Agenda Item D.2
Attachment 2 **(Electronic Only)**
November 2018

SACRAMENTO RIVER FALL CHINOOK

DRAFT 6_OCTOBER 2018

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
CDWR	California Department of Water Resources
CNFH	Coleman National Fish Hatchery
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
FRH	Feather River Hatchery
GAM	generalized additive models
ISBM	individual stock-based management
JPI	juvenile production index
KMZ	Klamath management zone (ocean zone between Humbug Mountain and Horse Mountain)
KOHM	Klamath Ocean Harvest Model
KRFC	Klamath River fall Chinook
LAR	Lower American River
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
NFH	Nimbus Fish Hatchery
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
RBDD	Red Bluff Diversion Dam
RBFO	Red Bluff Field Office
RER	rebuilding exploitation rate

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

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})
SRFC	Sacramento River fall Chinook
SRWC	Sacramento River winter Chinook
STT	Salmon Technical Team
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
VSI	visual stock identification
WDFW	Washington Department of Fish and Wildlife

1.0 EXECUTIVE SUMMARY

To be developed for final Rebuilding Plan report.

2.0 INTRODUCTION

In 2018, Sacramento River fall Chinook salmon (SRFC) met the criteria for overfished status as defined in section 3.1 of the Pacific Coast Salmon Fishery Management Plan (FMP) (PFMC 2016a). 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 SRFC, the maximum sustainable yield spawner escapement level (S_{MSY}) is defined as 122,000 hatchery and natural-area adult spawners. The MSST for SRFC is defined as 91,500 hatchery and natural-area adult spawners, with MSST = 0.75 × S_{MSY}. The geometric mean of SRFC hatchery and natural-area adult spawners over years 2015-2017 was 76,714, and thus in 2018 the stock met the criteria for overfished status. Figure 2.0.a displays the time series of SRFC hatchery and 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 SRFC is defined as the MSY fishing mortality rate (F_{MSY}) of 0.78. It is possible that overfished status could be the result of normal variation in abundance, as has been the case 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 SRFC stock, the geography of the Sacramento 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.

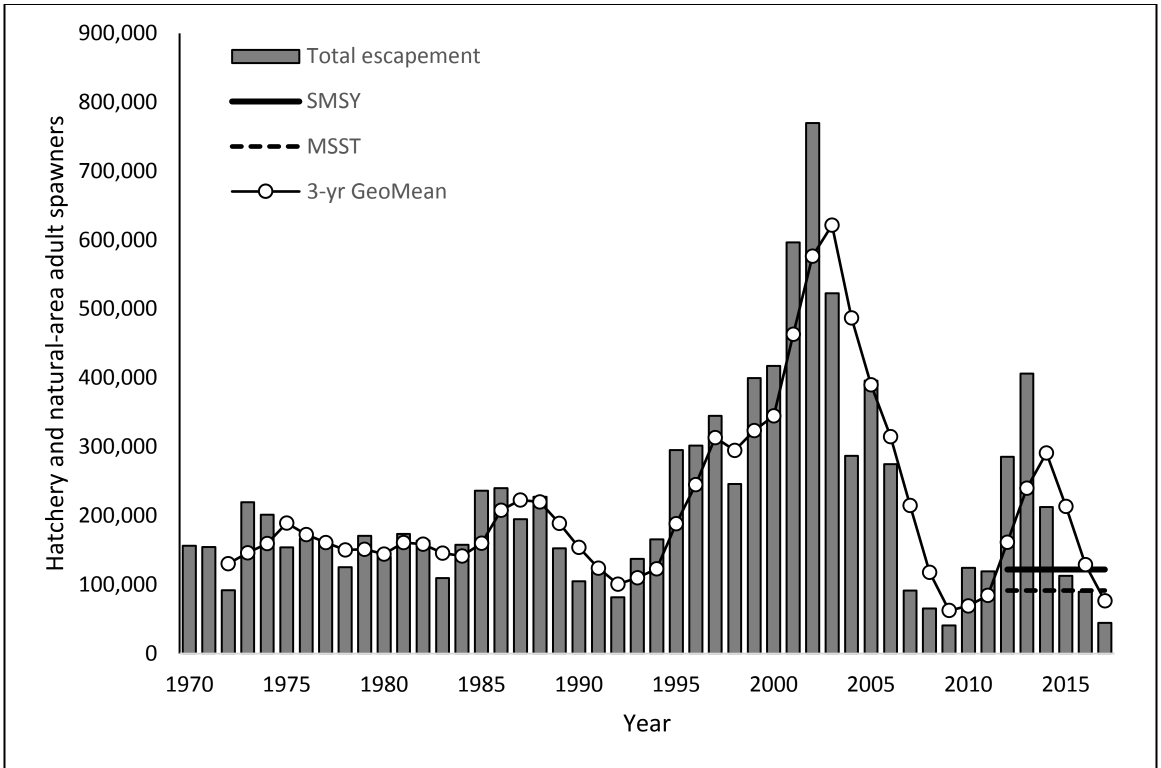

Figure 2.0.a. Sacramento River Fall Chinook spawner escapement of hatchery and natural-area adults.

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 SRFC 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 economic effects on 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 SRFC. 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 SRFC, which NMFS determined, in 2018, to be overfished under the MSA.

2.2 Stock overview

2.2.1 Location and geography

The Sacramento River Basin comprises approximately 26,000 square miles between the Sierra Nevada and Cascade ranges to the east and the Coast Range to the west. The headwaters of the Sacramento River lie in the Cascade Range, near Mount Shasta. The river flows south to the Sacramento-San Joaquin River Delta, which begins just downstream of the city of Sacramento, then into San Francisco Bay and ultimately into the Pacific Ocean (Figure 2.2.1.a). Major tributaries to the Sacramento River include the Feather River, Yuba River (which itself is a tributary of the Feather River), and the American River. Numerous smaller tributaries flow from the Sierra Nevada, and to a lesser extent, from the Coast Range into the Sacramento River. Many of these tributaries are important spawning and rearing areas for SRFC.

Four runs of Chinook salmon, named after the season in which mature fish enter the river to spawn, are present in the Sacramento River and its tributaries. These runs include SRFC, late-fall run, winter run, and spring run. Yoshiyama et al. (1998) notes that each run features a somewhat protracted run timing that can lead to substantial temporal overlap in the Sacramento Basin. As such, the Sacramento River is known to have adult Chinook salmon present in the system throughout the year. Two of the runs that utilize the Sacramento River are listed under the Endangered Species Act (ESA): spring run are listed as Threatened and winter run are listed as Endangered. These listings are in large part due to extensive loss of the cold headwater habitats that these runs require. Fall run, and to a lesser degree late-fall run, are not as dependent on high-elevation and/or spring-fed habitats as spring and winter Chinook.

