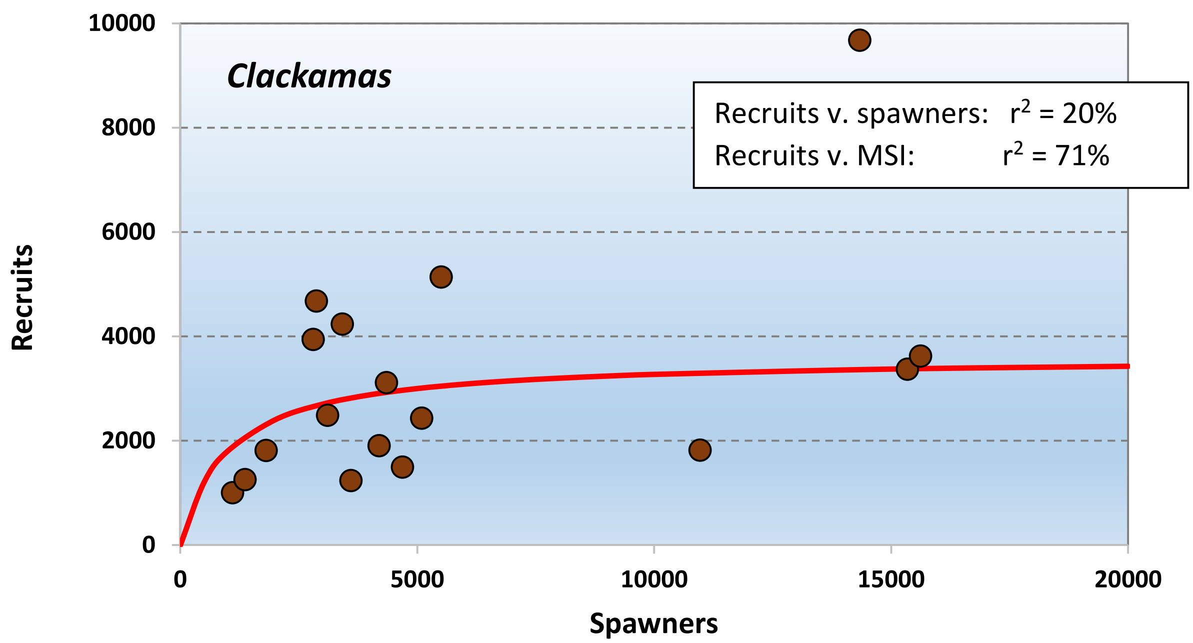


Figure 11. Relationship between marine survival index and ocean abundance of lower Columbia River coho for 2000—2013. The index and abundance are both predominately hatchery-origin fish.

6.2 Population Seeding Levels

Across the entire range of values, spawner abundance is less correlated with subsequent returns for LCN coho populations than is marine survival where data is sufficient to evaluation these relationships. Although at low spawner abundances, spawner abundance is relatively well correlated to subsequent production, marine survival index counts for a much larger proportion of the variability in return over the most common ranges of abundance. This pattern is commonly seen among coho populations throughout the eastern Pacific.



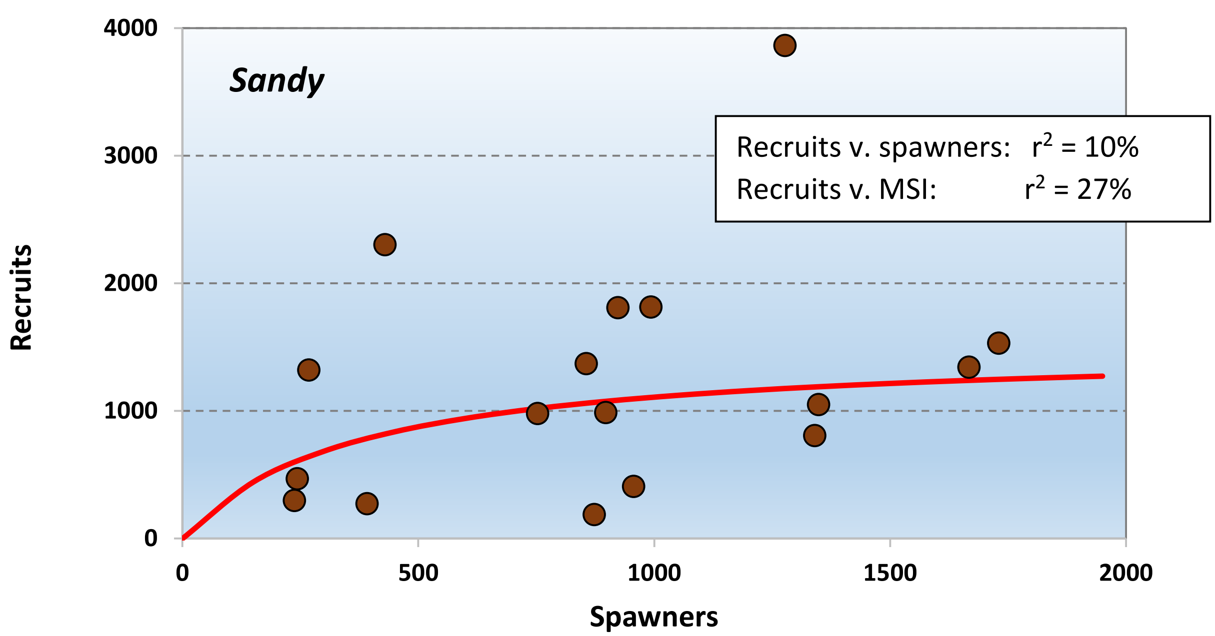


Figure 12. **Stock-recruitment relationships for Clackamas (top) and Sandy (bottom) natural coho populations, 1993-2009 brood years (data from Kern and Zimmerman 2013).**

Mean seeding levels across all populations of less than 50% were regularly observed among lower Columbia River coho populations from 1974-2012 (Figure 13). These values occurred during a period of much greater fishery exploitation rates than current levels.

Average seeding levels of less than 50% of full seeding estimates are rarely if ever projected to occur among lower Columbia River coho populations based on the population risk model (Figure 14). Historical and projected future seeding levels cannot be directly compared due to very large reductions in exploitation in recent years, and lack of historical data for many populations. Model projections are based on substantially lower exploitation rates than historically occurred which would consistently produce much greater spawning escapements on average. On an individual population basis, specific populations would be expected to fall below 50% periodically.

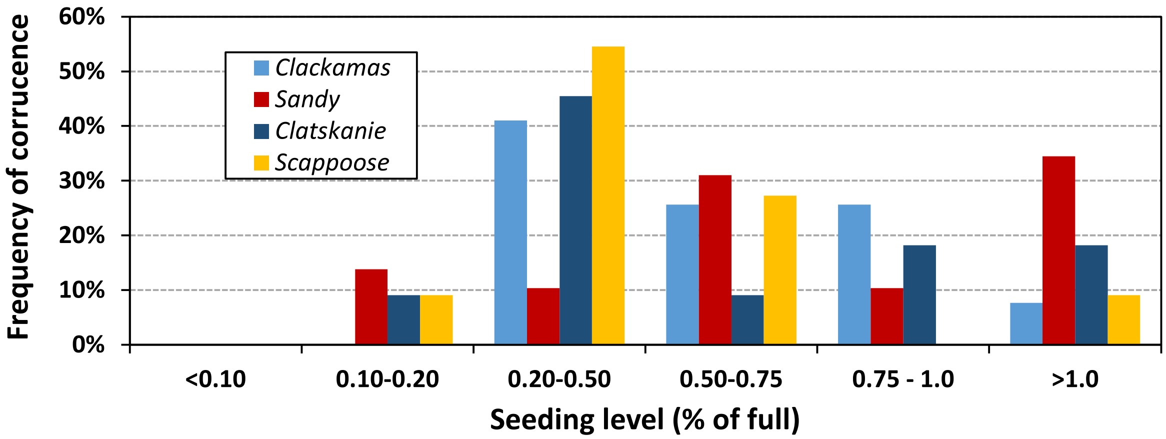


Figure 13. Frequency distribution of seeding relative to full seeding levels for Oregon LCN populations, 1974-2012 (as available).

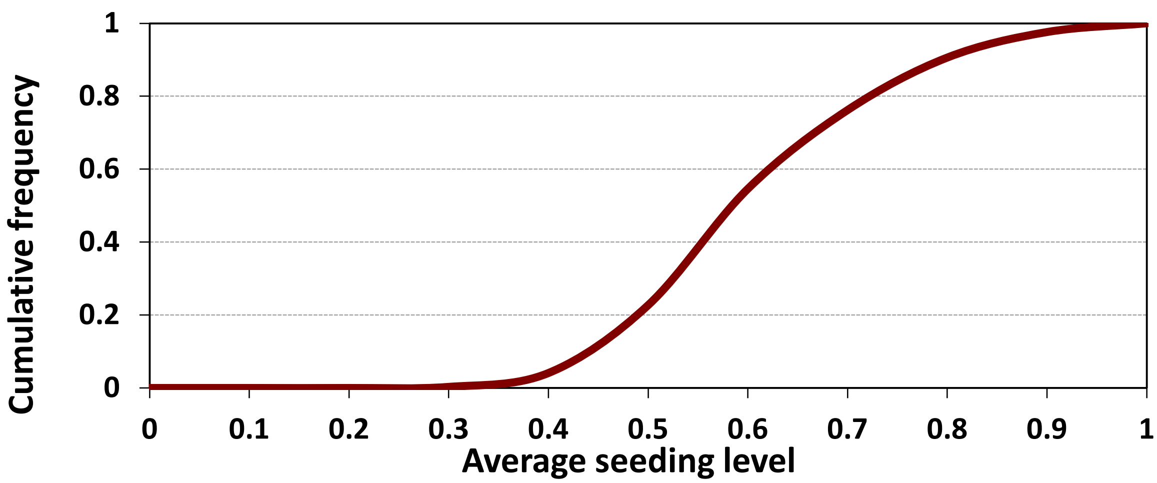


Figure 14. Cumulative frequency distribution for average seeding level of selected primary LCN coho populations in risk assessment model simulations based on historical stock-recruitment data and normal variation in marine survival. Populations include Clatskanie, Scappoose, Elochoman/Skamokowa, Grays/Chinook, Clackamas, Sandy, L Cowlitz, Toutle, Coweeman, and EF Lewis.

6.3 Cell Frequency of Occurrence

Many cells in the current matrix are rarely or never utilized because cell thresholds were imported from a similar matrix for Oregon Coast Naturals, not on values observed in the historical LCN coho data. As a result projections using the risk model indicate that many cells will not be utilized under normal variation in parental seeding or marine survival.

Table 9. Projected frequency of occurrence of combinations of marine survival and parental seeding level (average of all populations) under the current matrix.

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

Table 10. Pros and cons for including seeding level in the harvest matrix.

Drop

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

Keep

- Established practice
- Stock-recruitment theory
- Perception value

7 Risk Assessment

Conservation risks associated with alternative fishing strategies were analyzed with the same methodology developed in 2013 using an adaptation of the Lower Columbia River tule fall Chinook risk model. The original coho harvest matrix was designed to limit conservation risks of weak coho stocks by reducing fishing rates during periods of low abundance. Seeding levels were included on the assumption that returns were strongly correlated with spawners. Marine survival was included because of its strong influence on coho returns and thus, potential spawning and fish available for harvest. Seeding level and MSI categories were based on a series of assumptions and expectations which may or may not pan out as hypothesized. The risk analysis provides an explicit quantitative methodology for estimating outcomes associated with various designs including the original matrix.

7.1 Methodology

7.1.1 Model Description

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

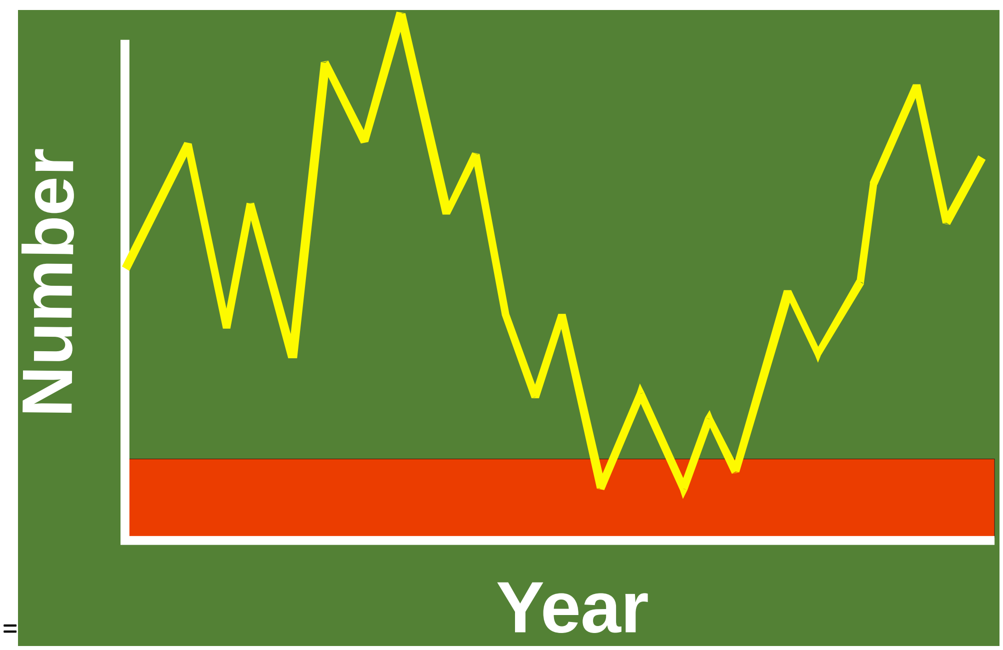


Figure 15. Population risks are assessed in the population viability analysis based on the projected frequency of falling below a critical population level of concern.

7.1.2 SSC Review of Methodology

The 2013 LCN assessment was vetted in a 2013 salmon methodology review (November 2013 Briefing Book, Agenda Item C.2.s, Attachment 2, available on the Council web site). At the November 2013 Council session, the Scientific and Statistical Committee evaluated the data reconstruction techniques used and technical aspects of the PVA. They concluded that the analysis framework is suitable for ranking the relative risk of various harvest scenarios, but not for estimating actual probabilities of extinction. The analysis is complex, and the SSC identified several areas where alternative analytical techniques could be applied. However, they concluded that the basic technique and application are sound, and relative rankings of scenarios are not likely to be greatly affected by the statistical refinements suggested.

