Agenda Item F.5
Attachment 1(**Electronic Only**)
April 2019

DRAFT 11
KLAMATH RIVER FALL CHINOOK

(MARCH, 2019)

SALMON REBUILDING PLAN,
ENVIRONMENTAL ASSESSMENT*,
MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ANALYSIS*,
REGULATORY IMPACT REVIEW*, AND
INITIAL REGULATORY FLEXIBILITY ANALYSIS*

REGULATORY IDENTIFIER NUMBER 0648-BI04

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
ACL	annual catch limit
BY	brood year
CDFW	California Department of Fish and Wildlife
CoTC	Coho Technical Committee (of the PSC)
Council	Pacific Fishery Management Council
CWT	coded-wire tag
EA	Environmental Assessment
EEZ	exclusive economic zone (from 3-200 miles from shore)
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESU	evolutionarily significant unit
F_{ABC}	exploitation rate associated with ABC
F_{ACL}	exploitation rate associated with ACL (= F_{ABC})
FMP	fishery management plan
F_{MSY}	maximum sustainable yield exploitation rate
F_{OFL}	exploitation rate associated with the overfishing limit (= F_{MSY}, MFMT)
FONSI	Finding of No Significant Impacts
FRAM	Fishery Regulatory Assessment Model
GAM	generalized additive models
IGD	Iron Gate Dam
IGH	Iron Gate Hatchery
ISBM	individual stock-based management
KMZ	Klamath management zone (ocean zone between Humbug Mountain and Horse Mountain)
KOHM	Klamath Ocean Harvest Model
KRFC	Klamath River fall Chinook
MFMT	maximum fishing mortality threshold
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSM	mixed stock model
MSST	minimum stock size threshold
MSY	maximum sustainable yield
NA	not available
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NPGO	North Pacific Gyre Oscillation
NS1G	National Standard 1 Guidelines
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
OY	Optimum Yield
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council (Council)
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
RER	rebuilding exploitation rate
S_{ABC}	spawning escapement associated with ABC
S_{ACL}	spawning escapement associated with ACL (= S_{ABC})
SHM	Sacramento Harvest Model
SI	Sacramento Index
S_{MSY}	MSY spawning escapement
S_{OFL}	spawning escapement associated with the overfishing limit (= S_{MSY})

LIST OF ACRONYMS AND ABBREVIATIONS *(continued)*

SRFC	Sacramento River fall Chinook
SRWC	Sacramento River winter Chinook
STT	Salmon Technical Team
TRH	Trinity River Hatchery
VSI	visual stock identification
WDFW	Washington Department of Fish and Wildlife

1.0 EXECUTIVE SUMMARY

To be developed for final Rebuilding Plan.

2.0 INTRODUCTION

In 2018, Klamath River fall Chinook salmon (KRFC) met the criteria for overfished status as defined in section 3.1 of the Pacific Coast Salmon Fishery Management Plan (FMP) (PFMC 2016). In response, the Pacific Fishery Management Council (Council) directed the Salmon Technical Team (STT) to propose a rebuilding plan for Council consideration within one year. The FMP, and the Magnuson-Stevens Fishery Conservation and Management Act (MSA), requires that a rebuilding plan must be developed and implemented within two years of the formal notification from National Marine Fisheries Service (NMFS) to the Council of the overfished status. Excerpts from the FMP relevant to status determinations and rebuilding plans are provided in Appendix A.

The Council's criteria for overfished status is met if the geometric mean of escapement, computed over the most recent three years, falls below the minimum stock size threshold (MSST) which is defined for applicable stocks in Table 3-1 of the FMP. For KRFC, the maximum sustainable yield spawner escapement level (S_{MSY}) is defined to be 40,700 natural-area adult spawners. The MSST for KRFC is defined as 30,525 natural-area adult spawners, with MSST = 0.75 x S_{MSY}. The geometric mean of KRFC natural-area adult spawners over years 2015-2017 was 19,358, and thus in 2018 the stock met the criteria for overfished status. Figure 2.0.a displays the time series of KRFC natural-area adult escapement and the running three year geometric mean of escapement relative to S_{MSY} and the MSST. The FMP identifies the default criterion for achieving rebuilt status as attainment of a 3-year geometric mean of spawning escapement exceeding S_{MSY}.

Overfished status is defined by recent spawner escapement for salmon stocks, which is not necessarily the result of overfishing. Overfishing occurs when in any one year the exploitation rate on a stock exceeds the maximum fishing mortality threshold (MFMT), which for KRFC is defined as the MSY fishing mortality rate (F_{MSY}) of 0.71. It is possible that overfished status could be the result of normal variation in abundance, as has been seen in the past for several salmon stocks. However, the occurrence of reduced stock size or spawner escapements, depending on the magnitude of the short-fall, could signal the beginning of a critical downward trend. Imposing fisheries on top of already low abundances could further jeopardize the capacity of the stock to produce MSY over the long term if appropriate actions are not taken to ensure that conservation objectives are achieved.

In this rebuilding plan, we begin by providing an overview of the KRFC stock, the physical setting of the Klamath Basin, and fisheries management. We then review the potential factors that may have contributed to the overfished status. Recommendations regarding alternative rebuilding actions are proposed, as are recommendations for actions outside of the management of salmon fisheries. We end with a socioeconomic analysis of the impact of the recommended rebuilding alternatives.

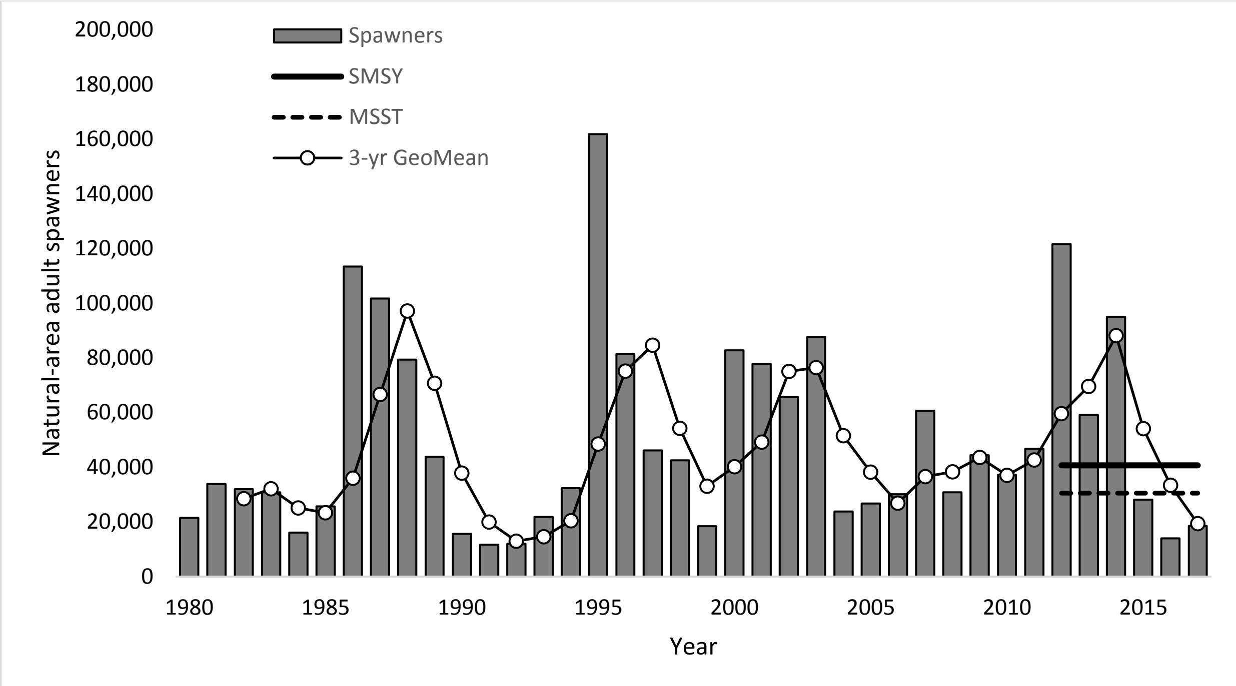

Figure 2.0.a. Klamath River Fall Chinook spawning escapement of natural-area adults.

2.1 National Environmental Policy Act

In addition to addressing the requirements of the FMP and MSA, this rebuilding plan document integrates the environmental assessment required under the National Environmental Policy Act (NEPA).

2.1.1 Proposed Action

The Proposed Action is for the Council to adopt and NMFS to approve a rebuilding plan for the KRFC salmon stock, which has been determined by NMFS to be overfished under the MSA. The rebuilding plan must be consistent with the MSA and the provisions of the FMP; therefore, The plan shall include a control rule and a specified rebuilding period. The specified rebuilding period shall be as short as possible, taking into consideration the needs of the commercial, recreational and tribal fishing interests and coastal communities.

2.1.2 Purpose and Need

The purpose of the proposed action is to develop and implement a harvest control rule that will be applied to setting annual ocean salmon fishery management measures that impact KRFC. This harvest control rule will be designed to attain a three-year geometric mean spawning escapement that meets the S_{MSY} specified for that stock in the FMP in the least amount of time possible while taking into account the biology of the stock, international agreements, and the needs of fishing communities, but not to exceed 10 years. The need for the proposed action is to rebuild KRFC, which the NMFS determined, in 2018, to be overfished under the MSA.

2.2 Stock overview

2.2.1 Location and geography

The Klamath Basin lies in Northern California and Southern Oregon and encompasses 40,632 km^2 (Figure 2.2.2.a). More than half of the watershed (20,875 km^2) lies in the upper Klamath Basin, defined here as upstream from Iron Gate Dam (IGD). Anadromy in the upper basin was cut off by the construction of Copco Dam #1 in 1917, and was further limited by construction of IGD in 1962, built to re-regulate the discharge from Copco Dam. Access to the upper Trinity Basin was cut off by the construction of Trinity Dam in 1962 and its re-regulation dam (Lewiston) in 1963, which together blocked access to the upper 459,264 acres (1,859 km^2) of the Trinity Basin, leaving an accessible watershed area of 17,898 km^2. There are various other smaller dams and water diversions in the basin. All remaining habitat accessible to anadromous fish lies in California, though portions of the lower Klamath Basin Watershed extend into Oregon. Major tributaries to the Klamath River within the lower basin include the Trinity, Salmon, Scott, and Shasta Rivers, and Bogus Creek, all of which support naturally spawning populations of KRFC (PFMC 2008).

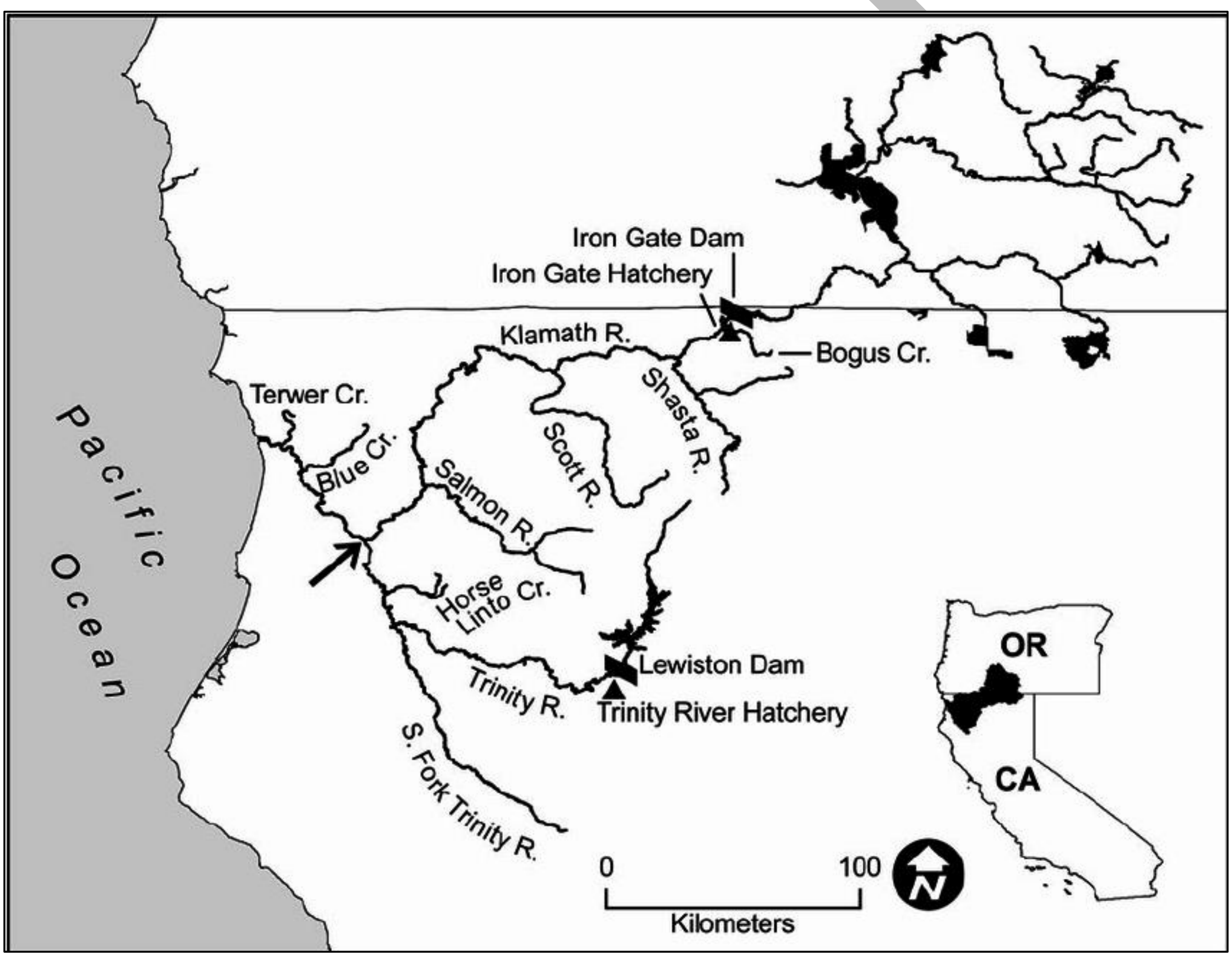

Figure 2.2.2.a. Klamath River Basin map (reproduced from PFMC 2008)

2.2.2 Stock composition

Fall Chinook are the predominant salmon run type in the Klamath Basin. Naturally spawning KRFC enter freshwater to spawn during August-September and deposit their eggs during October-December. The eggs incubate in the gravel during October-January and young fish emerge in February-March. Downstream migration begins soon after emergence. When ready to enter the ocean, juveniles reach the estuary during June-August and ocean entrance is generally complete by the end of September. In August-September following the year of ocean entry, a small proportion of each cohort, mostly males (jacks), returns to the river to spawn as age-2 fish. The first major contribution to adult spawning escapement takes place during August-September after the second year of ocean entry, as age-3 fish. The majority of the adult fish in each cohort are destined to spawn by age-4, although the actual number of fish that survive to spawn may be less than the age-3 return due to variation in ocean and river survival rates. The very few remaining fish of each cohort mature at age-5 or very rarely at age-6.

Hatchery KRFC production occurs at Iron Gate Hatchery (IGH) located at the base of IGD at the upper limit of anadromous migration in the Klamath River and at Trinity River Hatchery (TRH) located at the base of Lewiston Dam at the upper limit of anadromous migration in the Trinity River. Both facilities were constructed to mitigate for habitat loss resulting from construction of the major dams on the mainstem of the Klamath and Trinity Rivers, respectively. At both hatcheries the majority of juvenile fish are released directly into the river as fingerlings at or near the respective facilities. This generally occurs during June of the year following spawning, although release timing can be advanced if river water temperatures are projected to be less than optimal during the downstream migration period. A proportion of each hatchery's production goal is released as yearlings in October and November (PFMC 2008). Additional information is provided in section 3.1.4. of this report.

2.3 Management Overview

2.3.1 Conservation objectives

Table 3-1 in the FMP (PFMC 2016) defines the current conservation objective for KRFC:

> *At least 32 percent of potential adult natural spawners, but no fewer than 40,700 naturally-spawning adults in any one year. Brood escapement rate must average at least 32 percent over the long-term, but an individual brood may vary from this range to achieve the required tribal/nontribal annual allocation. Natural area spawners to maximize catch estimated at 40,700 adults* (STT 2005).

Prior to adoption of Amendment 16 to the salmon FMP in 2012, the KRFC conservation objective was defined as:

> *33-34 percent of potential adult natural spawners, but no fewer than 35,000 naturally spawning adults in any one year. Brood escapement rate must average 33-34 percent over the long-term, but an individual brood may vary from this range to achieve the required tribal/nontribal annual allocation.*

Further information on and justification for this conservation objective can be found in Table 3-1 of PFMC (2003).

Prior to 2012, the conservation objective defined in PFMC (2003) guided fishery management for KRFC. Fisheries were planned so as to result in a projected natural-area adult escapement of at least 35,000 adults in most years. Upon adoption of Amendment 16 to the FMP in 2012, annual fishery management of the KRFC stock has been guided by a harvest control rule that incorporates some aspects of the current conservation objective (PFMC 2016).

2.3.2 Management strategy

Current management of KRFC is guided by a control rule that specifies the maximum allowable exploitation rate on the basis of a forecast of the natural-area adult escapement in the absence of fisheries (E0) (Figure 2.2.4.a). The exploitation rate cap specified by the control rule includes harvest and incidental impacts in both ocean and river fisheries.

For KRFC, potential spawner abundance in the absence of fisheries is forecast each year based on age-specific ocean abundance forecasts, ocean natural mortality rates, age-specific maturation rates, stray rates, and the proportion of escapement expected to spawn in natural areas (PFMC 2018c). The result is the number of natural-area adult spawners expected given no ocean fisheries between Cape Falcon, OR, and Point Sur, CA, and no river fisheries.

At high levels of potential spawner abundance, the control rule specifies a maximum allowable exploitation rate of 0.68, the fishing mortality rate associated with the Acceptable Biological Catch (F_{ABC}). At moderate abundance levels, the control rule specifies an allowable exploitation rate that varies with abundance to result in an expected spawner escapement of $S_{MSY} = 40{,}700$ natural-area adults (the curved portion of the control rule). At low levels of abundance, the control rule specifies *de minimis* exploitation rates that allow for some fishing opportunity but result in the expected escapement falling below 40,700 natural-area adult spawners.

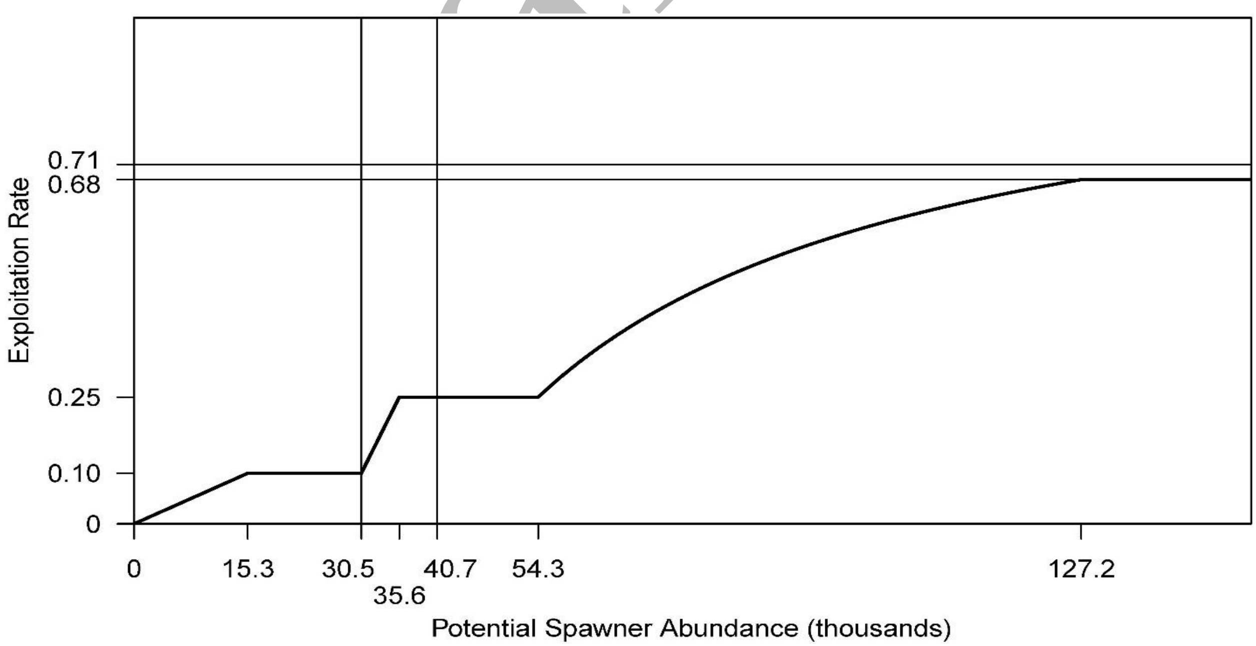

Figure 2.2.4.a. Klamath River fall Chinook control rule. Potential spawner abundance is the predicted natural-area adult spawners in the absence of fisheries. See the salmon FMP, Section 3.3.6, for control rule details.

3.0 REVIEW OF POTENTIAL FACTORS LEADING TO OVERFISHED STATUS

3.1 Freshwater survival

3.1.1 Review of freshwater conditions

River Flows and Temperatures during spawning

Fall Chinook salmon in the Klamath River Basin typically spawn during October and November. Flows on the mainstem Klamath River during the spawning period were low for brood years 2012, 2013, and portions of 2014 compared to brood years 2000-2010 (Figure 3.1.1.a). On the Trinity River, flows during the spawning period for brood years 2011-2014 were qualitatively similar to flows for brood years 2000-2010 (Figure 3.1.1.b).

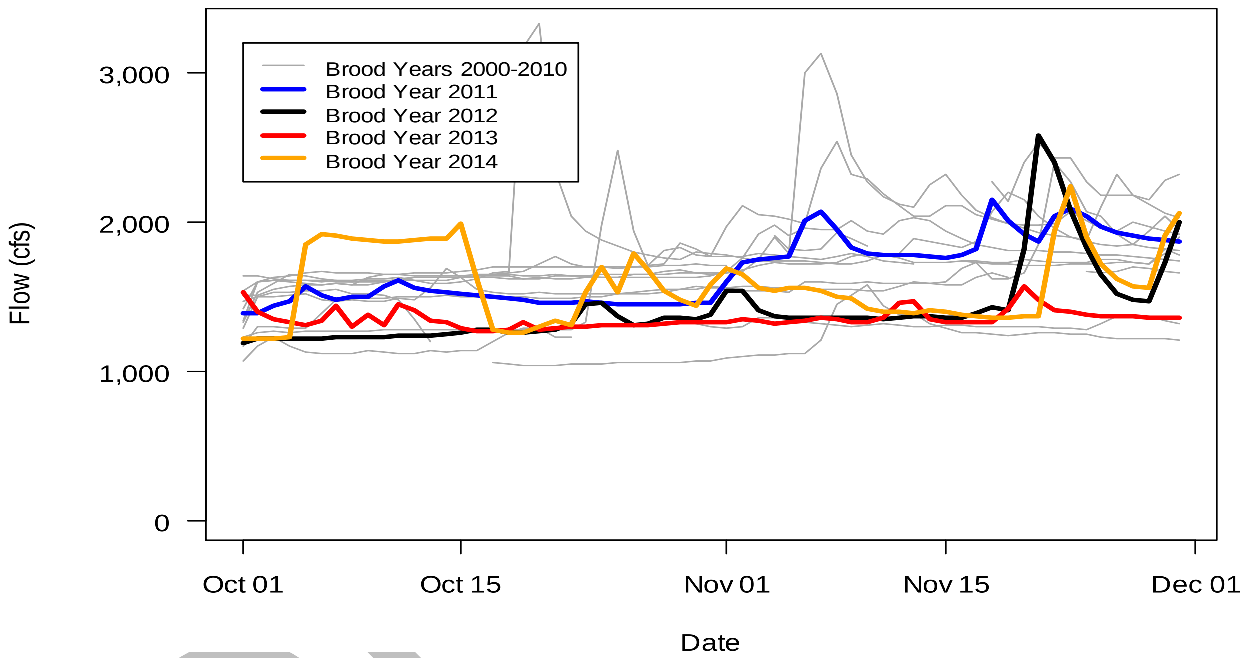

Figure 3.1.1.a. Flows during the spawning period on the Klamath River at the Seiad Valley USGS gauge (Gauge 11520500, at rkm 209) for brood years 2000-2014.

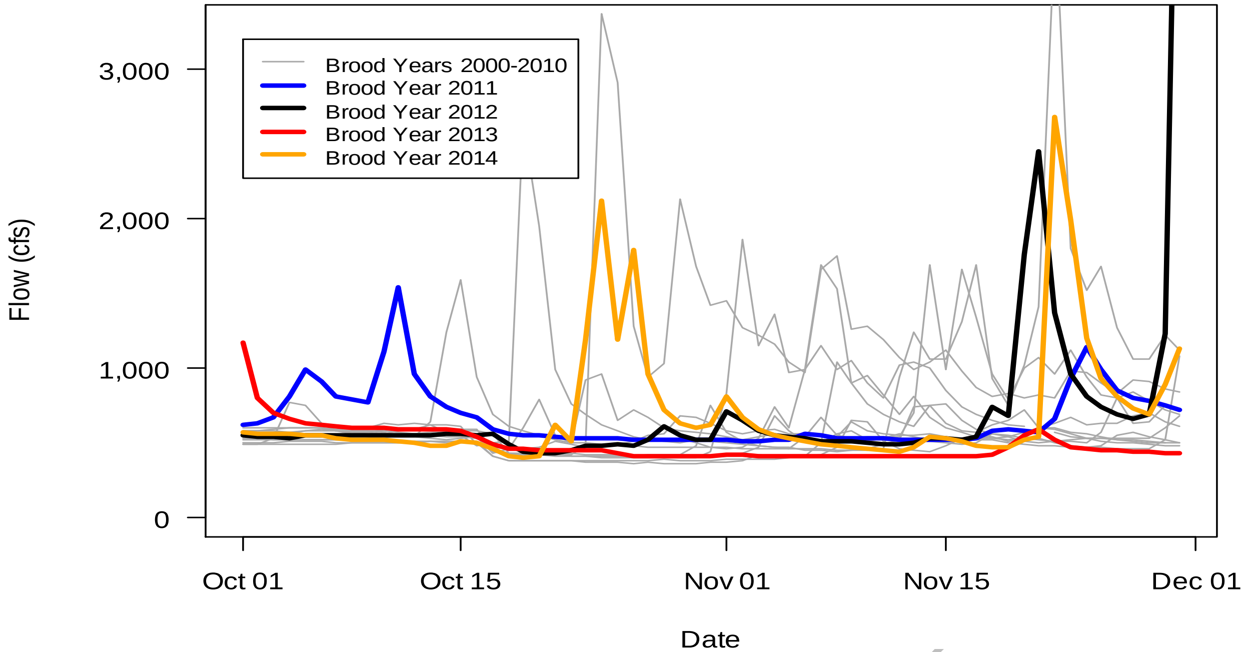

Figure 3.1.1.b. Flows during the spawning period on the Trinity River at the Burnt Ranch USGS gauge (rkm 79) for brood years 2000-2014.

The U.S. Environmental Protection Agency (EPA) has identified criteria for Pacific Northwest water temperatures to protect Pacific salmon (USEPA 2003). David and Goodman (2017) summarized river temperatures at index sites within the Klamath River and compared temperatures to the EPA 13˚C seven-day average daily maximum (7DADM) criterion for spawning, incubation, and emergence during October 1 – April 30 each year. For brood years 2011-2013, the 13˚C criterion was exceeded for 30-37 days at the site on the Klamath River above the Scott River (Figure 3.1.1.c). For brood year 2014 the criterion was exceeded for 52 days.

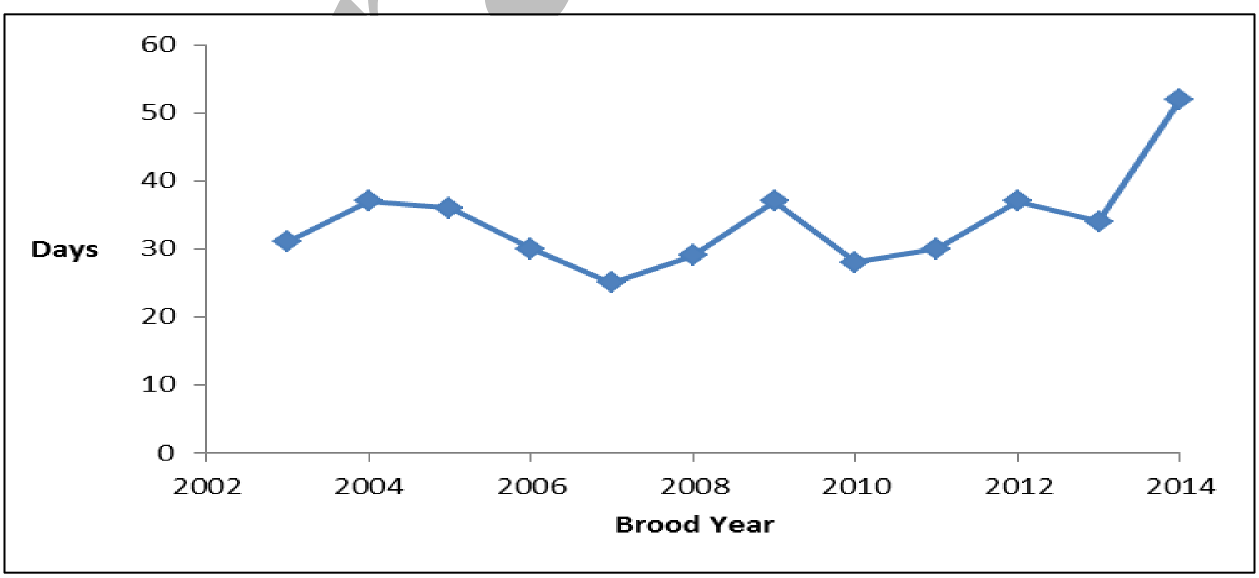

Figure 3.1.1.c. Number of days exceeding the 13˚C seven-day average daily maximum (7DADM) EPA criterion for spawning, incubation, and emergence at the Klamath River above the Scott River (David and Goodman 2017).

High water temperatures during the spawning period were frequently observed on the Trinity River based on observations at the USGS gauge near Hoopa, California (Figure 3.1.1.d). During the month of October, water temperatures were mostly above the EPA 13˚C criterion for spawning, incubation, and emergence, and were occasionally near the 16.7˚C level associated with 100% egg mortality. In 2013, water temperatures were generally below the 13˚C criterion for most of the spawning period, except during the first half of October when temperature measured above the 13˚C criterion. Water temperatures in 2011, 2012, and 2014 were well above the 13˚C criterion for most of October.

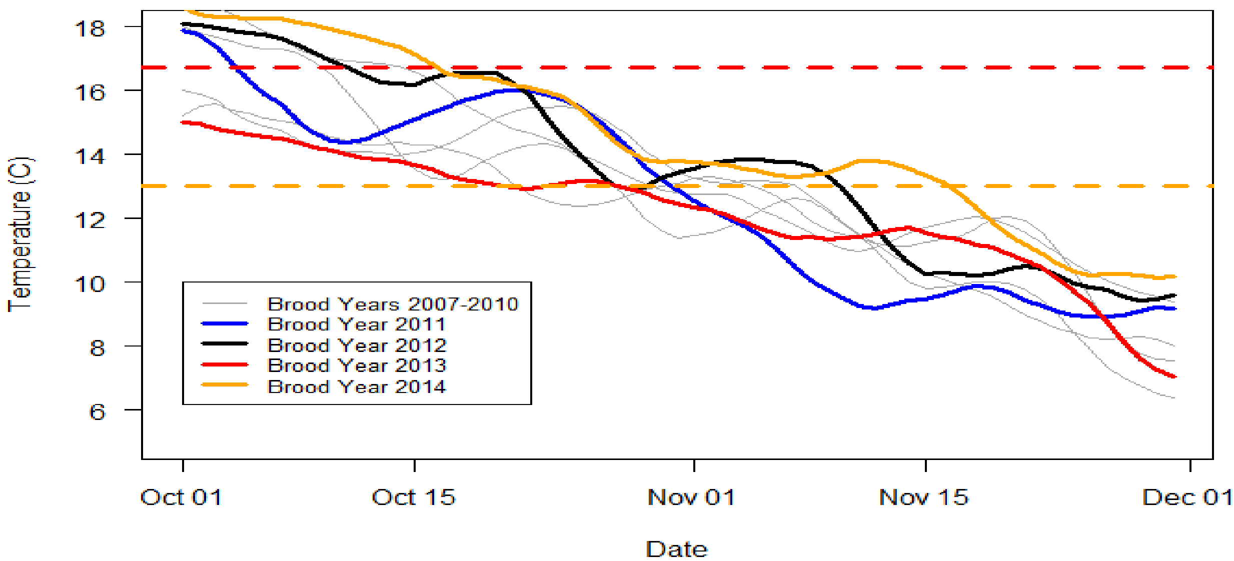

Figure 3.1.1.d. Seven-day average water temperatures in the Trinity River near Hoopa, California (rkm 20) during the spawning period for fall Chinook salmon across brood years 2007-2014. The dashed orange line represents the EPA 13˚C criterion for spawning, incubation, and emergence and the dashed red line represents the temperatures associated with 100% egg mortality (16.7˚C).

<u>Flows and temperatures during rearing and outmigration</u>

Flows in the Klamath Basin during the emergence, rearing, and outmigration period were low for brood years 2012-2014 compared to flows experienced by juveniles from brood years 2000-2011 (Figure 3.1.1.e). The emergence, rearing, and outmigration flow levels experienced by brood years 2012-2014 were some of the lowest observed during this time period.

The EPA has identified criteria for Pacific Northwest water temperatures to protect Pacific salmon (USEPA 2003). These include a 15˚C temperature criterion for juvenile rearing. Water temperatures in the Klamath River, measured at the USGS gauge at Klamath, California indicated that the EPA 15˚C rearing criterion was exceeded beginning in late April or May for brood years 2012-2014 and in June for brood year 2011 (Figure 3.1.1.f). Brood years 2012-2014 experienced comparatively warmer temperatures throughout the January 1 – June 30 period.