The Sacramento River and its tributaries have been heavily modified over time by a variety of actions, including dam construction, flood control efforts, and water diversions for agriculture and domestic uses. Keswick Dam, near the city of Redding and approximately nine miles downstream of Shasta Dam, is the upstream terminus of anadromy for the Sacramento River. Dams are also present on the Feather, Yuba, and American rivers, as well as many of the smaller tributaries, eliminating a substantial amount of Chinook spawning habitat. Hatcheries are used to mitigate for the lost production of salmon due to impassable dams. Historical accounts of salmon abundance in the Sacramento Basin, and descriptions of the physical changes to the Sacramento River and its tributaries can be found in Fisher (1994) and Yoshiyama (1998).

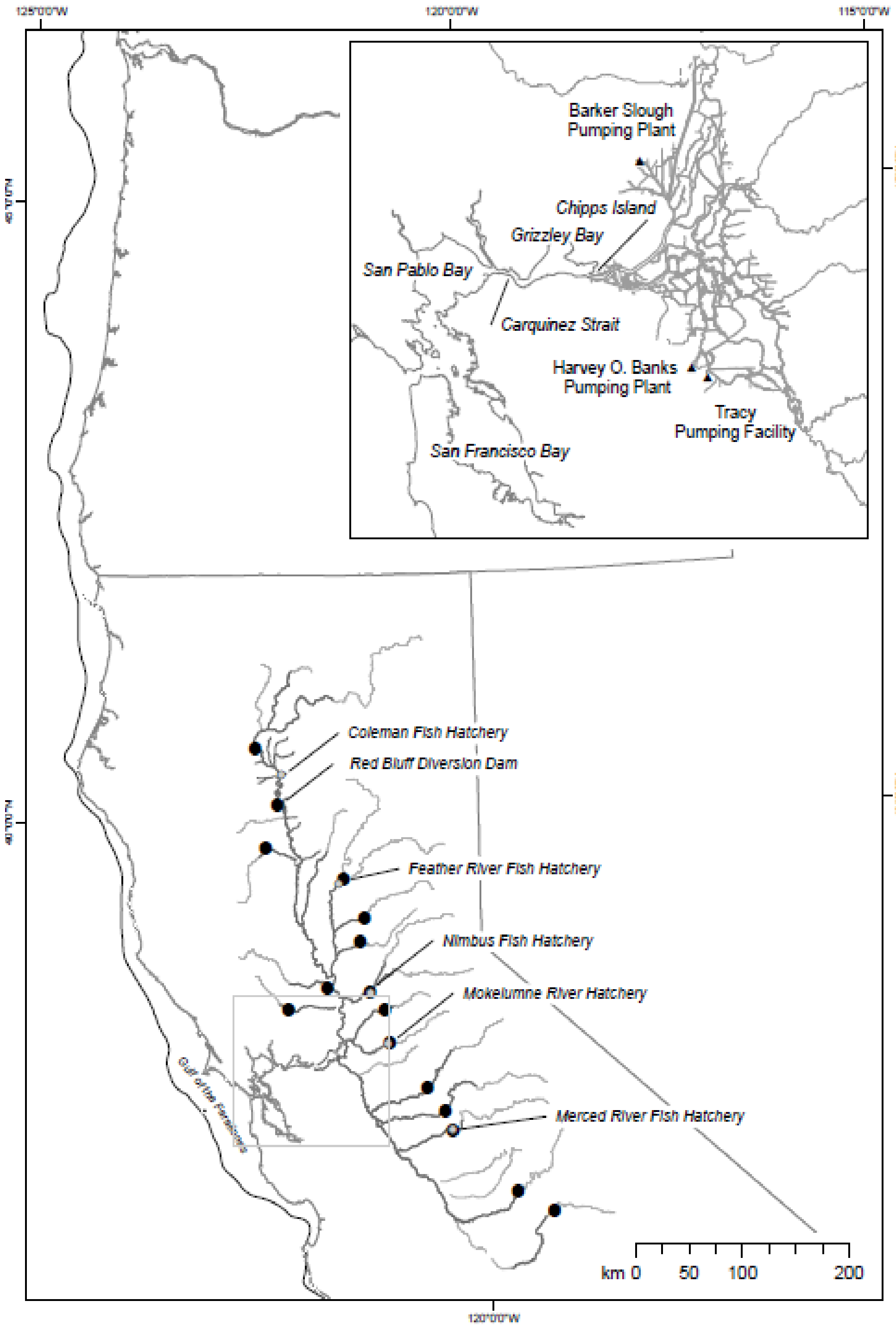

Figure 2.2.1.a. Map of the Sacramento River Basin, Delta, and coastal ocean. Black dots indicate impassable dams. Coleman, Feather River, and Nimbus fish hatcheries produce SRFC. Figure reproduced from Lindley et al. (2009).

2.2.2 Stock composition

Mature SRFC return to hatcheries and natural spawning areas. Although a portion of the spawning stock every year consists of age-2 fish, primarily males referred to as “jacks,” only age-3 and older fish are considered adults and thus used to assess stock status. Since 1970, and excluding the years that contributed to the current overfished status (2015-2017), natural-area escapement (which includes both natural- and hatchery-origin fish) has represented on average 81 percent of the total adult escapement in the Sacramento Basin (PFMC 2018b). However, while this percentage has greatly fluctuated over time, in general there has been a decreasing trend. Every decade, the average percentage of adult escapement occurring in natural areas has declined, beginning with 91 percent in the 1970s, 84 percent in the 1980s, 80 percent in the 1990s, 75 percent in the 2000s, and only 63 percent since 2010. During 2015-2017, the average was even lower at 55 percent, with 2017 being the lowest on record at only 39 percent of the adult return. This is 14 percent less than the next lowest percentage on record, which was 53 percent in 2005 (Figure 2.2.2.a; PFMC 2018b).

SRFC spawn in the fall and the fry emerge during winter through early spring. Juveniles enter the ocean from spring through mid-summer, spending little time in the estuary. Ocean harvest data indicates that SRFC are primarily caught from the coast of northern Oregon to southcentral California, which in terms of fishery management translates to Cape Falcon, Oregon to the U.S./Mexico border. Within this ocean range, SRFC generally compose larger portions of the overall harvest in areas closer to San Francisco Bay. These fish typically spend around a year and a half to three years in the ocean before returning to freshwater, although waiting four, and to a lesser extent five, years to mature is not uncommon. SRFC that spend less than two years in the ocean are considered age-2 when they return and, as mentioned above, are not considered adults.