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

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

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

7.1.3 Populations Considered

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

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

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

Seeding levels used in matrix strategies as a basis for selecting fishing rates were based on ten primary LCN populations. These populations include Clatskanie, Scappoose, Elochoman/Skamakowa, Grays/Chinook (Coast Strata), and Clackamas, Sandy, Lower Cowlitz, Toutle, Coweeman, and East Fork Lewis (Cascade strata). Seeding level of parental escapement is expressed as a percentage of the full seeding level. In modeling exercises and the proposed matrix approach, percentages greater than 100% are set at 100% to avoid over-weighting of the status of the ESU. Full seeding levels for Oregon populations were defined based on a combination of stock-recruitment and habitat analyses. Full seeding levels for Washington populations were defined as equilibrium abundance of natural spawners in stock-recruitment parameters inferred with the Ecosystem Diagnosis and Treatment Model from assessments of the available habitat quantity and quality. Descriptions of the methods used for these analyses are provided in Kern and Zimmerman 2013.

Viability risks associated with alternative fishing strategies were calculated with the model for each population. The work group compared effects of fishing strategies on LCN risk based on: 1) median risk value for all populations and 2) average risk value for the five highest risk populations among those evaluated. The five weakest populations were selected to provide a precautionary assessment of fishery-related relative risks. These populations were at the greatest absolute risk and the most sensitive to changes in exploitation rates. These populations were identified as “most sensitive” by model sensitivity analysis to differences in fixed exploitation rates and the risk effects of fixed rates are very similar to those from sliding-scale rates of approximately equal average rates over time. This approach also provides a precautionary approach towards gorge strata populations, for which no data was available to inform this risk assessment.

7.1.4 Alternative Model Structures

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

Model 1 - Current Matrix (Sandy-Clackamas Seeding)

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

Model 2 – Fixed Rate

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

Model 3 – Current Matrix (Population Average Seeding)

- Same categories and rates as Model 1.

Model 4 – 1x4 Matrix

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

Model 5 – 1x5 Matrix

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

Model 6 – Continuous

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

Model 7 – 2x5 Matrix

Parental escapement (% of full seeding)	Marine Survival Index				
	Critical	Low	Medium	High	V High
High (≥ __%)	ER ≤ __%	ER ≤ __%	ER ≤ __%	ER ≤ __%	ER ≤ __%
Low (< __%)	ER ≤ __%	ER ≤ __%	ER ≤ __%	ER ≤ __%	ER ≤ __%

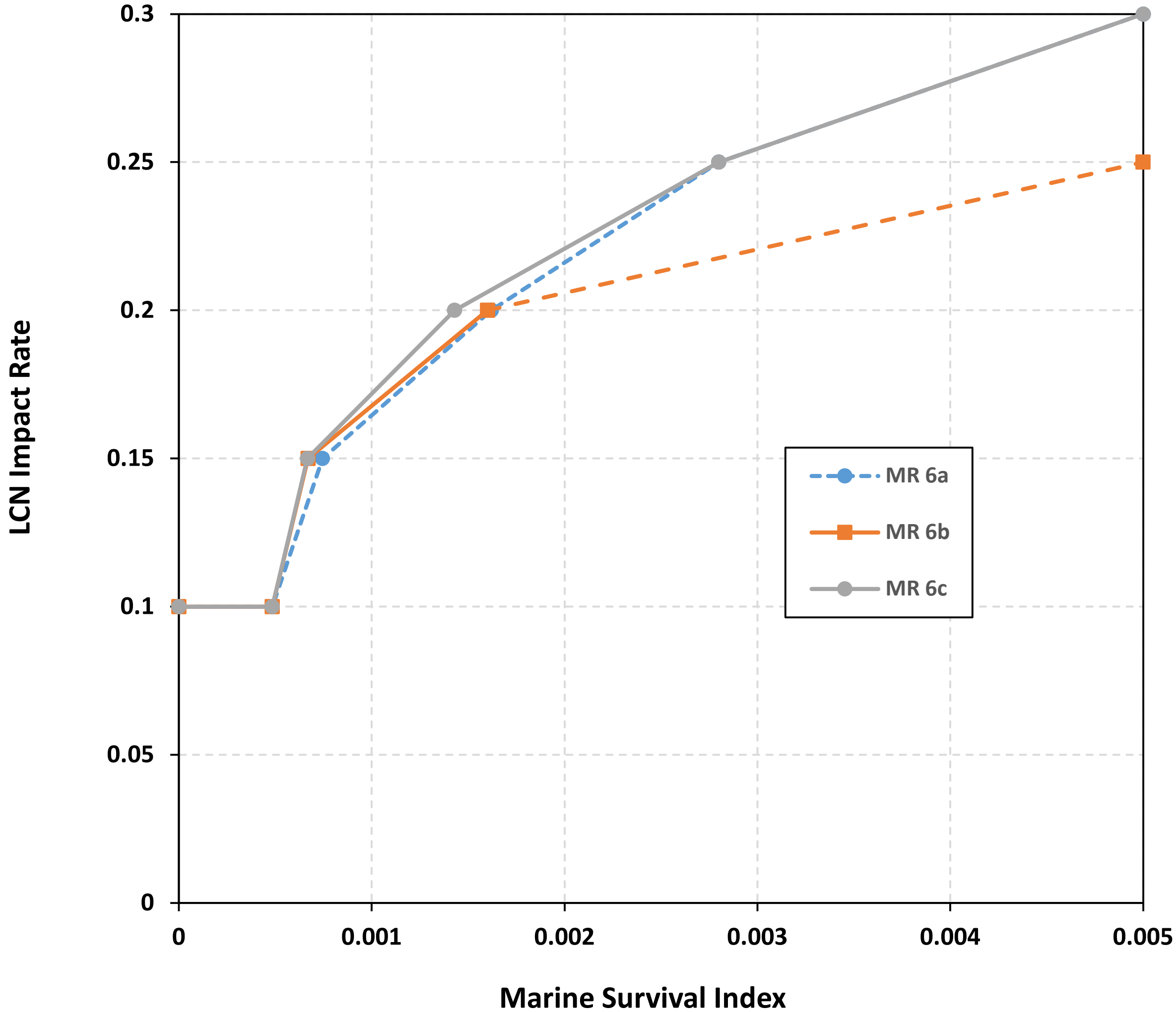


Figure 16. Examples of continuous models.

7.2 Results

7.2.1 Population risk sensitivity to fishing

Risks are relatively insensitive to fishing within the 10 to 30% range of exploitation under consideration for LCN coho for many populations and for median or average values of multiple populations. Sensitivity of individual populations can be greater, particularly among the smaller, less-productive populations evaluated.

The median value for all populations considered in this analysis is also relatively insensitive to fishing rates in the current range due to inclusion of the larger, more productive populations in the ESU. The high risk average is more sensitive to fishing rates in the current range and represents the weaker populations among those targeted in the recovery plan for high levels of viability or substantial levels of improvement.

We should also note that the ESU also includes smaller, less productive populations identified as stabilizing or contributing in the recovery plans. These populations were not modeled but will also be expected to be relatively insensitive to effects of fishing – risks will be high even when little or no fishing mortality occurs.

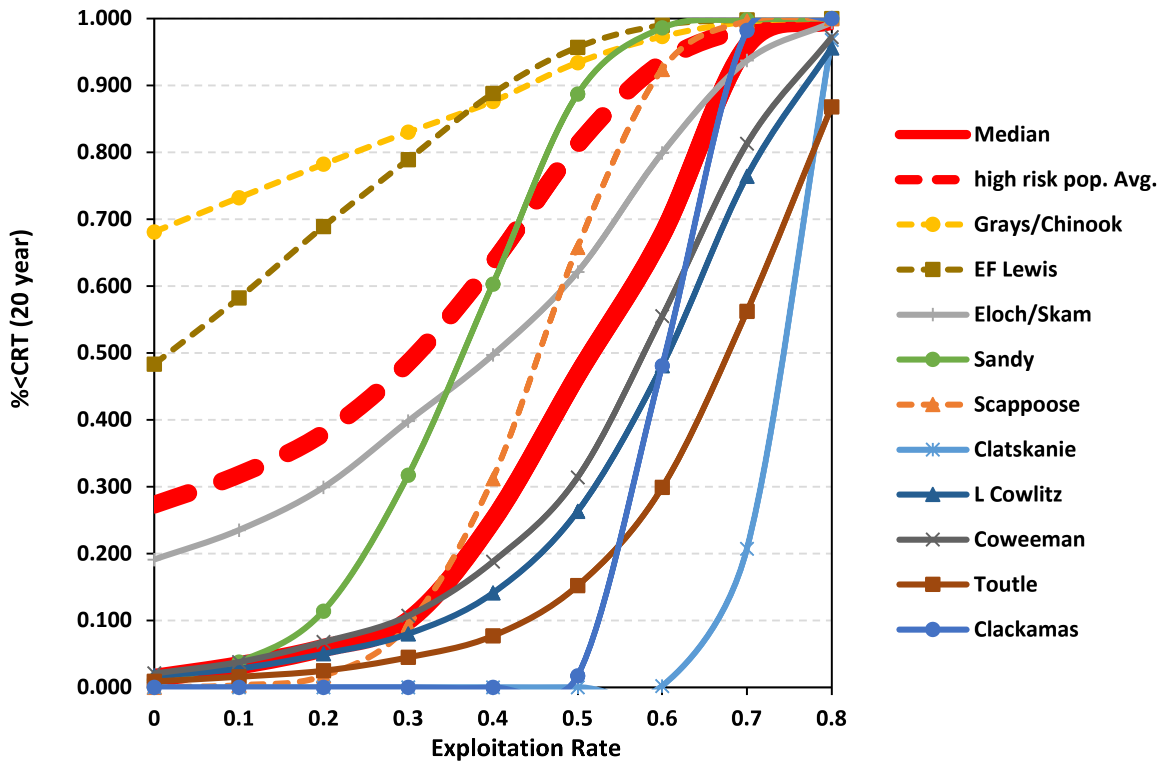


Figure 17. Population risk response to fixed annual exploitation rates and depiction of summary metrics utilized for comparison of the relative effects of alternative fishery strategies. Metrics included median risk value for all populations and average risk value for the five highest risk populations among those evaluated. Risk is based on the frequency of simulations where wild spawning escapement falls below critical levels during three successive years over a 20-year period.

7.2.2 Model Run Descriptions

Table 11 summarizes results from a series of model runs. Brief descriptions of example model runs are as follows:

"Actual" describes current exploitation rates and frequencies for the last 10 years since the current harvest control rule was in place under the current harvest matrix which is based on Sandy and Clackamas population seeding levels.

Model 1 is a future projection on what we would expect to happen over the long term if the current rules were maintained.

Model 3a is the current matrix based on an average seeding by all primary populations in the dataset rather than just Sandy and Clackamas.

Model 4b is a simplified matrix based only on marine survival with annual exploitation rates from 10% to 25% and an effective average exploitation rate of 18% (based on preliminary NMFS discussions). Note that moving from an effective exploitation rate of 16% to 18% produces only a 1.8% increase in low population risk for the weak populations in the dataset.

Model 5b is similar to 4a but includes 30% as the top end. Frequencies were adjusted to maintain effective exploitation rate at 18%. Adding higher annual rates on the top end requires increasing frequencies in the low range to stay even.

Model 6b is a continuous variation on 5b which graduates changes in allowable rates across steps. This version is consistent with an effective average exploitation rate of 18%.

Model 6c is similar to 6b but allows for higher annual exploitation rates on the top end. This version produces an effective average exploitation rate of 18.6%. It highlights marginal risk impacts of small increases in effective exploitation rates.

Model 7-5b1 is similar to 5b but also identifies reduced annual exploitation rates under conditions of low seeding. In this example, the seeding level was selected as a contingency in the event that substantially-lower marine survival rates occur in the future. Note that a comparable low-seeding row can be added to any of the 0ne-row matrix alternatives.

Model 8a is a new model run discussed at the SAS meeting. It is a simple 1x3 model topping out at 22.5%. This version produces an effective average exploitation rate of 18.5%.

Model 9a is a new model run discussed at the September SAS/LRC Workgroup meeting. It includes seeding level based on the weakest of the Cascade and Coast strata when considered separately. This alternative produces similar outcomes to the other models but includes a more-detailed and explicit treatment of weak-stock management in the design.[1]

[1] *This alternative uses strata-specific seeding criteria rather than average population seeding criteria reflected in Model 7-5b1. This alternative uses average seeding among the populations in each strata to determine their fraction of full seeding. The row in the matrix would be determined by the lesser stratum. This alternative also suggests a definition of "critical" marine survival based approximately upon the lowest observed marine survival rate, seen in brood year 1991.*

Table 11. Model runs. A subset of model runs identified in specific discussions is highlighted.

Model	No.	Structure	Exploitation Rates (%)[a]	Frequencies (%)	Seeding categories	Effective ER[b]	Risk median	Risk 5 high[c]
actual	--	--	8/15/20/22.5	10/60/20/10	--	16.0%	--	--
1	a	Current (Sandy/Clack)	8/11/15/20/25/30/38+	24/0/54/17/0/5/1	0/0.10/0.20/0.50/0.75	15.1%	0.044	0.342
2	a	Fixed	0	100	--	0%	0.014	0.273
2	b	Fixed	8	100	--	8%	0.028	0.307
2	c	Fixed	12	100	--	12%	0.037	0.329
2	d	Fixed	16	100	--	16%	0.050	0.354
2	e	Fixed	18	100	--	18%	0.053	0.366
2	f	Fixed	19	100	--	19%	0.056	0.372
2	g	Fixed	20	100	--	20%	0.059	0.380
3	a	Current (all pops)	8/11/15/20/25/30/38+	24/0/48/20/0/8/1	0/0.10/0.20/0.50/0.75	15.7%	0.045	0.346
4	a	1 x 4	8/15/20/25	10/70/11/9	--	15.7%	0.046	0.350
4	b	1 x 4	10/15/20/25	10/25/60/5	--	18.0%	0.054	0.364
4	c	1 x 4	8/15/20/25	10/25/60/5	--	17.8%	0.054	0.363
5	a	1 x 5	8/15/20/25/30	10/65/15/5/5	--	15.7%	0.046	0.349
5	b	1 x 5	10/15/20/25/30	10/35/45/5/5	--	18.0%	0.053	0.364
5	c	1 x 5	10/15/20/25/30	10/20/55/10/5	--	19.0%	0.056	0.369
5	d	1 x 5	10/15/20/25/30	10/10/55/20/5	--	20.0%	0.059	0.377
5	e	1 x 5	10/15/18/20/23	10/10/36/34/10	--	18.0%	0.053	0.364
5	f	1 x 5	10/15/18/20/30	10/10/46/29/5	--	18.0%	0.053	0.364
5	g	1 x 5	10/15/18/23/30	10/12/55/21/1	--	18.0%	0.053	0.364
6	a	Continuous	10/10-15/15-20/20-25/25-30	5/15/53/22/5	--	18.0%	0.054	0.363
6	b	Continuous	10/10-15/15-20/20-25/25-30	5/10/58/27/0	--	18.0%	0.054	0.363
6	c	Continuous	10/10-15/15-20/20-25/25-30	5/10/50/30/5	--	18.6%	0.055	0.368
7	5b1	2 x 5	10/15/20/25/30 10/10/15/20/25	= 10/35/45/5/5 0/100 =	-- 0/.3	18.0%	0.053	0.364
7	5b2	2 x 5	10/15/20/25/30 10/10/15/20/25	= 14/36/40/5/4 12/88 =	-- 0/.5	17.5%	0.051	0.361
7	5b3	2 x 5	10/15/20/25/30 10/10/15/20/25	= 12/39/30/5/3 38/62 =	-- 0/.6	16.3%	0.047	0.350