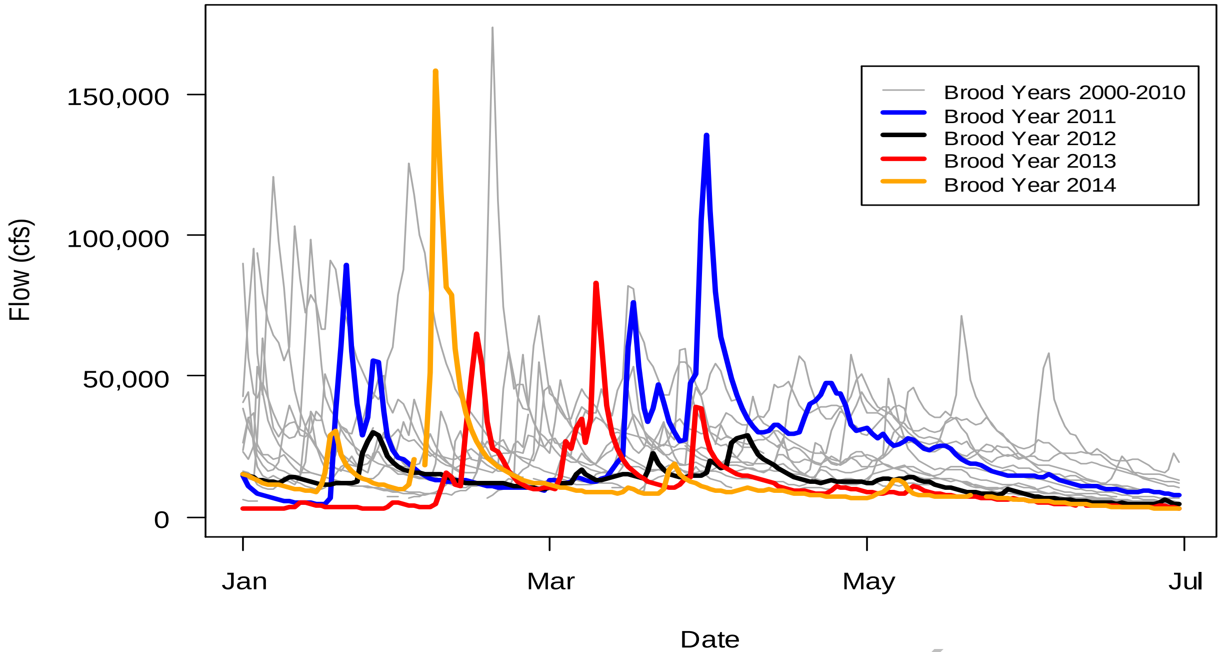

Figure 3.1.1.e. Flows during the emergence, rearing, and juvenile outmigration period on the Klamath River measured at Klamath, California (USGS gauge 11530500) for brood years 2000-2014.

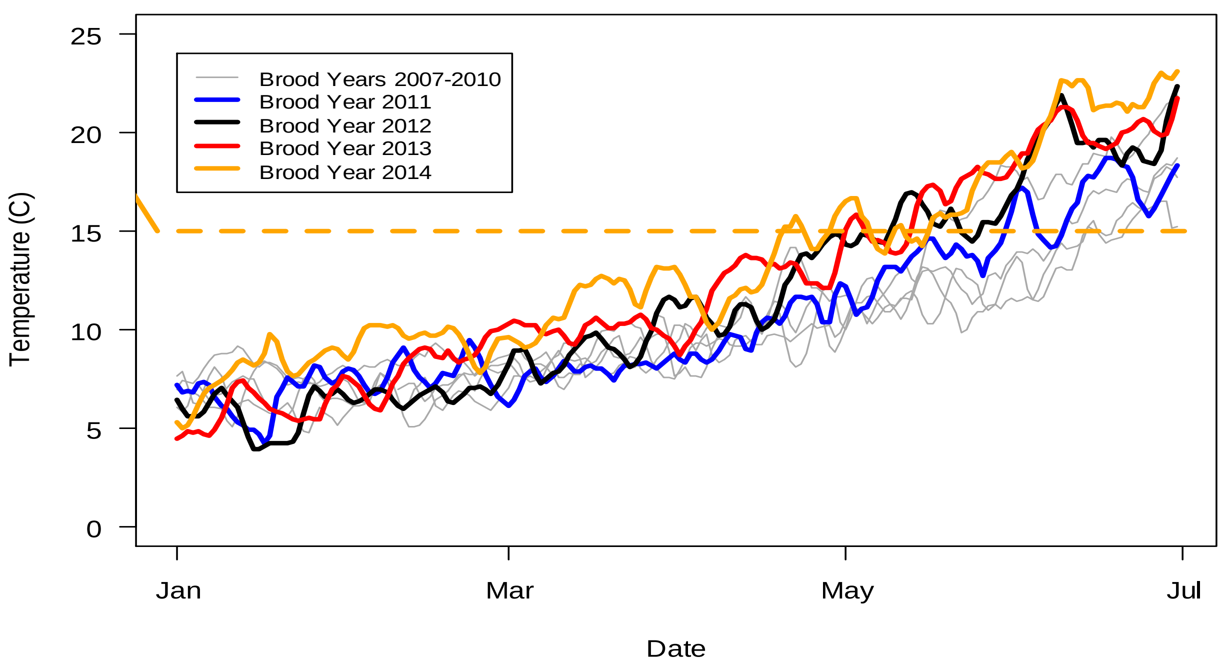

Figure 3.1.1.f. Klamath River water temperatures measured at the USGS gauge at Klamath, California (USGS gauge 11530500) during January 1 through June 30 experienced by juveniles from brood years 2007-2014. The EPA 15˚C rearing criterion is represented by the dashed line.

3.1.2 Parental stock size and distribution

Parental abundance of natural-area spawners for the critical broods[1] of 2011-2014 was generally near or above average compared to the previous 33-year averages (Figure 3.1.2.a). The Scott and Shasta Rivers, and Bogus Creek, did experience below average escapement in 2011, however, adult escapement the following year was above average, particularly in the Shasta River. Adult escapement to natural areas in the Klamath Basin in 2011 was the lowest (46,763) for the critical broods, however the number of adult natural-area spawners that year still exceeded the S_{MSY} escapement objective of 40,700. The subsequent broods (2012-2014) all surpassed the S_{MSY}. Two of the broods, 2012 and 2014, were two (2014) to three (2012) times the KRFC S_{MSY} value. Parental escapement for the critical broods did not limit recruitment due to low numbers, though the large escapements for the 2012 and 2014 broods may have potentially reduced future recruitment due to density dependent factors. See Figure 3.1.2.a and Table 3.1.2.a for details.

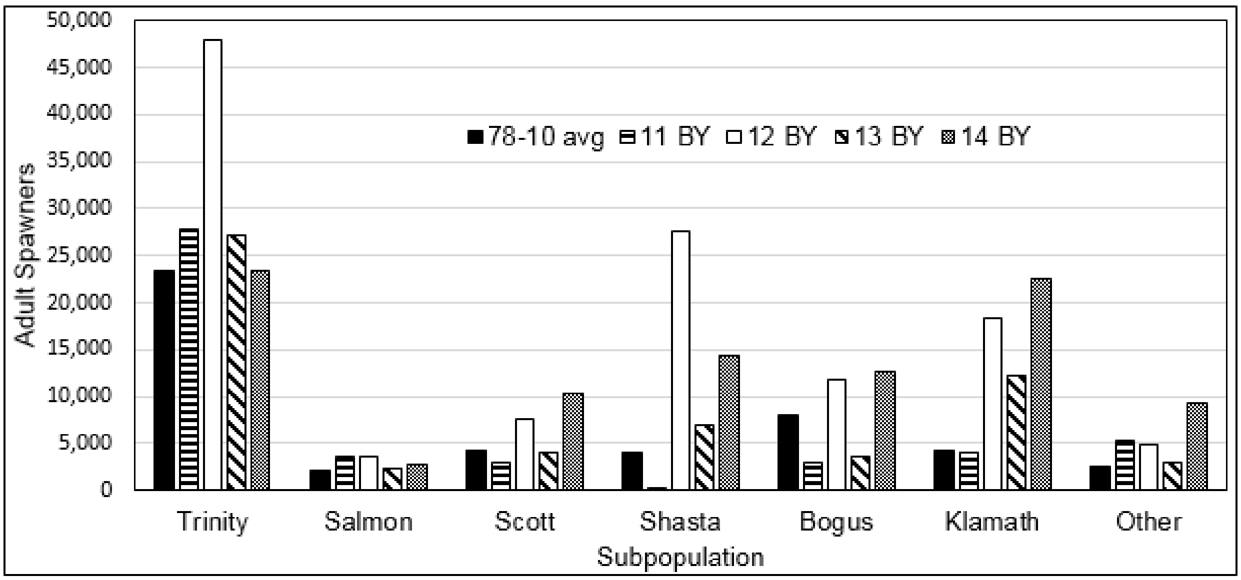

Figure 3.1.2.a. Adult spawning escapement to natural areas for 2011-2014 brood years (BY) compared to 1978-2010 averages.

[1] We define "critical broods" as the brood years that primarily contributed to escapement in 2015-2017.

Table 3.1.2.a. Klamath River Fall Chinook natural-area and hatchery adult spawner escapement.

Year	Upper Trinity[a/]	Salmon River	Scott River	Shasta River	Bogus Creek	Mainstem Klamath[b/]	Other Tributaries[c/]	Total Natural	Hatchery: Iron Gate	Hatchery: Trinity	Total Hatchery	Grand Total
1978	31,052	2,600	3,423	12,024	4,928	1,700	2,765	58,492	6,945	6,034	12,979	71,471
1979	8,028	1,000	3,396	7,111	5,444	4,190	1,468	30,637	2,301	1,335	3,636	34,273
1980	7,700	800	2,032	3,762	3,321	2,468	1,400	21,483	2,412	4,099	6,511	27,994
1981	15,340	750	3,147	7,890	2,730	3,000	1,000	33,857	2,055	2,370	4,425	38,282
1982	9,274	1,000	5,826	6,533	4,818	3,000	1,500	31,951	8,353	2,058	10,411	42,362
1983	17,284	1,200	3,398	3,119	2,713	1,800	1,270	30,784	8,371	5,494	13,865	44,649
1984	5,654	1,226	1,443	2,362	3,039	1,350	990	16,064	5,330	2,166	7,496	23,560
1985	9,217	2,259	3,051	2,897	3,491	468	4,294	25,677	19,951	2,583	22,534	48,211
1986	92,548	2,716	3,176	3,274	6,124	603	4,919	113,360	17,096	15,795	32,891	146,251
1987	71,920	3,832	7,769	4,299	9,748	863	3,286	101,717	15,189	13,934	29,123	130,840
1988	44,616	3,273	4,727	2,586	16,215	2,982	4,987	79,386	16,106	17,352	33,458	112,844
1989	29,445	2,915	3,000	1,440	2,218	1,011	3,839	43,868	10,859	11,132	21,991	65,859
1990	7,682	4,071	1,379	415	732	505	812	15,596	6,719	1,348	8,067	23,663
1991	4,867	1,337	2,019	716	1,261	572	877	11,649	4,002	2,482	6,484	18,133
1992	7,139	778	1,873	520	598	366	754	12,028	3,581	3,779	7,360	19,388
1993	5,905	3,077	5,035	1,341	3,285	647	2,568	21,858	20,828	815	21,643	43,501
1994	10,906	3,216	2,358	3,363	7,817	3,249	1,424	32,333	13,808	3,264	17,072	49,405
1995	77,876	4,140	11,198	12,816	45,225	6,472	4,067	161,794	22,681	15,178	37,859	199,653
1996	42,646	5,189	11,952	1,404	10,420	2,790	6,925	81,326	13,622	6,411	20,033	101,359
1997	11,507	5,783	8,284	1,667	9,809	3,472	5,622	46,144	13,275	5,387	18,662	64,806
1998	24,460	1,337	3,061	2,466	6,630	2,913	1,621	42,488	14,923	14,296	29,219	71,707
1999	6,753	670	3,021	1,296	3,537	1,978	1,202	18,457	9,290	5,037	14,327	32,784
2000	23,468	1,544	5,729	11,025	34,678	3,271	3,013	82,728	71,635	25,976	97,611	180,339
2001	35,991	2,607	5,398	8,452	11,927	9,832	3,627	77,834	37,204	17,908	55,112	132,946
2002	10,880	2,669	4,261	6,432	17,530	21,650	2,213	65,635	23,667	3,516	27,183	92,818
2003	31,173	3,302	11,988	4,134	15,422	17,722	3,901	87,642	31,970	29,812	61,782	149,424
2004	12,718	282	445	833	3,493	5,037	1,023	23,831	10,582	12,399	22,981	46,812
2005	12,987	401	698	2,018	5,341	4,622	722	26,789	13,955	13,744	27,699	54,488
2006	15,375	1,278	3,007	789	3,368	4,538	1,808	30,163	11,604	7,918	19,522	49,685
2007	39,038	1,377	4,494	2,009	4,677	6,914	2,161	60,670	16,969	18,081	35,050	95,720
2008	11,006	1,749	3,445	2,741	3,001	5,830	3,078	30,850	9,101	4,451	13,552	44,402
2009	16,168	2,204	2,167	6,145	5,455	7,945	4,325	44,409	12,263	7,351	19,614	64,023
2010	21,579	2,478	2,114	1,261	3,180	3,684	2,929	37,225	10,278	7,774	18,052	55,277
2011[d/]	**27,718**	**3,674**	**3,019**	**213**	**2,919**	**3,933**	**5,287**	**46,763**	**8,490**	**13,847**	**22,337**	**69,100**
2012[d/]	**47,921**	**3,561**	**7,569**	**27,600**	**11,792**	**18,249**	**4,851**	**121,543**	**38,478**	**17,461**	**55,939**	**177,482**
2013[d/]	**27,127**	**2,240**	**4,036**	**6,925**	**3,682**	**12,192**	**2,954**	**59,156**	**13,431**	**3,717**	**17,148**	**76,304**
2014[d/]	**23,312**	**2,706**	**10,419**	**14,412**	**12,607**	**22,443**	**9,205**	**95,104**	**24,300**	**6,975**	**31,275**	**126,379**
2015[e/]	**4,727**	**1,978**	**2,092**	**6,612**	**2,308**	**7,407**	**2,988**	**28,112**	**7,956**	**3,129**	**11,085**	**39,197**
2016[e/]	**3,444**	**1,032**	**1,376**	**2,754**	**830**	**2,902**	**1,599**	**13,937**	**2,436**	**1,142**	**3,578**	**17,515**
2017[e/f/]	**4,534**	**1,338**	**2,269**	**3,287**	**1,874**	**3,922**	**1,290**	**18,514**	**7,443**	**3,770**	**11,213**	**29,727**
78-14 avg.	24,278	2,304	4,415	4,819	7,924	5,250	2,937	51,927	15,449	9,008	24,457	76,384
11-14 avg.	**31,520**	**3,045**	**6,261**	**12,288**	**7,750**	**14,204**	**5,574**	**80,642**	**21,175**	**10,500**	**31,675**	**112,316**
15-17 avg.	**4,235**	**1,449**	**1,912**	**4,218**	**1,671**	**4,744**	**1,959**	**20,188**	**5,945**	**2,680**	**8,625**	**28,813**
78-17 avg.	22,775	2,240	4,227	4,774	7,455	5,212	2,864	49,546	14,736	8,533	23,269	72,816

[a/] Trinity River basin upstream of Willow Creek weir, excluding Trinity River Hatchery.
[b/] Mainstem Klamath River excluding all tributaries and Iron Gate Hatchery.
[c/] All tributaries to the Klamath River excluding Salmon, Scott, Shasta, and Bogus, and tributaries to the Trinity River downstream of Willow Creek weir.
[d/] Parent broods associated with returns comprising the overfishing assessment period.
[e/] Return years comprising the overfishing assessment period.
[f/] Estimates are provisional.

The U.S. Fish and Wildlife Service (USFWS) has conducted mark-recapture studies using salmon carcasses to quantify the total number of spawners in the Klamath River from IGD to the confluence with the Shasta River (Gough and Som 2017). The USFWS has also quantified the number of redds within standardized index reaches of the mainstem Klamath River (Gough et al. 2018). In addition to the spawning that occurs in the mainstem Klamath River, spawning escapement estimates have been generated for Bogus Creek and the Shasta River (CDFW 2018), as well as many other tributaries.

For later comparisons with juvenile production estimates, in section 3.1.7 *Stock and recruitment* we estimated the combined number of spawners in the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River from IGD downstream to the confluence with the Scott River. This combined estimate consisted of the California Department of Fish and Wildlife (CDFW) estimates of the number of spawners from the Bogus Creek Basin and the Shasta River Basin (CDFW 2018), the USFWS estimates of the number of spawners in the Klamath River from IGD to the confluence with the Shasta River (Gough and Som 2017), and the USFWS estimates of the number of redds in the Klamath River from the confluence with the Shasta River downstream to the Scott River. The number of redds in this reach was multiplied by two to estimate the number of spawners in this reach.

The combined number of spawners upstream of the confluence with the Scott River ranged from a low of 4,900 in 2016 to a high of 53,588 in 2012, with an average of 20,509 across brood years 2001 through 2016 (Figure 3.1.2.b). The estimated number of spawners in brood years 2012 and 2014 were well above average, the number of spawners in 2013 was average, and the number of spawners in 2011 was below average.

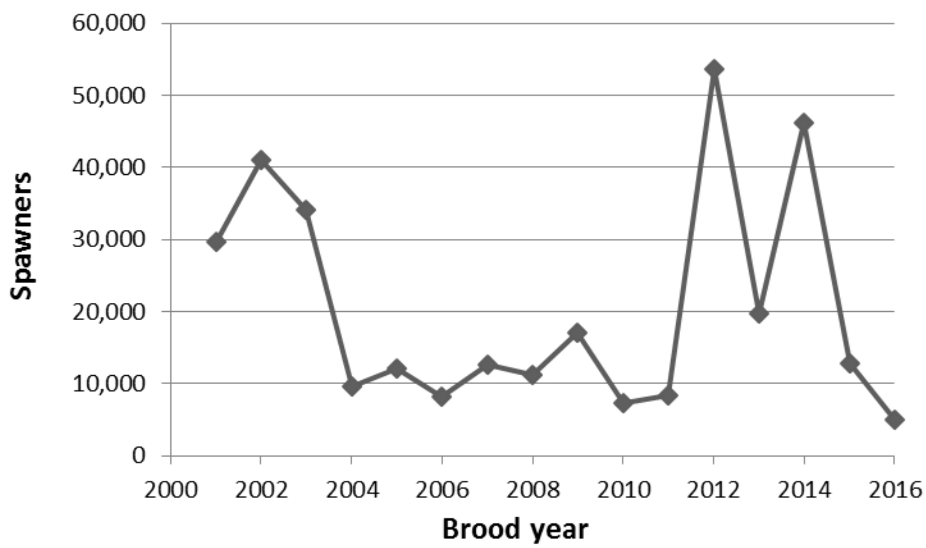

Figure 3.1.2.b. Estimated total number of spawners in the Shasta River Basin, the Bogus Creek Basin, and the mainstem Klamath River upstream of the confluence with the Scott River 2001-2016.

Gough and Som (2017) provide estimates of the percentage of females that were pre-spawn mortalities and females that were partially spawned in the mainstem Klamath River between IGD and the confluence with the Shasta River over brood years 2001 through 2016 (Figure 3.1.2.c). Across those brood years, the average levels of pre-spawn mortality and partial spawning has been 8.3 percent and 4.4 percent, respectively. Estimates for brood years 2011-2014 were qualitatively similar to estimates from the previous years.

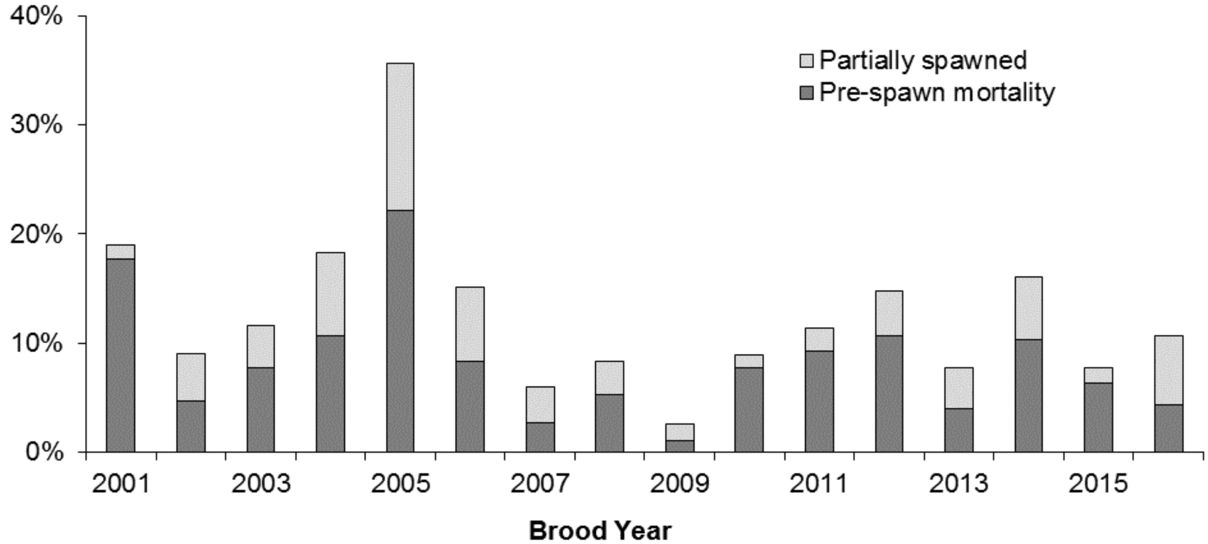

Figure 3.1.2.c. Estimates of the percentage of females that were partially spawned or were pre-spawn mortalities in the mainstem Klamath River between Iron Gate Dam and the confluence with the Shasta River.

Redd dewatering can occur when there is a reduction in flow following redd construction. Data collected on the Trinity River during 2013-2016 found evidence of redd dewatering following the termination of flow augmentation releases, but the number of dewatered redds was estimated to be less than 1% of the total number of redds in the mainstem Trinity River (Stephen Gough, USFWS, personal communication). Based on these data, redd dewatering does not appear to have been a substantial factor influencing the 2013 and 2014 brood years.

Hatchery escapement trends of adult KRFC were similar to natural areas. IGH and TRH received an average of 31,675 adult KRFC during the critical brood years, which is above the 1978 through 2014 average of 24,457. The average return for 2015-2017 was 8,625 returning adult spawners, approximately 27 percent of the 2011-2014 average. See Table 3.1.2.a for details.

3.1.3 Juvenile production estimates

CDFW has used rotary screw traps annually since 2000 on the Scott River and 2001 on the Shasta River (brood years 1999 and 2000, respectively) to estimate the number of out-migrating juvenile KRFC (emigrants). CDFW also monitors KRFC in the Scott and Shasta Rivers to enumerate adult returns using video weir and mark recapture methods. The Scott River averaged 112 emigrants produced per adult and the Shasta River averaged 405 emigrants produced per adult over the entire time series (Tables 3.1.3.a, 3.1.3.b). Both rivers show a positive correlation between number of adults and number of emigrants produced (correlation coefficients estimated to be 0.52 and 0.80 for the Scott and Shasta Rivers, respectively). For the critical broods of 2011-2014, the mean number of emigrants per adult spawner on the Scott River was 61 percent of the mean across broods 1999-2015 (Table 3.1.3.a). Each of the critical broods had emigrants per spawner values lower than the mean value computed across all broods. For the Shasta River, the mean number of emigrants per spawner for the critical broods exceeded the mean value computed across all broods, but individual years varied widely (Table 3.1.3.b). Brood years 2011 and 2013 had among the highest estimates of emigrants per spawner for the entire time series while the 2012 and 2014 broods were lower than the long-term average.

The number of total emigrants from the Scott River, averaged over the critical broods, was very similar to the average over all broods (Table 3.1.3.a). For the Shasta River, the average number of emigrants for the critical broods exceeded the average over all broods by a factor of 1.7. The two largest estimates of emigrating juveniles across all years with data were from broods 2012 and 2013 (Table 3.1.3.b).

Table 3.1.3.a. Scott River adult spawner and emigrant Chinook salmon estimates. Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
1999	160,906	52,719	269,093	3,021	53
2000	457,800	398,422	517,177	5,729	80
2001	239,483	140,620	338,346	5,398	44
2002	125,909	78,709	173,109	4,261	30
2003	1,029,696	870,359	1,189,033	11,988	86
2004	178,885	154,929	202,840	445	402
2005[b/]	10,890	6,982	14,797	698	16
2006	435,279	401,400	469,158	3,007	145
2007	552,472	500,947	603,997	4,494	123
2008	930,731	876,028	985,433	3,445	270
2009	655,467	571,177	739,757	2,167	302
2010	126,104	111,480	140,727	2,114	60
2011	**173,602**	**149,325**	**197,879**	**3,019**	**58**
2012	**656,031**	**606,468**	**705,594**	**7,569**	**87**
2013	**423,085**	**364,462**	**481,709**	**4,036**	**105**
2014	**243,431**	**210,816**	**276,047**	**10,419**	**23**
2015	56,634	16,799	63,880	2,092	27
1999-2015 avg.	379,789	324,214	433,446	4,347	112
2011-2014 avg.	374,037	332,768	415,307	6,261	68

a/ Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.
b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

Table 3.1.3.b. Shasta River adult spawner and emigrant Chinook salmon estimates. Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
2000	4,203,764			11,025	381
2001	3,509,388			8,452	415
2002	1,020,905			6,432	159
2003	2,486,076	2,194,650	2,777,503	4,134	601
2004	297,208	282,945	311,472	833	357
2005[b/]	83,387	76,439	90,335	2,018	41
2006	579,735	556,443	603,026	789	735
2007	938,503	872,905	1,004,102	2,009	467
2008	718,949	687,412	750,486	2,741	262
2009	2,347,783	2,265,226	2,430,341	6,145	382
2010	654,625	631,256	677,994	1,261	519
2011	166,500	159,571	173,429	213	782
2012	**5,218,270**	**4,916,768**	**5,519,771**	**27,600**	**189**
2013	**4,744,838**	**4,591,469**	**4,898,206**	**6,925**	**685**
2014	**2,901,966**	**2,772,054**	**3,031,878**	**14,412**	**201**
2015	**2,757,850**	**2,661,219**	**2,854,481**	**6,612**	**417**
2016	776,697	725,794	827,601	2,754	282
2000-2016 avg.	1,965,085	1,671,011	1,853,616	6,139	405
2011-2014 avg.	3,257,894	3,109,966	3,405,821	12,288	464

a/ Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.

b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

The USFWS, in collaboration with the Karuk Tribe and the U.S. Geological Survey (USGS), has used rotary screw traps and frame nets to estimate juvenile production of age-0 KRFC at three index sites in the Klamath River (Gough and Som 2017). The downstream-most Kinsman site (rkm 237.55) samples juveniles from the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River upstream of the confluence with the Scott River. The Kinsman site is also located downstream of a known infectious zone for *Ceratonova shasta* (see section 3.1.5, *Disease*). Because this site effectively samples all production upstream of the confluence with the Scott River, and it is located downstream of the *C. shasta* infectious zone, it provides a useful indicator of juvenile production in the Klamath River basin.

Across brood years 2001-2014, the number of age-0 KRFC at the Kinsman site has averaged 2.4 million fish, ranging from a low of 0.3 million fish produced from brood year 2011 to a high of 7.7 million fish produced from brood year 2012 (Figure 3.1.3.a). The estimates of juvenile production were the lowest for brood year 2011, but were above-average for brood years 2012-2014.

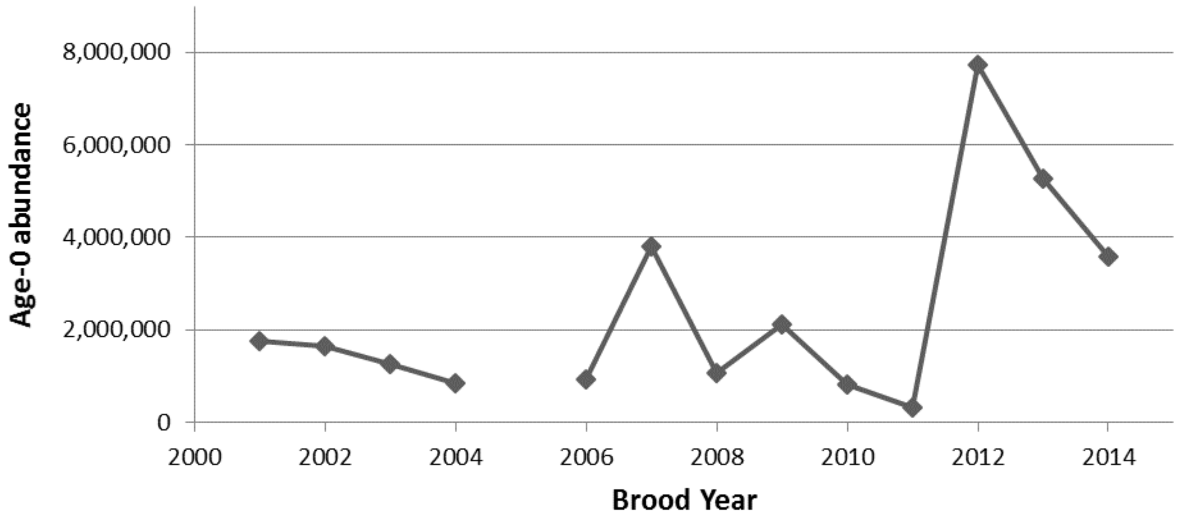

Figure 3.1.3.a. Estimates of age-0 KRFC abundance at the Kinsman site on the Klamath River from brood years 2001-2014 (Gough and Som 2017). Estimates for brood year 2005 could not be generated due to high flow conditions in 2006.

The Yurok Tribe, in collaboration with the USFWS, has used rotary screw traps and mark-recapture efforts to estimate population size of Chinook salmon emigrants (fall and spring) on the Trinity River near Willow Creek, CA since 2002. The USFWS operated this trapping location from 1989-2001, using slightly different methods to estimate population (data not presented) (Petros et al. 2016). The screw traps encounter both hatchery and naturally produced emigrants. However, the data presented are only the estimates of naturally produced emigrants. CDFW monitors adult returns of fall and spring Chinook using weirs and mark recapture methods near Willow Creek (for fall run) and Junction City (for spring run). The Trinity River averaged 90 emigrants per adult from 2002-2016 (Table 3.1.3.c) with a weak positive correlation between the number of adults and the number of emigrants produced. For the critical broods of 2011-2014, the mean number of emigrants per adult spawner on the Trinity River was 92 percent of the mean across broods 2001-2016. Brood years 2011 and 2012 had the two highest estimated number of emigrants across the time series, 2013 was near the average, and 2014 was below average.

Table 3.1.3.c. Trinity River adult spawner (fall and spring run) and emigrant (fall and spring run) Chinook salmon estimates from Willow Creek. Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
2001	1,225,557	698,882	2,079,775	46,275	26
2002	572,740	201,691	1,282,301	34,625	17
2003	739,138	315,402	1,573,826	64,474	11
2004	2,681,621	1,403,019	5,648,278	18,417	146
2005[b]	223,767	118,293	430,031	20,071	11
2006	1,864,654	1,361,552	2,566,689	18,330	102
2007	2,112,760	1,637,110	2,765,686	47,192	45
2008	2,950,452	2,191,155	3,954,788	15,476	191
2009	3,578,162	2,229,153	5,538,099	19,892	180
2010	2,802,970	1,924,965	4,413,722	28,196	99
2011	**5,345,168**	**2,220,686**	**14,548,896**	**35,027**	**153**
2012	**4,728,170**	**3,411,455**	**7,852,721**	**64,038**	**74**
2013	**2,409,657**	**1,784,133**	**3,293,980**	**33,083**	**73**
2014	**880,976**	**592,851**	**1,414,138**	**26,145**	**34**
2015	791,407	612,261	1,027,141	6,782	117
2016	741,581	640,038	856,552	4,775	155
2001-2016 avg.	2,103,049	1,333,915	3,702,914	30,175	90
2011-2014 avg.	3,340,993	2,002,281	6,777,434	39,573	83

[a/] Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.

[b/] Redd Scour in December 2005 appeared to reduce emigrant production in 2006.

3.1.4 Disease

Low river flows caused in part by drought, and in part by water management practices upriver, above average temperatures, and decades of low winter flows and sediment flow interruption from water management and the presence of the dams, have all combined to send fish disease rates to very high levels.

Infection of juvenile salmonids from the parasite *Ceratonova shasta* (*C. shasta)* in the Klamath River has been substantial in many recent years, but especially in 2014 and 2015. *C. shasta* is a myxozoan parasite with a complex life cycle, and it infects both salmonids and the freshwater polychaete worm *Manayunkia speciosa* (*M. speciosa*). Infected *M. speciosa* produce actinospores which infect salmonids. Infected salmonids produce myxospores which in turn infect *M. speciosa*. Clinical signs of the disease that are exhibited by infected salmonids include necrosis of intestinal tissue that can be accompanied by a severe inflammatory reaction (enteronecrosis) and subsequent death (Bartholomew et al. 1989). In the wild, heavily infected fish show lethargy and appear bloated.

Concerns regarding high disease levels in the Klamath River during the early 2000's led to a collaborative research and monitoring effort that was initiated in 2005 by the USFWS, Oregon State University, the Yurok and Karuk Tribes, and others. These research and monitoring efforts have resulted in a robust knowledge of the basic lifecycle of *C. shasta*, the factors that exacerbate its infection of salmonids, the genetic factors of different strains of the parasite, as well as information on spore infectivity, mortality rates of fish related to spore concentrations, effects of temperature, and so forth.