Hatchery production of SRFC comes from Coleman National Fish Hatchery (CNFH), operated by the U.S. Fish and Wildlife Service (USFWS), and from Feather River Hatchery (FRH) and Nimbus Fish Hatchery (NFH), operated by the California Department of Fish and Wildlife (CDFW). CNFH is located on Battle Creek, a tributary near the upper limit of anadromy in the Sacramento mainstem, and smolts are typically released directly into the creek. However, in response to severe drought conditions in the Sacramento River, brood years 2013 and 2014 had 62 percent and 100 percent of their smolts, respectively, trucked to the delta and released into net pens. The Feather River is located downstream of Battle Creek, and almost all fall-run production from FRH is trucked (or sometimes barged) and released into net pens in the delta and San Pablo/San Francisco Bay, as well as coastal net pens located in Half Moon Bay and Santa Cruz. The American River, where NFH is located, is even further downstream and flows through the city of Sacramento. While a portion of the production at NFH is always trucked to the delta or bay and released into net pens, brood years 2013 and 2014 were entirely trucked, again due to extreme drought conditions in-river.

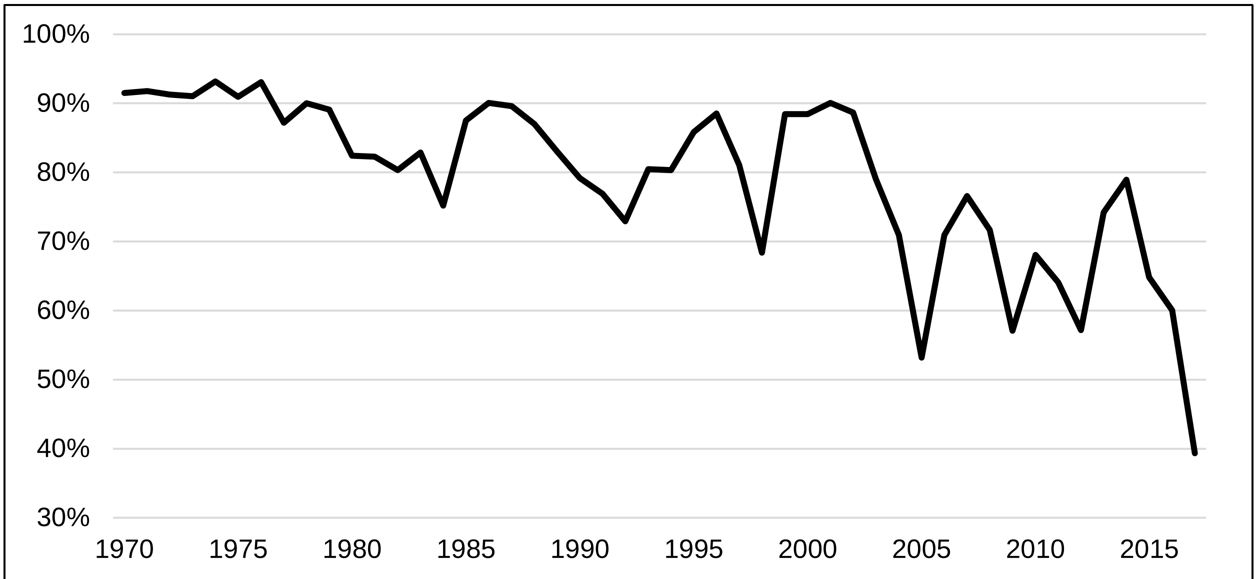

Figure 2.2.2.a. Historical percentages of the adult Sacramento River fall Chinook escapement that consisted of natural area spawners, as opposed to hatchery spawners.

2.3 Management Overview

2.3.1 Conservation objectives

Table 3-1 in the FMP (PFMC 2016a) defines the conservation objective for SRFC as: "122,000-180,000 natural and hatchery adult spawners (MSY proxy adopted 1984)". Justification for this conservation objective and citations for supporting documents are also found in Table 3-1 of the FMP (PFMC 2016a).

Prior to 2012, the conservation objective guided annual fisheries management for this stock. Fisheries were planned so as to achieve hatchery and natural-area adult escapement levels within the goal range, when possible. Upon adoption of Amendment 16 to the FMP in 2012, annual fishery management of the SRFC stock has been guided by a harvest control rule that incorporates some aspects of the conservation objective (PFMC 2016a).

2.3.2 Management strategy

Current management of SRFC is guided by a control rule that specifies the maximum allowable exploitation rate based on a forecast of potential spawner abundance, which is the hatchery and natural-area adult escapement in the absence of fisheries (Figure 2.3.2.a). The exploitation rate cap specified by the control rule includes harvest impacts of both ocean and river fisheries.

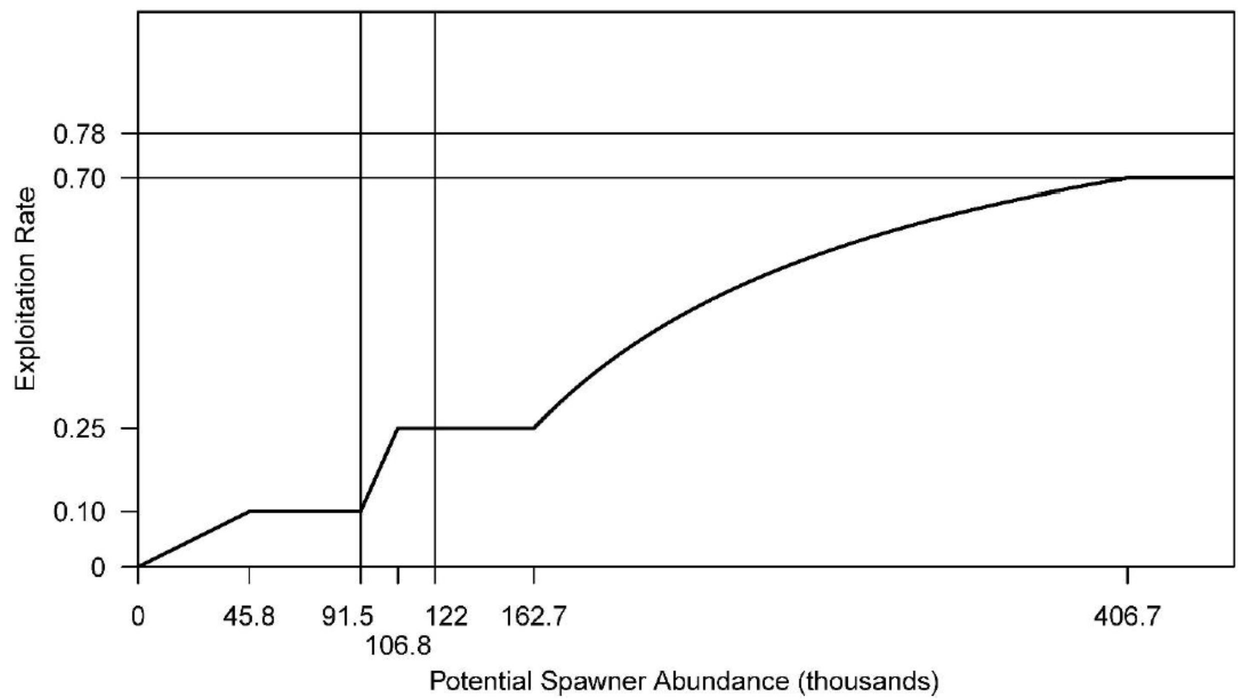

Figure 2.3.2.a. Sacramento River fall Chinook control rule. Potential spawner abundance is the predicted hatchery and natural area adult spawners in the absence of fisheries, which is equivalent to the Sacramento Index. See the salmon FMP, Section 3.3.6, for control rule details.