Model	No.	Structure	Exploitation Rates (%)[a]	Frequencies (%)	Seeding categories	Effective ER[b]	Risk median	Risk 5 high[c]
7	5e1	2 x 5	10/15/18/20/23	10/10/36/34/10	--	18.0%	0.053	0.364
			<10/<15/18/20/23	0/100 =	0/.3			
7	5f1	2 x 5	10/15/18/20/30	10/10/46/29/5	--	18.0%	0.053	0.364
			<10/<15/18/20/30	0/100 =	0/.3			
7	5g1	2 x 5	10/15/18/23/30	10/12/55/21/1	--	18.0%	0.053	0.364
			<10/<15/18/23/30	0/100 =	0/.3			

7.2.3 Effects of Fishery Alternatives

- Comparable levels of risk can be achieved with a variety of exploitation rate strategies. For instance, the current coho matrix produces population risk levels equivalent to a fixed 15-16% harvest rate. A more complicated design, involving strata and seeding, may or may not produce a more or less conservative outcome.
- Abundance-based management defined by a matrix approach can provide significant fishery benefits by allowing increased opportunity during large return years when risks of low escapement are negligible.
- Neither median nor the 5-population average risks are particularly sensitive to exploitation rate strategy within the range under consideration.
- A greater frequency of higher exploitation rates in years of good marine survival indices has little impact on the level of risk.
- Effective exploitation rates and risks are not particularly sensitive to low seeding levels because of a very low incidence of occurrence in the model.
- Risks are directly and positively correlated with effective exploitation rates whether fixed or sliding scale.
- Of all the models considered, only models 2a, 2b, and 2c (fixed harvest rates of 0, 8%, and 12%) have lower risks than the current matrix. Because risks are marginally sensitive to exploitation rate in the current range, the work group was unable to configure an abundance-based alternative which appreciably reduced risk without also decreasing fishing opportunity.
- It will be difficult to further reduce current fishery-related risk levels and further risk reductions would have significant fishery repercussions. Unlike tule Fall Chinook, current low fishing levels for LCN coho do not provide room for a “win-win” strategy where both reduced risk and increased flexibility can be achieved. The win-win solution was possible for fall Chinook where fishing rates were substantially greater and within an effective range. A number of alternative fishery strategies might increase fishery opportunities with no or little effective increase in wild population risk. A key consideration will be whether marginal increases in model-derived risks relative to the current level are significant in the broader context of current coho information and status.

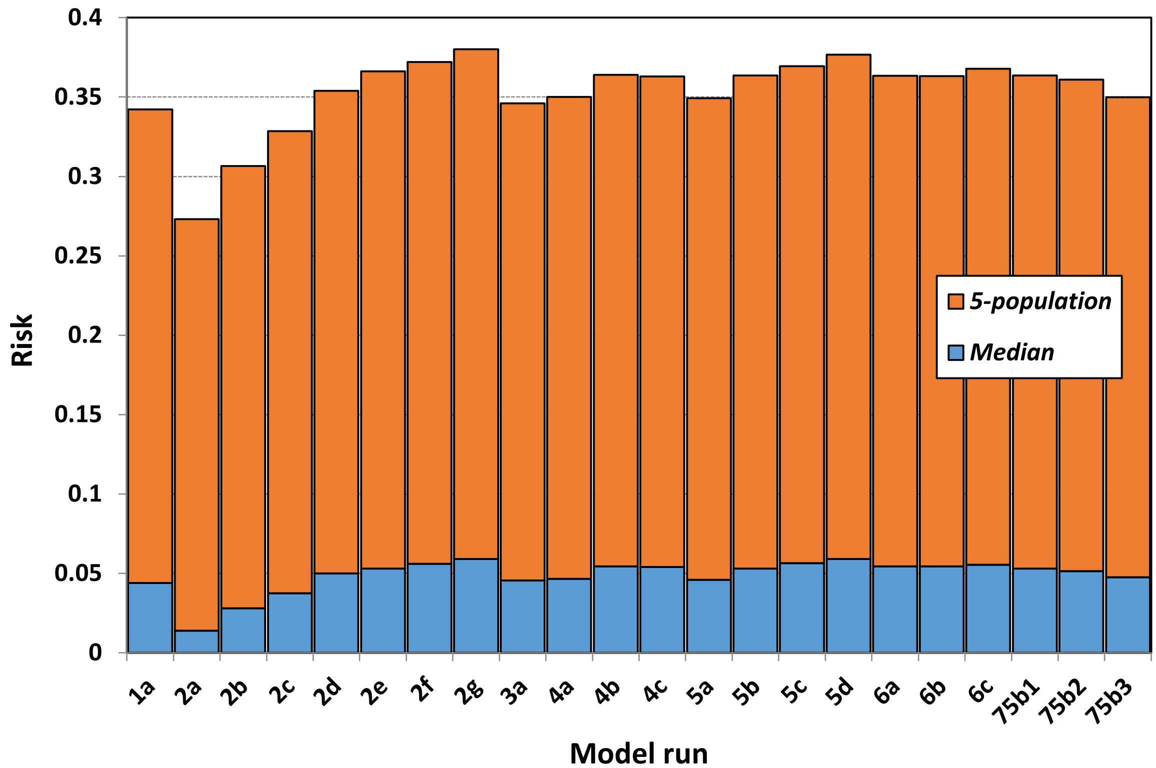


Figure 18. LCN population risks corresponding to alternative exploitation rate strategies.

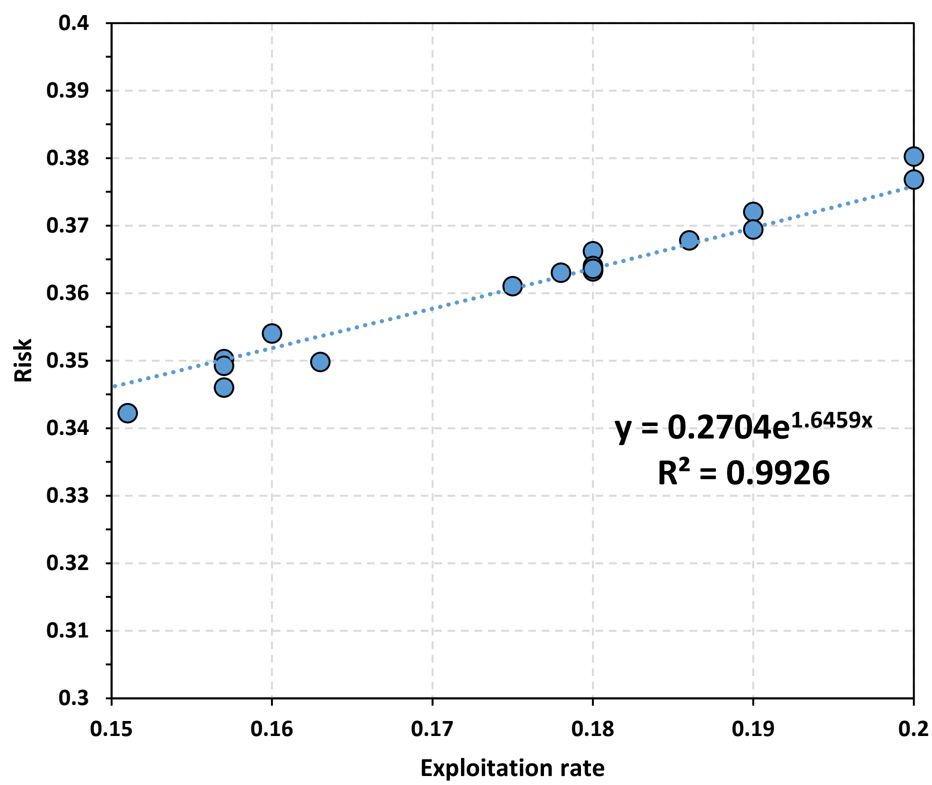


Figure 19. Relationship of effective exploitation rate and average risk for the 5 highest risk and most sensitive model populations.

7.2.4 Key Uncertainties

These include:

- Productivity parameters of representative populations with short data time series'.
- Productivity and abundance trends (especially relative to marine survival and seeding levels) for populations with short data time series'.
- Hatchery-related assumptions, hatchery fractions, and effects of hatchery management.
- Population-specific exploitation rates relative to traditional early/late stock complexes and/or hatchery/wild run timing.
- Assumptions that future marine survival patterns will closely resemble recent past patterns.

Substantial uncertainty exists in stock-recruitment parameters and theoretical full seeding levels for many populations outside of the Sandy or Clackamas populations. For instance, current stock-recruitment analyses for Clatskanie coho describe relative high productivity (5.3) and capacity (3,400) parameters. This accounts for the low modeled risk. However the full seeding level was independently derived by Oregon based on habitat and is substantially lower (1,200). Parameter uncertainties are also highlighted by the Scappoose where initial simulations had it as one of the most at-risk populations, but a single year of new data produced new parameters that shifted it to one of the least at-risk.

The key for the risk analysis is whether the modeled range in population responses is representative of what we might expect across the coho ESU. Uncertainty in the response of any individual population needs to be qualified. Are we sure the Clatskanie population will respond as modeled? No. But do we think the parameters of all the modeled populations encompass a reasonable spectrum of the expected response. Probably so.

It should be noted that the modeling captures only the things we think we know and can quantify. The modeling does not anticipate unprecedented events such as a stock collapse (e.g. Sacramento Chinook) or a long-term shift in ocean environmental regime.

7.2.5 Effect of Fishing on Hatchery-Origin Spawners

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

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

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

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

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

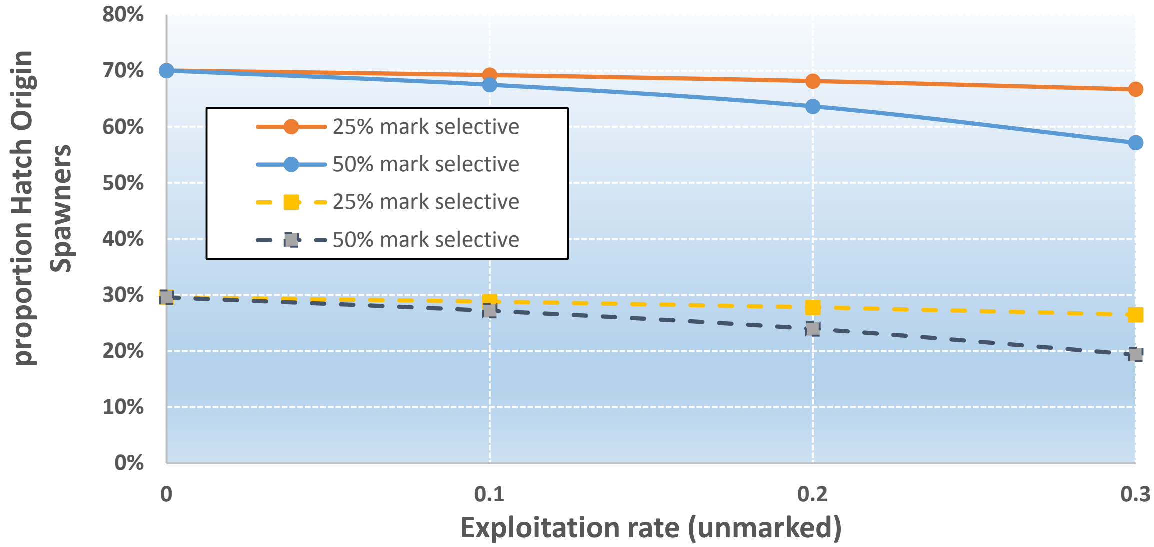


Figure 20. Hypothetical example of the effect of exploitation in mark-selective fisheries on the incidence of hatchery-origin spawners in natural production areas.

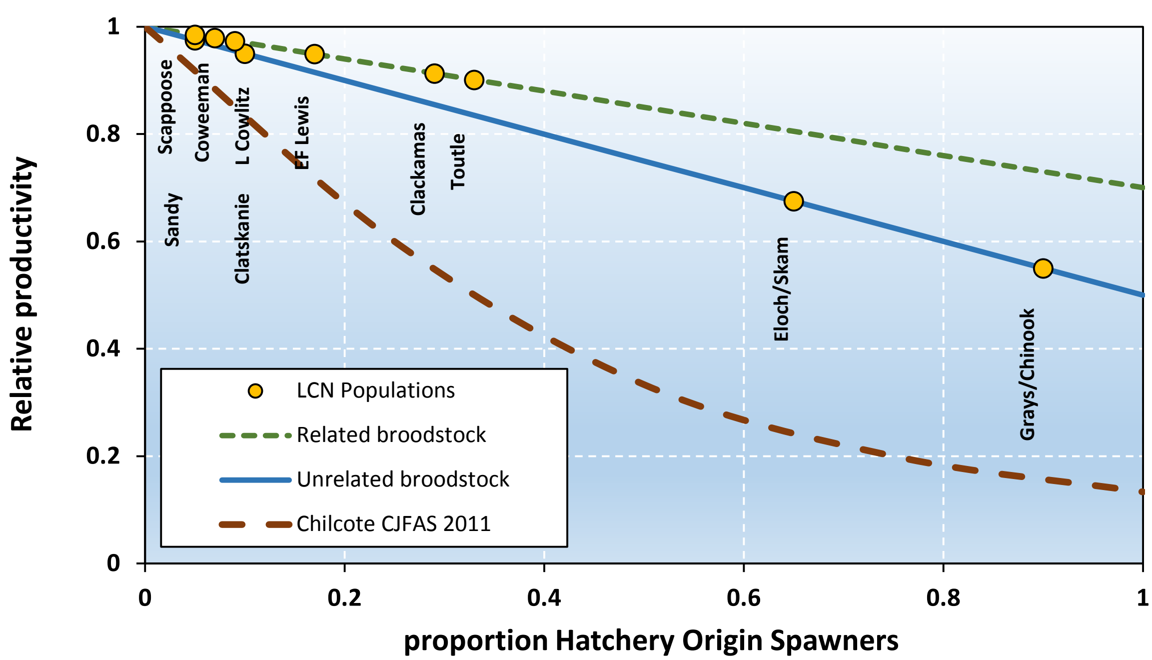


Figure 21. Example relationships of relative productivity to the proportion of hatchery spawners based on population-specific hatchery contributions and relative fitness assumptions documented in the Washington salmon recovery plan. Alernative assumptions by Chilcote et al. (2011) are also depicted.