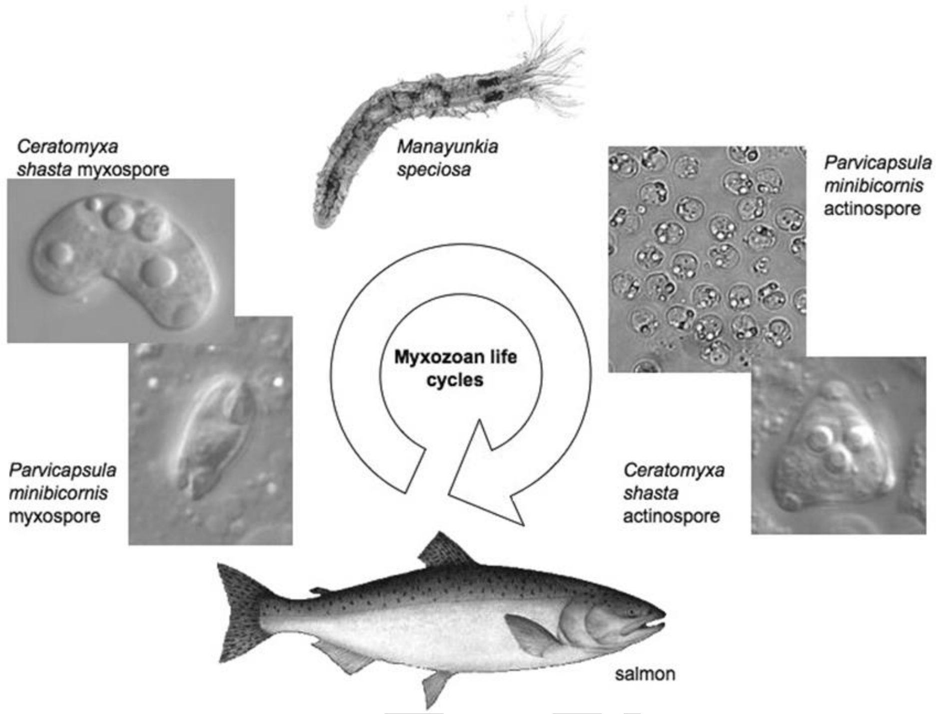

Figure 3.1.4.a. The life cycle of *Ceratanova shasta* (formerly *Ceratomyxa shasta*) and *Parvicapsula minibicornis*. *Manayunkia speciosa* is a small freshwater polychaete worm (3-5 mm in length) and intermediate host of both parasites. (Graphic provided with permission from J. Bartholomew and Steve Atkinson, Oregon State University).

Observed prevalence of infection (POI) of juvenile KRFC sampled between the Shasta River confluence and the Trinity River confluence in May through July of 2014 and 2015 were 81 percent and 91 percent respectively (True et al. 2016). This considerably exceeds the take limit of 49 percent infection in Chinook salmon as a surrogate for infection in coho salmon in the Biological Opinion (BiOp) for Southern Oregon Northern California Coast coho Salmon (SONCC) for the federally operated Klamath Irrigation Project (NMFS and USFWS 2013).

Violation of the take threshold identified in the BiOp led to litigation (*Hoopa Valley Tribe, Yurok Tribe, PCFFA v. US Bureau of Reclamation*, 2017) resulting in efforts to address the disease issue. First, the Arcata USFWS office summarized the known information on the parasite and the factors causing it to cause mortality in juvenile salmon in the Klamath River and summarized this information in four technical memoranda [Shea et al. 2016 (aka Geomorphology Memo), Som and Hetrick, 2016 (aka Spore Memo), Som et al. 2016a (aka Fish Infection Memo), and Som et al. 2016b (aka Polychaete Memo)]. This information was used in a Guidance Document (Hillemeier et al. 2017) that made six management recommendations. Several of the recommendations were implemented in 2017 and 2018, including higher winter flow releases to cause river bed movement below Iron Gate Dam and an emergency flow release in response to rising prevalence of *C. shasta* infection in 2018.

Estimated *C. shasta* infection rates in natural KRFC populations at the Kinsman trap location (rkm 237.5) were lower than observed sample POI in 2014 and 2015, although still substantial (Table 3.1.4.a, 3.1.4.b). Infection rates of sampled fish are typically higher than estimated natural Chinook salmon population infection rates because: 1) weekly sample sizes aren't weighted by abundance, but remain constant even as the natural juvenile emigration wanes and infection rates increase, and 2) weekly samples include hatchery fish that are typically released after natural fish emigrate past the Kinsman Trap location, at a time when disease infection rates are elevated. Furthermore, the Kinsman Trap, where the natural population abundance is estimated, is located 237.5 kilometers upriver from the Pacific Ocean. It is likely that POI rises as fish move downriver, because the exposure of these fish to the pathogen continues during their emigration to the ocean, at a time when water temperatures are typically increasing (see Figure 3.1.1.f). Increased water temperature is known to exacerbate POI by *C. shasta* (Som et al. 2016a, Figure 3).

Table 3.1.4.a. Historic annual prevalence of *Ceratanova shasta* infection (% positive by assay) in all juvenile Chinook salmon collected from the main stem Klamath River between Iron Gate Dam and Trinity River confluence during May through July, 2006-2017 (True et al., 2017).

Year	Histology (% Positive)	QPCR (% Positive)
2006	21	34
2007	21	31
2008	37	49
2009	54	45
2010	15	17
2011	2[1]	17
2012	9[1]	30
2013	16[1]	46
2014	42[1]	81
2015	62[1]	91
2016	14[1]	48
2017	8[1]	26
Mean	**25**	**43**

[1]Histology limited to two reaches in 2011 (K4 and K1); and two reaches in

Table 3.1.4.b. Estimate of proportion of population of natural fish infected with *Ceratonova shasta* at Kinsman Trap (rkm 235) for 2005-2015. Pop. LCL is lower confidence limit, Pop. Est is estimated proportion of natural fish infected with *C. shasta*, Pop. UCL is upper confidence limit. POI is percent of sampled fish infected with *C. shasta*. QPCR was used to detect *C. shasta* (Som et al. 2016a).

Year	Origin	POI	Pop. LCL	Pop. Est	Pop. UCL
2005	All	0.41	0.26	0.38	0.47
2007	All	0.28	0.07	0.1	0.15
2008	All	0.6	0.43	0.51	0.58
2009	All	0.5	0.5	0.58	0.66
2010	Wild/ Unknown	0.12/ 0.15	0.02	0.04	0.07
2011	Wild	0.2	0.07	0.11	0.17
2012	Wild/ Unknown	0.06/ 0.00	0.04	0.08	0.14
2013	Wild	0.18	0.03	0.06	0.09
2014	Wild	0.67	0.12	0.18	0.26
2015	Wild/ Unknown	0.66/ 0.96	0.2	0.29	0.39

Disease rates from *C. shasta* infection are largely a function of flow regimes, water temperature, adult salmonid carcass densities, sediment regimes, and are potentially exacerbated by hatchery production goals and fish release strategies. The operation of the U.S. Bureau of Reclamation (USBR) Klamath Irrigation Project affects the total volume of flow in the Klamath River, the hydrograph, and generally alters the geomorphological features of the Klamath River (NMFS and USFWS 2013, Shea et al. 2016). A consequence of the impaired natural flow is the elevated rate of *C. shasta* infection in SONCC (NMFS and USFWS 2013, p. 341) and KRFC populations.

As stated in a USFWS technical memorandum (Shea et. al 2016) regarding the geomorphic aspects of the *C. shasta* disease and it's obligate parasite in the Klamath River:

> *Development of flow releases from Iron Gate Dam that are intended to adversely impact the* C. shasta *life cycle by targeting the disruption of the obligate invertebrate host as suggested by Alexander et al. (2016) should identify specific physical objectives. The specification should identify the desired form of bed modifications (e.g., sand mobilization or gravel mobilization) and the extent of the mobilization (e.g., from riffles, from channel margins, from pools, etc.). The frequency and seasonal timing of environmental flows should also be specified. Seasonal timing should be based on biological objectives and constraints. Seasonal timing might also be based on physical objectives such as sequencing flows to occur simultaneously or following unregulated tributary peak flows.*

Since the year 2000, peak flows during the winter period have decreased significantly (Figure 3.1.4.b). At the same time, the presence of the dams has interrupted the transport of sediment in the area below IGD. This stable flow and lack of sediment supply substantially increased the concentration of the polychaete worm that is an obligate alternate host for *C. shasta*, thereby increasing the infection and subsequent mortality of juvenile salmonids from *C. shasta*.

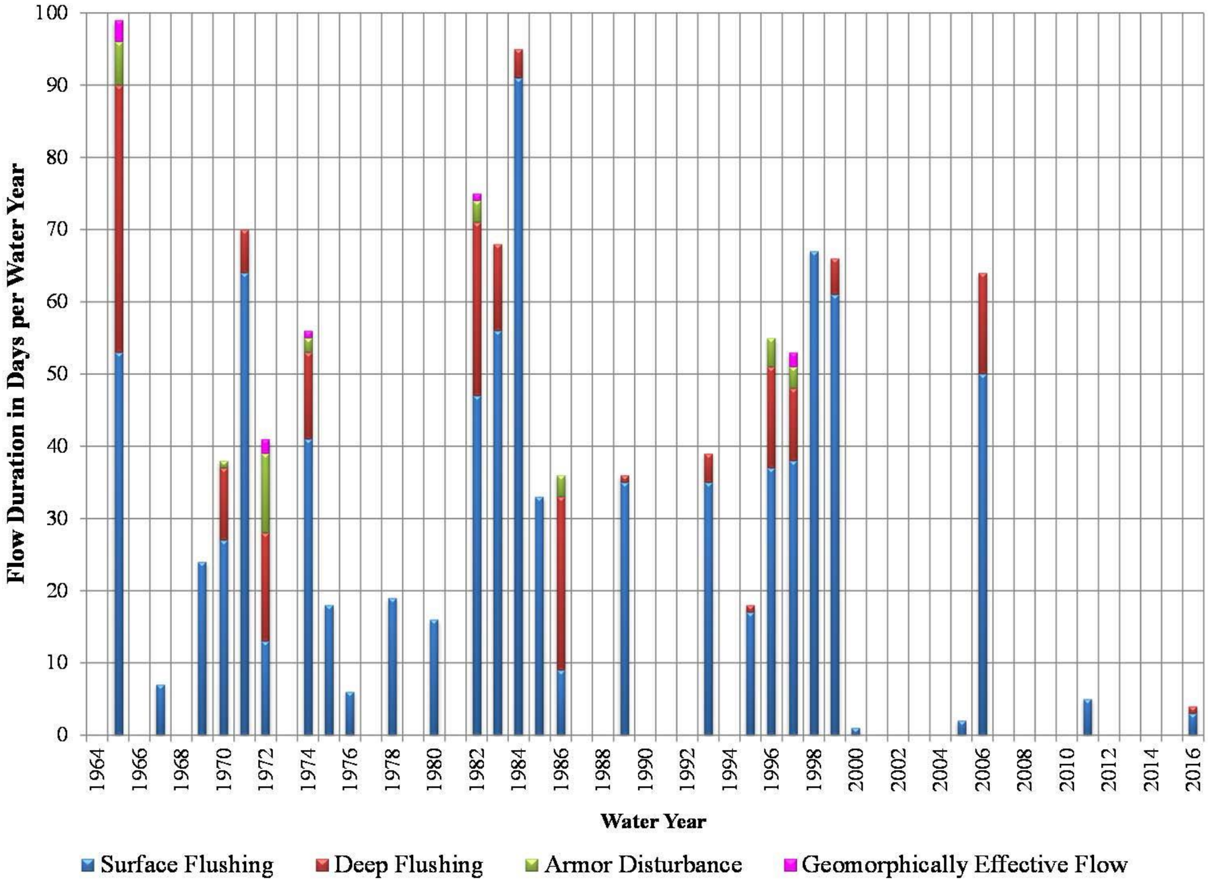

Figure 3.1.4.b: Duration of sediment mobilization flows in days per water year in the Klamath River below Iron Gate Dam water for water years 1964-2016 (taken from Shea et. al 2016).

Water flows were lower than average during 2013 – 2015 (Figures 3.1.1.a, 3.1.1.b, 3.1.1.e). In the years 2013 and 2014, the Klamath River experienced severe droughts. In 2015 precipitation was about average during the winter, but low snow pack and depleted groundwater from the previous drought, contributed to low spring/summer inflow to Upper Klamath Lake and associated Klamath River flows (Figure 3.1.1.e). Water temperatures were above average (Figure 3.1.1.f) during the spring of both years, and high temperatures are thought to be a contributing factor to high POI rates observed in Klamath River fish (Som et al. 2016a, Figure 3).

A critical stage of the life history of *C. shasta* includes high densities of myxospores being released from a small portion of decomposing salmon carcasses and subsequently floating downstream to be ingested by, and infect, polychaete worms (*M. speciosa*). Such infection of polychaete worms can be exacerbated by the relatively large number of adult salmon carcasses that are often concentrated downstream of IGD (upper limit of anadromy due to no fish passage). It is hypothesized that stable and low flows in the late fall/early winter, such as those experienced since 2000, minimize the distribution of these carcasses and the myxospores they release, thereby exacerbating the infection of polychaete worms by *C. shasta*.

IGH has a production goal to release 6,000,000 juvenile KRFC salmon annually. This production goal includes the release of 5.1 million fingerlings at 90 fpp in early June and the release of 900,000 yearlings at 10 fpp between October 15 and November 20 (CA HSRG 2012). The release period for fingerlings from IGH is later than when the majority of natural-origin KRFC fingerlings have emigrated from the upper river, and generally aligns with the highest weekly POI estimates for each year (Som et al. 2016a, Figure 5; Hillemeier et al. 2017, Table 1). Summaries of the weekly POI samples over the hatchery outmigration period suggest that a high proportion of the IGH stock may become infected with *C. shasta* during some years.

IGH fingerlings that die from *C. shasta* may perpetuate the life cycle of *C. shasta* in the Klamath River. Just as adult carcasses infected with *C. shasta* release myxospores that infect polychaetes, juvenile carcasses also release myxospores that can infect polychaetes. These infected polychaetes may then release actinospores that infect adult KRFC while migrating up the Klamath River en-route to spawning grounds. The actinospores within the adult salmon may then develop into myxospores, thereby increasing the magnitude of myxospores released by rotting adult salmon carcasses on the spawning grounds. An unknown in regard to this cycle is the effect that warm Klamath River water temperatures have upon this cycle, as warm water can affect the viability of *C. shasta*.

3.1.5 Stock and recruitment

Stock-recruitment relationships are used to characterize the relationship between the number of parental spawners and their progeny. The number of progeny produced per spawner is typically highest at low spawner abundance and declines with increasing spawner abundance due to density dependent effects (e.g., redd superimposition at high spawner densities). In addition to quantifying density-dependent effects, stock-recruitment relationships are also useful for quantifying density-independent effects (e.g., water temperature during egg incubation). Density-independent effects can be indexed by examining the residuals[2] from a stock-recruitment relationship, with negative residuals representing lower than expected recruitment given the number of parental spawners, and positive residuals representing higher than expected recruitment given the number of parental spawners. For these reasons, stock-recruitment relationships provide a useful framework for characterizing the levels of density-dependence alongside density-independent effects in a population.

The estimated number of spawners upstream of the Scott River and the juvenile production estimates at the Kinsman site provide the necessary components for examining the stock-recruitment relationship for this portion of the Klamath River Basin (Figure 3.1.5.a). The Ricker stock-recruitment function that was fit to these data indicated that mean age-0 abundance increases with increased spawner abundance, there was a relatively low amount of density-dependence, and there was a large amount of density-independent variation.

[2] Residuals are the difference between the observed $\log_e$ (recruits / spawners) and the predicted $\log_e$ (recruits / spawners) from the stock-recruitment relationship.

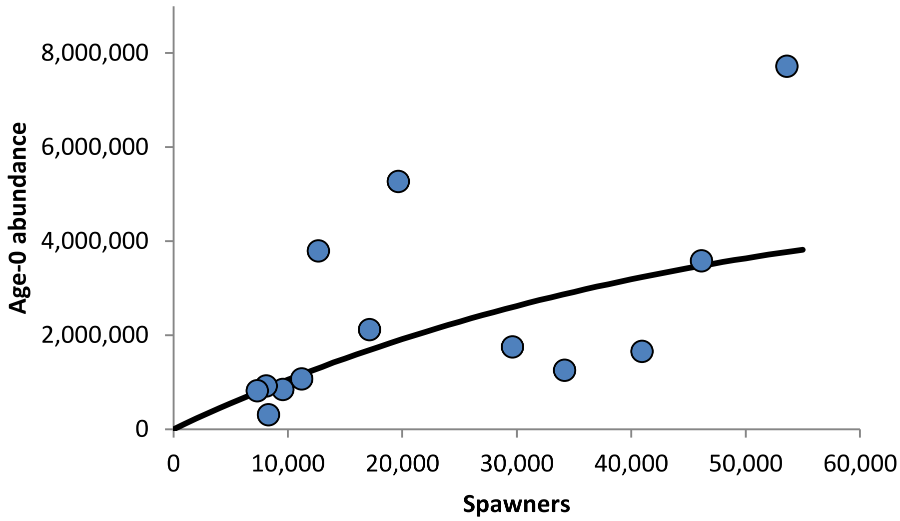

Figure 3.1.5.a. Estimates of the number of the total number of spawners in the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River upstream of the Scott River confluence and the age-0 abundance estimates at the Kinsman site for brood years 2001-2014. The black line represents the Ricker stock-recruitment function that was fit to the data.

As mentioned above, the residuals from the fitted stock-recruitment relationship characterize the density-independent factors influencing productivity, with negative residuals indicating lower-than-expected recruitment given spawner abundance and positive residuals indicating higher-than-expected recruitment given spawner abundance. Examining the residuals for the fitted stock-recruitment function for the Klamath River data indicated that brood years 2007, 2012, and 2013 had higher-than-expected recruitment given spawner abundance in those years (Figure 3.1.5.b). Brood years 2001-2004 and 2011 indicated lower-than-expected recruitment given spawner abundance in those years.

Figure 3.1.5.b. Residuals from the fitted stock-recruitment relationship by brood year for the Klamath River.

3.1.6 Hatchery production

KRFC are propagated at two hatcheries: Iron Gate Hatchery (IGH) at the base of IGD and Trinity River Hatchery (TRH) at the base of Lewiston Dam, the upper limits of anadromy for the Klamath and Trinity rivers, respectively. Both facilities were constructed to mitigate for habitat loss above the dams. Salmon from both hatcheries spawn in natural areas throughout the basin, especially in the vicinities of the hatcheries themselves, and thus contribute to the FMP-defined stock status which is solely based on natural area escapement. However, since neither of the facilities are operated as conservation hatcheries for their Chinook programs, but rather mitigation hatcheries, these fish are not intended to spawn in natural areas and interbreed with natural-origin KRFC. In recent years, both hatcheries have begun to incorporate recommendations from CA HSRG (2012) with respect to minimum levels of natural-origin inclusion in their broodstock. These new protocols are intended to transition Chinook production at these facilities to programs that are more integrated with their natural counterparts, lessening the genetic impacts to the natural population from interbreeding with hatchery-origin fish. However, these recommendations were not yet being implemented when the broods that contributed to the current overfished status were produced.

The two hatcheries have specific KRFC production goals, totaling 6 million fish at IGH and 2.9 million at TRH. The majority of these salmon (5.1 million at IGH and 2 million at TRH) are released directly into the river as smolts at or near their respective facilities when they reach an average length of about three inches and average weight of about 90 fish per pound (fpp). The target release time is during the first half of June, although release timing can be advanced if river water temperatures are projected to be less than optimal during the downstream migration period. The remaining 900,000 juveniles at each hatchery are retained until they reach an average weight of 10 fpp, and released as yearlings in October and November. In the past, an additional 180,000 yearlings were reared at Fall Creek Hatchery (FCH), an upstream facility built before construction of IGD, and released from IGH. This shifted the 6 million fish target at IGH to 4.92 million smolts and 1.08 million yearlings, however the additional rearing at FCH ceased after 2003 so the smolt target has reverted to 5.10 million. Table 3.1.6.a displays historical smolt and yearling release numbers for the 1981-2014 broods.

Table 3.1.6.a. Numbers of juvenile fish released from Iron Gate Hatchery (on the Klamath River) and Trinity River Hatchery for the 1981-2014 broods.

	Iron Gate Hatchery			Trinity River Hatchery			Hatchery
Brood Year	Smolts	Yearlings	IGH Total	Smolts	Yearlings	TRH Total	Releases
1981	852,092	165,820	1,017,912	939,300	1,093,613	2,032,913	3,050,825
1982	1,418,610	901,880	2,320,490	430,930	860,813	1,291,743	3,612,233
1983	2,993,372	1,323,738	4,317,110	2,575,335	967,781	3,543,116	7,860,226
1984	2,900,044	928,000	3,828,044	510,000	1,149,598	1,659,598	5,487,642
1985	12,204,669	1,952,688	14,157,357	1,556,569	1,017,849	2,574,418	16,731,775
1986	9,320,000	900,153	10,220,153	7,705,007	982,784	8,687,791	18,907,944
1987	6,260,000	1,898,000	8,158,000	2,350,205	93,223	2,443,428	10,601,428
1988	10,186,000	807,070	10,993,070	2,822,022	1,112,987	3,935,009	14,928,079
1989	5,100,000	0	5,100,000	2,749,774	524,688	3,274,462	8,374,462
1990	5,182,309	990,000	6,172,309	0	643,910	643,910	6,816,219
1991	6,757,600	1,755,694	8,513,294	581,539	933,796	1,515,335	10,028,629
1992	3,300,312	947,024	4,247,336	2,342,037	971,588	3,313,625	7,560,961
1993	4,962,344	824,589	5,786,933	202,275	213,101	415,376	6,202,309
1994	4,777,556	904,096	5,681,652	2,153,982	950,015	3,103,997	8,785,649
1995	5,618,804	404,172	6,022,976	2,037,759	909,622	2,947,381	8,970,357
1996	5,280,648	1,085,526	6,366,174	2,099,346	916,971	3,016,317	9,382,491
1997	5,097,161	0	5,097,161	2,397,657	907,354	3,305,011	8,402,172
1998	4,949,084	0	4,949,084	2,045,197	1,013,543	3,058,740	8,007,824
1999	5,007,431	1,045,306	6,052,737	1,967,853	859,486	2,827,339	8,880,076
2000	4,939,997	911,147	5,851,144	2,149,891	872,665	3,022,556	8,873,700
2001	4,967,089	1,087,081	6,054,170	2,065,049	925,162	2,990,211	9,044,381
2002	5,116,165	1,083,902	6,200,067	2,083,157	953,197	3,036,354	9,236,421
2003	5,182,092	685,819	5,867,911	2,149,880	906,234	3,056,114	8,924,025
2004	5,369,792	842,848	6,212,640	2,047,269	940,547	2,987,816	9,200,456
2005	6,171,838	874,917	7,046,755	2,070,713	950,932	3,021,645	10,068,400
2006	5,364,332	984,271	6,348,603	2,021,056	965,516	2,986,572	9,335,175
2007	5,290,005	1,104,870	6,394,875	1,804,492	995,750	2,800,242	9,195,117
2008	3,983,360	773,583	4,756,943	2,045,097	1,043,517	3,088,614	7,845,557
2009	4,528,056	855,000	5,383,056	2,041,026	928,142	2,969,168	8,352,224
2010	3,953,247	1,053,482	5,006,729	1,975,984	954,381	2,930,365	7,937,094
2011	**4,665,888**	**1,148,850**	**5,814,738**	**1,895,326**	**867,882**	**2,763,208**	**8,577,946**
2012	**4,136,672**	**979,668**	**5,116,340**	**1,757,825**	**982,968**	**2,740,793**	**7,857,133**
2013	**4,481,905**	**993,717**	**5,475,622**	**2,166,642**	**988,251**	**3,154,893**	**8,630,515**
2014	**3,794,691**	**943,489**	**4,738,180**	**1,404,634**	**987,101**	**2,391,735**	**7,129,915**
1981-2010 avg	5,234,467	903,023	6,137,490	1,997,347	885,292	2,882,639	9,020,128
2011-2014 avg	4,269,789	1,016,431	5,286,220	1,806,107	956,551	2,762,657	8,048,877

The production goals at IGH may change if removal of the four most downstream dams on the Klamath River, including IGD, occurs as planned beginning in 2021. The existing fish collection facility will be demolished in the process, and the water supply will be lost once reservoir drawdown commences. Solutions to these problems are currently being assessed.

Hatchery spawning techniques promote exceptionally high egg fertilization rates, and due to their confinement, the resulting fry are able to avoid most of the perils that naturally produced fish encounter during their juvenile freshwater residency. Diseases and parasites are treated promptly, steps are taken to minimize bird predation, and fish are fed special high protein diets that increase growth rates and result in smolts that are probably larger than their naturally produced counterparts. Yearlings however, while released at a larger size than smolts, are likely smaller at that date than the surviving natural-origin and smolt-released hatchery fish that have already resided in the ocean for several months. The policy to delay smolt releases until June when the fish are ready to migrate to sea is intended to minimize competition (interaction) with naturally produced KRFC rearing in-river. To the extent possible, river conditions are closely monitored at the hatcheries to ensure the fish are released when environmental conditions are suitable.

The maturation schedule for smolt releases is believed to be similar to that of naturally produced fish. While survival of yearling releases is higher than smolts, maturation is delayed because of their smaller size at age from extended hatchery rearing time (Hankin 1990), and the importance of size at age to the onset of sexual maturity in Pacific salmon (Hankin et al. 1993).

3.1.7 Other relevant factors

<u>Interactions between hatchery- and natural-origin adults on the spawning grounds</u>

Straying of hatchery-origin Chinook onto natural spawning grounds leads to interactions with natural-origin Chinook, potentially reducing spawning success and productivity of natural populations. In the Klamath Basin, these interactions are especially prevalent in the vicinities of the two hatcheries, most notably in Bogus Creek, a small Klamath tributary adjacent to IGH, and the Trinity River near TRH. This can lead to competition with natural-origin KRFC over spawning areas and redd superimposition (CDFG and NMFS 2001). In the Trinity River, a large percentage of the carcasses are typically recovered in the first several miles downstream of TRH, and it is believed that pre-spawn mortality is density-dependent in this portion of the basin (Hill 2014). Additional concerns for natural populations include disease transmission, and reduced fitness caused by genetic alterations from interbreeding with hatchery-origin Chinook (CDFG and NMFS 2001). In the Trinity River, there is also the potential for hatchery-origin fall-run Chinook to hybridize with spring-run Chinook, and vice versa. These concerns and potential long-term consequences of hatchery- and natural-origin Chinook interactions are discussed in more detail in CDFG and NMFS (2001).

Table 3.1.7.a displays the basin-wide natural area adult escapement since 1996, broken down into the estimated hatchery- and natural-origin components. Prior to 1996, IGH would sometimes close their fish ladder early if they received large numbers of spawners, forcing any remaining hatchery-bound KRFC to spawn in-river. Due to this practice, hatchery-origin contributions through 1995 are not directly comparable to the values reported here. If hatchery-origin Chinook compose a large percentage of the natural area escapement in consecutive years, it may be indicative of a downward trend in natural production, likely exacerbated by the processes outlined above. During 1996-2014, hatchery-origin KRFC constituted on average 24 percent of the total natural area adult escapement in the basin. However, during 2015-2017, hatchery-origin KRFC only composed an average of 9 percent of the natural area adult escapement. Thus, hatchery-origin Chinook did not appear to have an elevated influence on the broods that made up the 2015-2017 escapements. Also, it is not uncommon for hatchery-origin fish to compose smaller proportions of the natural area

escapement during years of low hatchery returns. Since hatchery-origin Chinook that spawn in natural areas tend to do so in the vicinities of the hatcheries, it is believed that a greater portion of them enter the hatchery when it is not as crowded, rather than resorting to spawning in-river. The IGH returns during 2015-2017 were the lowest since 1992. While TRH has experienced low escapement numbers in more recent years (e.g., 2013, 2008, and 2002), the returns during 2015-2017 were still much lower than average, and the 2016 return was the lowest on record (PFMC 2018b).

Table 3.1.7.a. Estimates of natural- and hatchery-origin adult spawners in Klamath Basin natural areas.

	Natural Area Adult Spawners			Percent
Year	Natural-Origin	Hatchery-Origin	Total	Hatchery-Origin
1996	67,458	13,868	81,326	17%
1997	42,230	3,914	46,144	8%
1998	31,074	11,414	42,488	27%
1999	12,600	5,856	18,456	32%
2000	58,753	23,976	82,729	29%
2001	56,187	21,648	77,835	28%
2002	60,399	5,236	65,635	8%
2003	64,245	23,399	87,644	27%
2004	10,957	12,874	23,831	54%
2005	17,472	9,318	26,790	35%
2006	21,066	9,095	30,161	30%
2007	51,416	9,254	60,670	15%
2008	25,503	5,346	30,849	17%
2009	38,608	5,803	44,411	13%
2010	33,602	3,623	37,225	10%
2011	27,666	19,099	46,765	41%
2012	96,576	24,969	121,545	21%
2013	46,137	13,018	59,155	22%
2014	74,451	20,653	95,104	22%
2015	**25,619**	**2,493**	**28,112**	**9%**
2016	**12,875**	**1,062**	**13,937**	**8%**
2017	**16,649**	**1,865**	**18,514**	**10%**
1996-2014 avg.	44,021	12,756	56,777	24%
2015-2017 avg.	18,381	1,807	20,188	9%

If the number of hatchery-origin KRFC spawning in natural areas were increased during 2015-2017 to reflect the 24 percent long-term average, escapements would have been 33,687, 16,929, and 21,892 adults, respectively. All of these values still fall below the S_{MSY} of 40,700 natural area adults, and two of the three years would still be below the MSST of 30,525. The three-year geometric mean would be 23,198 natural area adult spawners, which is below the MSST and thus KRFC would still be overfished.

3.2 Marine Survival

3.2.1 Review of Ocean Conditions

The California Current Large Marine Ecosystem, in which KRFC spends the majority of its ocean life history, spans nearly 3,000 km from southern British Columbia to Baja California. The California Current underwent an extreme warming event beginning in late 2014 with record high temperatures observed in 2015. During 2014-2015, an anomalously warm pool of water in the Gulf of Alaska, referred to as the "warm blob", began affecting temperatures in more southerly areas inhabited by KRFC. An intense El Niño event in 2015 and 2016 also contributed to the record high sea surface temperatures (SSTs) observed in the California Current (Figure 3.2.1.a).

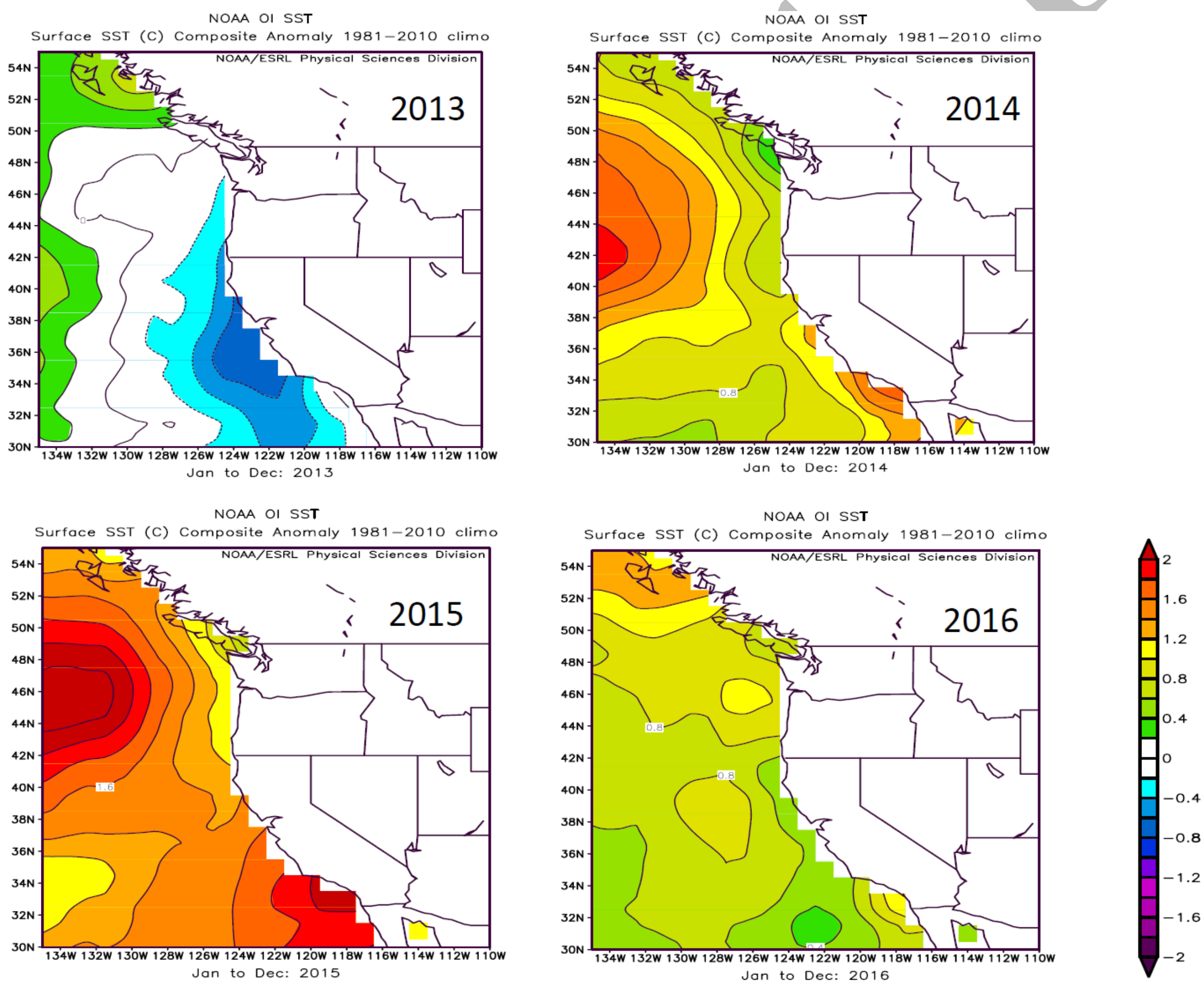

Figure 3.2.1.a. Annual sea surface temperature anomalies for years 2013-2016 (Nathan Mantua, NMFS, personal communication).