For SRFC, potential spawner abundance is represented by the forecast of the Sacramento Index (SI), the aggregate-age (> age-2) abundance index for this stock. The SI in year *t* is the sum of (1) adult SRFC ocean fishery harvest south of Cape Falcon, OR between September 1 (*t* – 1) and August 31 (*t*), (2) adult SRFC impacts from non-retention ocean fisheries when they occur, (3) the year *t* recreational harvest of adult SRFC in the Sacramento River Basin, and (4) the year *t* SRFC adult spawner escapement. A detailed description of the SI and the estimation of its components can be found in O'Farrell et al. (2013). A forecast of the SI is made annually, and the methods used to forecast this index have changed over time. Since 2014, the SI has been forecast using a log-log model relating jacks (t-1) to the SI (t) with lag-1 autoregressive errors fitted to SI data from 1983-forward. A description of this approach can be found in PFMC (2014), Appendix E, and in annual versions of Preseason Report I since 2014.

At high levels of potential spawner abundance, the control rule specifies a maximum allowable exploitation rate of 0.70, the fishing mortality rate associated with the acceptable biological catch (F_{ABC}). At moderate abundance, the control rule specifies an allowable exploitation rate that results in an expected escapement of S_{MSY} = 122,000 hatchery and 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 122,000 adults.

3.0 REVIEW OF POTENTIAL FACTORS LEADING TO OVERFISHED STATUS

3.1 Freshwater survival

3.1.1 Review of freshwater conditions

3.1.1.1 Sacramento River mainstem

Data from the U.S. Geological Survey (USGS) gauge located downstream of Keswick Dam on the Sacramento River was used to characterize water temperatures and flows during spawning (Figures 3.1.1.1.a and 3.1.1.1.b). In terms of incubation temperatures, Martin et al. (2017) identified 12° C as the temperature below which there is no longer any temperature-induced mortality. Mortality rates are nearly 100 percent at temperatures of 16.7° C or greater (Myrick and Cech 2001). Water temperatures measured downstream of Keswick Dam were above 12° C during the spawning period in 12 of 18 brood years from 1997 through 2014. Water temperatures during 2014 approached the 16.7° C lethal limit and were the highest observed across brood years 1997-2014.

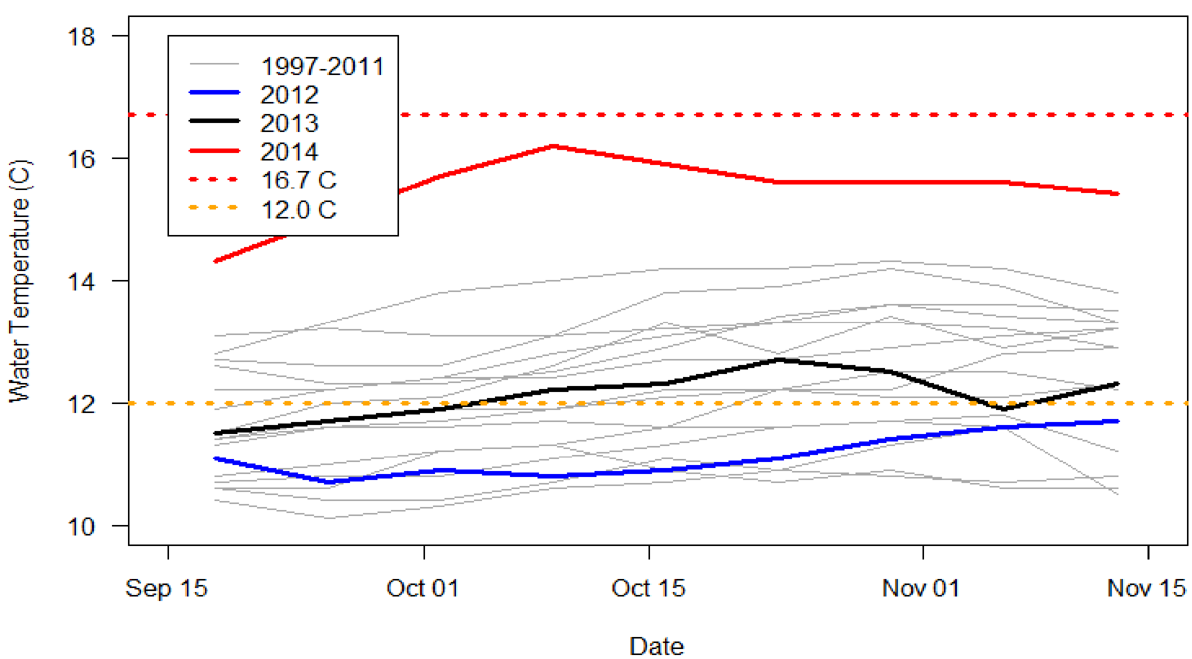

Figure 3.1.1.1.a. Water temperatures in the Sacramento River below Keswick Dam during the spawning period for fall Chinook salmon across brood years1997-2014 (data from Killam and Thompson 2015). The lower dashed line represents the temperature below which there is no mortality due to temperature (12˚C) and the upper dashed line represents the temperature associated with nearly 100 percent temperature-induced mortality (16.7˚C).

Flow levels influence the quantity and quality of spawning habitat. Sacramento River flow levels during the spawning period were relatively low during brood years 2012 and 2013 compared to previous years (Figure 3.1.1.1.b). However, brood year 2014 experienced the lowest flow levels in the time series.