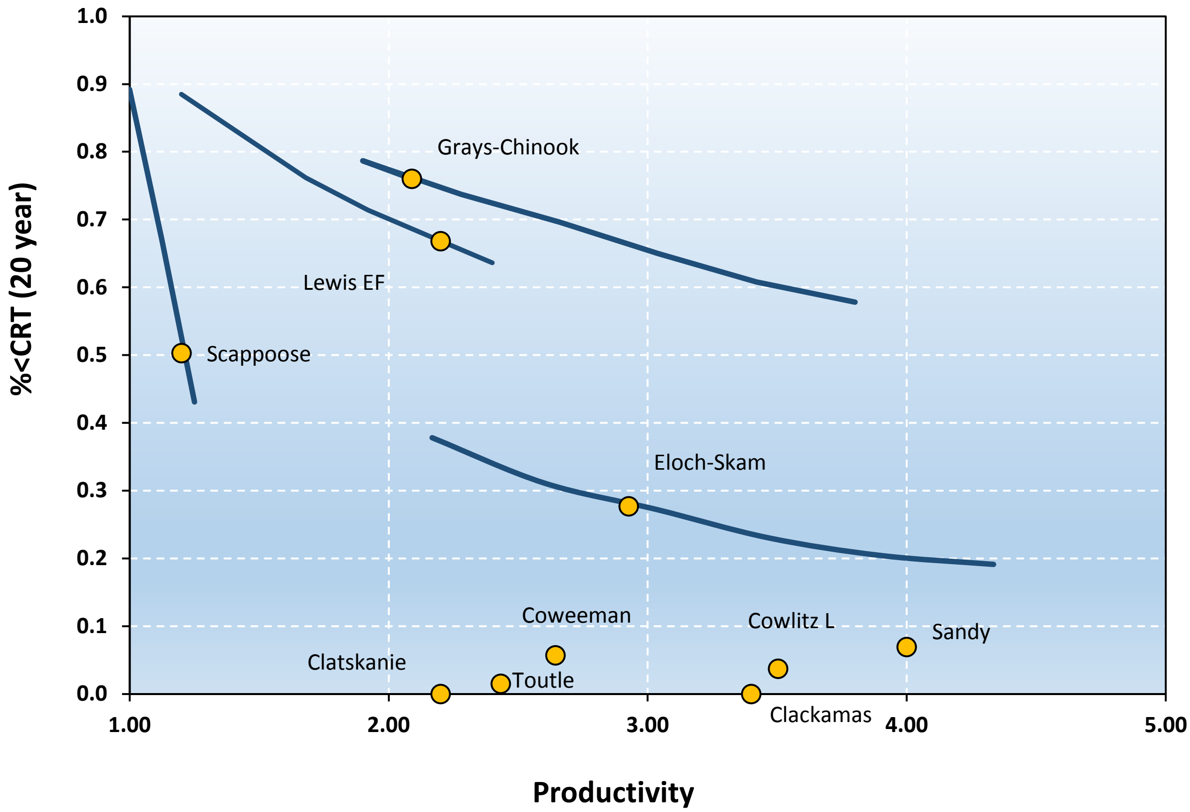


Figure 22. **Relationship of risk to population productivity based on risk model sensitivity to changes in hatchery origin spawners from zero to 100%. Points represent current levels.**

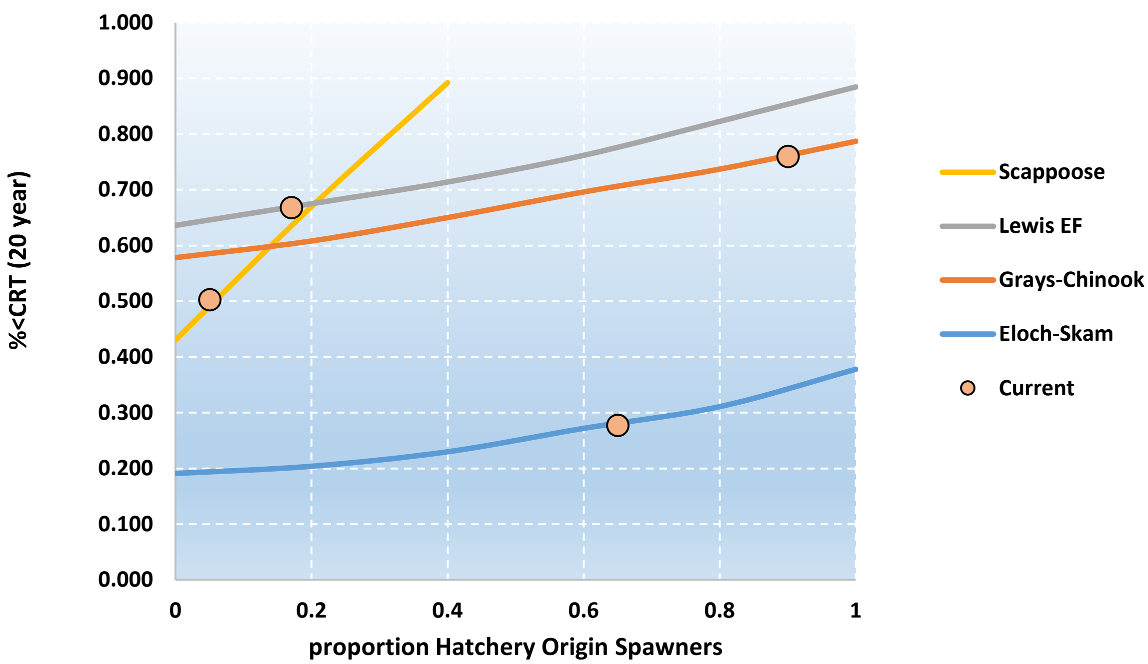
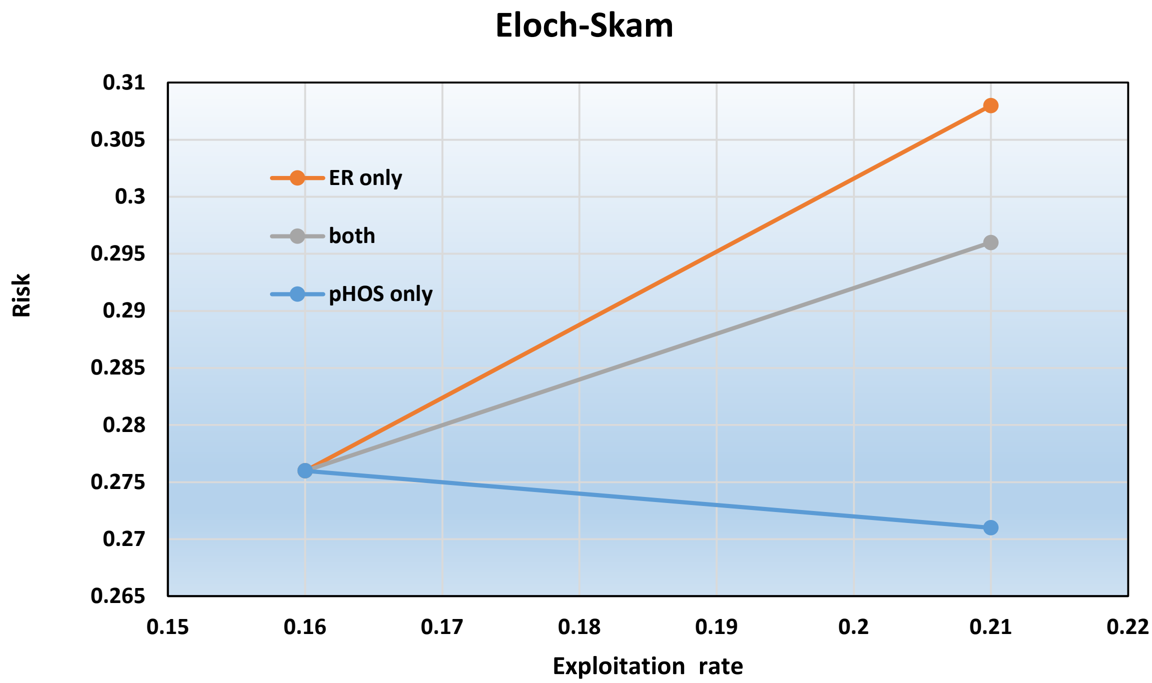


Figure 23. **Relationship between hatchery contribution and risk based on model simulations of changes in population productivity associated with changes in the proportion of hatchery-origin spawners.**



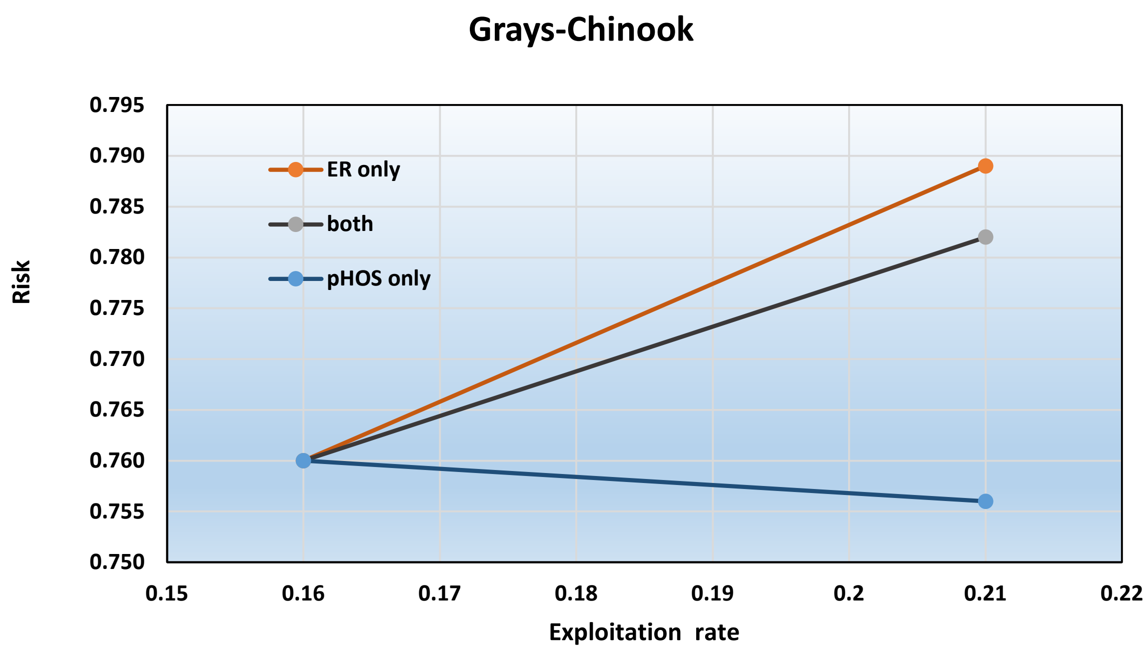


Figure 24. Effects of increased exploitation on risk with and without consideration of hatchery contributon effects. This example assumes that all of the increase in exploitation occurs in a mark-selective fishery with 20% catch and release mortality.

7.3 Alternatives highlighted for further consideration

7.3.1 Abundance-based Harvest Control Rules

- The following alternatives were identified for further consideration at a joint LRC Workgroup workgroup/SAS meeting on October 15, 2014. These were variations on Model 5b which was identified as one of four examples for further discussion at September Council meeting.
- Exploitation rates identified in these alternatives include Council fisheries in the ocean and lower Columbia River mainstem downstream from Bonneville Dam. They do not include mainstem fisheries upstream from Bonneville Dam or in lower Columbia River tributaries.
- An exploitation rate range of 10% to 30% was determined to provide for a reasonable range of fishing opportunities under current conditions including management and other stock constraints.
- The discussion focused on a 1x5 matrix structure. The 1x4 was not conducive to allowing for a full range of fishing rate alternatives without large steps between increments. The continuous alternative did not provide a substantial advantage over a 1x5.
- All four alternatives produce the desired effective exploitation rate 18.0%. Thus, each produces approximately equivalent conservation risks.
- Projected frequencies of occurrence in each exploitation rate category are based on historical marine survival patterns from 1974-2009.
- Approximate coho run sizes are identified for each marine survival range based on historical numbers during a period of comparable hatchery production (see pg. 3 for additional details). Actual ranges in each category will be broader due to normal unpredictability of coho returns.

Model 5b

Concentrates frequencies in the 15-20% exploitation rate range while allowing occasional exploitation rates up to 30%.

	Marine Survival Index				
	Very Low ≤0.059%	**Low** ≤0.109%	**Medium** ≤0.23%	**High** ≤0.28%	**Very High** >0.28%
Exploitation rate	**10%**	**15%**	**20%**	**25%**	**30%**
(Frequency of occurrence)	*(10%)*	*(35%)*	*(45%)*	*(5%)*	*(5%)*
Coho ocean abundance (thousands)	*<300*	*300-500*	*500-950*	*950-1,200*	*>1,200*

Model 5e

Concentrates frequencies in the 18-20% exploitation rate range while limiting the maximum exploitation rate to 23%.

	Marine Survival Index				
	Very Low ≤0.06%	**Low** ≤0.0755%	**Medium** ≤0.127%	**High** ≤0.23%	**Very High** >0.23%
Exploitation rate	**10%**	**15%**	**18%**	**20%**	**23%**
(Frequency of occurrence)	*(10%)*	*(10%)*	*(36%)*	*(34%)*	*(10%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-600*	*600-1,000*	*>1,000*

Model 5f

Concentrates frequencies in the 18-20% exploitation rate range while allowing occasional exploitation rates up to 30%.

	Marine Survival Index				
	Very Low ≤0.06%	**Low** ≤0.0755%	**Medium** ≤0.23%	**High** ≤0.28%	**Very High** >0.28%
Exploitation rate	**10%**	**15%**	**18%**	**20%**	**30%**
(Frequency of occurrence)	*(10%)*	*(10%)*	*(46%)*	*(29%)*	*(5%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-1,000*	*1,000-1,200*	*>1,200*

Model 5g

Concentrates frequencies in the 18-23% exploitation rate range while allowing for exploitation rates up to 30% in the event that very high marine survival occurs.

	Marine Survival Index				
	Very Low ≤0.06%	**Low** ≤0.078%	**Medium** ≤0.174%	**High** ≤0.40%	**Very High** >0.40%
Exploitation rate	**10%**	**15%**	**18%**	**23%**	**30%**
(Frequency of occurrence)	*(10%)*	*(12%)*	*(55%)*	*(21%)*	*(1%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-700*	*700-1,600*	*>1,600*

7.3.2 Seeding Level Option

1. The work group recognized the value of including seeding level in the harvest control rule as a contingency in the event of very low escapements. This provides a contingency in the event a stock collapse should occur in the future (e.g. Sacramento Index).
2. This view is consistent with recommendations by the SSC and STT that seeding level should be included in the harvest control rule. The STT recommended a provision for very low seeding levels to serve as a backstop to prevent too much fishing on a very depressed natural stock.
3. Analyses of stock-recruitment data for wild coho indicate that production and abundance is most sensitive to spawning escapements at very low seeding levels and is less sensitive to spawner abundance under moderate to high marine survival conditions.
4. Therefore, the work group recommends that harvest control rule contingencies for very low seeding should reduce coho exploitation rates during very low to low marine survival periods in order to avoid risks due to compounding the negative effects of low escapement and low marine survival. Very low seeding levels should be accompanied by more conservative management of the corresponding brood year during periods of low marine survival.
5. The work group identified the following condition for inclusion with any of the alternative fishing control rules/models identified above.