Large scale indices of ocean climate suggested generally unproductive conditions in the California Current beginning in 2014 and lasting through at least 2016. Figure 3.2.1.b displays time series for three relevant North Pacific climate indices.

The Oceanic Niño Index (ONI) is a three-month running mean of SST anomalies averaged over the eastern Pacific equatorial region that is used to gauge the state of the El Niño/Southern Oscillation (ENSO). The period from 2010 through late 2014 was generally neutral or cool. However, the period from late 2014 through mid-2016 was characterized by strongly positive (warm) SST anomalies that were similar to or surpassed the warm anomalies from the strong ENSO events of the early 1980s and late 1990s.

The Pacific Decadal Oscillation (PDO) is an index that describes the temporal evolution of the dominant spatial pattern of sea-surface temperature anomalies over the North Pacific (Mantua et al. 1997), and is often closely correlated with the ONI. Positive values of the PDO are generally associated with warm conditions along the U.S. West Coast. The PDO switched from a negative to positive phase beginning in 2014, with very high values observed in 2015 and 2016.

The North Pacific Gyre Oscillation (NPGO) is well correlated with salinity, nutrients, and chlorophyll-a in the California Current (Di Lorenzo et al. 2008). Negative NPGO values are associated with decreased equatorward flow in the California Current and thus less subarctic source waters, lower nutrients, reduced upwelling, and reduced chlorophyll-a. Since 2014, the NPGO has primarily been in a negative phase, suggesting lower productivity in the central and southern California Current.

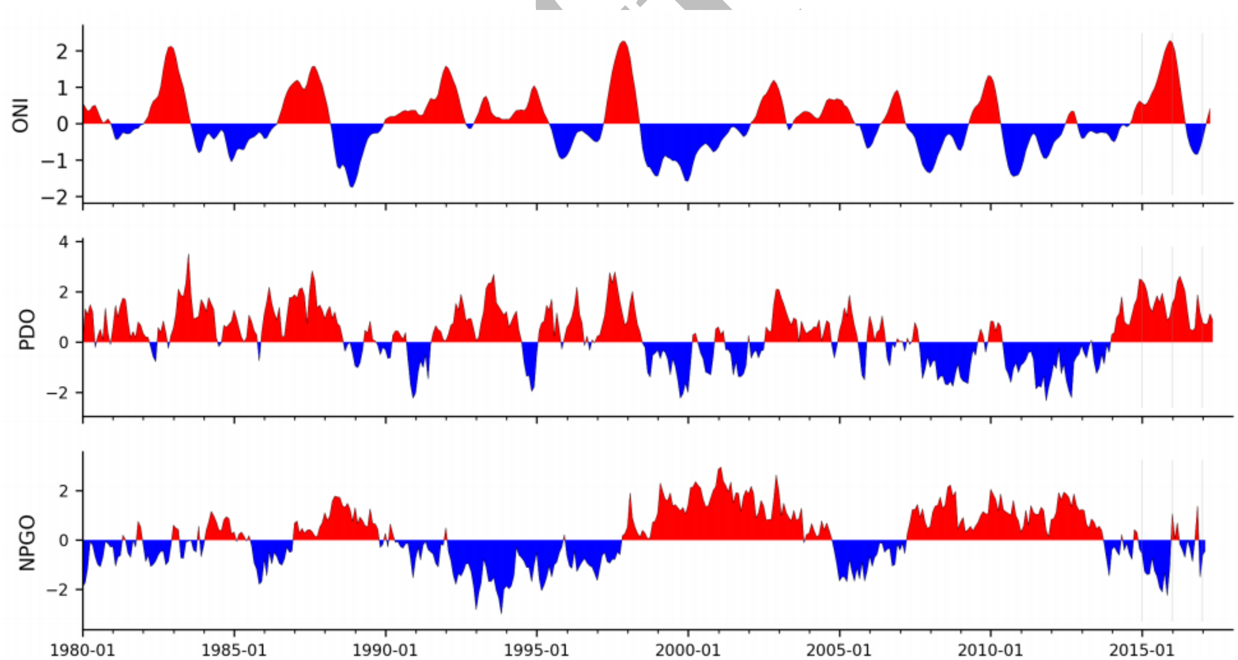

Figure 3.2.1.b. Time series for three ocean climate indices relevant to productivity of the California Current: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), and the North Pacific Gyre Oscillation (NPGO). Tick marks represent January values. Figure reproduced from Wells et al. (2017).

Local-scale ocean conditions relevant to KRFC also demonstrate relatively warm, unproductive conditions present for juvenile salmon entering the ocean from 2014 through 2016, corresponding to brood years 2013-2015, with better conditions encountered by the earlier critical brood years.

McClatchie et al. (2016) compared sea surface temperature anomalies from the 1997-1998 El Niño and the period from 2014-2016 for the region from Trinidad Head (just south of the Klamath River mouth) to Point Conception, California (Figure 3.2.1.c). In both coastal and more offshore areas in this region there were substantial positive SST anomalies from 2014-16, similar to or greater than those anomalies during the 1997-1998 El Niño event.

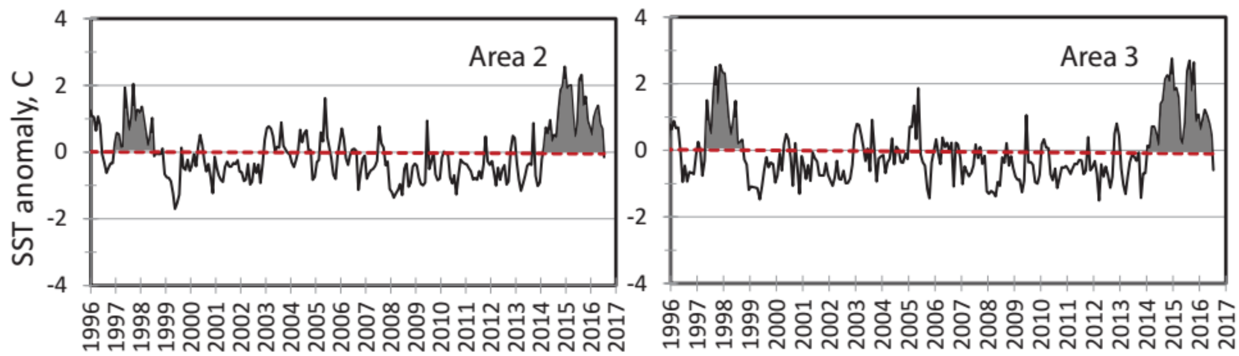

Figure 3.2.1.c. Anomalies of monthly mean sea-surface temperature in offshore (Area 2) and coastal (Area 3) areas off central California between Trinidad and Pt. Conception. Anomalies were calculated relative to the long-term (1981-2016) mean monthly values. The shaded areas correspond to the anomalies of 1997-1998 and 2014-2016. Figure adapted from McClatchie et al. (2016).

The Cumulative Upwelling Index (CUI) provides another indicator of productivity in the California current. It is defined as the cumulative sum of daily upwelling index (Bakun 1973; Schwing et al. 1996) values for the calendar year. Figure 3.2.1.d displays the CUI from 1967 through the middle of 2015, with years 2013-2015 highlighted. Of particular relevance for KRFC are the CUI values for 39° N and 42° N (The Klamath River enters the ocean near 41° N). In the region of interest, the CUI was either close to or greater than the 1967-2011 average in 2013-2015, with 2013 having among the highest level of CUI over the time series. CUI levels in the same region were generally near or above the mean in 2012 as well (Leising et al. 2014).

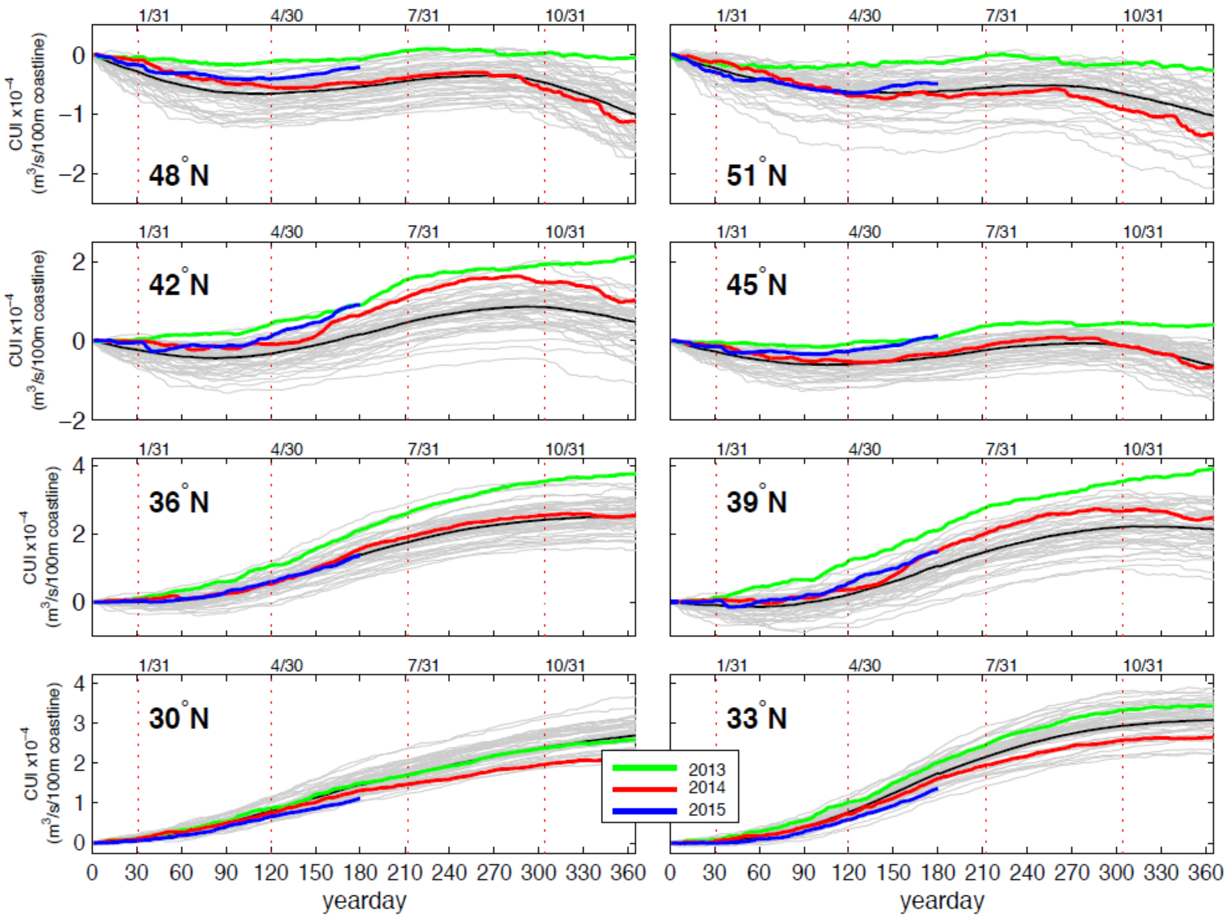

Figure 3.2.1.d. Plots of the Cumulative Upwelling Index (CUI) by latitude. The black line is the mean from 1967-2011 and grey lines are years 1967-2013. Years 2013-2015 are represented by the colored lines defined in the legend. Figure reproduced from Leising et al. (2015).

Zooplankton biomass has been used as an indicator of feeding conditions for juvenile salmon and the forage fishes that are important salmon prey. A change in the copepod community in central Oregon was associated with the record high SSTs in 2014-2016. From approximately 2011 through the summer of 2014, the biomass of lipid-rich, cold water, northern copepods was generally high off Newport, OR. As waters warmed in the area, the copepod community switched to one dominated by a lipid-poor, warm water, southern copepod assembly (Leising et al. 2015). The dominance of the warm water copepod assemblage continued into 2017, and the biomass of the lipid-rich northern copepods declined to the lowest levels observed (Wells et al. 2017; Figure 3.2.1.e). Off Trinidad Head, CA, a decline in northern copepods and increase in southern copepods was also noted, with general correspondence to the observations at Newport. A similar pattern was seen for krill populations at Trinidad, where northern species were supplanted by a krill assemblage dominated by southern and offshore species (Leising et al. 2015, McClatchie et al. 2016, Wells et al. 2017).

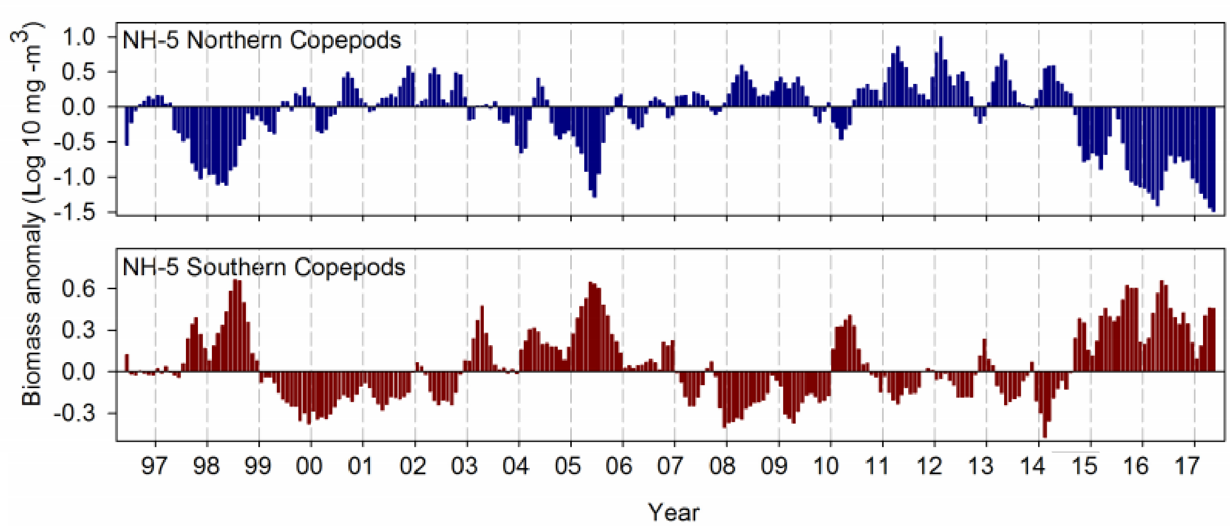

Figure 3.2.1.e. Time series plots of northern and southern copepod biomass anomalies in coastal Oregon waters, measured along the Newport Hydrographic Line. Figure reproduced from Wells et al. (2017).

Ichthyoplankton biomass can also be indicative of foraging conditions for juvenile salmon. Off Newport, OR, moderate to low biomass levels of ichthyoplankton considered to be important prey for salmon were observed in 2012-2014, which would correspond to the outmigration years for brood year 2011-2013 KRFC. The biomass of salmon-favored ichthyoplankton increased substantially in 2015, with major contributions from rockfish and anchovy. While ichthyoplankton surveys do occur off the coast of California, there are currently no winter surveys, which is the period of time most relevant to juvenile Chinook entering the ocean (Figure 3.2.1.f).

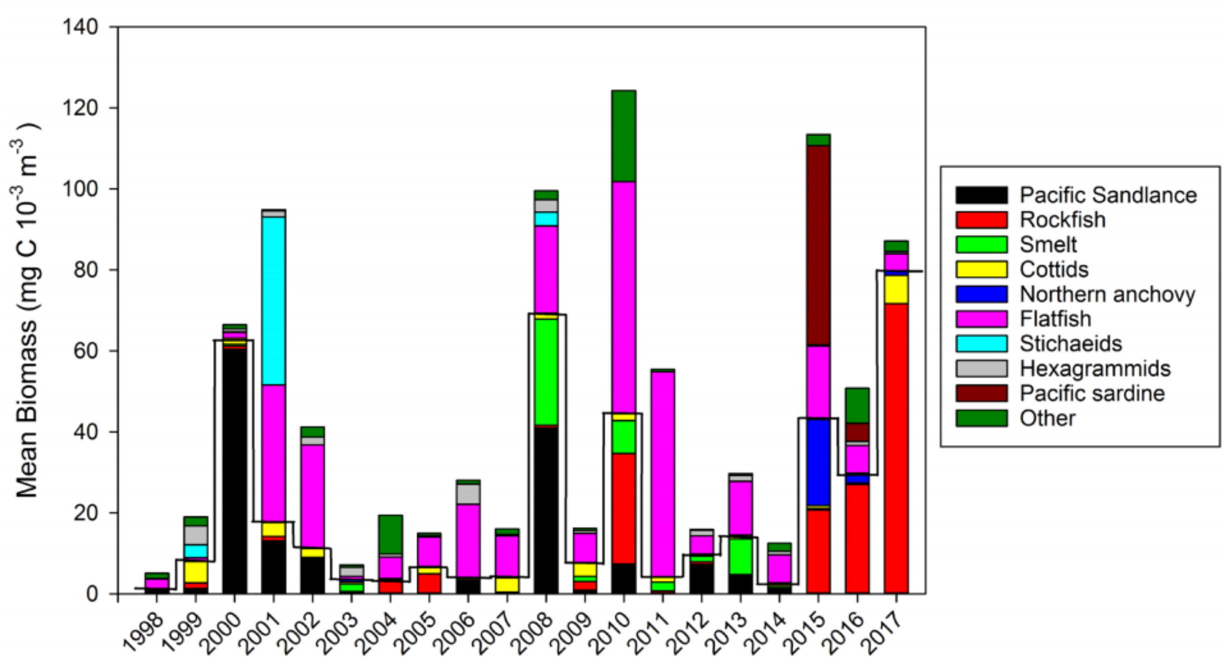

Figure 3.2.1.f. Annual mean biomass of five important juvenile salmon prey taxa (below solid line) and five other larval fish taxa (above solid line) collected during winter (January-March) along the Newport Hydrographic Line, 9-46 km off the coast of Oregon. Figure reproduced from Wells et al. (2017).

Seabird nest success and productivity over the critical period of 2012-2015 was mixed. At Castle Rock National Wildlife Refuge near Crescent City, CA, reproductive success of common murre was near average in 2013-2015, with no data reported for 2012 (McClatchie et al. 2016). Productivity of a variety of seabird species nesting at Southeast Farallon Island differed by species. McClatchie et al. (2016) observed that standardized productivity of several species was down in 2015 relative to 2014, but remained near or above long term averages. It was also noted that the 2015-2016 ENSO event did not appear to have as large an impact on seabird productivity at Southeast Farallon Island relative to previous strong ENSO events. While results for seabird nest success and productivity were mixed over the period of interest, there were indications that the warming that began in 2014 contributed to seabird mortality. Jones et al. (2018) describe a mass mortality event for Cassin's auklet from California to British Columbia that occurred in 2014-2015. The biomass of lipid-poor, southern copepods was identified as the most supported predictor of this event.

For the years of primary interest with regard to the KRFC overfished status (outmigration years 2012-2015), indicators of ocean productivity and feeding conditions for salmon were highly dynamic. Outmigration years 2012 and 2013 were characterized by generally cool SSTs in the California Current, relatively high biomass of northern copepods at the Newport line, and moderate levels of ichthyoplankton biomass for species known to be important prey for juvenile salmon. Upwelling indices were above average for these years, which indicated relatively high overall productivity in the California Current (IEA 2014). In 2014 the California Current began to shift to a much less productive system (IEA 2015). Basin-scale indices such as the PDO and NPGO switched phases from a generally high productivity phase to low productivity phase for the California Current. Upwelling was reduced relative to the very strong indices in 2013, though from 36^{o} N to 48^{o} N, upwelling generally remained at average or above average levels. Late in 2014, SSTs warmed and the copepod assemblage at the Newport Line transitioned to an assemblage dominated by northern copepods to one dominated by southern copepods. A similar shift in the zooplankton assemblage was observed further south at Trinidad Head. Winter ichthyoplankton biomass for important salmon prey species was very low in 2014, suggesting poor forage conditions for outmigrating salmon. A mass mortality event of a Cassin's auklet, a planktivorous seabird, from British Columbia to central California began in 2014. A strong ENSO event developed in 2015 and basin-scale indices (PDO and NPGO) strongly suggested low productivity conditions in the California Current (IEA 2016). Positive upwelling anomalies were observed in the spring and summer of 2015 between 36^{o} N to 48^{o} N, yet record high SSTs were observed off California and Oregon. The zooplankton community off Newport and Trinidad Head remained dominated by lipid-poor southern and offshore species. However, a relatively high salmon-favorable ichthyoplankton biomass was observed in 2015.

3.2.2 Early life survival rates

Data limitations do not allow for separate estimates of river and marine survival rates for juvenile KRFC. However, cohort reconstruction methods (Goldwasser et al. 2001, Mohr 2006a) applied to coded-wire tag recovery data and hatchery release information allow for the estimation of survival rates from hatchery release to age-2 in the ocean. Such survival rate estimates thus capture processes occurring during downstream migration as well as early ocean residence.

Figure 3.2.2.a. displays survival rate estimates for fingerling releases from IGH on the Klamath River and TRH. Fingerling releases more closely align with the life history of naturally-produced KRFC than the yearling release groups that are produced at both hatcheries. The estimated survival rates in Figure 3.2.2.a span the period from release (in the spring of brood year + 1) to the beginning of age-2 in the ocean (September of brood year + 1). However, since few age-2 KRFC are harvested in ocean fisheries, the relative survival rates index the survival from release to the time that maturing age-2 fish leave the ocean for the river (September of brood year + 2).

The most recent brood year for which survival rates are reported is 2014. This brood is “incomplete” as returns have not occurred for ages 4 and 5 (in 2018 and 2019, respectively). As such, survival rates for this brood are highly uncertain and could change substantially after the cohort reconstruction is updated with 2018 escapement data. The 2013 brood is also incomplete because returns have not occurred for age 5. However, since only a small fraction of KRFC cohorts return at age 5, the estimated early life survival rates for this brood is much less uncertain than the estimate for the 2014 brood.

Survival rates for fingerling releases from IGH and TRH are well correlated ($\rho = 0.53, p = 0.001$). Mean survival rates across years 1979-2014 were similar, though slightly higher for TRHF relative to IGHF. For brood years 2011-2014, which contributed to adult escapement in 2015-2017, survival rates were well below average (with exception of the IGHF survival rate for brood year 2011, which was near the long-term average).

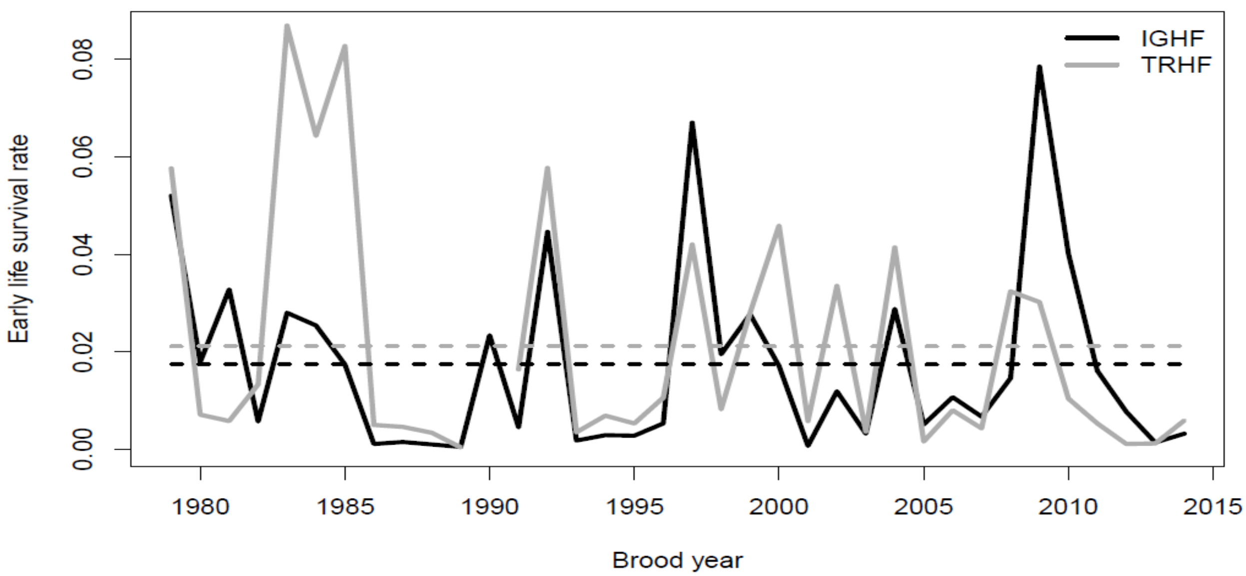

Figure 3.2.2.a. Estimated survival rates from hatchery release to age-2 in the ocean for Iron Gate Hatchery fingerlings (IGHF) and Trinity River Hatchery Fingerlings (TRHF). Dashed lines are averages computed over the entire time series.

3.3 Harvest Impacts

3.3.1 Ocean fisheries

Season Descriptions

In the ocean, KRFC are primarily contacted between Cape Falcon, Oregon and Pt. Sur, California, with contact rates generally higher closer to the Klamath River mouth. This includes the major management areas of Northern Oregon (Cape Falcon to Florence south jetty[3]), Central Oregon (Florence south jetty to Humbug Mt.), the Oregon KMZ (Humbug Mt. to the OR/CA border), the California KMZ (OR/CA border to Horse Mt.; Klamath River mouth within this zone), Fort Bragg (Horse Mt. to Pt. Arena), San Francisco (Pt. Arena to Pigeon Pt.), and Monterey North (Pigeon Pt. to Pt. Sur). Both commercial and recreational ocean salmon fisheries typically occur in all of these areas. The commercial fishery generally receives the greater share of the projected marine harvest, but their seasons are usually shorter due to the greater fishing power of the commercial fleet and the high social value placed on recreational fishing. Also, within a given area and time, KRFC are typically contacted at a higher rate by the commercial fleet. For these reasons, commercial fisheries in areas closer to the Klamath River mouth (i.e., both portions of the KMZ, Central Oregon, and Fort Bragg) are the most constrained when KRFC abundance is projected to be low. Fisheries in the Northern Oregon and Monterey North areas are only minimally influenced by KRFC stock status.

Commercial Ocean Seasons

Figure 3.3.1.a illustrates the general season structures of the 2015-2017 commercial ocean salmon fisheries between Cape Falcon and Pt. Sur. In general, seasons progressively became more restrictive between 2015 and 2017, largely due to low preseason KRFC forecast abundances, but also to protect endangered Sacramento River winter Chinook (SRWC) south of Pt. Arena.

In the Northern and Central Oregon areas, the season is typically open from mid-March/early-April through October, with various mid-season closures to reduce impacts on limiting stocks. There is also usually a November state-water-only fishery centered around the Elk River mouth in the Central Oregon area. Both areas had fairly typical seasons in 2015 and 2016, but Northern Oregon was slightly more constrained in 2017 and Central Oregon was closed to commercial fishing except for the late-season Elk River fishery. The Oregon KMZ typically opens in mid-March/early-April, with monthly quotas beginning in June. These quotas may run through September in years when KRFC is not constraining, but some of the late-summer/fall quotas are often eliminated. There is also usually an October state-water-only quota fishery centered around the Chetco River mouth. 2015 was a relatively typical season in the Oregon KMZ, but 2016 was more constrained, and in 2017 the commercial fishery was closed except for the late-season Chetco River fishery.

In the California KMZ, it is rare to have commercial fisheries outside of a September quota, although in years when KRFC is not limiting there have been quota fisheries in earlier months as well. Also, the southern end of this area has been closed to commercial salmon fishing since 1989. Punta Gorda was the original northern boundary of this closed subarea, but it has been the south

[3] While the line separating the Northern and Central Oregon management areas is now the southern end of Heceta Bank, Florence south jetty was used through the 2017 season.

jetty of Humboldt Bay since 1996. The seasons in the California KMZ consisted of the standard September quota fisheries in 2015 and 2016, but was completely closed to salmon fishing in 2017. Commercial fisheries in the Fort Bragg area tend to vary from year to year considerably more than other management areas, and are highly influenced by preseason KRFC abundances. This results in seasons with various blocks of open time between May and September. In 2015, this area had a relatively full season, but it was curtailed sharply in 2016, and was severely reduced further in 2017 to a September-only quota fishery. The San Francisco area is typically open May through September, with various mid-season closures to reduce impacts on limiting stocks, and also includes a small fishery centered around the Golden Gate Bridge during the first half of October. 2015 was a fairly typical season in the San Francisco area, but the number of open days decreased considerably in 2016, and then decreased even further in 2017 with the season being closed through July. In Monterey North, seasons are usually more influenced by allowable impacts on SRWC, but can run anytime May through September. Due to concerns over SRWC abundances during those three years, the 2015 season was restricted to approximately three months of open time, and the 2016 and 2017 seasons were limited to two months.

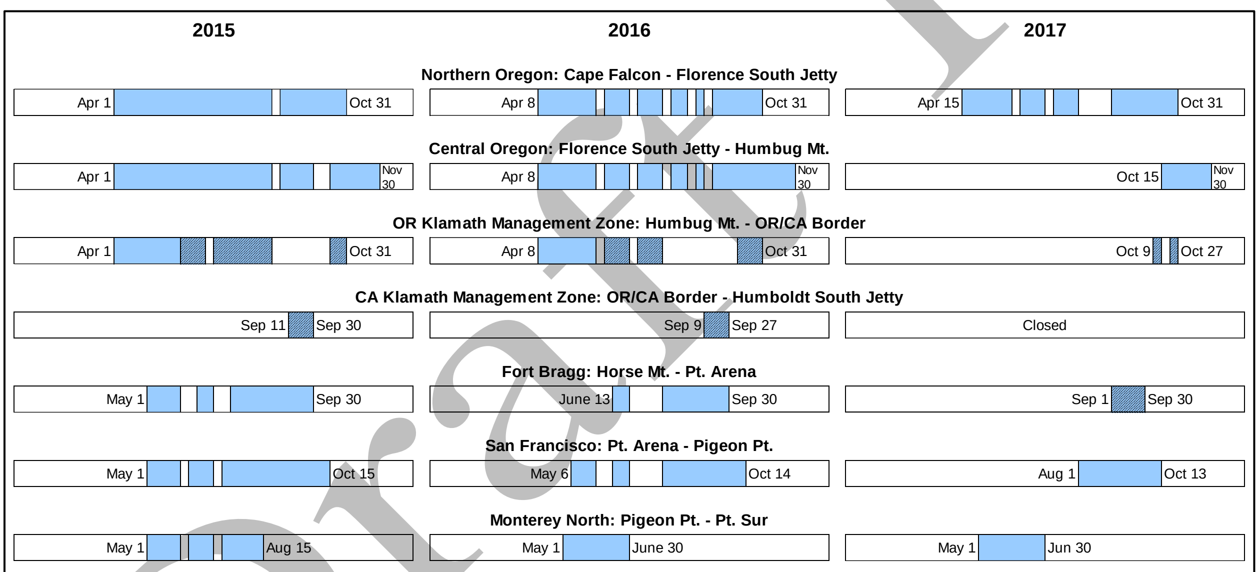

Figure 3.3.1.a. The general commercial ocean season structure for all management areas between Cape Falcon and Pt. Sur during 2015-2017, with the first and last open days of the season displayed. Open periods shown with a diagonal pattern were operated under quota systems.

<u>Recreational Ocean Seasons</u>

Figure 3.3.1.b illustrates the general season structures of the 2015-2017 recreational ocean salmon fisheries between Cape Falcon and Pt. Sur. Since the recreational fishery has relatively lower impacts on KRFC, season reductions when KRFC is limiting are mostly confined to the KMZ, although Fort Bragg was heavily impacted in 2017 as well. In the Northern and Central Oregon areas, the season is typically open from mid-March through October, often with various coho quota fisheries occurring concurrently with portions of the Chinook season. A November state-water-only fishery centered around the Elk River mouth in the Central Oregon area is also usually in place. These areas had typical seasons during all three years. Both portions of the KMZ are usually open early-May through early-September, although mid-season closures to limit KRFC impacts are common. A state-water-only fishery centered around the Chetco River mouth in the

Oregon KMZ during early-October also typically occurs. Both KMZ areas had full recreational seasons in 2015, but the number of open days decreased considerably in 2016, and in 2017 the entire KMZ was closed to salmon fishing except for the late-season Chetco River fishery. Recreational fisheries in the Fort Bragg and San Francisco areas are typically open from early-April through early-November, although during these three years the fishery in San Francisco only continued through October to reduce impacts on SRWC. With that exception, these areas had full seasons in 2015 and 2016. In 2017, the Fort Bragg area had a two and a half month closure in the middle of the season to limit KRFC impacts, and the San Francisco area had a two-week closure in early-May. In Monterey North, seasons are usually more influenced by allowable impacts on SRWC, and typically run early-April through early-October. Due to concerns over SRWC abundances during those three years, the 2015 season only continued through early-September, and the 2016 and 2017 seasons only continued through mid-July.

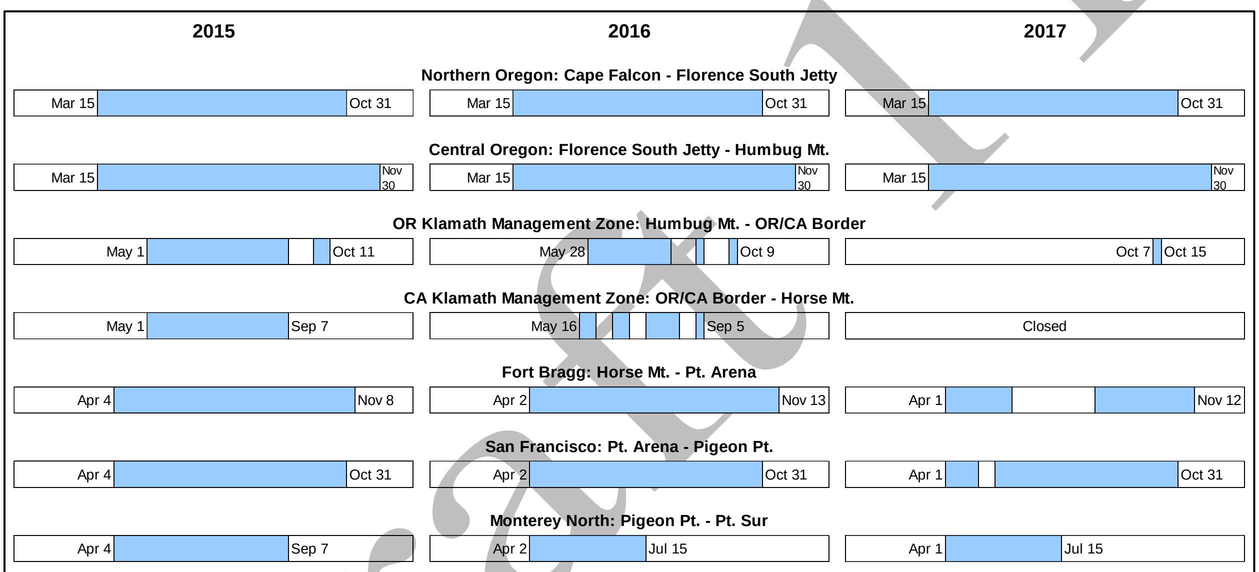

Figure 3.3.1.b. The general recreational ocean season structure for all management areas between Cape Falcon and Pt. Sur during 2015-2017, with the first and last open days of the season displayed.