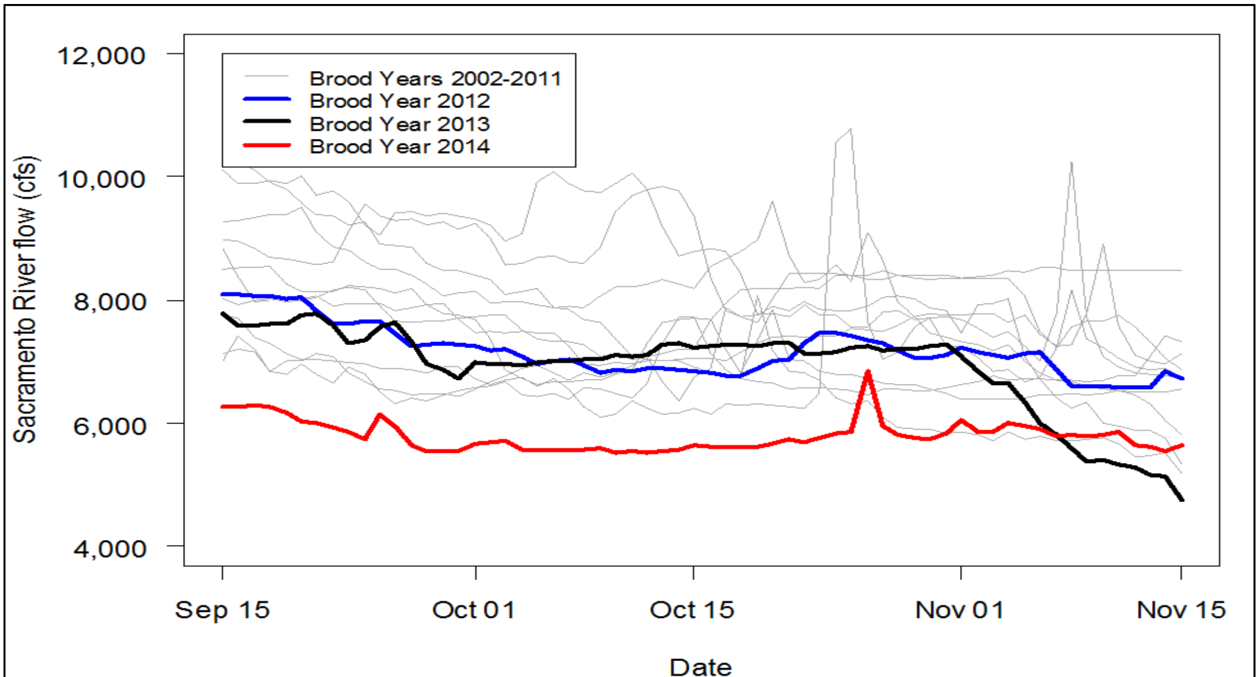

Figure 3.1.1.1.b. Sacramento River flow levels below Keswick Dam during the spawning period for brood years 2002-2014.

Water temperatures and flows experienced by juvenile SRFC were also indexed at the USGS gauge at Freeport, downstream of the city of Sacramento. Water temperatures were highest for brood year 2014 outmigrants (Figure 3.1.1.1.c). Flows were low for the 2012, 2013, and 2014 outmigrants (Figure 3.1.1.1.d).

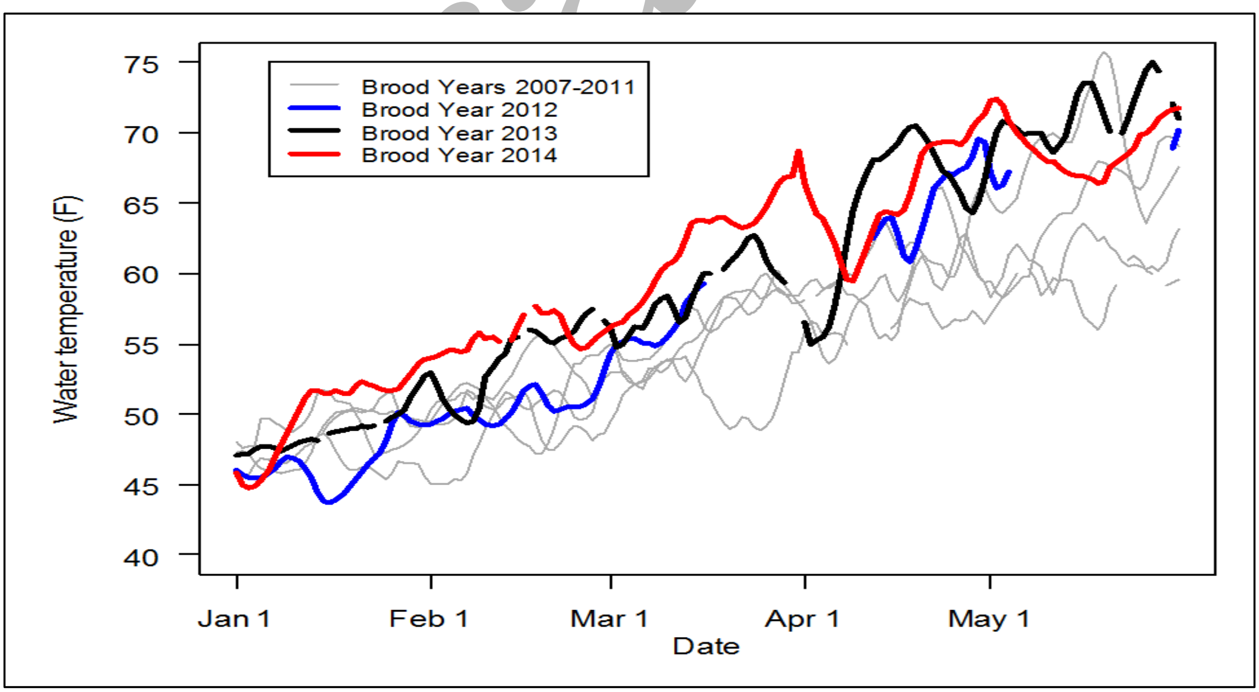

Figure 3.1.1.1.c. Sacramento River water temperature at Freeport (downstream of Sacramento) encountered by outmigrating fall Chinook juveniles from brood years 2007-2014.