** In the event that lower Columbia River natural coho average spawning escapements fall below 30% of full seeding when considered as an average of the ten reference populations, the Council shall:*

a. under conditions of <u>very low</u> marine survival as defined by the harvest control rule, work to the extent possible to minimize LCN coho exploitation rates on adult returns from the corresponding brood year, and in no case exceed 10%.

b. under conditions of <u>low</u> marine survival as defined by the harvest control rule, work to the extent possible to minimize LCN coho exploitation rates on adult returns from the corresponding brood year, and in no case exceed 15%.

Note that this approach is effectively equivalent to adding a second row to the harvest control rule matrix as follows based on Model 5g:

Parental Escapement (% of full seeding)	Marine Survival Index				
	Very Low ≤0.06%	Low ≤0.08%	Medium ≤0.17%	High ≤0.40%	Very High >0.40%
Normal	**10%**	**15%**	**18%**	**23%**	**30%**
Very Low	**<10%**	**<15%**	**18%**	**23%**	**30%**

This approach is similar in structure to Model 7 alternatives reviewed by the Council in September.

Inclusion of this condition does not affect model-predicted risk because the seeding level trigger is a contingency for lower escapements than are projected by the population model.

7.3.3 Retrospective Analysis

- This analysis shows how recent LCN coho limits would have changed under alternative matrices.
- These years represent a small sample of conditions that might be expected to occur over the longer term. The 2005-2010 brood year average was slightly below the 1974-2010 average (0.131%) and lower and higher MSI's observed in the long term dataset did not occur in 2005-2010.
- Actual LCN rates and fisheries in those years would, of course, have been dependent on a combination of objectives for other stocks.

Table 12. Retrospective analysis of effects on exploitation rate limits for LCN coho under the old and several alternative harvest control rules. Differences in rates from the old matrix are highlighted.

Year	MSI	LCR coho abundance		Old	New alternatives			
		Ocean	Col R	Matrix	5b	5e	5f	5g
2005	0.096%	403	355	15%	15%	18%	18%	18%
2006	0.101%	449	410	15%	15%	18%	18%	18%
2007	0.168%	479	349	20%	20%	20%	18%	18%
2008	0.069%	541	520	8%	15%	15%	15%	15%
2009	0.267%	931	759	20%	25%	23%	20%	23%
2010	0.114%	502	471	15%	20%	18%	18%	18%
2011	0.120%	412	383	15%	20%	18%	18%	18%
2012	0.073%	170	144	15%	15%	15%	15%	15%
2013	0.120%	279	243	15%	20%	18%	18%	18%
Avg.	*0.125%*	*463*	*404*	*15.3%*	*18.3%*	*18.1%*	*17.6%*	*17.9%*

8 References

Chilcote, M. W., K. W. Goodson, and M. R. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries and Aquatic Sciences 68:511-522.

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

LCFRB. 2010. Lower Columbia River salmon recovery and fish and wildlife subbasin plan.

ODFW. 2010. Lower Columbia River conservation and recovery plan for Oregon populations of salmon and steelhead. http://www.dfw.state.or.us/fish/CRP/docs/lower-columbia/OR_LCR_Plan%20-%20Aug_6_2010_Final.pdf

NMFS. 2013. ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead. Northwest Region. Portland, Oregon. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/willamette_lowercol/lower_columbia/final_plan_documents/final_lcr_plan_june_2013_-corrected.pdf

WDFW and ODFW. 2014. 2014 Joint staff report: stock status and fisheries for fall Chinook salmon, coho salmon, chum salmon, summer steelhead, and white sturgeon.

9 Appendix 1 – Willamette Coho Salmon Fact Sheet

The newly appointed Lower Columbia Natural Coho Workgroup (LRC Workgroup) met for the first time at the April 4, 2014 Pacific Fishery Management Council meeting. The LRC Workgroup discussed the process to follow, schedule for future meetings, and assignments. Members from NOAA's National Marine Fisheries Service (NMFS) and the Oregon Department of Fish & Wildlife (ODFW) agreed to take the lead on development of a Fact Sheet to provide information relative to coho populations above Willamette Falls and the existing Evolutionarily Significant Unit (ESU) boundary. NMFS was tasked with describing status, background and determination criteria for the existing boundary of the lower Columbia River (LCR) natural coho salmon ESU; ODFW was tasked with summarizing existing information regarding historical upstream passage and releases of hatchery coho salmon in areas above Willamette Falls. This report is intended to complete the assignment as we understood it.

In 2004 the Population Identification Subcommittee of the Willamette-Lower Columbia Technical Recovery Team (WLC-TRT) convened in response to the proposed listing of LCR natural coho under the U.S. Endangered Species Act (ESA). The Subcommittee determined 24 historical demographically independent populations (DIPs) of listed coho salmon (*Onchorhynchus kistuch*) in the LCR coho salmon ESU, with no coho salmon DIPs in the upper Willamette River (Myers et al. 2006). The authors relied on a number of types of information to identify historical populations. In general, there were six different types of information utilized:

1) geography,
2) migration fidelity,
3) genetic attributes,
4) life history patterns and morphological characteristics,
5) population dynamics, and
6) environmental and habitat characteristics.

Genetic analysis of coho salmon populations provided limited information about population distinctiveness. This was thought to be due in large part to the extensive programs of hatchery releases and interbasin transfers between hatcheries, in tandem with the small number of naturally produced fish. Therefore the boundaries for historical DIPs were in part established using information related to two isolating mechanisms: homing fidelity and migration timing. Homing fidelity was examined to estimate the extent of adult exchange among spawning populations, whereas adult run timing often is coordinated with stream hydrology. The WLC-TRT generally believed that the homing fidelity of coho salmon was more similar to steelhead than to Chinook salmon or chum salmon.

The environmental and habitat characteristics of Willamette Falls were determined to provide the isolating mechanism for it to serve as an ESU boundary and likely barrier for fall-migrating salmonids such as coho. This is consistent with the WLC-TRT separating the LCR Chinook salmon ESU from the Upper Willamette River Chinook salmon ESU and the LCR steelhead Distinct Population Segment (DPS) separated from the Upper Willamette River steelhead DPS.

The WLC-TRT noted a number of contemporary references documenting the presence of coho salmon in tributaries to the Willamette River above Willamette Falls. The first recorded observations of naturally occurring coho salmon in all cases followed either opening access to the area via construction of the fish ladder at Willamette Falls in 1882 or the introduction of LCR coho salmon by ODFW into those subbasins[2] (Table 1). The WLC-TRT reported old-time residents claiming that silver salmon were not present in these streams prior to about 1920, and that Dimick and Merryfield (1945) asserted that coho salmon above Willamette Falls were an “artificial establishment from hatchery-reared fish.” These findings lead the WLC-TRT to determine that coho salmon historically would not have ascended Willamette Falls before it was laddered. According to passage records from ODFW dating back to 1966, coho have been observed utilizing the Willamette Falls fish ladder annually (Table 2). Observations of fin-marked adult coho passing the falls show that hatchery-origin fish continue to make their way into the upper basin (Table 3).

The most current NMFS LCR natural coho salmon ESU status review (Ford 2011) discussed the transitional zone between the gorge boundary and the interior Columbia River region. The WLC-TRT’s LCR coho salmon ESU boundary designation, is based largely on extrapolation from information about the boundaries for Chinook salmon and steelhead, with Ford (2011) suggesting it would be reasonable to assign the Klickitat population to the LCR coho salmon ESU. This would thereby establish the use of Celilo Falls (The Dalles Dam) as a common boundary for LCR ESUs and DPSs. No other boundary modifications have been considered since the original boundary designations were determined.

The NMFS’s next status review is scheduled to be completed by 2016. NMFS’s West Coast Region and Northwest and Southwest Fisheries Science Centers are currently discussing the scope of the next status review. Boundary delineation questions concerning the Willamette Falls and Celilo Falls for the LCR coho salmon ESU have been queued for consideration, but they will not be resolved until then. Therefore NMFS will continue to use the current WLC-TRT designated LCR coho salmon ESU populations when considering the status of the ESU, which does not include coho above Willamette Falls or within the Klickitat River basin.

[2] The majority of hatchery fish released into areas above Willamette Falls were sourced from LCR hatcheries. The releases were comprised primarily of fry, sub-yearlings, yearlings, or smolts; however, some adults were also introduced. The vast majority appear to be LCR early stock. There were instances of Oregon coastal stocks released during the late 1950s (two years), the late 1960s (five years), and early 1970s (two years) but these fish made up a relatively small proportion of the releases during those years.

References:

Dimick, R. E., and F. Merryfield. 1945. The Fishes of the Willamette River System in Relation to Pollution. Oregon State College, Engineering Experiment Station, Corvallis.

Ford, M. J., editor. 2011. Status Review Update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-113. 281p.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. V. Doornik, and M. T. Maher. 2006. Historical population structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-73, 311p.

Table 1. Hatchery coho salmon releases into areas above Willamette Falls, Brood Years 1951–1996.

Brood Year	Fry	Fed Fry	Fingerling	Yearling	Pre-smolt	Smolt	Total
1951			500,000				500,000
1952				10,000			10,000
1953			275,000				275,000
1954			56,000	50,486			106,486
1955			80,000	104,877			184,877
1956	24,549		529,862				554,411
1957			722,196	90,316			812,512
1958			344,696				344,696
1959			277,199	91,784			368,983
1960			100,913	105,717			206,630
1961	1,572,068			138,318			1,710,386
1962	5,359,996			61,814			5,421,810
1963				178,571			178,571
1964	6,886,100		816,360	296,224			7,998,684
1965	9,727,546						9,727,546
1966	9,777,986		886,105				10,664,091
1967	6,511,935						6,511,935
1968	5,700,471		249,490	1,154,129			7,104,090
1969	6,613,306		78,020	1,375,798			8,067,124
1970	883,235			1,236,601			2,119,836
1971	1,364,132			1,253,855			2,617,987
1972	1,601,177		469,172	1,270,174			3,340,523
1973	258,366		373,000	189,746			821,112
1974	448,963		330,301	607,522			1,386,786
1975				410,553			410,553
1976	635,742			169,836			805,578
1977				164,983			164,983
1978				60,102			60,102
1979				59,892			59,892
1980	370,560			54,943			425,503
1981						182,000	182,000
1982					2,917,000	60,000	2,977,000
1983					648,000	250,000	898,000
1984					3,891,500		3,891,500
1985					188,000	60,000	248,000
1986					501,000	167,000	668,000
1987						60,000	60,000
1988						60,000	60,000
1989						60,229	60,229
1990						59,913	59,913
1991						60,052	60,052
1992						60,239	60,239
1993						59,250	59,250
1994		15,102				59,919	75,021
1995		7,969				60,000	67,969
1996						60,152	60,152
Totals	57,736,132	23,071	6,088,314	9,136,241	8,145,500	1,318,754	82,448,012

(Information for years 1951-80 from: *Williams, R. 1983. Releases of Coho Salmon into the Upper Willamette River, Oregon. Information Report Number 83-3*; for years 1981-88 from: *Kostow, K. 1991. Columbia [sic] Basin Coho, Complied [sic] as comments to NMFS Endangered Species Act Record*; and for years 1989-96 from: *RMPC Data Run 04-29-2014*)

Table 2. Escapement of coho salmon over Willamette falls, 1966–2013. (ODFW 2014)

Year	Adults	Jacks	Total
1966-69 Average Range	6,800 3,300 – 12,000	5,100 1,600 – 14,000	11,900 6,300 – 17,700
1970-74 Average Range	10,400 1,500 – 17,900	7,800 1,600 – 19,500	18,200 5,400 – 37,400
1975	5,922	6,927	12,849
1976	2,333	2,217	4,550
1977	1,007	2,120	3,127
1978	1,711	3,891	5,602
1979	1,788	1,691	3,479
1980	1,276	1,365	2,641
1981	1,032	2,417	3,449
1982	1,702	3,517	5,219
1983	949	2,840	3,789
1984	2,735	2,560	5,295
1985	2,788	2,278	5,066
1986	2,930	2,240	5,170
1987	1,589	3,224	4,813
1988	3,707	4,985	8,692
1989	1,946	1,741	3,687
1990	901	1,817	2,718
1991	921	815	1,736
1992	940	588	1,528
1993	427	236	663
1994	685	174	859
1995	582	600	1,182
1996	315	976	1,291
1997	1,407	428	1,835
1998	373	386	759
1999	635	623	1,258
2000	2,839	773	3,612
2001	1,736	402	2,138
2002	2,337	2,417	4,754
2003	7,908	1,869	9,777
2004	2,849	524	3,373
2005	1,322	271	1,593
2006	6,186	1,614	7,800
2007	6,678	924	7,602
2008	4,048	2,971	7,019
2009	25,298	2,094	27,392
2010	20,103	1,988	22,091
2011	3,393	1,969	5,362
2012	6,573	6,370	12,943
2013	18,627	4,111	22,738

Table 3. Fin-mark status of adult coho observed passing Willamette Falls, 2007–2013. (ODFW 2014)

Year	Fin-marked	Unmarked	Total
2007	588	6,092	6,680
2008	462	3,586	4,048
2009	664	24,625	25,298
2010	409	19,691	20,100
2011	128	3,264	3,393
2012	36	6,535	6,571
2013	361	18,261	18,622

LOWER COLUMBIA NATURAL COHO WORKGROUP REPORT ON THE LOWER COLUMBIA RIVER COHO HARVEST MATRIX

The Lower Columbia River Natural Coho Workgroup (LRC Workgroup) met with the Salmon Advisory Subpanel (SAS) in Portland, Oregon on October 15, 2014 to further refine the analyses and alternatives in support of potentially recommending revisions to the current harvest policy for Lower Columbia River natural (LCN) coho. Working together, the LRC Workgroup and SAS revised and narrowed the alternatives discussed at the September 2014 Council meeting and recommends a focused consideration of the alternatives presented herein. The SAS is scheduled to meet at the November Council meeting in Costa Mesa, California to develop their final recommendations to the Council.

Additionally, this report provides two summary analyses requested by the SAS, one regarding the relationship between marine survival and Lower Columbia River coho abundance and another regarding a retrospective comparison of allowable exploitation rates under the current harvest matrix and the alternatives discussed on October 15th.

Harvest Matrix Alternatives

Model 5b

Concentrates frequencies in the 15-20% exploitation rate range while allowing occasional exploitation rates up to 30%.