<u>Adult Harvest</u>

Table 3.3.1.a displays historical ocean harvest levels of adult KRFC. For ocean harvest, the year (t) is actually September 1 in the prior year (t-1) through August 31 (t). Within the KMZ, the commercial fishery had low levels of adult KRFC harvest during the 2015 and 2016 seasons, but none in 2017. This was not entirely unexpected for 2017 since the fishery was closed within the KMZ and thus would only include fall harvest (September-December) from 2016. The recreational KMZ fishery also had a low level of adult KRFC harvest in 2015, and very low levels in 2016 and 2017. Again, since the recreational fishery was closed within the KMZ in 2017, any harvest from that year occurred during fall 2016. The average KMZ ocean harvest during 2015-2017, commercial and recreational combined, was only 5 percent of the long-term average. Outside of the KMZ, adult KRFC harvest in 2015 was 40 percent of the long-term average. This was followed by a sharp decline in 2016, and then a further decline in 2017 when even areas outside of the KMZ were heavily constrained, particularly in the commercial fishery. The average harvest outside of the KMZ during 2015-2017 was only 16 percent of the long-term average. At no point during the critical years did ocean harvest of adult KRFC approach the long-term average.

During 2015, 2016, and 2017, ocean fisheries harvested an estimated 68 percent, 47 percent, and 246 percent, respectively, of the non-Tribal ocean allocation of adult KRFC.

Table 3.3.1.a. Ocean harvest of adult Klamath River fall Chinook. Table modified from Table II-6 in PFMC (2018c).

	Klamath Management Zone (KMZ)			North of	South of		Total Ocean
Year (t)	Troll	Sport	Subtotal	KMZ	KMZ	Subtotal	Harvest
1986	43,379	6,104	49,483	97,898	154,825	252,723	302,206
1987	38,972	14,251	53,223	117,389	107,290	224,679	277,902
1988	28,425	9,960	38,385	55,545	159,956	215,501	253,886
1989	11,693	21,829	33,522	49,676	40,928	90,604	124,126
1990	5,457	7,881	13,338	79,738	22,105	101,843	115,181
1991	100	2,023	2,123	2,627	5,039	7,666	9,789
1992	171	101	272	2,859	147	3,006	3,278
1993	0	977	977	2,493	8,040	10,533	11,510
1994	42	1,730	1,772	1,295	4,892	6,187	7,959
1995	0	1,342	1,342	15,012	16,793	31,805	33,147
1996	866	3,533	4,399	10,939	30,296	41,235	45,634
1997	130	737	867	2,980	5,140	8,120	8,987
1998	2	113	115	4,310	467	4,777	4,892
1999	78	755	833	3,154	1,130	4,284	5,117
2000	599	4,175	4,774	10,996	26,280	37,276	42,050
2001	1,424	1,086	2,510	8,606	10,008	18,614	21,124
2002	3,122	1,973	5,095	4,413	19,385	23,798	28,893
2003	1,102	1,798	2,900	10,529	57,600	68,129	71,029
2004	2,321	3,149	5,470	25,123	33,733	58,856	64,326
2005	301	885	1,186	6,851	4,770	11,621	12,807
2006	572	1,377	1,949	6,699	1,790	8,489	10,438
2007	1,040	10,630	11,670	6,447	12,133	18,580	30,250
2008	6,839	1,129	7,968	637	113	750	8,718
2009	0	51	51	0	0	0	51
2010	142	101	243	1,057	3,145	4,202	4,445
2011	752	1,295	2,047	1,240	8,709	9,949	11,996
2012	1,457	13,735	15,192	1,686	16,108	17,794	32,986
2013	5,217	12,712	17,929	5,090	35,976	41,066	58,995
2014	1,292	2,071	3,363	25,964	10,775	36,739	40,102
2015	**321**	**832**	**1,153**	**8,437**	**10,300**	**18,737**	**19,890**
2016[a/]	**50**	**255**	**305**	**741**	**1,881**	**2,622**	**2,927**
2017[b/]	**0**	**129**	**129**	**207**	**1,349**	**1,556**	**1,685**
1986-2014 avg.	5,362	4,397	9,759	19,354	27,503	46,856	56,615
2015-2017 avg.	124	405	529	3,128	4,510	7,638	8,167

a/ Preliminary: incomplete cohort data (age-5 data unavailable).
b/ Preliminary: incomplete cohort data (age-4 and age-5 data unavailable).

3.3.2 In-river Fisheries

<u>Tribal Fisheries</u>

Tribal fisheries with recognized federal fishing rights occur on the Yurok and Hoopa Valley reservations located on the Lower Klamath and Trinity Rivers, respectively. The Yurok and Hoopa Valley tribal authorities adopt annual tribal fishing regulations for their respective reservations.

The Yurok Tribal Council regulates the KRFC fishery via annual Fall Harvest Management Plans, which are based upon the tribal allocation and subsequent regulations regarding sub-area quotas, conservation measures, and potential commercial fisheries. When the Tribal Council allows a portion of the allocation to go to commercial fishing, then most harvest is taken in the estuary where commercial fisheries are implemented. Subsistence and ceremonial fisheries are spread throughout the reservation. The Yurok Tribe manages their fishery to target no more than 80% of the harvestable surplus that has been identified for Klamath Basin Tribes with federally reserved fishing rights. This inter-tribal allocation scheme of 80%:20% for the Yurok and Hoopa Valley Tribes, respectively, is congruent with management of the Yurok fishery by the federal government in the early 1990s, prior to the tribe's assumption of management responsibility.

The Hoopa Tribal Fishery is conducted in accordance with the Hoopa Valley Tribe's Fishing Ordinance. Fishing by tribal members occurs within the exterior boundaries of the Hoopa Valley Reservation. The Hoopa Valley Tribal Council is the sole authority responsible for the conduct of the tribe's fishery, enforces the fishing ordinance, and ensures collection of harvest statistics through its Fisheries Department. Summary catch data for spring and fall Chinook harvested in the tribe's fishery are provided annually to co-managers and published by the Council.

The tribal fisheries prioritize the use of fish for ceremonial purposes throughout the year. Subsistence needs are the next highest priority use of KRFC by the Tribes. The subsistence catch has been as high as 32,000 fish since 1987 when separate tribal use accounting was implemented. Generally, commercial fishing has been allowed when the total allowable tribal catch was over 11,000 –16,000 adult KRFC.

The Yurok Tribal fishery occurs within the lower 44 miles of the Klamath River. The Hoopa Tribal fishery occurs in the Trinity River from one mile upstream of the confluence with the Klamath River upstream to the boundary of the Hoopa Valley Reservation (HVR), approximately 12 river miles. The primary gear type used is gill nets; however, a small portion of the KRFC harvest is taken by dip nets, hook and line, and a selective harvest weir operated within the HVR. KRFC are typically harvested from early August through November, with peak harvest in the estuary occurring in late August through mid-September and in the Trinity River from mid-August through mid-December, with peak harvest typically occurring in late-September to early-October.

Table 3.3.2.a displays historical levels of the tribal fisheries adult harvest. The 2016 allocation for Klamath Basin Tribes with federally reserved fishing rights was the second lowest on record since 1978 and the allocation in 2017 was the lowest on record. During 2015, 2016, and 2017 the Hoopa Valley Tribe harvested 5 percent, 10 percent and 204 percent of the overall tribal allocation, respectively, and the Yurok Tribe harvested 60 percent, 60 percent, and 27 percent of the overall tribal allocation, respectively. In light of the low projected escapement of natural-area spawners in 2017 (11,379 adults), the Yurok Tribe completely closed their subsistence gill net fishery, with the exception of a small elders fishery program.

<u>River Recreational Fisheries</u>
Recreational river fisheries for KRFC occurred in 2015 and 2016, but was closed in 2017 throughout the Klamath Basin due to the extremely low preseason KRFC ocean abundance. In most years, however, this fishery occurs from August through December. Angler effort is highest

in the lower Klamath River, peaking in September (50 percent of the total KRFC allocation is reserved for the lower Klamath River). From October through early December fishing effort is more dispersed throughout the upper Klamath and Trinity Rivers. During this time angling effort somewhat follows the upstream migration of Chinook as they move towards the two basin hatcheries and natural spawning areas. By mid- to late-December Chinook fisheries have generally ceased due to quota attainment or by the diminished quality and quantity of the remaining Chinook. All tributary streams, with the exception of the mainstem Trinity River, are closed to the take of Chinook salmon.

Recreational fisheries are managed using a quota system for fish over 22 inches (i.e., adults); sub-quotas have been established for all open areas of the Klamath system. In-river recreational fisheries are managed by the California Fish and Game Commission. Annual regulations are generally responsive to the adult KRFC quota allocations for each particular year. In years of low quota allocations, daily and weekly bag limits are reduced so that all sub-quota area fisheries can participate. In high abundance years bag limits are increased up to a maximum of three adults per day.

Table 3.3.2.a displays historical levels of the recreational river harvest of adult KRFC. The 2015 harvest was very similar to the long-term average. The 2016 harvest was the fourth lowest on record, primarily due to a small quota of 1,110 fish over 22 inches. In 2017 the fishery was closed, although there were still a small number of KRFC adults harvested in the spring Chinook fishery (which was still open) and by steelhead anglers. In anticipation of some incidental catch of KRFC by fisheries targeting other species and runs, a recreational river allocation of 129 adults was in place for 2017. The 2017 incidental KRFC catch of 71 adults was 55 percent of the river recreational fishery allocation. The average harvest during 2015-2017 was only 40 percent of the long-term average.

Table 3.3.2.a. Klamath River fall Chinook in-river adult harvest (tribal and recreational)

	Recreational River Fishery			Tribal River Fishery					
Year	Quota	Harvest	Harvest as Percent of Quota	Quota	Yurok Harvest	Hoopa Harvest	Total Tribal Harvest	Harvest as Percent of Quota	Total River Harvest
1986	7,800	21,027	270%	28,250	20,319	4,808	25,127	89%	46,154
1987	17,900	20,169	113%	59,000	48,114	4,982	53,096	90%	73,265
1988	15,575	22,203	143%	51,725	46,581	5,070	51,651	100%	73,854
1989	15,600	8,775	56%	52,500	42,091	3,474	45,565	87%	54,340
1990	6,500	3,553	55%	24,500	7,095	811	7,906	32%	11,459
1991	2,600	3,383	130%	10,300	8,918	1,280	10,198	99%	13,581
1992	800	1,002	125%	4,920	4,839	946	5,785	118%	6,787
1993	2,700	3,172	117%	18,500	8,144	1,492	9,636	52%	12,808
1994	1,400	1,832	131%	11,800	9,426	2,266	11,692	99%	13,524
1995	1,800	6,081	338%	15,300	12,174	3,383	15,557	102%	21,638
1996	15,700	12,766	81%	104,100	53,706	2,770	56,476	54%	69,242
1997	3,500	5,676	162%	21,600	10,849	1,238	12,087	56%	17,763
1998	1,800	7,710	428%	12,000	8,652	1,535	10,187	85%	17,897
1999	2,900	2,282	79%	15,300	11,682	2,978	14,660	96%	16,942
2000	4,200	5,650	135%	28,200	23,453	5,962	29,415	104%	35,065
2001	29,800	12,134	41%	75,500	33,691	4,954	38,645	51%	50,779
2002	20,500	10,495	51%	50,430	23,406	1,168	24,574	49%	35,069
2003	10,800	9,680	90%	41,400	27,263	2,771	30,034	73%	39,714
2004	4,700	4,003	85%	31,122	24,114	1,689	25,803	83%	29,806
2005	1,200	1,985	165%	8,300	5,607	2,409	8,016	97%	10,001
2006	0	62	NA	10,039	6,122	4,161	10,283	102%	10,345
2007	10,600	6,312	60%	40,775	25,275	2,298	27,573	68%	33,885
2008	22,500	1,919	9%	26,998	20,346	1,913	22,259	82%	24,178
2009	30,800	5,651	18%	30,895	24,234	4,153	28,387	92%	34,038
2010	12,000	3,035	25%	34,608	26,186	3,701	29,887	86%	32,922
2011	7,900	4,147	52%	34,821	21,490	4,863	26,353	76%	30,500
2012	67,600	13,876	21%	159,989	91,241	4,145	95,386	60%	109,262
2013	40,006	19,800	49%	114,828	60,017	3,019	63,036	55%	82,836
2014	4,128	5,386	130%	27,294	23,528	2,439	25,967	95%	31,353
2015	**14,133**	**7,842**	**55%**	**43,581**	**26,028**	**2,020**	**28,048**	**64%**	**35,890**
2016	**1,110**	**1,310**	**118%**	**7,404**	**4,409**	**751**	**5,160**	**70%**	**6,470**
2017	**0**	**71**	**NA**	**814**	**216**	**1,660**	**1,876**	**230%**	**1,947**
1986-2017 avg.	11,830	7,281	62%	37,400	23,726	2,847	26,573	71%	33,854
2015-2017 avg.	5,081	3,074	61%	17,266	10,218	1,477	11,695	68%	14,769

3.4 Assessment and management

3.4.1 Overview

The Klamath Ocean Harvest Model (KOHM) is used by the PFMC during the annual salmon season setting process to forecast the KRFC natural-area adult escapement and exploitation rate given a set of fishery management measures (e.g., time/area/fishery openings, quotas, and minimum size limits). A description of the KRFC assessment process can be found in Mohr (2006b), while KOHM documentation can be found in Mohr (2006c). The following description of the KOHM and the methods used to assess performance generally follow PFMC (2008).

In the KOHM, age a specific forecasts of natural-area escapement (E_a) are made using the relationship

$$E_a = N_a \, o_a \, m_a \, (1 - w_a) \, r_a \, g_a, \quad (1)$$

where N_a is an age-specific ocean abundance forecast, o_a is the ocean survival rate (which accounts for both natural and fishing mortality), m_a is the maturation rate, w_a is the out-of-basin stray rate,

r_a is the river survival rate (which accounts for fishing mortality), and g_a is the proportion of fish spawning in natural areas.

Summing E_a over ages 3-5 results in a forecast of natural-area adult spawners, which can be expressed as

$$E = N\ \bar{o}\ \bar{m}\ (1\text{-}\bar{w})\ \bar{r}\ \bar{g}, \qquad (2)$$

where N is the summed ocean abundance forecasts for ages 3-5. The bars over the terms on the right hand side of Equation (2) indicate mean values of the age-specific rates weighted by the age-specific abundance immediately prior to that stage. The expected escapement absent fishing can be determined from Equations (1) and (2), assuming no fishing mortality in the ocean and river.

The expected exploitation rate, F, which for KRFC has been referred to as the spawner reduction rate (SRR), is defined as

$$F = 1\text{-}(E/E0). \qquad (3)$$

To assess the roles of assessment and fisheries management on natural-area adult escapement in 2015, 2016, and 2017, we examined whether KRFC would have met the criteria for overfished status (1) in the absence of ocean and river fisheries and (2) with fisheries but assuming no forecast or implementation error. We then examined preseason predictions versus postseason estimates of the components on the right hand side of Equations (1) and (2) to assess how relative errors in the KOHM components affected escapement projections in 2015-2017.

3.4.2 Performance

If no fishing mortality occurred on KRFC in 2015, 2016, and 2017, and escapement was assumed equal to the postseason estimate of the natural-area adult escapement absent fishing (E0), the stock would have exceeded the MSST of 30,525 [geometric mean (GM) = 31,504], and would not have been classified as overfished. However, natural-area adult escapement would have been below S_{MSY} in two of the three years (2016 and 2017), and the stock would be very close to being overfished given the MSST of 30,525 natural-area adult spawners.

Given perfect knowledge of abundance (natural-area adult spawners absent fishing), and imposing the exploitation rates defined by the control rule given the known abundance with no error, the stock would be overfished (GM = 24,582), with escapements equaling 40,700, 19,836, and 18,399, in 2015, 2016, and 2017, respectively.

We can therefore conclude that aspects of the assessment and management of KRFC contributed to their overfished status, yet, in the absence of any fishing mortality in 2015, 2016, and 2017, the stock would very nearly meet overfished status. Thus, there were serious abundance problems independent of fisheries that contributed to the current overfished status.

Table 3.4.2.a. Klamath Ocean Harvest Model (KOHM) preseason forecasts (pre) compared to postseason estimates (post) for years 2015-2017. See text for definitions of column headers.

Year	Age	Type	N	o	m	1-w	r	g	E	F	E0
2015	3	pre	342,229	0.53	0.40	1.00	0.58	0.69	29,283	0.47	55,577
		post	110,391	0.56	0.60	1.00	0.56	0.73	15,086	0.47	28,240
		post/pre	0.32	1.05	1.48	1.00	0.97	1.06	0.52	0.98	0.51
	4	pre	71,110	0.64	0.89	1.00	0.37	0.73	10,792	0.71	36,916
		post	60,980	0.58	0.97	1.00	0.50	0.68	11,492	0.64	32,097
		post/pre	0.86	0.91	1.09	1.00	1.35	0.93	1.06	0.91	0.87
	5	pre	10,414	0.62	1.00	0.99	0.12	0.80	625	0.91	6,608
		post	13,283	0.54	1.00	1.00	0.25	0.85	1,534	0.83	9,061
		post/pre	1.28	0.86	1.00	1.01	2.07	1.06	2.45	0.92	1.37
	adults	pre	423,753	0.55	0.51	1.00	0.48	0.70	40,700	0.59	99,101
		post	184,654	0.56	0.75	1.00	0.50	0.72	28,112	0.59	69,398
		post/pre	0.44	1.02	1.46	1.00	1.04	1.02	0.69	1.01	0.70
2016	3	pre	93,393	0.56	0.41	1.00	0.87	0.66	12,250	0.16	14,633
		post	33,546	0.57	0.45	0.99	0.83	0.66	4,761	0.18	5,833
		post/pre	0.36	1.02	1.12	0.99	0.95	1.00	0.39	1.13	0.40
	4	pre	45,105	0.71	0.89	1.00	0.80	0.76	17,245	0.29	24,240
		post	24,712	0.71	0.89	1.00	0.66	0.89	9,030	0.42	15,512
		post/pre	0.55	0.99	1.00	1.00	0.82	1.17	0.52	1.45	0.64
	5	pre	3,671	0.68	1.00	0.99	0.71	0.81	1,415	0.40	2,339
		post	1,142	0.45	1.00	1.00	0.38	0.76	146	0.79	695
		post/pre	0.31	0.66	1.00	1.01	0.53	0.94	0.10	2.00	0.30
	adults	pre	142,169	0.61	0.60	1.00	0.82	0.72	30,910	0.25	41,211
		post	59,400	0.63	0.66	0.99	0.71	0.80	13,937	0.37	22,040
		post/pre	0.42	1.02	1.10	1.00	0.86	1.11	0.45	1.47	0.53
2017	3	pre	42,026	0.58	0.41	1.00	0.96	0.59	5,571	0.05	5,888
		post	111,964	0.57	0.36	1.00	0.94	0.57	12,509	0.08	13,586
		post/pre	2.66	0.99	0.88	1.00	0.98	0.98	2.25	1.47	2.31
	4	pre	10,558	0.77	0.89	1.00	0.93	0.73	4,882	0.10	5,439
		post	10,545	0.76	0.89	1.00	0.92	0.71	4,670	0.13	5,349
		post/pre	1.00	0.99	1.00	1.00	0.98	0.99	0.96	1.24	0.98
	5	pre	1,662	0.78	1.00	0.99	0.90	0.80	927	0.12	1,057
		post	1,973	0.77	1.00	1.00	0.92	0.96	1,335	0.11	1,508
		post/pre	1.19	1.00	1.00	1.01	1.01	1.19	1.44	0.93	1.43
	adults	pre	54,246	0.62	0.55	1.00	0.94	0.65	11,379	0.08	12,383
		post	124,482	0.59	0.43	1.00	0.93	0.62	18,514	0.09	20,443
		post/pre	2.29	0.95	0.79	1.00	0.99	0.95	1.63	1.16	1.65

In 2015, natural-area adult escapement (escapement) was overpredicted (post/pre = 0.69). Much of the discrepancy between the preseason forecast and postseason estimate can be attributed to the ocean abundance component. Postseason estimates of ocean abundance fell below preseason forecasts for age-3 and age-4 fish, with the largest discrepancy for age-3 fish. Overall, this led to the postseason estimate of the escapement absent fishing being 0.70 of the preseason forecast. The ocean and river survival rates for adults, which account for fishing mortality, were well predicted, and thus the SRR was very well predicted (post/pre = 1.01). Maturation rates for age-3 and 4 fish were above preseason predictions, and thus a larger fraction of the age-3 and 4 cohorts entered the river to spawn relative to the KOHM prediction. This had the effect of offsetting the influence of the abundance forecast errors on escapement. Overall, in 2015 the ocean abundance forecasts errors for age-3 and age-4 fish can largely explain the difference between observed and predicted adult escapement.

In 2016, natural-area adult escapement was overpredicted by a substantial amount (post/pre = 0.45). The preseason forecast of escapement for each of the three age classes exceeded postseason estimates. Ocean abundance forecasts were much higher than postseason estimates for age 3-5 fish. Ocean survival rates and maturation rates were generally well predicted, while the estimated river survival rate was somewhat lower than the preseason prediction. Overall, the predicted exploitation rate F was lower than the postseason estimate. The combination of overpredicted abundance and underpredicted SRR thus contributed to the discrepancy between observed and predicted escapement.

In 2017, natural-area adult escapement was underpredicted (post/pre = 1.63). Much of this result can be explained by underpredicting the age-3 ocean abundance by a substantial amount (age-4 and age-5 abundance were adequately forecast). Ocean and river survival rates were well forecast, as was the SRR. The postseason estimate of the maturation rate was lower than predicted, with this difference being entirely attributed to forecast error for the age-3 component. The primary cause of the under-prediction of adult escapement was therefore the under-prediction of the age-3 ocean abundance.

While fishing contributed to the KRFC stock meeting the criteria for overfished status, overfishing (as defined in the FMP) did not occur in 2015-2017; the SRR was below F_{MSY} =0.71 in each of these years.

3.5 Summary of potential causal factors

Each of the critical broods (2011-2014) had low age-3 and age-4 ocean abundances relative to long-term averages (PFMC 2018c, Table II-4). Brood year 2012 was extraordinarily weak, with near record low age-3 and age-4 abundance in 2015 and 2016, respectively. The 2013 brood appears to be the weakest of the critical broods. Postseason estimates of age-3 ocean abundance in 2016 and age-4 ocean abundance in 2017 were the lowest on record for those respective ages. Brood year 2014 appears to be relatively weak as well, given the low estimated age-3 abundance in 2017. However, we note that the 2014 brood is incomplete and thus there is currently a relatively high level of uncertainty in the reconstructed age-3 ocean abundance.

Parental spawner levels were near or above average in the Klamath Basin and select tributaries for the critical broods. The estimated number of juvenile outmigrants in the upper Klamath Basin and the Trinity River were mostly above average for the critical broods. However, there was high incidence of disease in juveniles in the Klamath River for brood years 2013 and 2014, which was likely associated with the below average flows and above average temperatures experienced in 2014 and 2015. While there were generally above average numbers of juveniles estimated to outmigrate from the upper Klamath River, disease-related mortality may have affected the survival of those broods during the downstream migration or after ocean entry.

A relatively cool, productive ocean was in place for brood year 2011 and 2012 KRFC smolts entering the ocean in 2012 and 2013, respectively. However, both large and local scale indices of ocean productivity changed in 2014. Warming sea surface temperatures, a shift from a lipid rich to lipid poor copepod community, and a seabird mass mortality event began in 2014 and continued into 2015. Record high sea surface temperatures and a very strong ENSO event characterized 2015. These lines of evidence suggest that fish from brood years 2013 and 2014 encountered very poor ocean conditions upon ocean entry that likely contributed to the low escapements in 2016 and 2017. The poor ocean conditions in 2014 and 2015 may have affected adult natural mortality for fish from brood years 2011 and 2012, but we lack the data to directly evaluate this.

Hatchery-origin fingerling survival rate estimates covering the period of time from hatchery release to early marine residence were generally well below average for all of the critical broods.

Overall, there were very low levels of recruitment to fisheries in 2015-2017. If fisheries were assessed and managed without error, the KRFC stock would still have met the criteria for overfished status, and would have nearly done so in the absence of any fishing. Thus assessment and management errors likely played a relatively small role in the overfished status of KRFC.

The exceptionally low abundance for brood year 2013 could be explained by a combination of poor conditions for rearing and outmigration in the river, high incidence of disease, and degrading ocean conditions in the year of ocean entry. Poor river conditions, high disease incidence, and a very warm, unproductive ocean also likely contributed to the weak 2014 brood. The low abundance observed for brood years 2011 and 2012 are more difficult to explain given the freshwater, marine, and fishery information analyzed in this report.

The relative contributions of individual factors that led to the overfished status cannot be determined given the existing data for KRFC. Yet, it is clear that both river and ocean conditions were not conducive to high survival rates for broods 2013 and 2014. The potential factors that led to the somewhat low abundance of the 2011 brood and the very weak 2012 brood are not readily apparent given the suite of indicators we examined here.

4.0 RECOMMENDATIONS FOR ACTION

4.1 Recommendation 1: Rebuilt Criterion

Consider the KRFC stock to be rebuilt when the 3-year geometric mean of natural-area adult escapement meets or exceeds S_{MSY}. This is the default rebuilt criterion in the FMP.

4.2 Recommendation 2: Management Strategy Alternatives

Recommend the Council adopt a management strategy (control rule) that will be used to guide management of fisheries that impact KRFC until rebuilt status is achieved. We offer three Alternative management strategies for consideration. The rebuilding time frame under each of the three Alternatives are not expected to exceed 10 years. The probability of achieving rebuilt status for years 1 through 10 are projected for the three Alternatives in Section 4.6 *Analysis of Alternatives*.

The description of Alternatives may include references intended to meet NEPA or MSA criteria. Guidelines suggest that alternatives are identified as either an 'action' or a no-action' alternative, and that the minimum time (T_{MIN}) and maximum time (T_{MAX}) estimated to achieve rebuilt status is acknowledged within the suite of alternatives.

Alternative I. Status quo control rule. During the rebuilding period continue to use the KRFC control rule and reference points, as defined in the FMP, to set maximum allowable exploitation rates on an annual basis. Projected rebuilding time is two years (see Section 4.6). This is considered a 'no-action' alternative, and represents T_{MAX}.

Alternative II. Status control rule with buffers on maximum exploitation rates and escapement-based reference points until rebuilt status is achieved. Specifically:

Reduce the maximum allowable exploitation rate by 20 percent (to 54.4 percent), increase the S_{MSY} escapement level by 20 percent (to 48,840 natural-area adult spawners), and maintain the current relationship between the increased S_{MSY} and MSST (MSST = $0.75 * S_{MSY} * 1.20$).

Under this Alternative, changes to the S_{MSY} and MSST reference points defined in the salmon FMP are not proposed. Rather, these values are modified only for the purpose of reducing exploitation rates relative to the status quo control rule (Alternative I). Projected rebuilding time is two years (see Section 4.6). This is considered an 'action' alternative.

Alternative III. Suspend all salmon-directed ocean and in-river fisheries in the area from Cape Falcon, Oregon south to Point Sur, California until rebuilt status is achieved. Projected rebuilding time is one year (see Section 4.6). This is considered an 'action' alternative, and represents T_{MIN}.

While the Council does not have jurisdiction over tribal and inriver recreational fisheries, this Alternative is provided to serve as a bookend in the analysis of rebuilding probabilities over a ten year period when assuming an exploitation rate of zero. This Alternative fulfills the requirement of National Standard 1 in calculating the minimum time (T_{MIN}) estimated to achieve rebuilt status.

4.3 Recommendation 3: Fall Fisheries

While the stock is rebuilding, consider eliminating, or limiting, post-September 1 "fall" ocean salmon fisheries. There are inherent uncertainties with fall fisheries as abundance forecasts are not yet available. Limiting fall fisheries is precautionary because fishing mortality is not incurred (or is limited) prior to obtaining a preseason abundance forecast for KRFC. Also, no or limited fall fisheries reduce the likelihood of heavily constrained fisheries in the spring and summer of the following year.

4.4 Recommendation 4: *de minimis* fisheries

While the stock is rebuilding, consider limiting *de minimis* fisheries specified by the control rule at low forecast abundance. The FMP provides a list of circumstances the Council shall consider when recommending *de minimis* exploitation rates, including whether the stock is currently overfished.

4.5 Recommendation 5: Habitat Committee

This report has identified that habitat conditions appear to have contributed to escapement shortfalls and thus the overfished status determination. It is recommended that the Council direct the Habitat Committee to work with tribal, federal, state, and local habitat experts to review the status of the essential fish habitat affecting the overfished stock and, as appropriate, provide recommendations to the Council for restoration and enhancement measures within a suitable time frame, as described in the FMP. We also recommend that the Council direct the Habitat Committee to evaluate the topics provided in Section 4.7*: Further Recommendations.* The habitat-related topics in that section lie outside the expertise of the STT and thus the Habitat Committee is better suited to conduct e review.

4.6 Analysis of Alternatives

The STT has developed a model to assess the probability of a stock achieving rebuilt status in the years following an overfished declaration. In this model, future abundance is based on a distribution fitted to past observed abundances, accounting for lag-1 autocorrelation (the dominant lag for KRFC). Realistic levels of error in abundance forecasts, escapement estimates, and exploitation rate implementation contribute to the projected adult spawner escapement. Replicate simulations are performed to allow for projecting of the probability of achieving rebuilt status by year. The model framework allows for evaluation of alternative rebuilding plans by specifying the rebuilding plans as alternative harvest control rules. Model structure, parameterization, and additional results are presented in Appendix B.

This model was applied to KRFC in order to provide projected rebuilding times. The projected rebuilding time is defined here as the number of years needed for the probability of achieving rebuilt status to meet or exceed 0.50. Given this assumption, rebuilding times are projected to be two, two, and one years for Alternatives I, II, and III, respectively (Table 4.6.a). The rebuilding probabilities in Table 4.6.a are displayed graphically in Figure 4.6.a. The buffered control rule, Alternative II (Figure 4.6.b), has intermediate rebuilding probabilities in each year relative to the status quo control rule (Alternative I) and no fishing (Alternative III). While a probability of 0.5 has been used here to define rebuilding times, the Council has the discretion to recommend a probability greater than 0.5 to be used for this purpose.

If there have been trends in productivity future, abundance may be more similar to recent abundance estimates than abundance estimates from early in the available time series. To address this, we considered a "recent abundance" scenario where future abundance was based on abundance estimates from the relatively recent past. Results for the "recent abundance" scenario are presented in Appendix B. In addition, simulations were performed under a scenario where abundance forecasts were potentially biased. Results for this scenario can also be found in Appendix B.

Table 4.6.a. Projected rebuilding probabilities by year for each of the Alternatives.

	Year									
	1	2	3	4	5	6	7	8	9	10
Alternative I	0.105	0.608	0.631	0.690	0.752	0.800	0.838	0.869	0.893	0.912
Alternative II	0.231	0.767	0.787	0.842	0.887	0.918	0.939	0.954	0.967	0.975
Alternative III	0.592	0.888	0.910	0.942	0.967	0.980	0.988	0.992	0.996	0.997

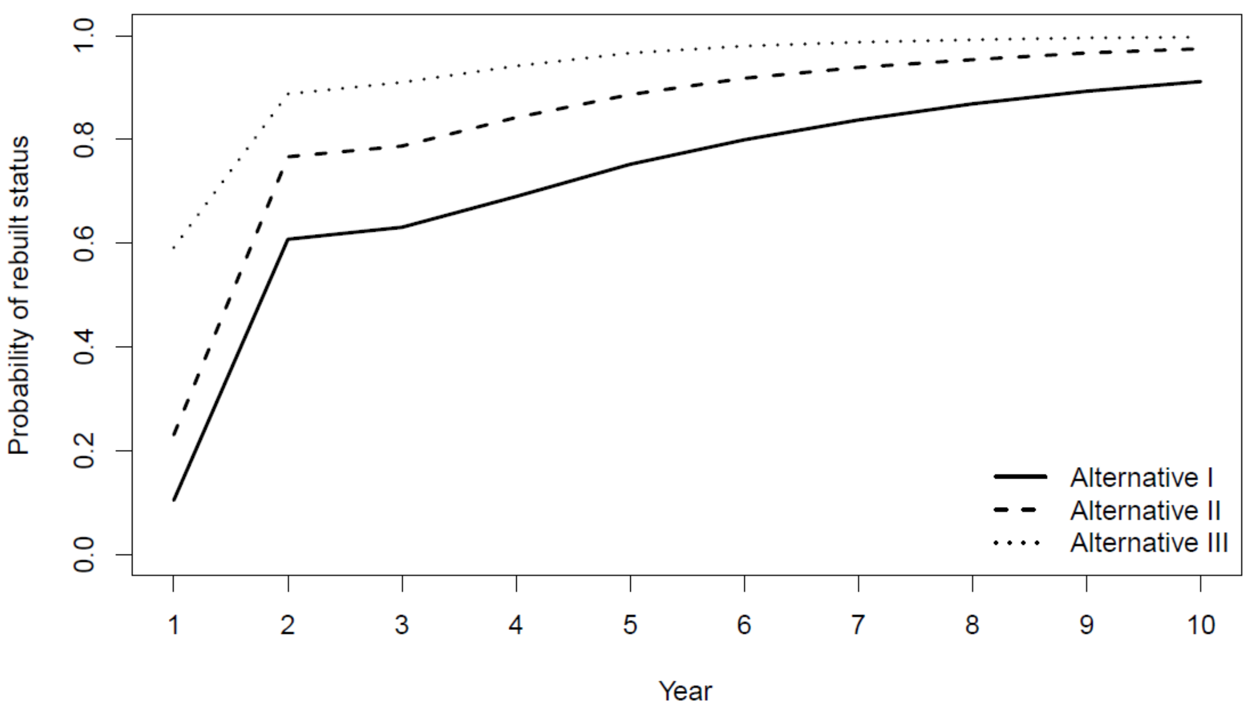

Figure 4.6.a. Projected probability of achieving rebuilt status by year under the three alternative rebuilding plans.