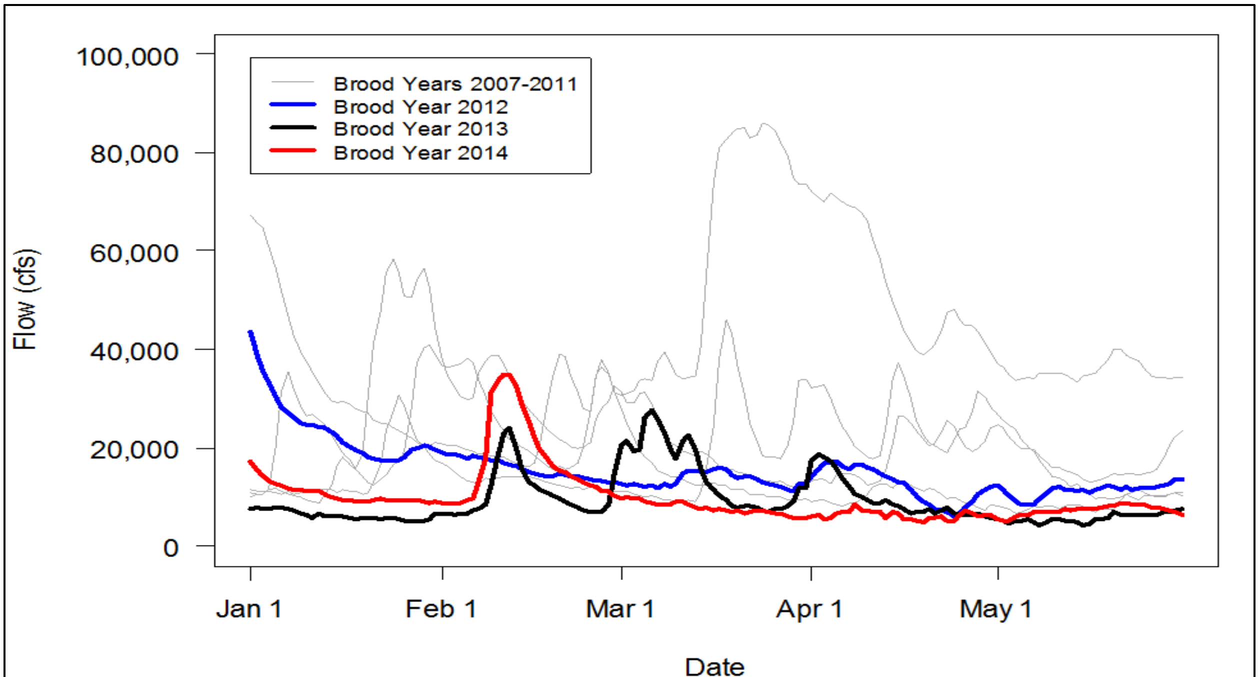

Figure 3.1.1.1.d. Sacramento River flow (cfs) at Freeport (downstream of Sacramento) encountered by outmigrating fall Chinook juveniles from brood years 2007-2014.

As previously mentioned, SRFC typically spawn from late September through mid-November, with the peak spawning occurring in October. Table 3.1.1.1.a presents the observed timing of SRFC spawning by week, for the period September 3 through December 10. Data are based on observations of fresh female carcasses encountered during spawning seasons 2003 through 2017.

Table 3.1.1.1.a. Timing of Sacramento River fall-run Chinook spawning by week, for spawning seasons 2003 through 2017.

Week Beginning	Average Percent of Total Redds	Cumulative Percent of Total Redds
Sep 3	0.1%	0.1%
Sep 10	0.2%	0.3%
Sep 17	1.4%	1.7%
Sep 24	5.0%	6.7%
Oct 1	7.8%	14.5%
Oct 8	11.3%	25.8%
Oct 15	19.4%	45.2%
Oct 22	18.0%	63.3%
Oct 29	12.2%	75.5%
Nov 5	7.7%	83.2%
Nov 12	5.5%	88.7%
Nov 19	5.1%	93.7%
Nov 26	2.9%	96.7%
Dec 3	2.2%	98.9%
Dec 10	1.1%	100.0%

Reductions in flow during the spawning and egg incubation period can lead to redd dewatering. Since fall of 2013, the CDFW Red Bluff Field Office (RBFO) has actively monitored the fate of

SRFC redds constructed in shallow water spawning habitat in the mainstem Sacramento River using funding through the Anadromous Fish Restoration Program. Newly constructed redds are marked with a unique marker and given a GPS waypoint, depth measurements are recorded, and current flow releases from Keswick Dam are noted. Field crews then return to these redds following scheduled flow reductions from Keswick Dam. The shallow water redd survey is conducted from Tehama Bridge at river mile (RM) 237 to Keswick Dam at RM 302. Table 3.1.1.b details the number of shallow redds identified and marked, and the number of those redds de-watered following flow reductions. While data do not exist for brood year 2012, there were generally low percentages of redds dewatered for brood years 2013 and 2014. It should be noted that these data only quantify redds that have been completely de-watered. It does not quantify redds partially dewatered nor changes in habitat associated with flow reductions, including velocity of water and dissolved oxygen in the egg pocket of shallow water redds.

Table 3.1.1.1.b. The number of shallow fall-run Chinook redds identified and marked, and the number of those redds de-watered following flow reductions on the main-stem Sacramento 2013 through 2017.

Year	Total Shallow Redds Identified	Percent De-watered
2013	515	2.7%
2014	43	0.3%
2015	291	2.1%
2016	0	NA
2017	15	1.5%

High river temperatures may contribute to pre-spawn mortality. As noted in Figure 3.1.1.1.a, temperatures during the spawning period were well above average for brood year 2014. CDFW provided estimates of pre-spawn mortality for brood years 2003-2017 based on sampling conducted in the Sacramento River mainstem (Figure 3.1.1.1.e). The average rate of pre-spawn mortality was 2.1 percent and in most years the rate was less than 4 percent. The notable exception was brood year 2014 where pre-spawn mortality was estimated to be 8.9 percent.

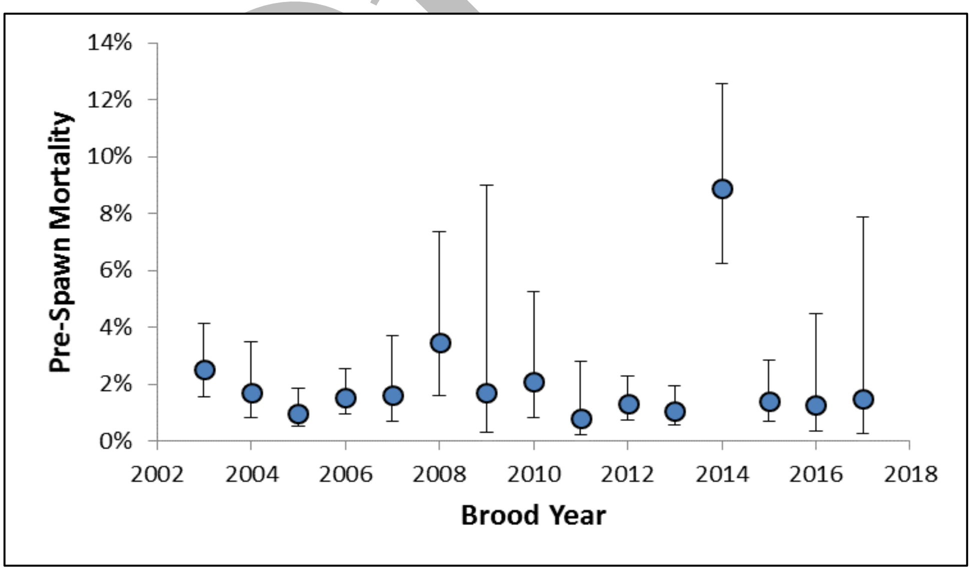

Figure 3.1.1.1.e. Estimates of pre-spawn mortality for Sacramento River fall Chinook (circles) along with 95 percent confidence intervals (whiskers) across brood years 2003-2017. Data source: CDFW.