	Marine Survival Index				
	Very Low **≤0.059%**	**Low** **≤0.109%**	**Medium** **≤0.23%**	**High** **≤0.28%**	**Very High** **>0.28%**
Exploitation rate	**10%**	**15%**	**20%**	**25%**	**30%**
(Frequency of occurrence)	*(10%)*	*(35%)*	*(45%)*	*(5%)*	*(5%)*
Coho ocean abundance (thousands)	*<300*	*300-500*	*500-950*	*950-1,200*	*>1,200*

Model 5e

Concentrates frequencies in the 18-20% exploitation rate range while limiting the maximum exploitation rate to 23%.

	Marine Survival Index				
	Very Low **≤0.06%**	**Low** **≤0.0755%**	**Medium** **≤0.127%**	**High** **≤0.23%**	**Very High** **>0.23%**
Exploitation rate	**10%**	**15%**	**18%**	**20%**	**23%**
(Frequency of occurrence)	*(10%)*	*(10%)*	*(36%)*	*(34%)*	*(10%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-600*	*600-1,000*	*>1,000*

Model 5f

Concentrates frequencies in the 18-20% exploitation rate range while allowing occasional exploitation rates up to 30%.

	Marine Survival Index				
	Very Low **≤0.06%**	**Low** **≤0.0755%**	**Medium** **≤0.23%**	**High** **≤0.28%**	**Very High** **>0.28%**
Exploitation rate	**10%**	**15%**	**18%**	**20%**	**30%**
(Frequency of occurrence)	*(10%)*	*(10%)*	*(46%)*	*(29%)*	*(5%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-1,000*	*1,000-1,200*	*>1,200*

Model 5g

Concentrates frequencies in the 18-23% exploitation rate range while allowing for exploitation rates up to 30% in the event that very high marine survival occurs.

	Marine Survival Index				
	Very Low **≤0.06%**	**Low** **≤0.078%**	**Medium** **≤0.174%**	**High** **≤0.40%**	**Very High** **>0.40%**
Exploitation rate	**10%**	**15%**	**18%**	**23%**	**30%**
(Frequency of occurrence)	*(10%)*	*(12%)*	*(55%)*	*(21%)*	*(1%)*
Coho ocean abundance (thousands)	*<300*	*300-400*	*400-700*	*700-1,600*	*>1,600*

1. The above alternatives were identified for further considerations – these were variations on Model 5b which was identified as one of four examples for further discussion at September Council meeting.
2. Exploitation rates identified in these alternatives include Council fisheries in the ocean and lower Columbia River mainstem downstream from Bonneville Dam. They do not include mainstem fisheries upstream from Bonneville Dam or in lower Columbia River tributaries.
3. An exploitation rate range of 10% to 30% was determined to provide for a reasonable range of fishing opportunities under current conditions including management and other stock constraints.
4. The discussion focused on a 1x5 matrix structure. The 1x4 was not conducive to allowing for a full range of fishing rate alternatives without large steps between increments. The continuous alternative did not provide a substantial advantage over a 1x5 strategy when increments between the steps was not that great.
5. All four alternatives produce the desired effective exploitation rate 18.0%. Thus, each produces approximately equivalent conservation risks.
6. Projected frequencies of occurrence in each exploitation rate category are based on historical marine survival patterns from 1974-2009.
7. Approximate coho run sizes are identified for each marine survival range based on historical numbers during a period of comparable hatchery production (see pg. 3 for additional details). Actual ranges in each category will be due to normal unpredictability of coho returns.

Seeding Level Option

1. The LRC Workgroup recognized the value of including seeding level in the harvest control rule as a contingency in the event of very low escapements
2. This view is consistent with recommendations by the SSC and STT that seeding level should be included in the harvest control rule.
3. Analyses of stock-recruitment data for wild coho indicate that production and abundance is most sensitive to spawning escapements at very low seeding levels and is less sensitive to spawner abundance under moderate to high marine survival conditions.
4. Therefore, the LRC Workgroup recommends that harvest control rule contingencies for very low seeding should reduce coho exploitation rates during very low to low marine survival periods in order to avoid risks due to compounding the negative effects of low escapement and low marine survival. Very low seeding levels should be accompanied by more conservative management of the corresponding brood year during periods of low marine survival.
5. The LRC Workgroup identified the following condition for inclusion with any of the alternative fishing control rules/models identified above.

** In the event that lower Columbia River natural coho average spawning escapements fall below 30% of full seeding when considered as an average of the ten reference populations, the Council shall:*

a. under conditions of <u>very low</u> marine survival as defined by the harvest control rule, work to the extent possible to minimize LCN coho exploitation rates on adult returns from the corresponding brood year, and in no case excced10%.

b. under conditions of <u>low</u> marine survival as defined by the harvest control rule, work to the extent possible to minimize LCN coho exploitation rates on adult returns from the corresponding brood year, and in no case exceed 15%.

Note that this approach is effectively equivalent to adding a second row to the harvest control rule matrix as follows based on Model 5g:

Parental Escapement (% of full seeding)	**Marine Survival Index**				
	Very Low ≤0.06%	**Low ≤0.08%**	**Medium ≤0.17%**	**High ≤0.40%**	**Very High >0.40%**
Normal	**10%**	**15%**	**18%**	**23%**	**30%**
Very Low	**<10%**	**<15%**	**18%**	**23%**	**30%**

This approach is similar in structure to Model 7 alternatives reviewed by the Council in September.

Inclusion of this condition does not affect model-predicted risk because the seeding level trigger is a contingency for lower escapements than are projected by the population model.

Marine Survival Index vs. Ocean Abundance of LCR Coho

1. Additional information on this relationship was requested by the SAS in order to place marine survival indices and frequencies of occurrence of various fishing rates described by alternatives in context of how many coho were available for harvest at various fishing levels.
2. The figure below describes this relationship based on recent information. This relationship was the basis for coho run size numbers identified for each matrix cell on page 2.

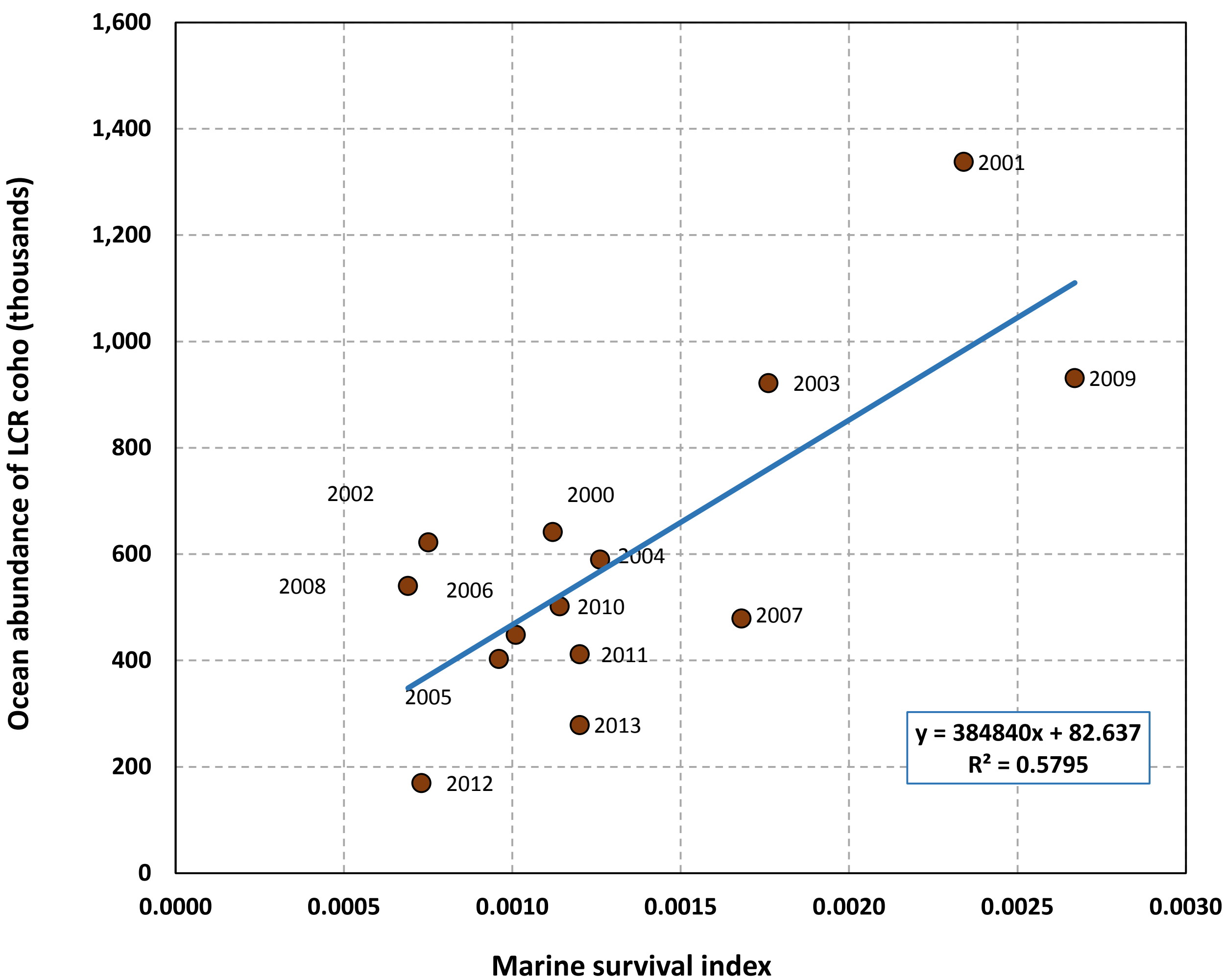


Figure 1. Relationship between marine survival index and ocean abundance of lower Columbia River coho for 2000—2013. The index and abundance are both predominately hatchery-origin fish.

RETROSPECTIVE ANALYSIS

- This analysis shows how recent LCN coho limits would have changed under alternative matrices.
- These years represent a small sample of conditions that might be expected to occur over the longer term. The 2005-2010 brood year average was slightly below the 1974-2010 average (0.131%) and lower and higher MSI's observed in the long term dataset did not occur in 2005-2010.
- Actual LCN rates and fisheries in those years would, of course, have been dependent on a combination of objectives for other stocks.

Table 1. Retrospective analysis of effects on exploitation rate limits for LCN coho under the old and several alternative harvest control rules. Differences in rates from the old matrix are highlighted.

Year	MSI	LCR coho abundance		Old	New alternatives			
		Ocean	Col R	Matrix	5b	5e	5f	5g
2005	0.096%	403	355	15%	15%	18%	18%	18%
2006	0.101%	449	410	15%	15%	18%	18%	18%
2007	0.168%	479	349	20%	20%	20%	18%	18%
2008	0.069%	541	520	8%	15%	15%	15%	15%
2009	0.267%	931	759	20%	25%	23%	20%	23%
2010	0.114%	502	471	15%	20%	18%	18%	18%
2011	0.120%	412	383	15%	20%	18%	18%	18%
2012	0.073%	170	144	15%	15%	15%	15%	15%
2013	0.120%	279	243	15%	20%	18%	18%	18%
Avg.	*0.125%*	*463*	*404*	*15.3%*	*18.3%*	*18.1%*	*17.6%*	*17.9%*

PFMC
10/21/14

HABITAT COMMITTEE REPORT ON LOWER COLUMBIA COHO HARVEST MATRIX

The Habitat Committee (HC) was asked to provide the Council with a status report on habitat conditions in the Lower Columbia River coho salmon evolutionarily significant unit (ESU). The Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW) assembled available information for the portions of the ESU lying within the two states.

Both States reported that they do not have adequate monitoring information available for a meaningful trend analysis of habitat conditions at this time. Habitat restoration activities have been initiated in both States but the lack of monitoring information makes the effectiveness of this work difficult to assess.

Oregon has initiated an aquatic inventory program which examines a series of habitat variables. Limited assessment to date indicates that habitat quality in the ESU remains in the low to moderate range.

ODFW also conducted an analysis of coho parr density within a recent eight year period. This study indicates that coho habitat quality remains low and is not demonstrating an upward trajectory. The HC is concerned that this analysis was not portrayed in terms of juveniles/spawners, but recognizes the preliminary nature of the analysis.

Habitat restoration projects continue in watersheds in the ESU in both States. While there have been significant accomplishments in some watersheds, completion of projects in most areas in Oregon appear to be well below the pace necessary to meet the 2025 restoration goals.

Washington has not identified comparable goals but their pace of habitat project implementation is similar (see complete Oregon and Washington reports). Until last year, projects needed to implement the long-term Intensively Monitored Watershed studies in Washington State were stalled because of funding shortfalls. Starting in 2015, these projects will move ahead, however it could take at last 10 years to detect trends in habitat restoration effectiveness at the population level.

Both states report that the pace of habitat restoration activities, as well as monitoring programs, are limited by lack of funding. It must be noted that significant habitat degradation continues to occur and available monitoring information does not allow this factor to be quantified. In addition, there are emerging threats including climate change, human population growth, and potential water reallocations associated with the Columbia River Treaty.

If the Council will be forwarding recommendations to NOAA in regards to management of ESA-listed species, the HC recommends that monitoring of habitat status and trends be adequately funded.

PFMC
11/14/14

Agenda Item F.4.c
Supplemental HC Report 2
November 2014

HABITAT COMMITTEE ADDENDUM TO THE LOWER COLUMBIA RIVER HARVEST MATRIX

The Habitat Committee (HC) was asked to provide the Council with a status report on habitat conditions for the LCR Coho salmon ESU. Specifically, the HC was asked:

"Is the habitat for the lower Columbia coho ESU better, worse, or roughly the same as it was around 2005?"

HC members from ODFW and WDFW provide their respective agency's response to this question.

ODFW Response:

At this time, ODFW's Conservation and Recovery Program does not have sufficient repeat monitoring events for a statistically-meaningful trend analysis of habitat conditions. Although habitat restoration efforts have been underway for many years, it may take years to decades before habitat is restored to functional order. To answer this question for the Council in the interim, we performed a modeling exercise using habitat restoration monitoring data to quantify habitat restoration, along with coho parr (juvenile) abundance as a proxy for habitat quality. The model estimates the capacity of the habitat (based on habitat quality) to support juvenile coho salmon. Annual comparison since 2006 is provided.

Coho Habitat Quality

The ODFW Aquatics Inventory Program has conducted statistically randomized sampling events in the LCR salmon ESU to monitor habitat conditions since 2006. Habitat variables (stream morphology, substrate composition, in-stream rugosity, riparian structure, and channel complexity) are then modeled to provide an estimate of the habitat's capacity to support juvenile coho salmon. The habitat is classified as high or low quality, with high quality habitat believed to support roughly twice as many parr per km of stream as low quality habitat (1,850 and $\leq$900 parr, respectively).