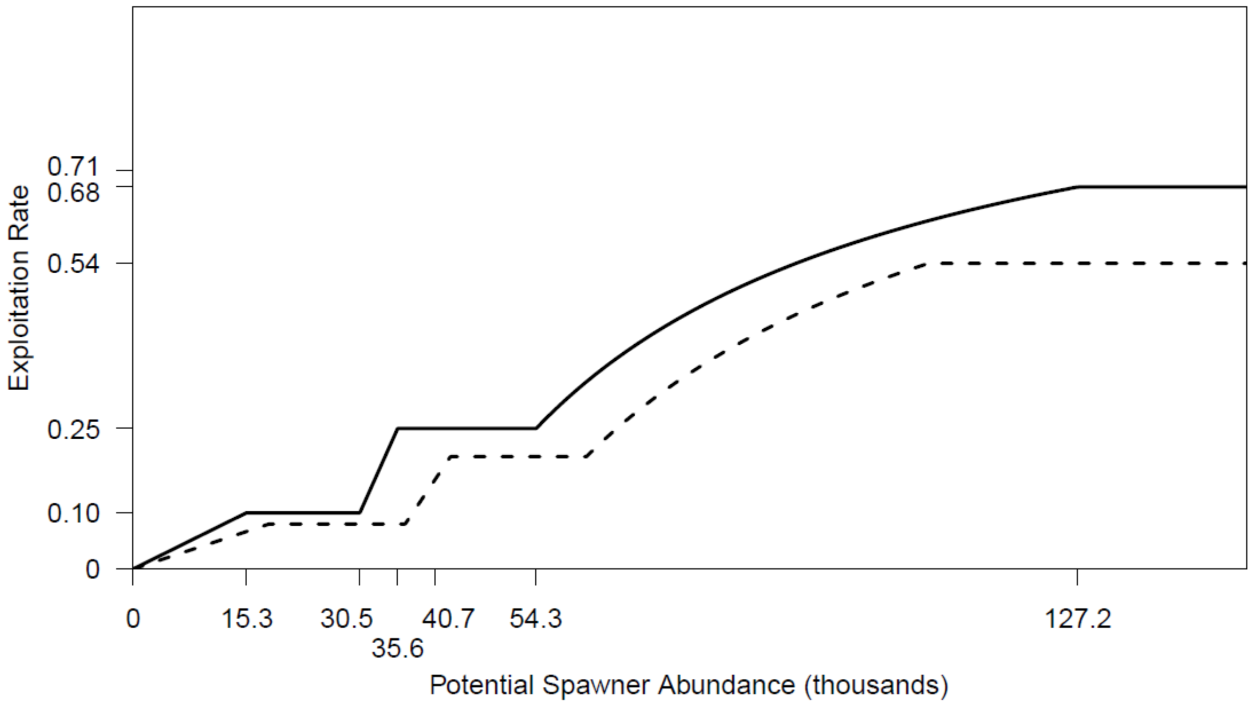

Figure 4.6.b. Control rules corresponding to Alternatives I (status quo, solid line) and II (buffered, dashed line). Alternative III (not pictured) is an exploitation rate of zero across all levels of potential spawner abundance.

The model described here was created to allow for a quantitative assessment of rebuilding alternatives. The tool has some elements of a management strategy evaluation (MSE), but lacks an explicit biological operating model. It relies on autocorrelated draws from an abundance distribution informed by past abundance levels. As such, no explicit population dynamics are included in the model. Data limitations and the short time frame for development of rebuilding plans did not allow constructing a more detailed operating model. The model also does not account for mixed-stock effects, where another stock could limit access to KRFC in ocean fisheries and prevent attainment of allowable exploitation rates. Rather, the model assumes that fisheries would be managed to target the exploitation rate specified by the control rule in each year and replicate simulation.

The probability of achieving rebuilt status for alternative rebuilding plans within a 10 year window is the core result of this analysis. The results for particular alternatives may be most useful if interpreted in a relative rather than absolute sense. Actual rebuilding periods may be somewhat shorter or longer than these results suggest due to the vagaries of future production and fisheries.

4.7 Further recommendations

1. Support management of flow in the Klamath River that can help ameliorate *C. shasta* infection rates and associated fish mortality. Such flow management includes providing high winter substrate mobilization flows and emergency "dilution" flows during the spring. In general, it appears that bed mobility in high winter flow events is a key river function that keeps the polychaete worm host of the disease from proliferating.

2. Support dam removal efforts in the Klamath Basin to provide increased cold water refugia. Although there is little that can be done to lower mainstem Klamath River water temperatures on a large scale, dam removal will provide access to cold water tributaries that are currently located out of reach above the dams, as well as access to large Cascade spring complexes such as exist near J.C. Boyle Dam. These refugia will provide relief from high water temperatures, and access to these cold water areas may lower prevalence of infection. Dam removal will also reconnect the sediment budget downstream of the dams, thereby increasing bed mobility and reducing the abundance of polychaete worms that are host to juvenile disease in the Klamath River.

5.0 SOCIO-ECONOMIC IMPACTS OF MANAGEMENT STRATEGY ALTERNATIVES

5.1 Approach to the Socio-economic Analysis and Benchmark/Baseline

The approach for the analysis is to provide the best information possible on the impacts of each of the alternatives (including both qualitative and quantitative information). This analysis will use recent levels of economic activity and personal income going back to 2004 as a benchmark to indicate the general magnitude of the impacts of the alternatives (the rationale for the timeframe used is discussed later in this section). Even under no action, the baseline (a projection of these benchmark values into the future) would likely vary from the economic activity occurring in recent years—for example, due to changing oceanographic and market conditions. However, development of a projection model for the baseline would be difficult and there would be a great deal of uncertainty about the results. These difficulties are exemplified by the current need for this rebuilding plans. Despite basing management on the best projection models scientists have been able to develop and setting regulations that appropriately manage for MSY spawner levels, certain stocks have declined to levels that meet the criteria for an overfished determination. Furthermore, quantifying the change in the baseline from historic conditions is not practical because of the numerous factors that interact to determine future fishing conditions, including the trends of multiple salmon stocks other than KRFC and a Council season setting process during which various biological, economic, and social factors are balanced in shaping each season and determining fishing opportunities. Thus, the baseline must be qualitative, but quantitatively informed by the benchmark. Since the baseline is difficult to predict, the information resulting from this analysis that is derived from benchmark information is more useful in describing the differences in impacts between the alternatives rather than the differences between any of the alternatives and the expected baseline (benchmark predicted into the future).

For the alternatives that would not change control rules or that would completely close fisheries south of Cape Falcon (Alternatives I and III, respectively), this is relatively straightforward. For the intermediate alternative (Alternative II), development of quantitative information to inform the assessment is more difficult and results of the analysis are therefore more indirectly informative. The challenges are both in predicting future year stock condition for not only KRFC but also the multiple other stocks that co-occur in the fishery. Each year the Council engages in an intensive public process in which it shapes seasons to optimize harvest by addressing allocation issues among various harvesting sectors and geographic areas while ensuring that the preseason expectation is that escapement objectives are met for all stocks. Therefore, for Alternative II (modified control rule), the approach that is taken is to address the following. First, is the question of whether this stock has typically been a constraint on ocean fisheries, i.e., historically, how frequently has the stock's status constrained ocean fisheries? To the degree that the stock has not or would not be a constraint, the short term economic impacts under a modified control rule would be minimal. Second, to what degree would the new control rule tighten that potential constraint, i.e., what is the effective percent reduction in exploitation rates that would result from the new control rule compared to the current rule for all possible stock abundance levels? Third, what is the effect of a tightening of the constraint for ranges of potential abundances that may be more likely, i.e., for the actual stock abundances observed in recent years (2004 to the present), how much of a reduction in the exploitation rates would the new rule require as compared to the current control rule (this analysis also involves applying the current control rule to years prior to when the current control rule was adopted)? And finally, looking retrospectively, for past years in which the stock was not constraining, would it likely have become constraining under the new control rule? This quantitative information is intended to provide a sense of the degree of potential constraint that would be likely under the new control rule in the context of the recent benchmark. This comparison is then used as a rough indicator of the magnitude of potential impact, quantitatively informing the qualitative assessment of impacts for Alternative II.

For purposes of describing the benchmark to inform the qualitative assessment of the baseline, data for port areas in California and Oregon south of Cape Falcon during 2004 to 2016 are used, excluding the two closure years (2008 and 2009) since those two years are not expected to be representative of possible outcomes under the current status quo control rule. There are currently five salmon rebuilding plans in development that are using the same 2004-2016 range for the economic analysis, including for three Washington coho stocks. The year 2016 was selected for the last year of the period because it was the most recent year for which data was available when models were developed. Years prior to 2004 are not included because quality of the coho data in those years was not as strong as the more recent years, and the desire to maintain consistency across plans. There are not strong reasons to deviate from using these same years across all five plans, and this consistency is expected to simplify review and comprehension of the analyses for both decision makers and the public. These years span recent history and provide a range of escapement levels that could reasonably be expected in future years, although due to ocean, climate and other conditions, the actual distribution may tend more toward one end of this spectrum than the other, or exhibit increased variability.

The main quantitative economic impact indicators used in this analysis are "personal income impacts." Personal income impacts are the personal income generated as a result of direct expenditures related to fishing (recreational and commercial), processing, and support industry activities. These include personal income earned directly by those participating in fishing and processing activities (including charter vessels providing recreational trips), personal income earned by those employed in businesses that supply and service commercial fishing, recreational fishing and processing support activities (e.g., fuel and bait suppliers and mechanics; also called indirect income), and the personal income generated by other businesses when those with direct and indirect income spend their money in the community (e.g. grocery stores and restaurants). Note that when fishing activity is reduced, personal income impacts may not be reduced proportionally because affected individuals may take up substitute economic activity in the same community. Additional information on the modeling and interpretation of personal income impacts (also termed community income impacts) is provided the Chapter IV of the most recent annual salmon review (PFMC,2018b).

It is important to recognize, that despite similarity in terminology, personal income impacts differ from the impacts of an alternative. Personal income impacts are the income associated with a particular activity, while the impacts of an alternative are the changes from status quo that occur as a result of implementing a new policy (an action alternative). For example, suppose that the personal income impacts associated with fishing under status quo are $10 million and those under an action alternative $9 million. Therefore the impact of the action alternative, as represented by the reduction or redistribution of personal income compared with status quo, would be $1 million.

Estimates of total personal income impacts in the affected coastal communities in California and Oregon south of Cape Falcon during the period for the non-tribal commercial ocean troll salmon fishery averaged approximately $25.6 million (in inflation-adjusted 2016 dollars), ranging from $4.6 million in 2010 to $57.6 million in 2004, and for the ocean recreational salmon fishery averaged approximately $19.9 million, ranging from $10.2 million in 2010 to $29.7 million in 2013. Total coastal community personal income impacts in the affected coastal communities in California and Oregon south of Cape Falcon from the combined non-tribal commercial troll and recreational salmon fisheries conducted in ocean areas therefore averaged approximately $45.6 million during the period, ranging from $14.8 million in 2010 to $85.1 million in 2004.[4]

For the five individual port areas in California, inflation-adjusted personal income impacts during the period from combined ocean non-tribal commercial troll and recreational salmon fisheries averaged approximately $5.3 million in Monterey, ranging from $1.9 million in 2016 to $11 million in 2005; $19.2 million in San Francisco, ranging from $3.9 million in 2010 to $36.9 million in 2004; $6.7 million in Fort Bragg, ranging from $2.4 million in 2010 to $12.8 million in 2013; $1.9 million in Eureka, ranging from $0.5 million in 2010 to $4.5 million in 2013; $0.5 million in Crescent City, ranging from $21 thousand in 2010 to $2.2 million in 2004.

For the four individual port areas in Oregon south of Cape Falcon, inflation-adjusted personal income impacts during the period from combined ocean non-tribal commercial troll and recreational salmon fisheries averaged approximately $1.3 million in Brookings, ranging from $0.4 million in 2016 to $2.4 million in 2004; $4.7 million in Coos Bay, ranging from $1.4 million in 2006 to $9.5 million in 2004; $4.5 million in Newport, ranging from $1.8 million in 2011 to $9.7 million in 2004; and $1.4 million in Tillamook, ranging from $0.7 million in 2016 to $2.4 million in 2014.

Excluding the two closure years (2008 and 2009), 2010 was the lowest year during the period for combined non-tribal ocean salmon fishery inflation-adjusted personal income impacts overall and for four of the nine affected port areas (San Francisco, Fort Bragg, Eureka and Crescent City). Three port areas experienced their lowest year in 2016 (Monterey, Brookings and Tillamook). The remaining two port areas experienced their lowest year in 2006 (Coos Bay) and 2011 (Newport).

[4] It is important to note that income impact estimates produced for years prior to the 2010 data year were derived using a different methodology than estimates for subsequent years. While strictly speaking, estimates produced using the two methodologies may not be directly comparable, for simplicity this limitation was overlooked for this analysis, since the change more or less equivalently affected both the commercial and recreational sectors and all port areas. A description of the transition to the current income impact methodology and comparisons of results from the earlier and current models are found in Appendix E of the Review of 2014 Ocean Salmon Fisheries.

The highest inflation-adjusted combined salmon fishery personal income impacts during the period overall was in 2004, which was also the highest year for five of the nine port areas (San Francisco, Crescent City, Brookings, Newport and Tillamook). The highest years for the other port areas were 2005 for Monterey, 2013 for Eureka and Fort Bragg, and 2014 for Tillamook. . Note that the Astoria port area is not included. While some catch from south of Cape Falcon is landed in Astoria, the predominance of landings are from the north of Cape Falcon area. Therefore, management changes in areas south of Cape Falcon to rebuild SRFC are anticipated to have a relatively lesser effect on Astoria than the other Oregon and California port areas.

Although not included in these economic impact estimates, KRFC are also taken in tribal net fisheries and recreational fisheries in the Klamath River and its tributaries, which also may contribute economically to the coastal communities and provide a benefit in addition to the economic contribution of the non-tribal ocean fisheries. Yurok and Hoopa Valley tribes share a federally-reserved right of 50 percent of the available harvest surplus of adult KRFC. During 2004-2016, Yurok and Hoopa Valley tribal harvests of adult KRFC averaged 30,474 fish, ranging from 95,386 fish in 2012 to 5,160 fish in 2016. During 2004-2016, excluding 2006 since retention of adult Chinook was prohibited that year), inriver recreational harvests averaged 6,272 KRFC, ranging from 19,800 fish in 2013 to 1,310 in 2016 (Table 3.3.2.a).

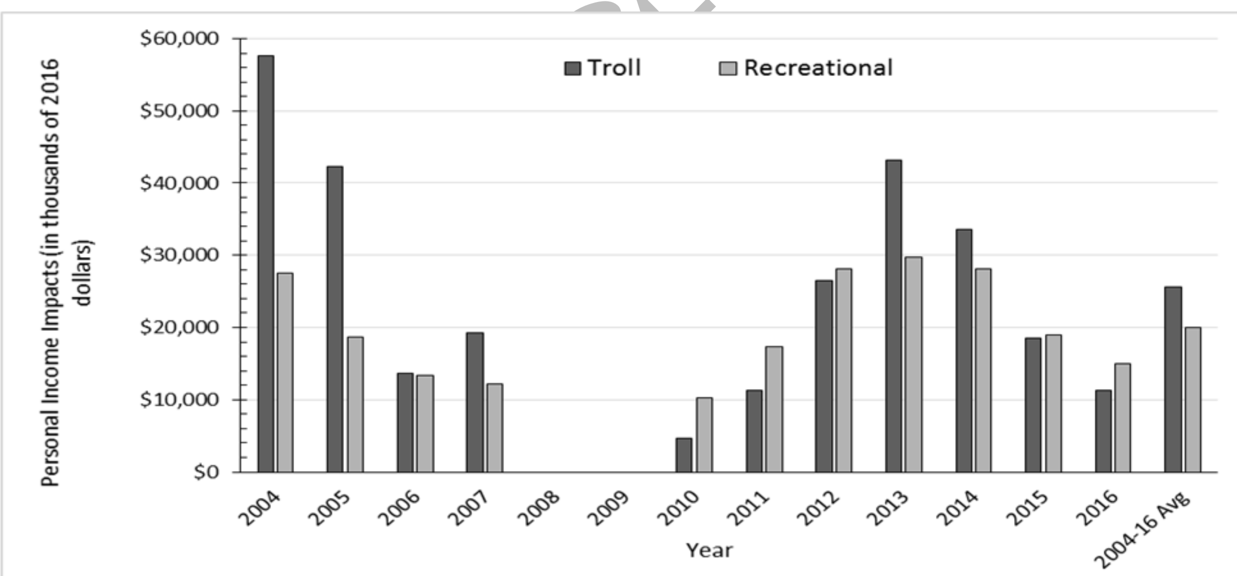

Figure 5.1.a. Estimates of total, aggregated personal income impacts in affected California and Oregon coastal communities south of Cape Falcon in thousands of real (inflation adjusted, 2016) dollars for the non-tribal commercial ocean troll and ocean recreational salmon fisheries.

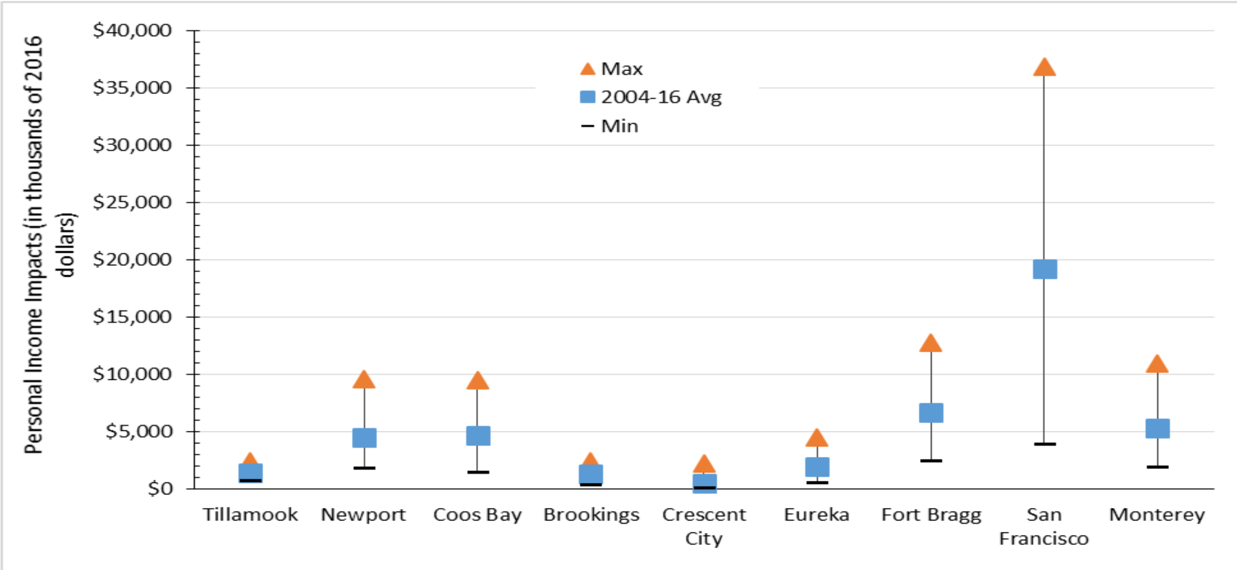

Figure 5.1.b. Estimates of personal income impacts by coastal community in thousands of real (inflation adjusted, 2016) dollars for the combined non-tribal commercial ocean troll and ocean recreational salmon fisheries in California and Oregon south of Cape Falcon.

Table 5.1.a. Estimates of personal income impacts by coastal community in thousands of real (inflation adjusted, 2016) dollars for the non-tribal commercial ocean troll and ocean recreational salmon fisheries for major California and Oregon port areas south of Cape Falcon.

OCEAN TROLL	Tillamook	Newport	Coos Bay	Brookings	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Total
2004	775	6,859	7,463	1,598	2,068	457	7,911	24,853	5,594	57,577
2005	1,336	5,713	5,660	1,340	154	465	5,767	14,360	7,537	42,332
2006	653	1,717	463	403	0	0	2,629	6,798	1,048	13,710
2007	439	715	2,085	830	354	877	3,625	8,651	1,764	19,338
2008	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-
2010	160	1,298	1,137	192	0	34	1,510	161	103	4,596
2011	59	531	2,366	264	36	442	4,247	2,690	655	11,290
2012	288	1,995	2,313	359	21	711	4,101	12,921	3,837	26,546
2013	496	1,570	6,675	625	111	1,746	10,203	19,792	2,008	43,226
2014	975	5,512	8,180	1,214	106	765	6,527	9,670	569	33,520
2015	650	2,633	3,810	515	27	440	5,175	4,409	836	18,495
2016	150	2,908	1,257	127	0	68	1,792	4,141	922	11,366
2004-16 Avg	**544**	**2,859**	**3,764**	**679**	**262**	**546**	**4,862**	**9,859**	**2,261**	**25,636**
Max	**1,336**	**6,859**	**8,180**	**1,598**	**2,068**	**1,746**	**10,203**	**24,853**	**7,537**	**57,577**
Min	**59**	**531**	**463**	**127**	**0**	**0**	**1,510**	**161**	**103**	**4,596**

RECREATIONAL	Tillamook	Newport	Coos Bay	Brookings	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Total
2004	1,447	2,788	2,077	800	145	1,162	2,315	12,035	4,724	27,493
2005	597	947	1,291	534	110	736	1,872	9,102	3,442	18,630
2006	703	744	923	454	65	726	1,543	6,184	2,072	13,414
2007	955	1,444	1,155	465	92	948	1,245	4,383	1,518	12,204
2008	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-
2010	745	1,309	333	339	21	449	927	3,757	2,344	10,224
2011	726	1,245	407	356	80	1,625	2,107	7,151	3,618	17,315
2012	688	1,434	679	1,080	827	2,816	2,123	12,602	5,914	28,163
2013	806	1,533	1,163	1,197	735	2,793	2,554	15,172	3,754	29,707
2014	1,432	3,723	1,154	1,003	473	2,015	2,561	12,258	3,505	28,122
2015	876	1,830	563	513	68	1,061	1,698	10,505	1,831	18,943
2016	585	771	422	238	59	1,038	1,319	9,669	926	15,026
2004-16 Avg	**869**	**1,615**	**924**	**634**	**243**	**1,397**	**1,842**	**9,347**	**3,059**	**19,931**
Max	**1,447**	**3,723**	**2,077**	**1,197**	**827**	**2,816**	**2,561**	**15,172**	**5,914**	**29,707**
Min	**585**	**744**	**333**	**238**	**21**	**449**	**927**	**3,757**	**926**	**10,224**

Combined	Tillamook	Newport	Coos Bay	Brookings	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Total
2004	2,222	9,647	9,540	2,397	2,213	1,619	10,225	36,888	10,318	85,071
2005	1,933	6,661	6,951	1,873	264	1,201	7,639	23,462	10,978	60,962
2006	1,357	2,460	1,386	856	65	726	4,172	12,982	3,120	27,124
2007	1,394	2,159	3,240	1,294	445	1,825	4,869	13,034	3,282	31,542
2008	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-
2010	905	2,606	1,471	531	21	484	2,438	3,918	2,446	14,821
2011	786	1,776	2,773	620	116	2,067	6,354	9,841	4,273	28,605
2012	976	3,430	2,992	1,438	848	3,527	6,224	25,523	9,751	54,709
2013	1,302	3,102	7,838	1,822	846	4,539	12,757	34,964	5,762	72,933
2014	2,407	9,235	9,334	2,217	579	2,780	9,088	21,927	4,074	61,642
2015	1,526	4,463	4,373	1,027	95	1,501	6,873	14,914	2,667	37,438
2016	735	3,679	1,679	365	59	1,106	3,111	13,809	1,849	26,392
2004-16 Avg	**1,413**	**4,474**	**4,689**	**1,313**	**505**	**1,943**	**6,704**	**19,206**	**5,320**	**45,567**
Max	**2,407**	**9,647**	**9,540**	**2,397**	**2,213**	**4,539**	**12,757**	**36,888**	**10,978**	**85,071**
Min	**735**	**1,776**	**1,386**	**365**	**21**	**484**	**2,438**	**3,918**	**1,849**	**14,821**

Income impact estimates from Review of 2017 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. Tables IV-16 and IV-17

5.2 Alternative I

Current management framework and reference points, as defined in the FMP, to set maximum allowable exploitation rates on an annual basis would remain in place. Domestic ocean fisheries impacting KRFC occur mainly in California and extend north into Oregon at least to Cape Falcon. These include ocean commercial and recreational fisheries and those tribal and recreational fisheries occurring inside the Klamath River estuary and drainage.

Status quo and Alternative I would not change harvest policy for KRFC; thus by definition there would be no direct or indirect economic impact from the rebuilding plan. The estimated timeframe needed to achieve rebuilt status (with a probability of at least 50 percent) under Alternative 1 exploitation rates is two years (Figure 4.6.a). The actual probability of rebuilding in two years or less is 61 percent and the probability of rebuilding in 6 years or less is 80 percent. Since harvest policy would not change, economic activity associated with Alternative I would not be expected to change from the baseline, and the general magnitude of that activity is reflected in the benchmark economic data provided in Section 5.1 (i.e., inflation-adjusted 2004-2016 average of $45.6 million per year in income from combined non-tribal ocean commercial and recreational salmon fisheries in the affected communities south of Cape Falcon). At the same time, note that actions under rebuilding plans for other salmon stocks may cause declines in the baseline.

Because there would likely be no differences in ocean regulations relative to the baseline, there would be no impact on other stocks and subsequent fishing opportunities and economic benefits.

Not including differences in short term impacts (impacts during the rebuilding period), the long-term impacts of Alternative I are expected to be similar to the other alternatives in that all the alternatives are expected to achieve rebuilding in a relatively few number of years.

5.3 Alternative II

Under Alternative II, rebuilding is estimated to occur with at least a 50 percent probability in two years, the same number of years as under status quo or Alternative I. The probability of rebuilding in two years or less is 77 percent (compared to 61 percent under Alternative I) and the probability of rebuilding in six years or less is 92 percent (compared to 80 percent under Alternative I). The cost of this increased probability of rebuilding is the reduced annual harvest opportunity times the number of years it takes to rebuild.[5] The baseline against which the reduction would be measured, and the general magnitude of that activity is reflected in the benchmark economic data provided in Section 5.1 (i.e., inflation-adjusted 2004-2016 average of $45.6 million per year in income from combined non-tribal ocean commercial and recreational salmon fisheries in the affected communities south of Cape Falcon). Additional detail is provided in Section 5.15. However, for Alternative II there are a number of uncertainties that must be taken into account in projecting harvest opportunities under reduced exploitation rates. These make it difficult to provide specific dollar value estimates for the reduced production expected under Alternative II. The challenges include the degree to which the Alternative II control rule for KRFC will constrain ocean harvest in a particular year relative to the constraints

[5] The analytical approach here is a quantitatively informed qualitative analysis. In an approach that was able to provide a more precise quantitative estimate of the expected annual changes in impacts, discount rates would be applied to the stream of expected changes.

imposed by other stocks and predicting the policy choices that the Council might make in its effort to balance maximization of harvest opportunity with between sector and geographic allocation issues (see additional discussion here and in Section 5.1).

The impact of the rebuilding policy in a particular year will depend first on the degree to which the new KRFC control rule constrains ocean regulations and harvest in a particular year. If KRFC is not constraining at either status quo or the Alternative II exploitation rates, then there would be no difference between Alternative I and II. The degree to w hich KRFC constrained ocean harvet in the past may indicate probability of constrains in the future (though the reduced exploitation rate control rule of Alternative II would increase the probability of constraint relative to the constraints shown in the historical data). Because of the large number of considerations that go into the deliberations on each year's salmon season it is sometimes difficult to determine with certainty whether or not KRFC was a constraint in any particular year. One indicator of whether SRFC was a constraint is to compare the projected spawning escapement to the spawning escapement goal. KRFC escapement equal to the goal would indicate a constraint on ocean fishery regulations, while excess escapement would indicate some stock other than KRFC was constraining ocean fisheries (first pair of columns of Table 5.3.a). While this approach might work fairly well for SRFC, Klamath in-river fisheries provide an opportunity to absorb excess escapement such that total escapement might have equaled the escapement goal even though ocean fisheries were not constraining. Expected harvest in the Klamath in-river recreational fishery that exceeds the minimum target for that fishery (generally 15 percent) might be an indicator that there was excess escapement from the ocean because a stock other than KRFC was constraining. These values are provided in the second pair of columns in Table 5.3.a. Another complicating factor is that KRFC 4-year olds serve as a proxy for ESA listed California coastal chinook stocks. Thus, even though abundance may be sufficient for the Klamath system escapement goals, if the number of KRFC 4-year olds is limited then KRFC could constrain ocean harvest on behalf of other coastal chinook stocks (third pair of columns in Table 5.3.a). However, the action alternatives would not alter the 4-year old ESA proxy escapement goals.

Table 5.3.a. Historic spawner reduction rate and minimum escapement rules and related preseason forecasts.

	Spawner Escapement		Spawner Reduction Rate		In -River Recreational Share		CA Coastal Chinook Proxy (Age-4 KRFC Ocean Harvest Rate)	
Year	Minimum Escapement	Pre-season Projection	Criteria	Pre-season Projection	Criteria	Pre-season Projection	Criteria	Pre-season Projection
2004	>35,000	35,000	<51.6%	51.6%	>15%	15.0%	<16%	15.0%
2005	>35,000	35,000	<19.7%	19.7%	>15%	15.0%	<16%	7.7%
2006	>35,000	21,100	<35.2	35.2%	>15%	0.0%	<16%	11.5%
2007	>35,000	35,000	<52.5%	52.5%	>15%	**26.0%**	<16%	16.0%
2008	>40,700	40,700	<47.1%	47.1%	>15%	**83.3%**	<16%	2.4%
2009	>40,700	40,700	*<50.1%*	50.1%	>15%	**99.6%**	<16%	<0.1%
2010	>40,700	40,700	*<52.8%*	52.8%	>15%	**34.6%**	<16%	12.3%
2011	>35,000	35,000	*<53.8%*	53.8%	>15%	**22.8%**	<16%	**16.0%**
2012	>86,300	86,300	<68.0%	68.0%	NA	**42.3%**	<16%	**16.0%**
2013	>73,800	73,800	<68.0%	68.0%	NA	**34.8%**	<16%	**16.0%**
2014	>40,700	40,700	<47.1%	47.1%	NA	15.1%	<16%	**16.0%**
2015	>40,700	40,700	<58.9%	58.9%	NA	**32.4%**	<16%	**16.0%**
2016	>30,909	30,909	<25%	25.0%	NA	15.0%	<16%	8.4%
2017	>11,379	11,379	<8.1%	8.1%	NA	15.9%	<16%	3.1%
2018	>40,700	40,700	<31.9%	31.9%	NA	**19.3%**	<16%	11.5%

Data from Table 5 of Preseason Report III for each year.
Note for 2006 River rec: 2005 California Fish and Game Commission specification; none specified for 2006. Equals 0.3 (thousand) adult fish catch and release mortality associated with other recreational inriver fisheries for anadromous species.

In determining whether KRFC was a constraint in a particularly year, it is helpful to examine other indicators and whether other stocks may have been constraining. Table 5.3.b displays the Klamath in river recreational fishery and KRFC age-4 escapement criteria as indicators of whether KRFC may have been constraining in a particular year. Table 5.3.b provides SRFC related management criteria and related preseason predictions to indicate whether other stocks may have been projected to be constraining in particular years. The last column of Table 5.3.b summarizes which stocks likely constrained development of the ocean harvest regulations in each year

Table 5.3.b. SRFC escapement criteria and winter run Chinook proxy criteria.

	SRFC		Winter Run Proxy (Age-3 Ocean Impact Rate in Fisheries South of Point Arena)		
Year	Min Escapement	Preseaon Projected Escapement	Control Rule	Preseaon Projection	Likely Constraint on Ocean Fishery Regulations
2004	122k-180k	457,500	NMFS ESA Guidance	Met	**KRFC**
2005	122k-180k	983,600	NMFS ESA Guidance	Met	**KRFC**
2006	122k-180k	368,000	NMFS ESA Guidance	Met	**KRFC**
2007	122k-180k	265,500	NMFS ESA Guidance	Met	CA Coastal Chinook
2008	122k-180k	59,000	NMFS ESA Guidance	Met	SRFC
2009	122k-180k	122,050	NMFS ESA Guidance	Met	SRFC
2010	180,000	180,000	NMFS ESA Guidance	Met	SRFC
2011	180,000	377,000	NMFS ESA Guidance	Met	CA Coastal Chinook
2012	≥245,820	455,800	≤13.7%	13.7%	CA Coastal Chinook; Winter Run Chin
2013	≥250,300	462,600	≤12.9%	12.9%	CA Coastal Chinook; Winter Run Chin
2014	≥190,395	314,700	≤15.4%	15.4%	**KRFC** (possibly), CA Coastal Chinook; Winter Run Chin
2015	≥195,600	341,000	≤19.0%	17.5%	CA Coastal Chinook
2016	≥122,000	151,100	≤19.9%	12.8%	**KRFC**
2017	≥122,000	133,200	≤15.8%	12.2%	**KRFC (possibly)**
2018	≥151,000	151,000	≤14.4%	8.5%	SRFC

On the basis of data shown in Table 5.3.a it seems likely that the rebuilding policy may result in additional constraints on ocean harvest in some years. For the 2004-2018 period, it appears that KRFC was likely constraining of the ocean fishery in 2004, 2005, 2006, 2016 and 2017 (conclusions summarized in last column of Table 5.3.b). It may also have been constraining in 2014, along with the proxy for listed California Chinook stocks. It appears that ocean constraints due to other stocks allowed for increased inside recreational fisheries (>15 percent) in 2007 through 2013, 2015, and 2018. Of these years, for 2007 and 2011 through 2015, there may have been an ocean harvest constraint based on the KRFC age-4 ocean harvest rate that serves as a proxy for listed California coastal chinook stocks. For 2008, 2009, and 2010, it appears that ocean fisheries may have been constrained by SRFC (Table 5.3.b). In 2012, 2013, and 2014 there may also have been winter run chinook constraints (Table 5.3.b).