3.1.1.2 Feather River

The Feather River is 67 miles long from the fish barrier dam (anadromous fish barrier) down to the confluence with the Sacramento River (Figure 2.2.1.a), and is the largest tributary to the Sacramento River. Although the Yuba and Bear rivers are considered major tributaries to the Feather River, under most conditions, Oroville Reservoir releases dictate the vast majority of the river flows. SRFC spawning activity in the Feather River primarily occurs upstream of RM 53 to RM 67 (Figure 3.1.1.2.a).

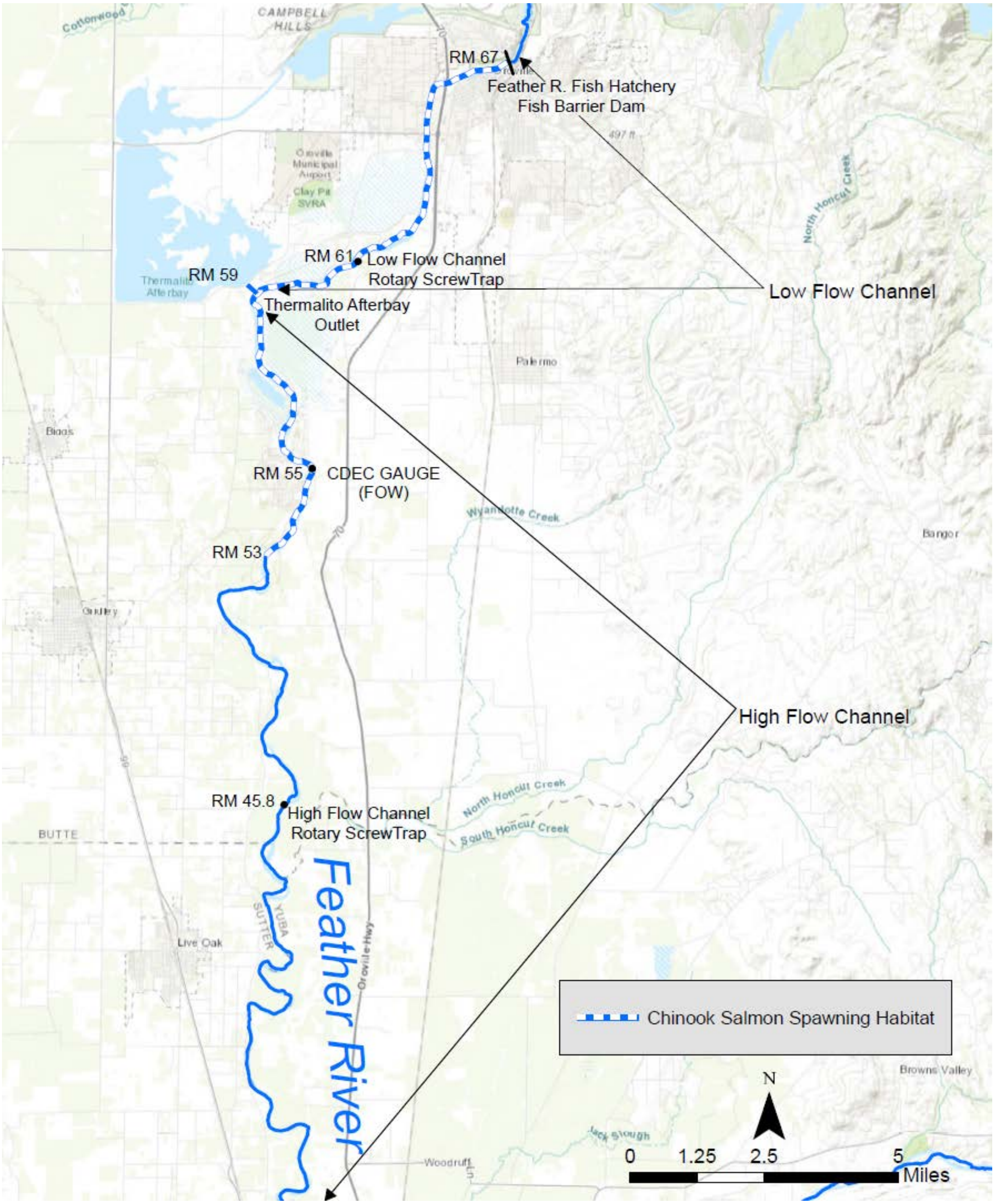

Figure 3.1.1.2.a. Map of the Feather River, including the fish barrier dam and the Thermalito Afterbay river outlet at RM 59.

Currently, an agreement between the California Department of Water Resources (CDWR) and CDFW (CDWR and CDFG 1983) regulates water temperature at FRH, located just below the barrier dam (see Figure 3.1.1.2.a). As a result, water temperatures in the low flow channel (between the fish barrier dam and the Thermalito Afterbay river outlet at RM 59) are often within a few degrees of required temperatures at the hatchery. In contrast, warm water releases from the Thermalito Afterbay river outlet (RM 59) frequently result in the exceedance of optimal spawning temperatures for SRFC during October downstream of RM 59. Temperature data in this portion of the Feather River were not available for 2012. In 2013, daily high temperatures were consistently over 56° F during October 1-28, with a high of 61° F on October 2. In 2014, daily high temperatures were consistently over 56° F during October 1-November 14, with a high of 64° F on October 2. (Figure 3.1.1.2.b). Water temperature data were collected by the California Data Exchange Center gauge located at RM 55 (Oroville Wildlife Area south boundary).

Temperature impacts on salmon can take the form of lethal and sub-lethal effects including adult pre-spawn mortality, reduced fecundity, egg and embryo mortality, and increased susceptibility to disease. It is likely that temperatures exceeding suitable spawning temperatures limited available spawning habitat for adult SRFC returning to the Feather River in the high flow channel over much of their spawning period between 2011 and 2017. To evaluate pre-spawn mortality, female SRFC carcasses encountered during the escapement survey were qualitatively checked for the presence of eggs. As population density, temperatures, habitat availability, and other factors can influence pre-spawn mortality, it is difficult to correlate observed pre-spawn mortality with water temperatures alone. However, pre-spawn mortality regardless of cause results in a reduction in potential juvenile production. Between 2011 and 2017, adult pre-spawn mortality ranged from a high of 30.3 percent in fall of 2013 to a low 1.2 percent in fall of 2017, with a mean of 17.2 percent (Table 3.1.1.2.a). High levels of pre-spawn mortality were observed for the critical broods.