The conclusion from this limited assessment is that habitat quality has consistently and statistically remained within the low to moderate range for supporting juvenile coho since 2006 (Figure 1). These findings are consistent with NOAA's 5-Year Review (2012):

Summary and Evaluation of listed LCR fish populations for habitat condition:

> "New information available since the last status review indicates that many restoration and protection actions have been implemented in freshwater and estuary habitat but does not reveal overall trends in habitat quality, quantity and function. In addition, we remain concerned with threats to habitat through the range of LCR salmon and steelhead, particularly with regard to activities that affect the quality and accessibly of habitat and

habitat forming processes, on private lands and considering the likelihood of continuing land use and development. We therefore conclude that the risk to the species persistence because of habitat destruction or modification has not changes since the last status review."

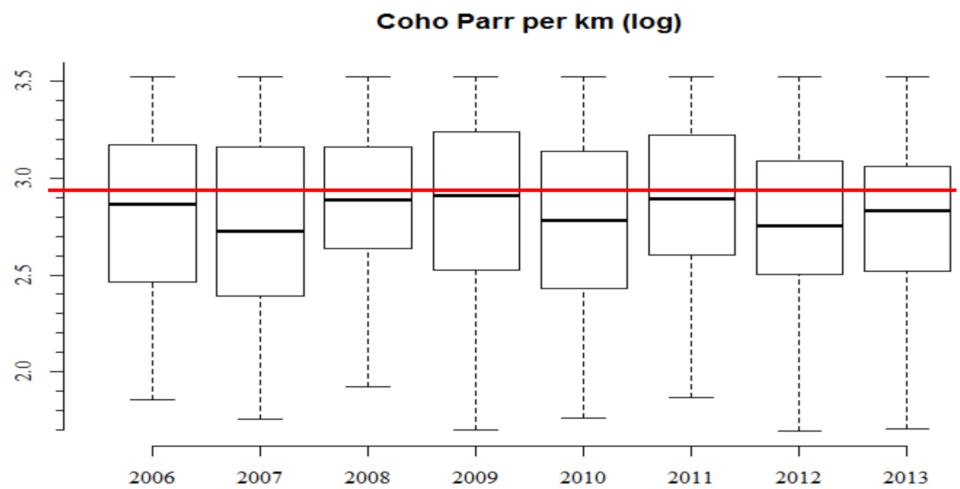


Figure 1. Habitat quality is indicated by the habitat's ability to support juvenile (parr) coho salmon, using parr abundance as a proxy for habitat quality. Y-axis is log-transformed salmon parr per kilometer of stream. Red line indicates threshold for low quality habitat (< 900 parr per km, log transformed = 2.95).

LCR Recovery Plan: ESU-wide Habitat Restoration Goal Tracking and Progress

The Oregon Lower Columbia River Salmon and Steelhead Recovery Plan (Recovery Plan) identifies six general threats to LCR Coho ESU that are central to Recovery Plan goals of delisting and "broad sense recovery" [1]. Two identified threats are habitat-specific: estuaries and tributary mortality. With respect to reducing tributary mortality for the ESU, ODFW established habitat restoration goals and "functional habitat" goals based on ODFW benchmark standards of: (1) miles of large woody debris (LWD), (2) miles of riparian planting, (3) square meters of off-channel habitat, and (4) miles of side channel habitat.

Tributary habitat restoration efforts began in 2010, with a desired outcome of total restoration implementation by 2025. In order to meet this long-term goal, tributary habitat restoration must stay on a steady annual trajectory. After 4 years on this 15-year trajectory, tributary restoration (measured as stream miles) should be at 25% of the goals for each independent population. Only a few (Sandy River, Youngs Bay, Clackamas, Scappoose, Hood) of the nine ESU independent populations are on course for meeting one or more benchmarks, and only in a few cases have they

[1] Recovery Plan definition of Broad Sense Recovery: "Having Oregon populations of naturally produced salmon and steelhead sufficiently abundant, productive, and diverse that the ESU as a whole will be self-sustaining and will provide significant ecological, cultural and economic benefits".

reached 25%. Figures 2 - 5 indicates restoration progress for each population for 2010-2013. This interim analysis does not evaluate the effectiveness of restoration projects. The next federal status assessment is planned for 2017.

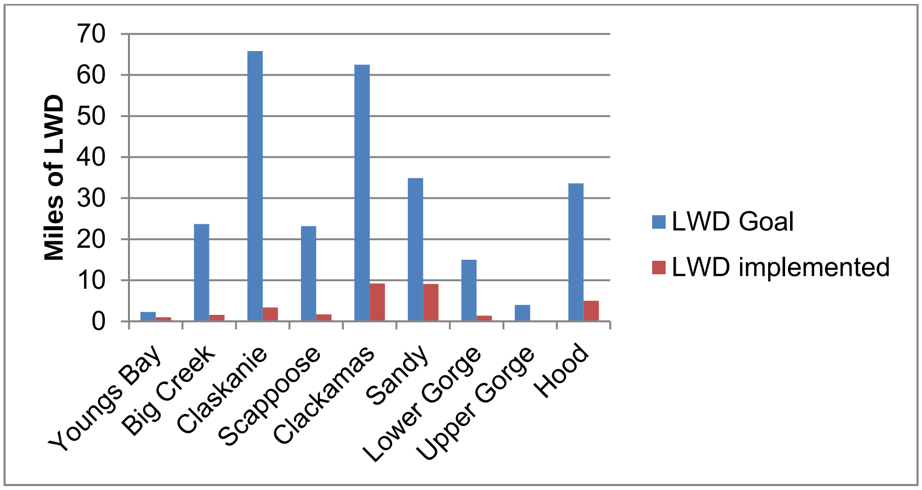


Figure 2. For **LWD goals** only the Sandy and Youngs Bay populations are on a trajectory to accomplish the long term goal (due to maintaining the populations status at very high risk for Youngs Bay population the restoration quantities needed are very low).

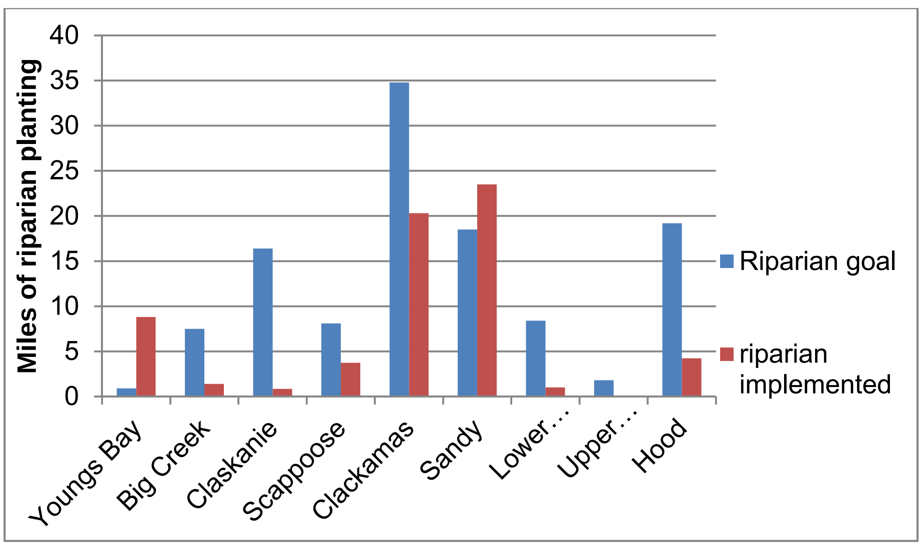


Figure 3. For **riparian goals** the Sandy and Youngs Bay populations have exceeded the goals and the Clackamas, Scappoose and Hood are tracking closely to the long term goals.

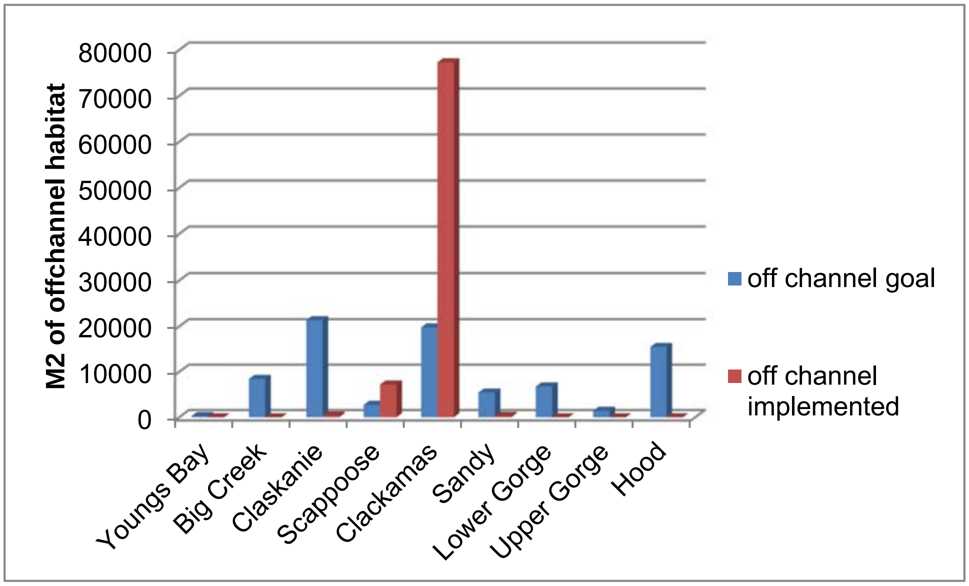


Figure 4. For **meters squared of off-channel habitat** both the Clackamas and the Scappoose implemented one or two extremely large projects and have met the goal, the remainder of the populations are at a very low level.

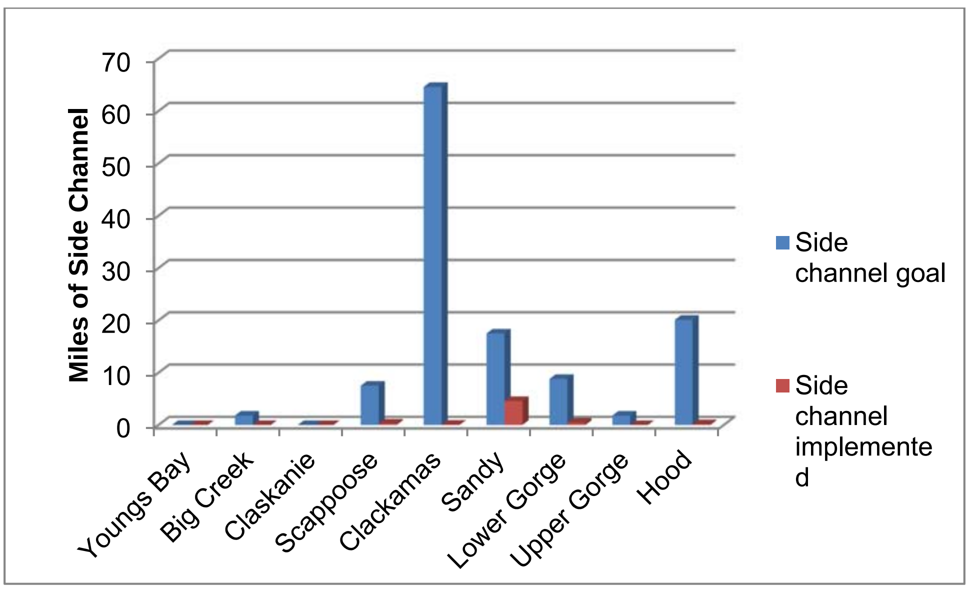


Figure 5. For **miles of side channel habitat** only the Sandy population is on a trajectory to meet the goal.

Emerging Threats

Habitat conditions are not worsening, per se, but there are new threats to consider. Most notable are climate change, human population growth and the Columbia River treaty. Several Coho salmon populations are located in the rain/snow dominated precipitation pattern that is likely to change to rain-only in the future. The change in precipitation pattern will affect all life history stages. As municipalities begin to address climate change there may be an increased effort to build water storage facilities, which could potentially impact high flow sediment regimes (discussions are already underway). The suburban areas of Portland are expanding and putting more pressure on natural resources affecting the Sandy and Clackamas populations.

Question: Is the habitat for the lower Columbia coho ESU better, worse, or roughly the same as it was around 2005?

Lower Columbia Fish Recovery Board is the regional organizations is responsible for coordinating and facilitating the Lower Columbia River Salmon Recovery Plans in Washington state. The have provided most of the information below.

No comprehensive habitat monitoring program currently exists or is funded for the Washington portion of the Lower Columbia coho Evolutionarily Significant Unit (ESU). Accordingly, the LCFRB has no monitoring data or analyses that provide a statistically-meaningful picture of coho habitat trends. However, while habitat status and trends information may be lacking, efforts to restore and protect salmon and steelhead habitat in the Lower Columbia have been ongoing for over 15 years. Protection actions are intended to prevent or minimize further habitat degradation. Restoration actions provide near-term habitat improvements, but their full potential may not be achieved for decades.

Habitat protection and restoration efforts are guided by the Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB 2010). The Plan identifies habitat restoration needs and priorities for each of 17 river subbasins. In doing so, it takes into consideration population priorities, key life history stages, and existing reach conditions to assess the restoration potential of each reach within a subbasin.

Habitat restoration and protection actions benefitting coho include:

- Habitat protection and restoration efforts funded primarily through the LCFRB and Washington Salmon Recovery Funding Board (SRFB) and implemented through local governments, the Cowlitz Indian Tribe, state and federal agencies, nonprofit organizations. Since 1998, 176 projects with a total value of $48.7 million have been implemented or funded by the SRFB on Lower Columbia tributary rivers and streams. Many of these benefit coho. Within the region there are a total of 466 stream reaches that are high priority to the recovery of Coho salmon. Since 1998, 36 projects have been implemented across 297 high priority coho reaches. Thirty-six (36) restoration projects have been built across 135 high priority reaches to improve and protect coho salmon habitat. See Tables Below.

- Pursuant to provisions of the Federal Columbia River Power System (FCRPS) habitat restoration efforts in the Columbia River mainstem and estuary are being undertaken by the Washington Department of Fish and Wildlife, the Cowlitz Indian Tribe, and several nonprofit organizations.

- The USFS has worked to improve instream habitat and watershed conditions in the Cowlitz, Cispus, North Fork Lewis, East Fork Lewis, and Wind Rivers. These efforts include road abandonment and upgrades, riparian restoration, side channel improvements, and large wood structures enhancing instream habitat complexity and quantity.

- State forest lands are managed by the Washington Department of Natural Resources (DNR) pursuant to a Habitat Conservation Plan (HCP) approved by the US Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). The Plan provides protection of riparian areas and unstable slopes as well as road maintenance actions needed to reduce fine sediments reaching fish bearing streams. DNR has also worked with local organizations to implement stream habitat restoration projects on state forest lands.

- Forest management activities on private forest lands are regulated by DNR pursuant to the state Forest Practices Act and an HCP approved by the USFWS and NMFS. These regulations provide for the protection of riparian areas, channel migration zones, and forested wetlands. They also require the maintenance or abandonment of forest roads in order to reduce stream sediment inputs.