The degree of constraint and resulting impacts under Alternative II might be indicated by the percentage reduction in the control rule exploitation rates. In general, Alternative II specifies a 20 percent reduction in exploitation rates. However, because the alternative also changes the thresholds used for applying *de minimis* exploitation rates, the percent change varies from 20 percent, as shown in Figure 5.3.a. Figure 5.3.a illustrates exploitation rates under Alternative II compared with status quo for a range of spawner abundance forecasts. Excluding from consideration very low abundance levels, the reductions shown in Figure 5.3.a range from a high of about 68 percent (at a potential spawner abundance in the absence of fishing of around 40,000 fish) to a low of about a 12 percent reduction (at around 107,000 fish).

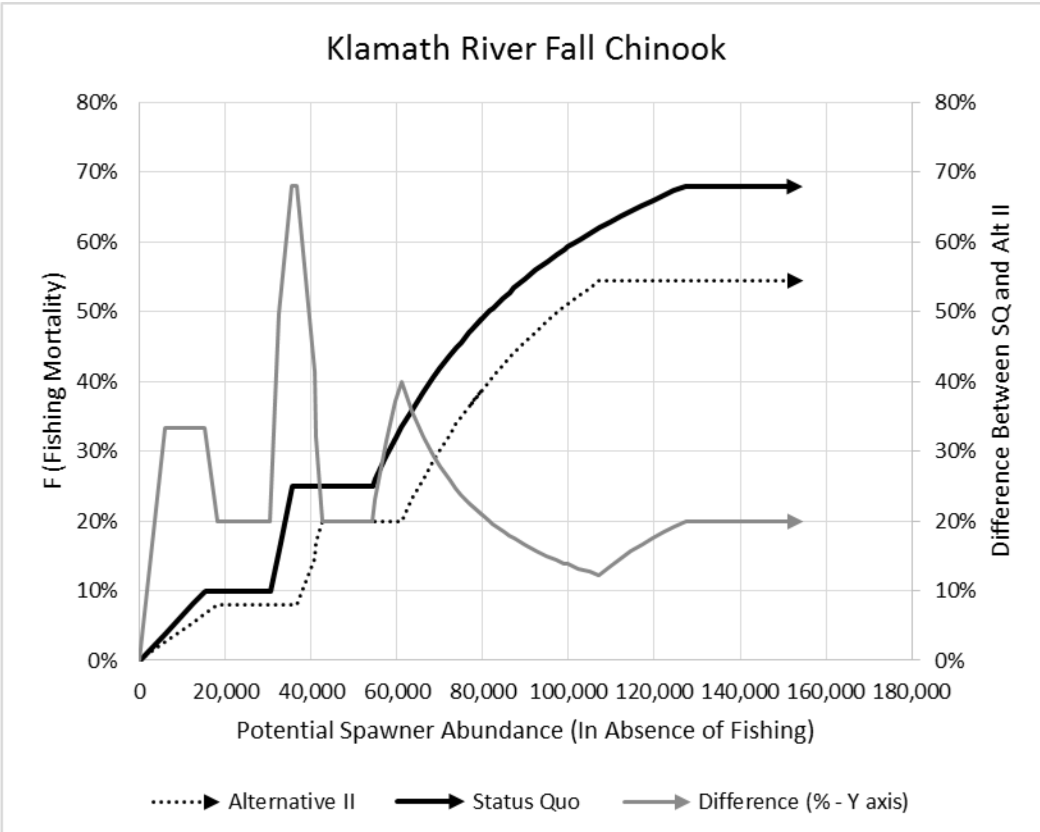

Figure 5.3.a. Comparison of Alternative II and Alternative I exploitation rate policies.

For any particular level of exploitation rate reduction, the Council will have numerous options for shaping ocean seasons. One approach might be to scale back all time-area openings proportionally by the percent reduction in the exploitation rate. With such an approach, a 20 percent reduction in exploitation rates would be expected to result in a reduction of economic benefits of about 20 percent (compared to no action). However, in order to mitigate the impact of reduced escapement, the Council is likely to shape seasons so that more of the reduction is taken in areas of higher stock impact, while at the same time taking allocation issues into consideration (such that harvest is not maximized to the degree it would be without these considerations). This shaping would reduce overall impacts by something less than would be projected based on proportional reductions in all times and areas. There are numerous alternative season shaping options that the Council could adopt to achieve the reductions, each with its own trade-off between total coastwide fishing opportunities and the burdens on sectors and/or local areas due to prioritizing the reductions in particular times and/or areas of higher impact.

Another indicator of the degree of impact that might be expected is a comparison of the exploitation rates that were in place (or for earlier years would have been in place under current policy) with those that would apply under Alternative II. The escapement rate objective in each year is determined by the potential spawner natural area abundance projection. Table 5.3.c provides a 15-year hindcast of the status quo policy and the Alternative II rebuilding policy. The percent difference column indicates the degree of additional constraint that Alternative II would have imposed and points to the magnitude of reductions in economic benefits that would be expected if the escapement rate objectives under Alternative II had been achieved through proportional reductions in all areas, without additional season shaping.

Table 5.3.c. Preseason predictions of potential spawner abundance (in the absence of fishing, 2004-2018) and a retrospective application of the corresponding exploitation rate policies for status quo/Alternative I and Alternative II (note the status quo policy was not in place prior to 2012).

Year	Potential Spawner Natural Area Abundance	Exploitation Rate Preseason Projection	Status Quo and Alternative I Exploitation Rate	Alt II Exploitation Rates	Percent Difference in Exploitation Rates
2004	72,337	51.6%	44%	32%	26%
2005	43,637	19.7%	25%	20%	20%
2006	32,526	35.2%	16%	8%	20%
2007	73,771	52.5%	45%	34%	25%
2008	76,891	47.1%	47%	36%	22%
2009	81,604	50.1%	50%	40%	20%
2010	86,186	52.8%	53%	43%	18%
2011	75,813	53.8%	46%	36%	23%
2012	269,649	68.0%	68%	54%	20%
2013	230,473	68.0%	68%	54%	20%
2014	76,952	47.1%	47%	37%	22%
2015	99,102	58.9%	59%	51%	14%
2016	41,211	25.0%	25%	17%	32%
2017	12,383	8.1%	8%	5%	33%
2018	59,733	31.9%	32%	20%	37%
Average (2004-2018)	**88,818**		**42%**	**33%**	**25%**

For 2004 through 2018, on average the reduction in exploitation rate would have been 25 percent. If all openings are reduced, on average, by 25 percent then the economic activity associated with the fishery would be expected to decline by 25 percent, assuming that stock abundances in the period of rebuilding are similar to the recent past. As discussed above, the years in which ocean fisheries appear to have been constrained by KRFC were 2004, 2005, 2006, 2014, 2016, and 2017.

For 2004 through 2006, the status quo/Alternative I exploitation rates would be lower than the policies in place during those years as reflected by the exploitation rate preseason projections relative to those for status quo/Alternative I. While 2007 through 2015 may have been constrained by other stocks historically, the retrospective application of the reduced exploitation rate policy of Alternative II (see the percent difference column of Table 5.3.c) may have shown that for some of those years KRFC could have been constraining.

Additionally, while the average reduction was 25 percent, there is substantial variability in the reductions depending on the stock abundance and whether KRFC is constraining. Given that the rebuilding periods are expected to be shorter, there may be more variability in the range than indicated by the longer term data series. For example, if the first two years of rebuilding are like 2015 and 2016, the reductions would be 14 percent and 32 percent, respectively, below the status quo exploitation rate policies (applied retrospectively back to 2004). Also, to the degree that

KRFC is not constraining of ocean fisheries, the average reduction in ocean fisheries attributed to the Alternative II KRFC rebuilding policy would be less than 25 percent.

At the same time, when KRFC is not constraining of ocean harvest, there would be greater inside fishing opportunities that would be reduced by the increased constraint under Alternative II.

These estimates should be considered upper bounds on the magnitude of economic effect under the action alternatives because it is assumed that equal, proportional management measures would be put in place for all ocean commercial and recreational fisheries in all affected areas along the coast, whereas past experience has shown that overall economic impacts may be mitigated in many cases by using an approach in which areas in the affected region are managed differentially depending on the degree of interaction between fisheries and stocks of concern in each area. Additionally, the economic contribution to coastal communities from in-river tribal and recreational fisheries in the Klamath River may also be effected by changes in ocean fisheries.

While historically KRFC have been constraining in most years, if under status quo policy there were a year in which it is not constraining, the degree of impact will depend on whether the reduction exploitation rate policy were enough to make the stock a constraint. For example, if the stock is not constraining but with a 5 percent reduction in the exploitation rate policy it becomes constraining, then the additional constraint of a 20 percent reduction would be 15 percent.

As mentioned above, to the degree that KRFC is not constraining of ocean harvest, there will be surplus escapement and increased opportunity for inside tribal and recreational fisheries. However, if ocean fisheries are not constrained by KRFC then the opportunities in inside fisheries will not be as great under Alternative II as they would be under status quo (Alternative I).

Alternative II (less than Alternative III) would increase escapement that may affect productivity of other stocks which may then also have economic impacts. Depending on spawner-recruit relationships, increased escapement of other stocks that results in increased spawning may positively or negatively impact long-term production and concurrent economic benefits.

The previous discussion is focused on characterizing short term differences in socio-economic impacts. Not including differences in short term impacts (impacts during the rebuilding period), the long-term impacts of Alternative II are expected to be similar to the other alternatives in that all the alternatives are expected to achieve rebuilding in a relatively few number of years.

5.4 Alternative III

Under Alternative III, there is at least a 50 percent probability that rebuilding would occur in year one, assuming an exploitation rate of zero during that time. For the duration of the rebuilding period, Alternative III would entirely eliminate south of Cape Falcon fisheries, which are associated with the benchmark income impact values, i.e., an inflation-adjusted 2004-2016 average of $45.6 million per year in income from combined non-tribal ocean commercial and recreational salmon fisheries in the affected communities. As discussed in Section 5.1 and for Alternative II in Section 5.3, substitute economic activity in coastal communities and increased inside fishing opportunities could make up for some of the potential loss. The total projected impact would be this annual impact multiplied by the number of years it takes to rebuild (if precise projections were being developed discount rates would also be applied reducing the weight of impacts in the more distant future relative to nearer term impacts).

While the 50 percent rebuilding probability level is reached in year one, the actual year one rebuilding probability is higher. There would be a 59 percent chance that rebuilding would occur in one year compared to a 23 percent chance under Alternative II and an 11 percent chance under Alternative I. Thus, there would also be some chance that rebuilding would require more than one year, thereby increasing the total short term impacts. For example, there would be an 89 percent chance that rebuilding would occur in two years or less, compared to a 77 percent chance under Alternative II and a 61 percent chance under Alternative I. And, the probability of rebuilding in 6 years or less is 98 percent, compared to a 92 percent chance under Alternative II and an 80 percent chance under Alternative I.

Alternative III (more than Alternative II) would also increase escapement that might benefit inside fisheries (e.g., Klamath in-river recreational fisheries) and may affect productivity of other stocks which may then also have economic impacts. Depending on spawner-recruit relationships, increased escapement of other stocks that results in increased spawning may positively or negatively impact long-term production and concurrent economic benefits.

Not including differences in short term impacts (impacts during the rebuilding period), the long-term impacts of Alternative III are expected to be similar to the other alternatives in that all the alternatives are expected to achieve rebuilding in a relatively few number of years.

5.5 Summary Economic Impact

The above estimates/indicators of short term impacts should be considered upper bounds on the magnitude of economic effect under the action alternatives because it is assumed that all ocean commercial and recreational time and area opportunities south of Cape Falcon would be reduced by the same proportions, whereas past experience has shown that overall economic impacts may be at least partially mitigated in many cases by using an approach in which fishery openings by area and sector in the affected region are managed differentially depending on the degree of interaction between fisheries and stocks of concern in each area. Additionally, the economic contribution to coastal communities from in-river recreational fisheries may also be affected by changes in ocean fisheries.

Table 5.5.a summarizes indications of the short-term economic trade-offs between the alternatives, assuming a 50 percent probability of rebuilding for each alternative. If rebuilding occurs more quickly (i.e., if a lower probability time to rebuilding occurs) then the impacts would be less than indicated, and if rebuilding occurs more slowly (i.e., if a higher probability time to rebuilding occurs) then the impacts would be greater than indicated. quantitative summary of Alternative II, in particular, must be understood in the context of the qualitative analysis which both describes the derivation of the percent reduction based on past average stock abundances (which may or may not be observed over the rebuilding period) and the Council's opportunity to mitigate some of the socio-economic impacts by season shaping, as discussed in the previous paragraph.

Table 5.5.a. Summary of economic impacts of the KRFC rebuilding alternatives

	Alt I	Alt II	Alt III
Rebuilding Time Based on a at least a 50% Rebuilding Probability	2 Years	2 Years	1 Years
Economic Impacts	None (no change from baseline)	Based on an average of the 2004-2018 hindcast years, a 25 percent reduction in ocean harvest-related economic activity each year during rebuilding period (as an upper bound). However, the upper bound values may range widely depending on stock abundances during rebuilding (12% to 68% reductions) the degree to which KRFC constrains ocean harvest., the degree to which other stocks constrain harvest, and how the Council balances harvest maximizing with sector and geographic allocation. There may be some offsets through substitute economic activity and gains in in-river fisheries. There may also be economic effects of increased escapement nof other stocks (either positive or negative).	Complete loss of SCF ocean harvest-related economic activity during rebuilding period (partially offset by gains through substitute economic activity and gains in in –river fisheries). There may also be economic effects of increased escapement of other stocks (either positive or negative and more than would occur under Alternative II).
Total Impacts (Years x Reduction in Economic Activity) (at least a 50% probability of rebuilding)	2 x (none) = 0 The probability of rebuilding in 2 years is 50% (a 61% probability for 2 years or less). There would be an 11% probability that it would take only one year to rebuild. The probability of taking three or more years would be 39%. Regardless of the rebuilding time, there would be no impact on economic benefits relative to the baseline.	2 x (economic effects of a 25% reduction in harvest, on average based on the hindcast--upper bound.) As noted above, in any particular year, the impacts would depend on the degree to which the stock was constraining in that year, other constraining stocks, how the Council balances maximizing harvest with allocation issues, and some small degree of partially offsetting gains. The probability of rebuilding in 2 years is 54% (a 77% probability for 2 years or less). There would be a 23% probability that it would take only one year to rebuild, in which case impacts would be projected at half the two year estimate. The probability of taking three or more years would be 21%.	1 x (complete losses of SCF ocean fishery + gains in-river) SCF Annual Personal Income Associated with the Fishery, 2004-2016 (Com and Rec) Average: $56,567,000 Max: $85,071,000 Min: $14,821,000 The probability of rebuilding in 1 year is 59%. There would be a 30% probability that it would take two years to rebuild, in which case impacts would be double the annual estimates provided here. The probability of taking three or more years would be 9%.

With respect to projecting Alternative II impacts, note that Table 5.3.b shows that while KRFC was constraining in only 6 out of the last 15 years, and SRFC was constraining in only as many as 4 out of the last 15 years, if rebuilding plans are implemented for both of these stocks at the same time the likelihood that one stock or the other would constrain ocean seasons increases. Either

KRFC or SRFC was constraining in 10 of the last 15 years, indicating the increased probability of a short term adverse economic impact from this policy. Additionally, while these stocks may not have been constraining in the other 5 years, it is possible that a hindcast would have indicated the possibility of a constraint in some of those years under the reduced exploitation rates that would be imposed under Alternative II.

6.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL EFFECTS OF MANAGEMENT STRATEGY ALTERNATIVES CONSIDERED

6.1 Introduction

This chapter will analyze the environmental impacts of the alternatives on the resources that would be more than minimally affected by the proposed action. This is a required component to adopt this integrated document as an environmental assessment under NEPA. The action area for the proposed action is the exclusive economic zone (EEZ), from three to 200 miles offshore of the coasts of Oregon and California, from Cape Falcon, Oregon to Point Sur, California. In this document, the action area and the analysis area are largely synonymous, exceptions are noted below.

6.2 Targeted Salmon Stocks

6.2.1 Affected Environment

Ocean salmon fisheries in the analysis area target Chinook salmon; recreational fisheries from Cape Falcon to the Oregon/California border also target coho salmon. Coho are not targeted south of the Oregon/California border and have not been legal to retain in California commercial and recreational fisheries since the 1990s.

The Council manages several stocks of Chinook salmon under the FMP (PFMC 2016). In the ocean, stocks of salmon comingle which results in mixed-stock fisheries. Non-target stocks, including ESA-listed stocks, will be encountered in mixed-stock fisheries. The Council's Salmon Technical Team (STT) models the degree to which target and non-target stocks are impacted by proposed fisheries, and the Council uses tools such as harvest restrictions, time and area closures, and mark-selective fisheries to limit impacts to non-target stocks (PFMC and NMFS 2017).

In the analysis area, the primary management tools are time and area closures and recreational bag limits; some fisheries also have quotas. The primary salmon stocks targeted in the analysis area are Sacramento River fall-run Chinook salmon (SRFC) and Klamath River fall-run Chinook salmon (KRFC). Southern Oregon Coast Chinook salmon are also considered a targeted stock. Fisheries in the analysis area are managed to meet FMP conservation objectives for these stocks, and to comply with ESA consultation requirements for any ESA-listed salmon stocks that are affected by salmon fisheries in the analysis area. As mentioned above, retention of coho in salmon fisheries off California has been unlawful since the 1990s.

Detailed information on spawning escapement and fisheries impacts on SRFC and KRFC are reported in the Council's annual Stock Assessment and Fishery Evaluation (SAFE) document, known as the Annual Review of Ocean Salmon Fisheries. These documents are available on the Council's website (www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/). Annual spawning escapement for these target stocks averaged 144,744 for SRFC and 50,571 for KRFC for the period 2007-2017 (PFMC 2018b and PFMC 2013).

6.2.2 Environmental Consequences of Alternatives on Target Salmon Stocks

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.3 Marine Mammals

6.3.1 Affected Environment

A number of non-ESA-listed marine mammal species occur in the analysis area. The non-ESA-listed marine mammal species that are known to interact with ocean salmon fisheries are California sea lion (*Zalophus californianus*) and harbor seals (*Phoca vitulina*), both species will feed on salmon, when available, and have been documented preying on hooked salmon in commercial and recreational fisheries (e.g., Weise and Harvey 1999). All marine mammals are protected under the Marine Mammal Protection Act (MMPA). Ocean salmon fisheries employ hook-and-line gear and are classified under NMFS' MMPA List of Fisheries as Category III (83 FR 5349, February 7, 2018), indicating there is no record of substantive impacts to marine mammals from these fisheries (MMPA 118(c)(1)).

ESA-listed marine mammal species that co-occur with Council-managed salmon fisheries include Guadalupe fur seal, southern sea otter, northern sea otter, and Southern Resident killer whale (SRKW). (S*ection incomplete*).

6.3.2 Environmental Consequences of Alternatives on Marine Mammals

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.4 ESA Listed Salmon Stocks

6.4.1 Affected Environment

Several ESUs of Pacific salmon that are ESA-listed as threatened or endangered occur in the areas where Council-managed ocean salmon fisheries occur. As stated above, the only salmon species encountered in fisheries in the action area are Chinook and coho salmon. ESA-listed Chinook and coho salmon ESUs that occur within the analysis area are listed in Table 6.4.1a.

Table 6.4.1.a. ESA-listed Chinook and coho salmon that occur within the analysis area.

ESA-listed ESUs	Status	Most recent citation
Chinook (*Oncorhynchus tshawytscha*)		
Sacramento River Winter-run	Endangered	70 FR 37160 (June 28, 2005)
Lower Columbia River	Threatened	70 FR 37160 (June 28, 2005)
Central Valley Spring-run	Threatened	70 FR 37160 (June 28, 2005)
California Coastal	Threatened	70 FR 37160 (June 28, 2005)
Coho (*Oncorhynchus kisutch*)		
Central California Coastal	Endangered	77 FR 19552 (April 2, 2012)
Southern Oregon/Northern California Coastal	Threatened	70 FR 37160 (June 28, 2005)
Oregon Coastal	Threatened	76 FR 35755 (June 20, 2011)
Lower Columbia River	Threatened	70 FR 37160 (June 28, 2005)

NMFS has issued biological opinions on the impacts of Council-managed salmon fisheries on ESA-listed salmon. Based on those biological opinions, NMFS provides guidance to the Council during the preseason planning process for setting annual management measures for ocean salmon fisheries based on the coming year's abundance projections. This guidance addresses allowable impacts on ESA-listed salmon. The Council structures fisheries to not exceed those allowable impacts. As mentioned above (section 6.2.1.), retention of coho in California fisheries is prohibited.

NMFS has previously consulted on the effects of Council-area salmon fisheries on the ESA-listed salmon ESUs in the analysis area, and has produced the biological opinions listed in Table 6.4.1.b.

Table 6.4.1.b. NMFS biological opinions regarding ESA-listed salmon ESUs likely to be affected by Council-area ocean salmon fisheries in the analysis area.

Date	Duration	Citation	Species Considered
28-Apr-99	Until reinitiated	NMFS 1999	S. Oregon/N. California Coasts coho Central California Coast coho Oregon Coast coho
28-Apr-00	Until reinitiated	NMFS 2000	Central Valley Spring-run Chinook California Coastal Chinook
13-Jun-05	Until reinitiated	NMFS 2005	California Coastal Chinook
26-Apr-12	Until reinitiated	NMFS 2012	Lower Columbia River Chinook
9-Apr-15	Until reinitiated	NMFS 2015	Lower Columbia River coho
30-Mar-18	Until reinitiated	NMFS 2018	Sacramento River winter-run Chinook

6.4.2 Environmental Consequences of Alternatives on ESA Listed Salmon Stocks

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.5 Non-target Fish Species

6.5.1 Affected Environment

Pacific halibut, and Pacific halibut fisheries, occur north of Point Arena, California. Reduced fishing opportunities in California for salmon and groundfish since 2006 have resulted in a shift of fishing effort toward halibut (CDFW 2017b). Halibut allocations are established annually in the International Pacific Halibut Commission's (IPHC) regulations and the PFMC's Area 2A Catch Sharing Plan (e.g., 82 FR 18581, April 20, 2017). Allocation of halibut quota to fisheries in the analysis area would not be affected by the Proposed Action, as the IPHC's halibut quota for the U.S. West Coast and the sub-area allocations set forth in the Catch Sharing Plan are set annually under separate processes from setting the annual salmon management measures.

Fisheries for coastal pelagic species (e.g., northern anchovy, market squid, Pacific sardine, Pacific mackerel, and jack mackerel), Dungeness crab, shrimp/prawns, and sea cucumbers occur in the analysis area and are managed by either NMFS and the PFMC (coastal pelagics) or the states (crab, shrimp/prawns, and sea cucumbers). The species targeted in these fisheries are not encountered in ocean salmon fisheries. It is possible that reductions in salmon fishing opportunities could result in a shift of effort toward these other species in California; however, we could not find any documentation to support this.

Fishermen that participate in salmon fisheries, both commercial and recreational, may also fish for groundfish (species such as rockfish and flatfish that live on or near the bottom of the ocean). Groundfish fisheries are managed under the Council's Groundfish FMP. Commercial salmon trollers that retain groundfish are considered to be participating in the open access groundfish fishery with non-trawl gear; therefore, they must comply with the regulations for the open access groundfish fishery. Likewise, recreational fishers that retain groundfish, must comply with recreational groundfish regulations. As fishery impacts to groundfish are managed under the Groundfish FMP and regulations, there would be no measurable effect on these species from the proposed action.

Albacore (Thunnus alalunga) is harvested on the West Coast, including the analysis area, by many of the same commercial and recreational fishermen that fish for salmon. Fishery impacts to albacore are managed under the Council's Highly Migratory Species FMP. Commercial and recreational fishers shift effort between salmon and albacore in response to available fishing opportunities, catch limits, angler demand (recreational fisheries), and changing prices for the species being harvested (commercial fisheries). As fishery impacts to albacore are managed under the Highly Migratory Species FMP and regulations, there would be no measurable effect on these species from the proposed action.

6.5.2 Environmental Consequences of Alternatives on Non-target Fish Species

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.6 Seabirds

6.6.1 Affected Environment

Numerous seabird species, as well as raptors, are protected under the Migratory Bird Treaty Act, including several species that are present in areas coincident with Pacific salmon. These seabirds include grebes, loons, petrels, albatrosses, pelicans, double-crested cormorants, gulls, terns, auks, and auklets (PFMC 2013c). ESA-listed seabird species include short-tailed albatross (endangered) and marbled murrelet (threatened). Interactions with the Pacific salmon fishery typically occur in two ways: when seabirds feed on outmigrating juvenile salmon, and when seabirds are entangled or otherwise interact with fishing gear or activities. Predation on juvenile salmon by seabirds is known to occur in estuarine environments, such as the lower Columbia River, as salmon smolts migrate downstream and into marine waters. We do not know the extent to which seabirds in the analysis area depend upon juvenile salmonids as prey. Council-managed ocean salmon fisheries are limited to hook-and-line tackle. Interactions with seabirds are uncommon in these fisheries.

6.6.2 Environmental Consequences of Alternatives on Seabirds

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.7 Ocean and Coastal Habitats and Ecosystem Function

6.7.1 Affected Environment

Salmon FMP stocks interact with a number of ecosystems along the Pacific Coast, including the California Current Ecosystem (CCE), numerous estuary and freshwater areas and associated riparian habitats. Salmon contribute to ecosystem function as predators on lower trophic level species, as prey for higher trophic level species, and as nutrient transportation from marine ecosystems to inland ecosystems. Because of their wide distribution in both the freshwater and marine environments, Pacific salmon interact with a great variety of habitats and other species of fish, mammals, and birds. The analysis area for the Proposed Action is dominated by the CCE. An extensive description of the CCE can be found in chapter three of the Council's Pacific Coast Fishery Ecosystem Plan (PFMC 2013c). Council managed salmon fisheries use hook and line gear, exclusively. This gear does not touch the ocean floor and does not disturb any habitat features. Therefore, salmon fisheries have no physical impact on habitat.

6.7.2 Environmental Consequences of Alternatives on Ocean and Coastal Habitats and Ecosystem Function

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.8 Cultural Resources

6.8.1 Affected Environment

As described in the FMP (section 5.3.3.1), the Yurok and Hoopa Valley Tribes of the Klamath River Basin have a federally protected right to the fishery resource of their reservations sufficient to support a moderate standard of living or 50 percent of the total available harvest of Klamath and Trinity River Basin salmon, whichever is less.

6.8.2 Environmental Consequences of Alternatives on Cultural Resources

{Section to be completed by NMFS after Council adopts a rebuilding plan}

6.9 Cumulative Impacts

{Section to be completed by NMFS after Council adopts a rebuilding plan}

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APPENDIX A - STATUS DETERMINATION CRITERIA

The following is an excerpt from the Salmon Fishery Management Plan

3.1 STATUS DETERMINATION CRITERIA

"Overfished. A stock or stock complex is considered ''overfished'' when its biomass has declined below a level that jeopardizes the capacity of the stock or stock complex to produce MSY on a continuing basis."

NS1Gs (600.310 (e)(2)(i)(E))

In establishing criteria by which to determine the status of salmon stocks, the Council must consider the uncertainty and theoretical aspects of MSY as well as the complexity and variability unique to naturally producing salmon populations. These unique aspects include the interaction of a short-lived species with frequent, sometimes protracted, and often major variations in both the freshwater and marine environments. These variations may act in unison or in opposition to affect salmon productivity in both positive and negative ways. In addition, variations in natural populations may sometimes be difficult to measure due to masking by hatchery produced salmon.

3.1.1 General Application to Salmon Fisheries

In establishing criteria from which to judge the conservation status of salmon stocks, the unique life history of salmon must be considered. Chinook, coho, and pink salmon are short-lived species (generally two to six years) that reproduce only once shortly before dying. Spawning escapements of coho and pink salmon are dominated by a single year-class and Chinook spawning escapements may be dominated by no more than one or two year-classes. The abundance of year-classes can fluctuate dramatically with combinations of natural and human-caused environmental variation. Therefore, it is not unusual for a healthy and relatively abundant salmon stock to produce occasional spawning escapements which, even with little or no fishing impacts, may be significantly below the long-term average associated with the production of MSY.

Numerous West Coast salmon stocks have suffered, and continue to suffer, from nonfishing activities that severely reduce natural survival by such actions as the elimination or degradation of freshwater spawning and rearing habitat. The consequence of this man-caused, habitat-based variation is twofold. First, these habitat changes increase large scale variations in stock productivity and associated stock abundances, which in turn complicate the overall determination of MSY and the specific assessment of whether a stock is producing at or below that level. Second, as the productivity of the freshwater habitat is diminished, the benefit of further reductions in fishing mortality to improve stock abundance decreases. Clearly, the failure of several stocks managed under this FMP to produce at an historical or consistent MSY level has little to do with current fishing impacts and often cannot be rectified with the cessation of all fishing.

To address the requirements of the MSA, the Council has established criteria based on biological reference points associated with MSY exploitation rate and MSY spawning escapement. The criteria are based on the unique life history of salmon and the large variations in annual stock abundance due to numerous environmental variables. They also take into account the uncertainty and imprecision surrounding the estimates of MSY, fishery impacts, and spawner escapements. In recognition of the unique salmon life history, the criteria differ somewhat from the general guidance in the NS1 Guidelines (§600.310).

3.1.4 Overfished

"For a fishery that is overfished, any fishery management plan, amendment, or proposed regulations… for such fishery shall (A) specify a time period for ending overfishing and rebuilding the fishery that shall:(i) be as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of the fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock within the marine ecosystem; and (ii) not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise…."

Magnuson-Stevens Act, §304(e)(4)

A stock will be considered overfished if the 3-year geometric mean of annual spawning escapements falls below the MSST, where MSST is generally defined as $0.5*S_{MSY}$ or $0.75*S_{MSY}$, although there are some exceptions (Table 3-1). Overfished determinations will be made annually using the three most recently available postseason estimates of spawning escapement.

3.1.4.1 Council Action

When the overfished status determination criteria set forth in this FMP have been triggered, the Council shall:

1) notify the NMFS NWR administrator of this situation;
2) notify pertinent management entities;
3) structure Council area fisheries to reduce the likelihood of the stock remaining overfished and to mitigate the effects on stock status;
4) direct the STT to propose a rebuilding plan for Council consideration within one year.

Upon formal notification from NMFS to the Council of the overfished status of a stock, a rebuilding plan must be developed and implemented within two years.

The STT's proposed rebuilding plan shall include:

1) an evaluation of the roles of fishing, marine and freshwater survival in the overfished determination;
2) any modifications to the criteria set forth in section 3.1.6 below for determining when the stock has rebuilt,
3) recommendations for actions the Council could take to rebuild the stock to S_{MSY}, including modification of control rules if appropriate, and;
4) a specified rebuilding period.

In addition, the STT may consider and make recommendations to the Council or other management entities for reevaluating the current estimate of S_{MSY}, modifying methods used to forecast stock abundance or fishing impacts, improving sampling and monitoring programs, or changing hatchery practices.

Based on the results of the STT's recommended rebuilding plan, the Council will adopt a rebuilding plan for recommendation to the Secretary. Adoption of a rebuilding plan will require implementation either through an FMP amendment or notice and comment rule-making process. Subject to Secretarial approval, the Council will implement the rebuilding plan with appropriate actions to ensure the stock is rebuilt in as short a time as possible based on the biology of the stock but not to exceed ten years, while taking into consideration the needs of the commercial, recreational and tribal fishing interests and coastal communities. The existing control rules provide a default rebuilding plan that targets spawning escapement at or above MSY, provided sufficient recruits are available, and targets a rebuilding period of one generation (two years for pink salmon, three years for coho, and five years for Chinook). If sufficient recruits are not available to achieve spawning escapement at or above MSY in a particular year, the control rules provide for the potential use of *de minimis* exploitation rates that allow continued participation of fishing communities while minimizing risk of overfishing. However, the Council should consider the specific circumstances surrounding an overfished determination and ensure that the adopted rebuilding plan addresses all relevant issues.

Even if fishing is not the primary factor in the depression of the stock, the Council must act to limit the exploitation rate of fisheries within its jurisdiction so as not to limit rebuilding of the stock or fisheries. In cases where no action within Council authority can be identified which has a reasonable expectation of contributing to the rebuilding of the stock in question, the Council will identify the actions required by other entities to recover the depressed stock. Due to a lack of data for some stocks, environmental variation, economic and social impacts, and habitat losses or problems beyond the control or management authority of the Council, it is possible that rebuilding of depressed stocks in some cases could take much longer than ten years. The Council may change analytical or procedural methodologies to improve the accuracy of estimates for abundance, harvest impacts, and MSY escapement levels, and/or reduce ocean harvest impacts when it may be effective in stock recovery. For those causes beyond Council control or expertise, the Council may make recommendations to those entities which have the authority and expertise to change preseason prediction methodology, improve habitat, modify enhancement activities, and re-evaluate management and conservation objectives for potential modification through the appropriate Council process.

In addition to the STT assessment, the Council may direct its Habitat Committee (HC) to work with federal, state, local, and tribal habitat experts to review the status of the essential fish habitat affecting the overfished stock and, as appropriate, provide recommendations to the Council for restoration and enhancement measures within a suitable time frame. However, this action would be a priority only if the STT evaluation concluded that freshwater survival was a significant factor leading to the overfished determination. Upon review of the report from the HC, the Council will consider appropriate actions to promote any solutions to the identified habitat problems.