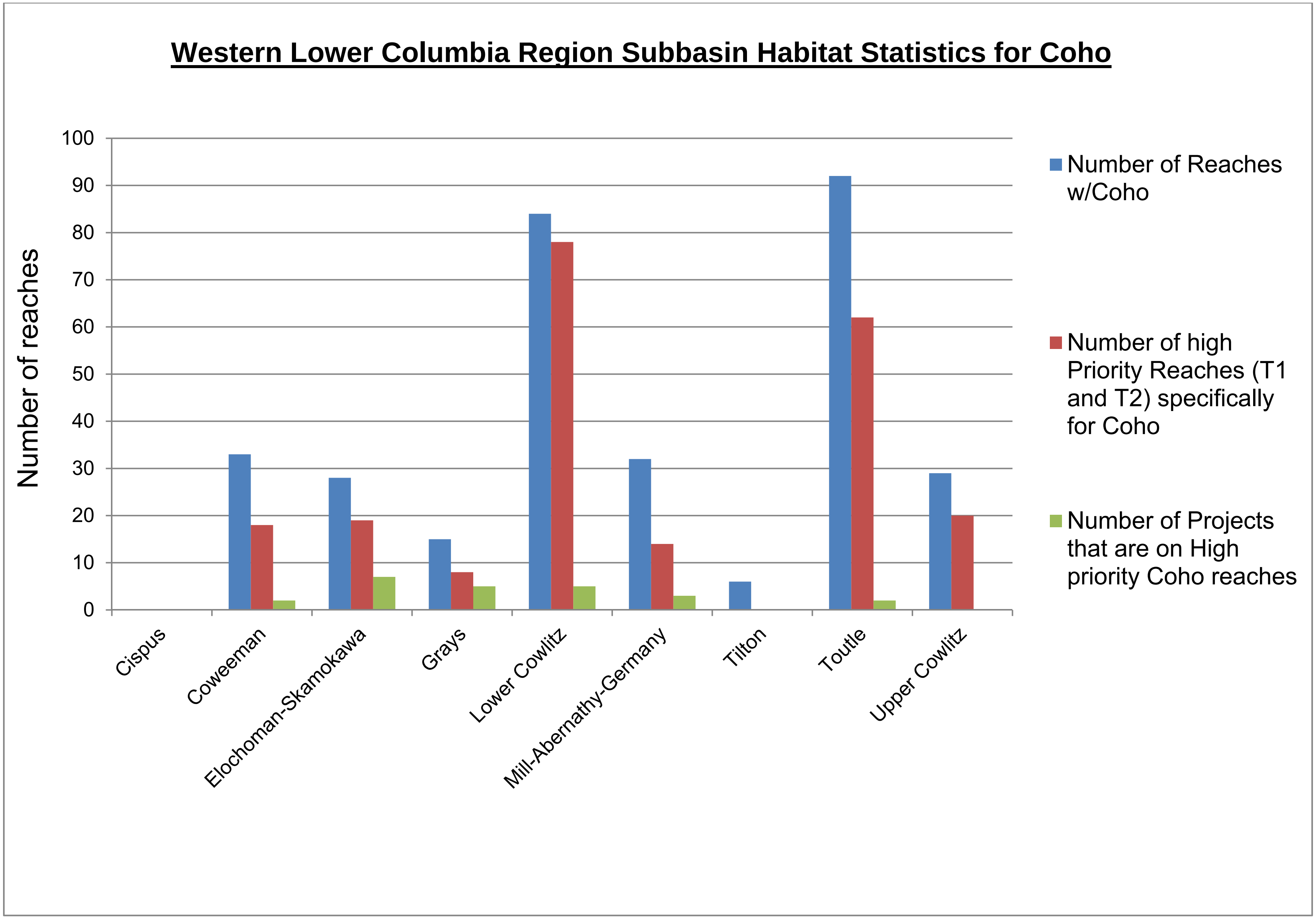
- Hydro-electric utilities are implementing fish passage measures to allow the reintroduction of coho above dams on the Cowlitz and North Fork Lewis Rivers. Pursuant to their federal licenses, the utilities are also funding habitat restoration in the Cowlitz and Lewis River watersheds. Removal of Condit Dam will allow coho to recolonize the White Salmon River.

- Counties and cities have adopted Critical Area Ordinances with provisions to protect fish habitat, riparian areas and wetlands. Clark County's updated Shoreline Master Plan draws upon the Lower Columbia recovery plan to identify habitat protection measures. Other jurisdictions are also updating their shoreline plans.

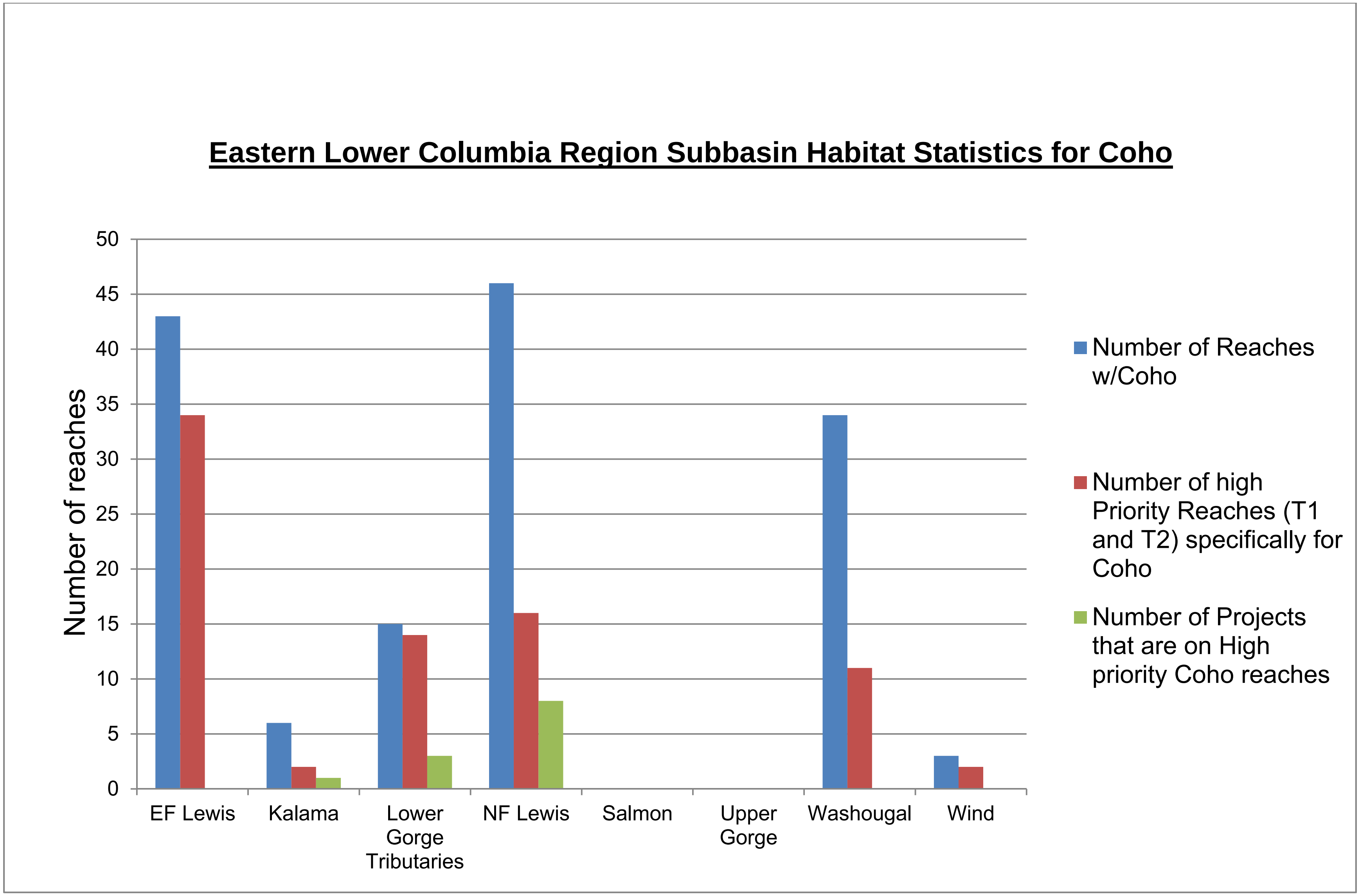
- The Washington Department of Ecology has adopted water management rules to protect stream flows in the Kalama, Lewis, and Washougal watersheds. Clark Public Utilities with funding support from the Department of Ecology is developing a regional water supply that will avoid impacts on stream flows of the East Fork Lewis. Water management plans for meeting future demands while protecting stream flows for fish have been adopted by local governments for the Grays, Elochoman, Skamokawa, Mill/Abernathy/Germany, Cowlitz, Toutle, Cispus, and Tilton subbasins.

- The Washington Department of Fish and Wildlife (WDFW) administers the Hydraulic Project Approval (HPA) permits for Washington State. Since 1943, anyone planning certain construction projects or activities in or near state waters has been required to obtain an HPA permit. Between 2006 and today, HPAs have been issued for 154 projects in Clark, Cowlitz, Lewis, Skamania, and Wahkiakum counties (that covers the majority of waters encompassed by the Lower Columbia River Coho ESU). In general these projects are for habitat improvement in those waters and can be broken down as follows:

    - Large wood installation or other structures that benefit naturally reproducing fish stocks = ~75%
    - Fish passage improvement = ~21%
    - Bioengineered bank protection = ~5%



Western Lower Columbia Region Subbasin Habitat Statistics for Coho
Number of reaches
100
90
80
70
60
50
40
30
20
10
0
Cispus
Coweeman
Elochoman-Skamokawa
Grays
Lower Cowlitz
Mill-Abernathy-Germany
Tilton
Toutle
Upper Cowlitz
Number of Reaches w/Coho
Number of high Priority Reaches (T1 and T2) specifically for Coho
Number of Projects that are on High priority Coho reaches



Eastern Lower Columbia Region Subbasin Habitat Statistics for Coho
Number of reaches
50
45
40
35
30
25
20
15
10
5
0
EF Lewis
Kalama
Lower Gorge Tributaries
NF Lewis
Salmon
Upper Gorge
Washougal
Wind
Number of Reaches w/Coho
Number of high Priority Reaches (T1 and T2) specifically for Coho
Number of Projects that are on High priority Coho reaches

Agenda Item F.4.c
Supplemental SAS Report
November 2014

SALMON ADVISORY SUBPANEL REPORT ON THE LOWER COLUMBIA COHO HARVEST MATRIX

The Salmon Advisory Subpanel (SAS) greatly appreciates the efforts of the Pacific Fishery Management Council and the ad hoc Lower Columbia River Natural Coho Workgroup (LRC Workgroup) to develop alternative harvest policy for Lower Columbia River natural (LCN) coho. This is a very important issue to the SAS, stakeholders, and fishing communities of the Columbia River and the West Coast.

The SAS unanimously recommends that the Council request that National Marine Fisheries Service consider replacing the existing harvest matrix for LCN coho under the Endangered Species Act with LRC Workgroup Alternative 5g, including the seeding level option on page 3 of LRC Workgroup Report 2 (Agenda Item F.4.b, LRC Workgroup Report 2). The SAS notes that Alternative 5g meets the objectives of incorporating new information on LCN coho, simplifies harvest policy, and provides moderate increases to harvest opportunity while staying within the stated National Marine Fisheries Service risk tolerance. The SAS worked cooperatively with the LRC Workgroup to develop a wide range of alternatives and spent considerable time working with a variety of fishery interests to find consensus on Alternative 5g.

The SAS is also appreciative of the efforts of States of Oregon and Washington to commit valuable resources to the monitoring of LCN coho. The SAS recommends and anticipates that these monitoring programs will continue to expand our understanding of LCN coho status. The SAS recommends that the Council conduct a review of: new information collected and management performance after three years of implementation of any new harvest matrix (three-year check in).

PFMC
11/16/14

SALMON TECHNICAL TEAM REPORT ON THE LOWER COLUMBIA COHO HARVEST MATRIX

The Salmon Technical Team (STT) has reviewed the reports from the Lower Columbia River Natural Coho Workgroup on the Lower Columbia River coho harvest matrix (Agenda Item F4.b, Report 1 and Report 2). We compared the range of exploitation rates in the alternatives against the range of exploitation rate ceilings that have been in place since 2005 as shown in the annual Preseason Report III (Council Adopted Management Measures and Environmental Assessment Part III). This retrospective comparison of preseason exploitation rates from FRAM (Fishery Regulation Assessment Model) with the range of exploitation rates in the alternatives was not a detailed quantitative analysis. We identified some key qualitative points to consider regarding the effect on Council-area and inside waters fisheries that have been limited by constraints on Lower Columbia natural coho and other stocks. The following is a summary of the key management issues and list of constraining stocks during 2005-2014.

- The Endangered Species Act (ESA) guidance limit on Lower Columbia natural coho for combined ocean and mainstem Columbia River fisheries ranged from a low of an 8 percent exploitation rate in 2008 to a high of 22.5 percent in 2014 and averaged 16 percent under the current matrix.
- In all years, Lower Columbia natural coho were a key constraining stock in Council fisheries when ocean impacts were combined with in-river impacts, where the latter can account for up to a third of the total impacts.
- Upper Fraser-Thompson stock coho was the other constraining stock caught in Council fisheries north of Cape Falcon. In some years, some Puget Sound stocks and Oregon coastal natural coho were near their conservation objective limits but were never the constraining stock.
- In 2008, the critical low status of Lower Columbia natural coho and the corresponding 8 percent ESA guidance limit significantly constrained all Council area coho fisheries as well as fisheries in the Columbia River. Catch quotas for coho were greatly reduced and mark-selective regulations were required in all nontreaty fisheries. A portion of the allowable impacts on coho are required to cover release mortality in Chinook-only fisheries.

After reviewing the range of alternatives shown in these reports in a retrospective overview of the management objectives and status of all stocks during these years, the STT has the following comments:

- An exploitation rate ceiling of 10 percent on Lower Columbia River natural coho should cover the fishing mortality impacts in Chinook-only fisheries as well as some very limited level of harvest in fisheries allowing retention of coho.
- The ability of ocean fisheries to respond to an increase in the allowable exploitation rate of Lower Columbia River natural coho may be limited as other stocks become the most constraining.

- As the allowable exploitation rate for Lower Columbia River natural coho approaches the upper limit shown in the matrices, there is a higher likelihood that the river fisheries will receive the greater increment in the proportion of total impacts.
- Since most conservation objectives are based on all-fishery impact limits, an increase in ocean fishery impacts may further constrain fisheries in inside waters in order to meet the objectives. Upper Fraser-Thompson coho stock is one example of a key constraining stock that would require further restrictions to fisheries in Puget Sound if ocean fisheries were expanded.
- In any given year, the most constraining stock(s) may differ and the allowable impacts in Council fisheries in combination with impacts in inside fisheries must meet the conservation objectives for all stocks in the Fishery Management Plan.
- The Lower Columbia River natural coho harvest matrix only affects the conservation objectives for this stock; the conservation objectives for other stocks remain unchanged.

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