3.1.5 Not Overfished-Rebuilding

After an overfished status determination has been triggered, once the stock's 3-year geometric mean of spawning escapement exceeds the MSST, but remains below S_{MSY}, or other identified rebuilding criteria, the stock status will be recognized as "not overfished-rebuilding". This status level requires no Council action, but rather is used to indicate that stock's status has improved from the overfished level but the stock has not yet rebuilt.

3.1.6 Rebuilt

The default criterion for determining that an overfished stock is rebuilt is when the 3-year geometric mean spawning escapement exceeds S_{MSY}; the Council may consider additional criteria for rebuilt status when developing a rebuilding plan and recommend such criteria, to be implemented subject to Secretarial approval.

Because abundance of salmon populations can be highly variable, it is possible for a stock to rebuild from an overfished condition to the default rebuilding criterion in as little as one year, before a proposed rebuilding plan could be brought before the Council.

In some cases it may be important to consider other factors in determining rebuilt status, such as population structure within the stock designation. The Council may also want to specify particular strategies or priorities to achieve rebuilding objectives. Specific objectives, priorities, and implementation strategies should be detailed in the rebuilding plan.

3.1.6.1 Council Action

When a stock is determined to be rebuilt, the Council shall:

1) notify the NMFS NWR administrator of its finding, and;
2) notify pertinent management entities.

3.1.7 Changes or Additions to Status Determination Criteria

Status determination criteria are defined in terms of quantifiable, biologically-based reference points, or population parameters, specifically, S_{MSY}, MFMT (F_{MSY}), and MSST. These reference points are generally regarded as fixed quantities and are also the basis for the harvest control rules, which provide the operative guidance for the annual preseason planning process used to establish salmon fishing seasons that achieve OY and are used for status determinations as described above. Changes to how these status determination criteria are defined, such as MSST = $0.50*S_{MSY}$, must be made through a plan amendment. However, if a comprehensive technical review of the best scientific information available provides evidence that, in the view of the STT, SSC, and the Council, justifies a modification of the estimated values of these reference points, changes to the values may be made without a plan amendment. Insofar as possible, proposed reference point changes for natural stocks will only be reviewed and approved within the schedule established for salmon methodology reviews and completed at the November meeting prior to the year in which the proposed changes would be effective and apart from the preseason planning process. SDC reference points that may be changed without an FMP amendment include: reference point objectives for hatchery stocks upon the recommendation of the pertinent federal, state, and tribal management entities; and Federal court-ordered changes. All modifications would be documented through the salmon methodology review process, and/or the Council's preseason planning process.

APPENDIX B - MODEL DESCRIPTION

Introduction

Salmon rebuilding plans must include, among other requirements, a specified rebuilding period. In addition, the National Environmental Policy Act (NEPA) analysis of rebuilding plans requires the development of rebuilding plan alternatives. In past assessments, the rebuilding period and alternative rebuilding plans were developed using expert knowledge, with no particular quantitative assessment. Beginning in 2018, the Salmon Technical Team (STT) developed a simple tool to assess the probability of a stock achieving rebuilt status in each year following an overfished declaration. Here we describe this model and provide additional results for the Klamath River fall Chinook (KRFC) salmon stock.

Methods

The methods described here are for a single replicate simulation.

For KRFC, there is substantial evidence for positive lag-1 autocorrelation in abundance (defined as the natural-area adult escapement in the absence of fisheries, K) on the log scale, with autocorrelation coefficient $\rho = 0.532$. To account for this, model log-scale abundance, $\log(N_t)$, is characterized by lag-1 autocorrelated draws from a Normal distribution with parameters estimated from the K series. Simulated abundance $\log(N_t)$ is thus a function of $\log(N_{t-1})$, ρ, and the distribution of past abundance on the log scale,

$$\log(N_t) = \rho[\log(N_{t-1})] + (1-\rho)Y_t, \tag{1}$$

with Y_t a random draw from the distribution

$$Y_t \sim \text{Normal}\left[\log(\overline{\text{K}}) - 0.5\sigma^2_{\log(\text{K})}, \sqrt{\frac{(1-\rho^2)\sigma^2_{\log(\text{K})}}{(1-\rho)^2}}\right] \tag{2}$$

and where $\overline{\text{K}}$ is the arithmetic mean of the observed K time series and $\sigma^2_{\log(\text{K})}$ is the variance of the log-transformed K time series. The standard deviation term in Equation 2 is the standard deviation of a sum of two random variables. Simulated log-scale abundance in year *t* is then back-transformed to the arithmetic scale, $N_t = \exp[\log(N_t)]$.

The forecast abundance ($\widehat{N}$) is drawn from a lognormal distribution,

$$\widehat{N}_t \sim \text{Lognormal}[\log(N_t) - 0.5\sigma^2_{\log(\widehat{N})},\ \sigma_{\log(\widehat{N})}] \tag{3}$$

with the bias corrected mean and standard deviation specified on the log scale. The log-scale standard deviation was calculated as

$$\sigma_{\log(\hat{N})} = \sqrt{\log\left(1 + \mathrm{CV}_{\hat{N}}^2\right)} \quad (4)$$

with $\mathrm{CV}_{\hat{N}}$ representing the coefficient of variation for the abundance forecast. $\mathrm{CV}_{\hat{N}}$ is a model parameter that defines the degree of abundance forecast error.

The forecast abundance $\hat{N}_t$ is applied to the harvest control rule to determine the allowable exploitation rate, $\hat{F}_t$. The hat notation for $\hat{F}$ indicates that this exploitation rate is a target exploitation rate that is derived from an abundance forecast.

Adult spawner escapement E_t is thus

$$E_t = N_t \times (1 - F_t) \quad (5)$$

where N_t is the "true" abundance and F_t is the realized exploitation rate. The realized exploitation rate is a random draw from the beta distribution

$$F \sim \mathrm{Beta}(\alpha, \beta) \quad (6)$$

with parameters

$$\alpha = \frac{1 - \hat{F}_t(1 + \mathrm{CV}_F^2)}{\mathrm{CV}_F^2} \quad (7)$$

and

$$\beta = \frac{\frac{1}{\hat{F}_t} - 2 + \hat{F}_t + \left(\hat{F}_t - 1\right)\mathrm{CV}_F^2}{\mathrm{CV}_F^2}. \quad (8)$$

The coefficient of variation for the exploitation rate implementation error, CV_F, is a model parameter that determines the degree of error between the target and realized exploitation rates.

Because escapement is estimated with error, escapement estimates $\hat{E}_t$ are drawn from a lognormal distribution,

$$\hat{E} \sim \mathrm{Lognormal}[\log(E_t) - 0.5\sigma_{\log(\hat{E})}^2,\ \sigma_{\log(\hat{E})}] \quad (9)$$

where the bias corrected mean and standard deviation are specified on the log scale. The log-scale standard deviation was computed in the same manner as Equation 4.

The procedure described above is repeated for each year (years 1 through 10 following the overfished status determination), and each replicate. Simulations are initiated with the 2018 estimated abundance; simulated abundance in t = 1 is therefore a function of the 2018 abundance, the autocorrelation coefficient, and a draw from the abundance distribution (Equation 1).

A stock is assumed to be rebuilt when the geometric mean of $\hat{E}$ computed over the previous three years exceeds the maximum sustainable yield spawner escapement, S_{MSY}. The probability of achieving rebuilt status in year t is the cumulative probability of achieving a 3-year geometric mean greater than or equal to S_{MSY} by year t.

Results

Results for KRFC presented here are the product of 10,000 replicate simulations of 10 years. The probability of being rebuilt in year t = 1 is the proportion of the 10,000 simulations that resulted in the geometric mean of the estimated natural-area adult KRFC escapement in t = -1 (19,904: the 2017 natural-area adult escapement), the estimated escapement in t = 0 (53,624: the 2018 natural-area adult escapement), and the simulated natural-area adult escapement estimate in year t = 1 (2019) exceeding S_{MSY}. For t = 2, the probability of being rebuilt is the probability that the stock was rebuilt in either t = 1 or t = 2.

Table 4.6.a and Figure 4.6.a in the body of the report display the probabilities of achieving rebuilt status under three management strategies: (I) the status quo control rule, (II) a buffered control rule (Figure 4.6.b), and (III) no fishing. For these simulations the following parameter values were assumed: $\mathrm{CV}_{\hat{N}} = 0.2$, $\mathrm{CV}_{\hat{E}} = 0.2$, and $\mathrm{CV}_{F} = 0.1$. The parameter values were chosen because they produce plausible levels of abundance forecast error, escapement estimation error, and implementation error for realized exploitation rates.

Rebuilding probabilities were also computed for the status quo control rule under an increased CV of the abundance forecast error ($\mathrm{CV}_{\hat{N}} = 0.6$), the escapement estimation error CV ($\mathrm{CV}_{\hat{E}} = 0.5$), and the CV of the exploitation rate implementation error (CV_{F} = 0.2). Figure 1 displays distributions of the abundance forecast error, escapement estimation error, and exploitation rate implementation error given the base case CVs and the CVs used for the alternative scenarios. Figure 2 displays results for these alternative scenarios under the status quo control rule. Overall, the probability of achieving rebuilt status by year is relatively insensitive to increased values of these parameters.

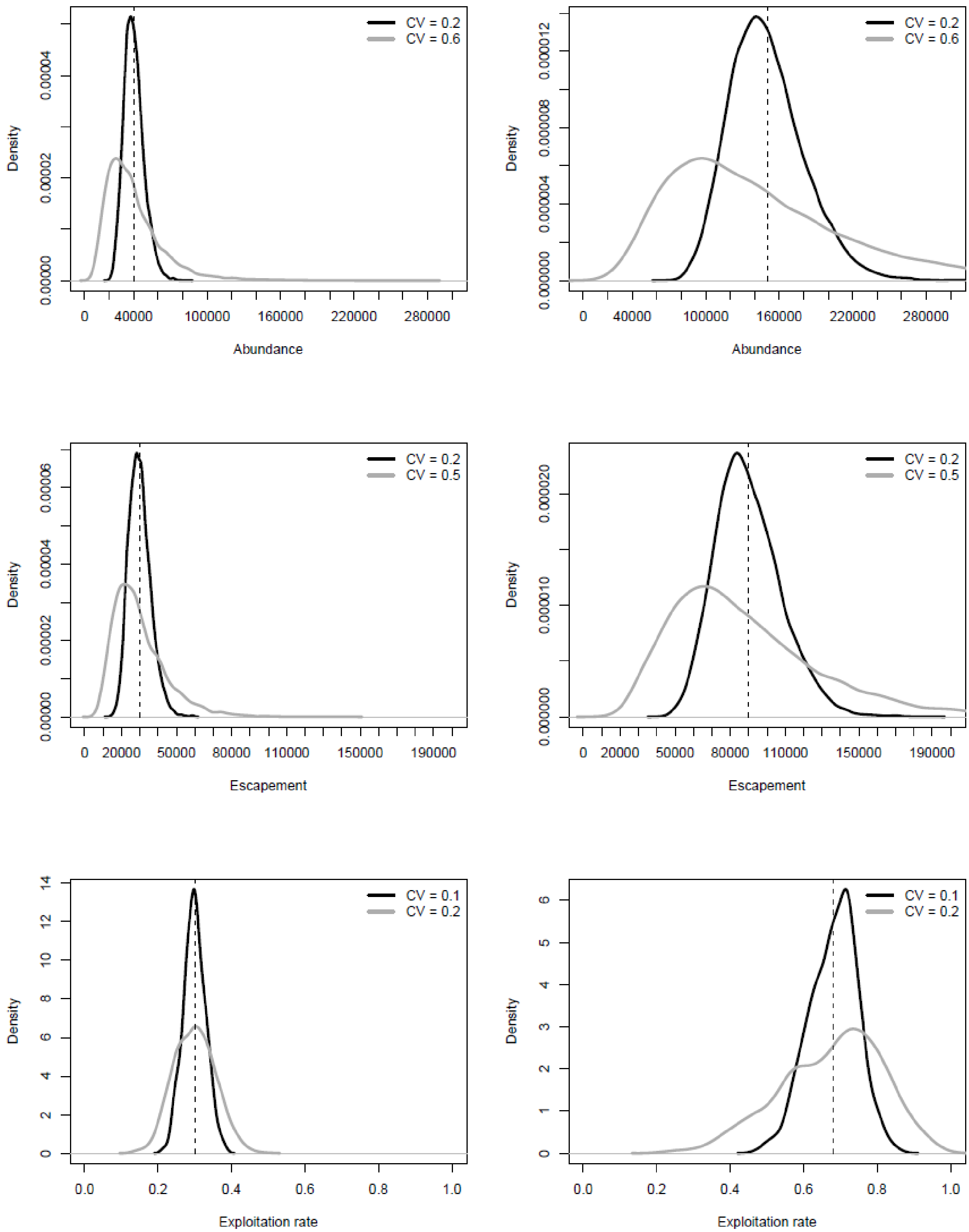

Figure 1. Distributions of the forecast abundance (top row), estimated escapement (middle row), and realized exploitation rate (bottom row) under different levels of known abundance, known escapement, and predicted exploitation rate. Known values are indicated by vertical dashed lines.

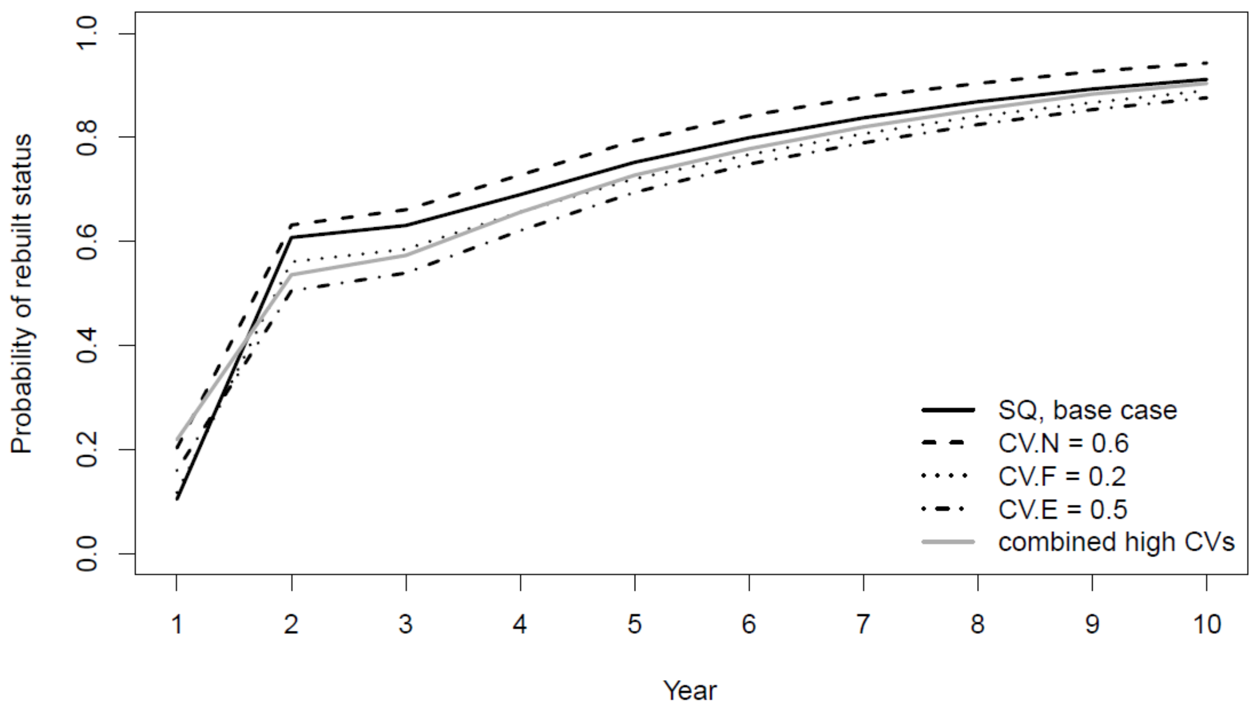

Figure 2. Probability of achieving rebuilt status in years 1 through 10 for the status quo control rule (Alternative I), given different parameter values.

Simulations were also performed assuming biased abundance forecasts. Bias was incorporated by modifying the log-scale mean term in Equation 3 by adding the log of the observed ratio of the preseason forecast of K to the postseason estimate of K. Thus, the mean term in Equation 3 becomes $\log(N_t) - 0.5\sigma^2_{\log(\hat{N})} + \log(r)$, where r is a draw (with replacement) from the set of 17 ratios of forecast to observed K. On the arithmetic scale this ratio ranges from 1.87 to 0.52 and r > 1 in 9 of 17 years. Figure 3 displays the effect of including this potential bias in abundance forecasts for KRFC, given management under the status quo control rule. Overall, there was little apparent bias in the abundance forecasts and therefore little difference in rebuilding probabilities when potential bias was accounted for.

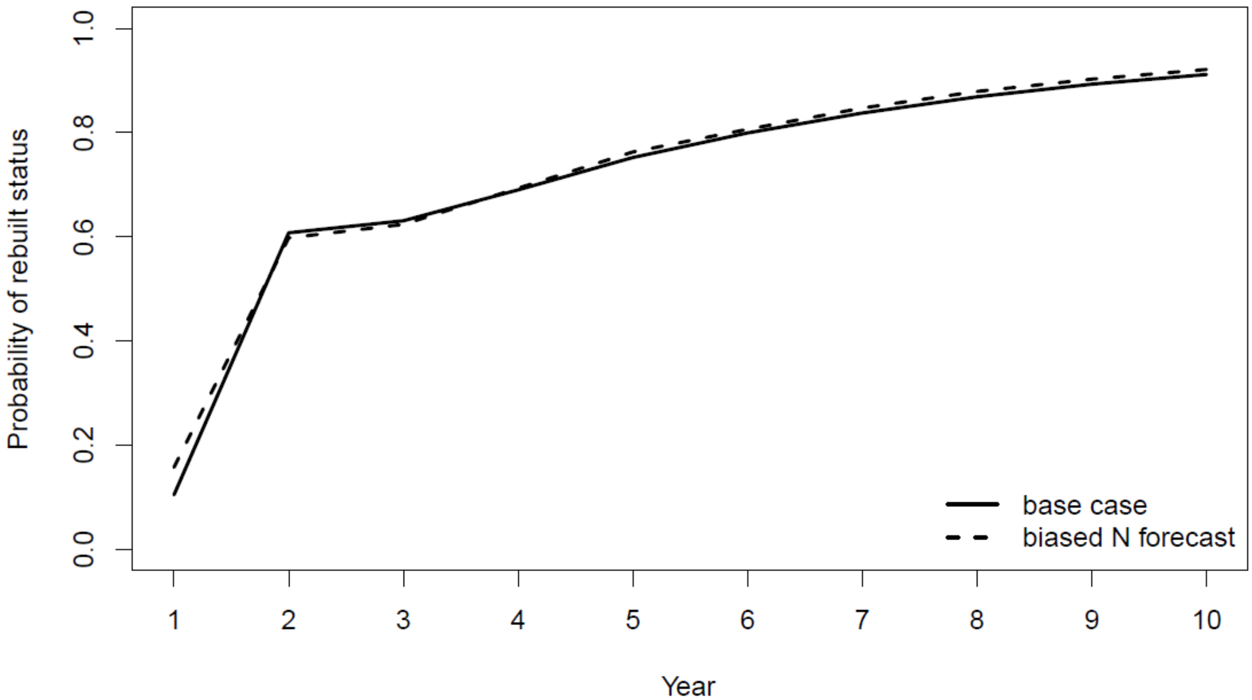

Figure 3. Probability of achieving rebuilt status under unbiased abundance forecasts and forecasts that are potentially biased.

Finally, a "recent abundance" scenario was considered. For the simulations described thus far the log-scale mean abundance, standard deviation of abundance, and autocorrelation coefficient have been estimated from the entire 1985-2018 set. For the recent abundance scenario, the mean and log-scale standard deviation are estimated over a more contemporary set of years, while the autocorrelation coefficient is estimated over the entire K time series. Figure 4 displays results for the recent abundance scenario, where mean and log-scale standard deviation were estimated over years 2004-2018. The probability of achieving rebuilt status is similar when contemporary levels of abundance, and variation in abundance, are assumed (compare Figure 4 to Figure 4.6.a). It should be noted that this result can be sensitive to the choice of the range of years considered to be "recent". However, using a year range of 2007-2018 results in very similar probabilities of achieving rebuilt status relative to the base case simulations and simulations based on observed abundances from 2004-2018 (Figure 5).

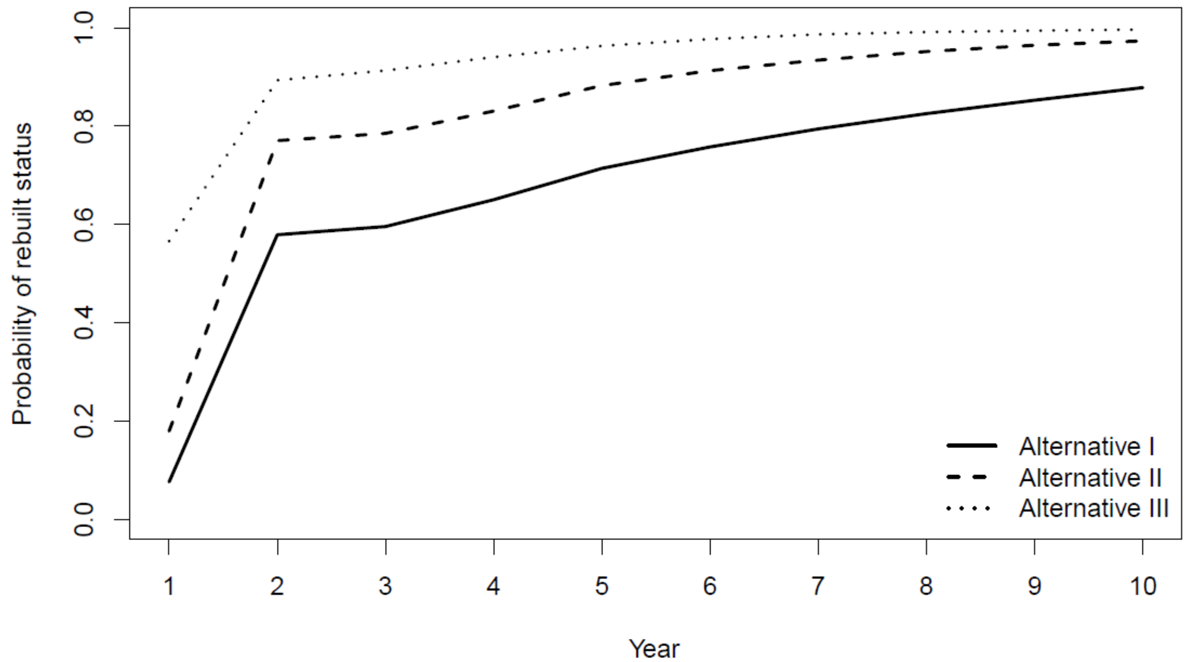

Figure 4. Probability of achieving rebuilt status in years 1 through 10, under the status quo control rule (Alternative I), the buffered control rule (Alternative II), and no fishing (Alternative III), using recent abundance values (2004-2018) to estimate the log-scale mean and standard deviation.

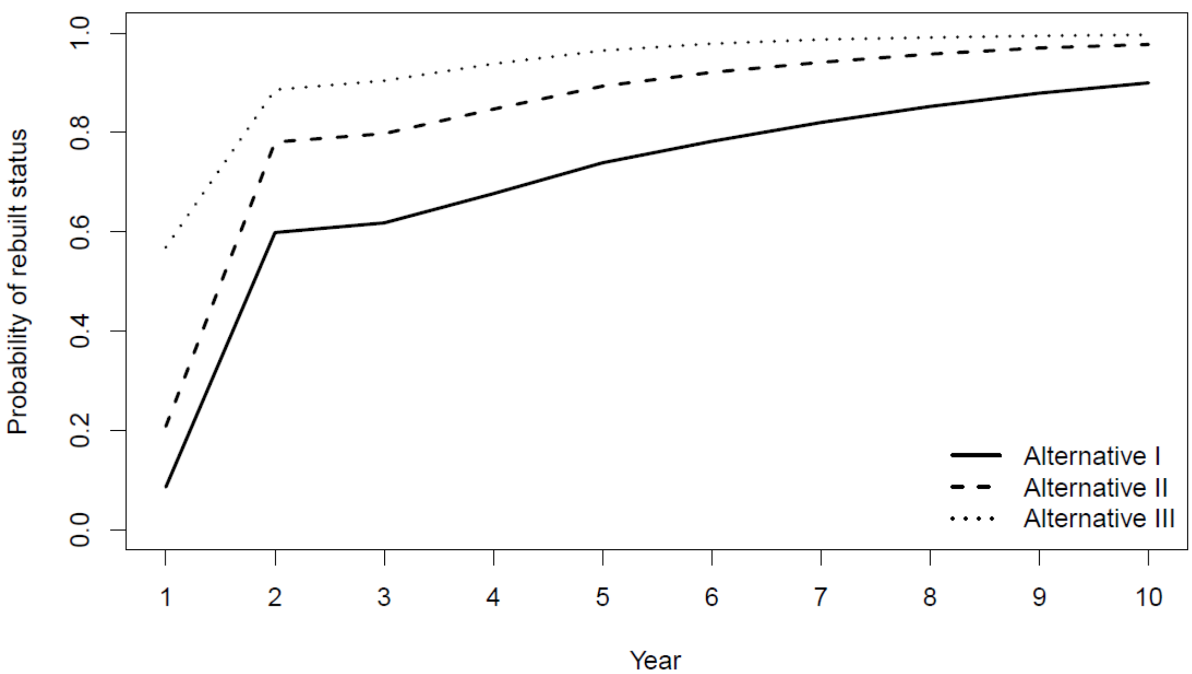

Figure 5. Probability of achieving rebuilt status in years 1 through 10, under the status quo control rule (Alternative I), the buffered control rule (Alternative II), and no fishing (Alternative III), using recent abundance values (2007-2018) to estimate the log-scale mean and standard deviation.

APPENDIX C - DRAFT FINDING OF NO SIGNIFICANCE

{Section to be completed by NMFS after Council adopts a rebuilding plan}

APPENDIX D - PAST, PRESENT, AND REASONALBY FORESEEABLE FUTURE IMPACTS

{Section to be completed by NMFS after Council adopts a rebuilding plan}

Fishery Actions

The Council sets management measures for ocean salmon fisheries annually based on stock forecasts and in accordance with conservation objectives set in the FMP and guidance provided by NMFS for managing impacts to ESA listed stocks. The Council manages ocean salmon fisheries through an intensive preseason analysis process to shape salmon fisheries impacts on salmon stocks within the parameters of the FMP conservation measures and ESA requirements.

Fisheries outside of the Council's jurisdiction also impact the Council-area salmon fishery. The Council considers fisheries managed by the states and treaty Indian tribes in the North of Falcon management process and Columbia River fisheries managed under *U.S. v. Oregon* Management Plan, as well as obligations for fisheries off Alaska and Canada under the Pacific Salmon Treaty (PFMC and NMFS 2014). Additionally, the Council and NMFS manage ocean salmon fisheries inseason to keep fisheries impacts within the constraints set preseason. The Council also conducts annual methodology reviews to improve models and other tools for assessing salmon stocks.

Non-Fishing Related Actions

Because salmon spend part of their lifecycle in fresh water, they are more vulnerable to a broad range of human activities (since humans spend most of their time on land) that affect the quantity and quality of these freshwater environments. These effects are generally well known and diverse. They include physical barriers to migration (dams), changes in water flow and temperature (often a secondary effect of dams or water diversion projects), and degradation of spawning environments (such as increased silt in the water from adjacent land use). Non-fishing activities in the marine environment can introduce chemical pollutants and sewage; and result in changes in water temperature, salinity, dissolved oxygen, and suspended sediment which poses a risk to the affected resources. Human-induced non-fishing activities tend to be localized in nearshore areas and marine project areas. When these activities co-occur, they are likely to work additively or synergistically to decrease habitat quality and may indirectly constrain the sustainability of the managed resources, non-target species, and protected resources. Decreased habitat suitability tends to reduce the tolerance of affected species to the impacts of fishing effort. Mitigation through regulations that would reduce fishing effort could negatively impact human communities. The overall impact to the affected species and their habitats on a population level is unknown, but likely neutral to low negative, since a large portion of these species have a limited or minor exposure to the localized non-fishing perturbations.

For many of the proposed non-fishing activities to be permitted by other Federal agencies, those agencies would examine the potential impacts on the affected resources. The Magnuson-Stevens Act (50 CFR 600.930) imposes an obligation on other Federal agencies to consult with the Secretary of Commerce on actions that may adversely affect EFH. The eight fishery management councils engage in the review process by making comments and recommendations on any Federal or state action that may affect habitat, including EFH, for their managed species and by commenting on actions likely to substantially affect habitat, including EFH. In addition, under the Fish and Wildlife Coordination Act (Section 662), "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the U.S., or by any public or private agency under Federal permit or license, such department or agency first shall consult with the U.S. Fish and Wildlife Service (USFWS), Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular state wherein the" activity is taking place. This act provides another avenue for review of actions by other Federal and state agencies that may impact resources that NMFS manages in the reasonably foreseeable future. In addition, NMFS and the USFWS share responsibility for implementing the ESA. ESA requires NMFS to designate "critical habitat" for any species it lists under the ESA (i.e., areas that contain physical or biological features essential to conservation, which may require special management considerations or protection) and to develop and implement recovery plans for threatened and endangered species. The ESA provides another avenue for NMFS to review actions by other entities that may impact endangered and protected resources whose management units are under NMFS' jurisdiction.

The effects of climate on the biota of the California Current ecosystem have been recognized for some time. The El Niño-Southern Oscillation (ENSO) is widely recognized to be the dominant mode of inter-annual variability in the equatorial Pacific, with impacts throughout the rest of the Pacific basin and the globe. During the negative (El Niño) phase of the ENSO cycle, jet stream winds are typically diverted northward, often resulting in increased exposure of the Pacific Coast of the U.S. to subtropical weather systems. The impacts of these events to the coastal ocean generally include reduced upwelling winds, deepening of the thermocline, intrusion of offshore (subtropical) waters, dramatic declines in primary and secondary production, poor recruitment, reduced growth and survival of many resident species (such as salmon and groundfish), and northward extensions in the range of many tropical species. Concurrently, top predators such as seabirds and pinnipeds often exhibit reproductive failure. In addition to inter-annual variability in ocean conditions, the North Pacific seems to exhibit substantial inter-decadal variability, which is referred to as the Pacific (inter) Decadal Oscillation (PDO).

Anomalously warm sea surface temperatures in the northeast Pacific Ocean developed in 2013 and continued to persist through much of 2015; this phenomenon was termed "the Blob." During the persistence of the Blob, distribution of marine species was affected (e.g., tropical and subtropical species were documented far north of their usual ranges), marine mammals and seabirds starved, and a coastwide algal bloom that developed in the summer of 2015 resulted in demoic acid poisoning of animals at various trophic levels, from crustaceans to marine mammals. In 2015-2016, a very strong El Niño event disrupted the Blob, which was declared "dead" by climatologists in December 2015. The extent of the impact of The Blob on salmon and salmon fisheries has not yet been fully determined. It is also uncertain if or when environmental conditions would cause a repeat of this event. However, NMFS' Northwest and Southwest Fisheries Science Centers presented information to the Council indicating that the broods that will contribute to 2018 harvest and escapement encountered poor ocean conditions in the California Current Ecosystem.

Within the California Current itself, Mendelssohn et al, (2003) described long-term warming trends in the upper 50 to 75 meters of the water column. Recent paleoecological studies from marine sediments have indicated that 20th century warming trends in the California Current have exceeded natural variability in ocean temperatures over the last 1,400 years. Statistical analyses of past climate data have improved our understanding of how climate has affected North Pacific ecosystems and associated marine species productivities.

In addition, changes in river flows and flow variability may affect population growth of anadromous fishes. Ward et al. (2015) found that increases in variability in freshwater flows may have a more negative effect than any other climate signal included in their model. Some climate change models predict that in the Pacific Northwest, there will be warmer winters and more variable river flows, which may affect the ability of anadromous fishes to recover in the future (Ward et al. 2015). However, our ability to predict future impacts on a large scale ecosystem stemming from climate forcing events remains uncertain.

APPENDIX E - LIST OF AGENCIES AND PERSONS CONSULTED

{Section to be completed by NMFS after Council adopts a rebuilding plan}
The following public meetings were held as part of the salmon management process (Council-sponsored meetings in bold):

March 2018
April 2018
May 17, 2018
June, 2018:
August 2018
September 2018
November 2018

The following organizations were consulted and/or participated in preparation of supporting documents:

California Department of Fish and Wildlife
Oregon Department of Fish and Wildlife
Washington Department of Fish and Wildlife

National Marine Fisheries Service, West Coast Region, Sustainable Fisheries Division
National Marine Fisheries Service, Northwest Fisheries Science Center
National Marine Fisheries Service, Southwest Fisheries Science Center
U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office
United States Coast Guard

Northwest Indian Fisheries Commission
Columbia River Intertribal Fish Commission
West Coast Indian Tribes

APPENDIX F - REGULATORY IMPACT REVIEW

{Section to be completed by NMFS after Council adopts a rebuilding plan}

APPENDIX G - INITIAL REGULATORY FLEXIBILITY ANALYSIS

{Section to be completed by NMFS after Council adopts a rebuilding plan}

APPENDIX H - NATIONAL STANDARDS ANALYSIS

{Section to be completed by NMFS after Council adopts a rebuilding plan}

APPENDIX I - CONSISTENCY WITH OTHER APPLICABLE LAWS ANALYSIS

{Section to be completed by NMFS after Council adopts a rebuilding plan}

- MSA
- CZMA
- ESA
- MMPA
- MBTA
- PRA
- EO 12898 Environmental Justice
- EO 13132 Federalism
- EO 13175 Tribal Consultation and Coordination
- Regulatory Flexibility Act
- EO 12866 Regulatory Planning and Review
- EO 13771 Reducing Regulation and Controlling Regulatory Costs