Although density dependent factors may be influencing these data and there may be multiple causes, these data suggest that adult pre-spawn mortality frequently decreases potential juvenile production in the Feather River. It is likely that reduction of temperature-suitable spawning habitat, and a consolidation of spawners returning to habitat in close proximity to the hatchery, contributed to the observed elevated annual pre-spawn mortality during the 2012-2014 spawning seasons.

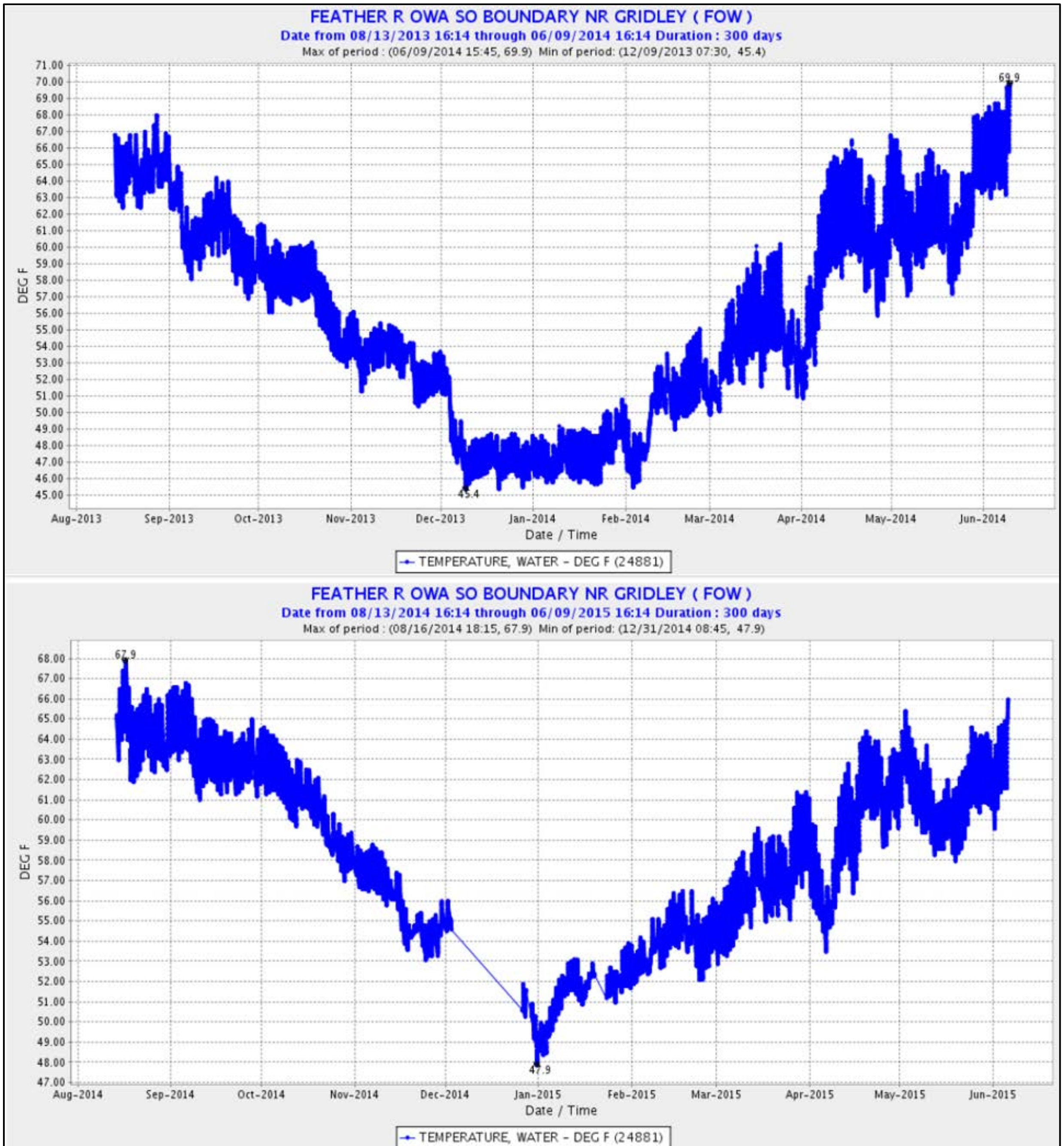

Figure 3.1.1.2.b. Feather River water temperatures (°F) downstream of the Thermalito Afterbay river outlet during the incubation, rearing, and outmigration periods for brood years 2013 and 2014. Temperatures affecting brood year 2012 were unavailable. Data was obtained from the CDWR gauge at the southern boundary of the Oroville Wildlife Area near Gridley, California.

Table 3.1.1.2.a. Total natural area escapement in the Feather River (including jacks) during 2011-2017, and the percentage of which that were estimated to have died prior to spawning.

Year	Feather River Natural Area Escapement[a/]	Percent Pre-spawn Mortality
2011	47,289	25.3%
2012	63,649	22.1%
2013	151,209	30.3%
2014	60,721	29.4%
2015	20,566	2.7%
2016	38,742	9.4%
2017	10,564	1.2%

a/ Spring-run Chinook are not distinguished from fall-run in the Feather River natural area spawning surveys, and thus are included in the escapement numbers reported here.

3.1.1.3 American River

The American River is the second largest tributary to the Sacramento River, a critical component of the San Francisco Bay/Sacramento-San Joaquin Delta ecosystem, and has historically contributed substantially to the overall SRFC stock. Folsom Reservoir on the American River is part of the Central Valley Project and along with upstream diversions has altered flow and temperature regimes in the Lower American River (LAR) (NMFS 2009a). The Central Valley Project has resulted in increasing fall (October through December) water temperatures in the LAR above historical averages, and has limited available spawning habitat. Over time, elevated water temperatures during the SRFC spawning period may be influencing spawn timing for American River-origin SRFC due to differential reproductive success of early versus late spawners. Though the American River has a long history of elevated water temperatures, adult SRFC retuning to the American River between 2013 and 2015 were subjected to prolonged periods of water temperatures that were far above the suitable spawning temperature within their spawning period (Figure 3.1.1.3.a). Brood year 2014 experienced especially poor conditions as water temperatures were not consistently below 60° F until December 6. Temperatures in 2015 did not contribute to the current overfished status since the progeny of that brood will not return as adults until 2018, but high temperatures are likely to hinder rebuilding in the short term. Similar examples of poor freshwater conditions outside of the critical years are provided in other sections of this plan, and while they cannot be considered causative factors for the current status, they are still noteworthy and critical to rebuilding. Water temperature data were collected by the USGS at the William B. Pond gauging station.

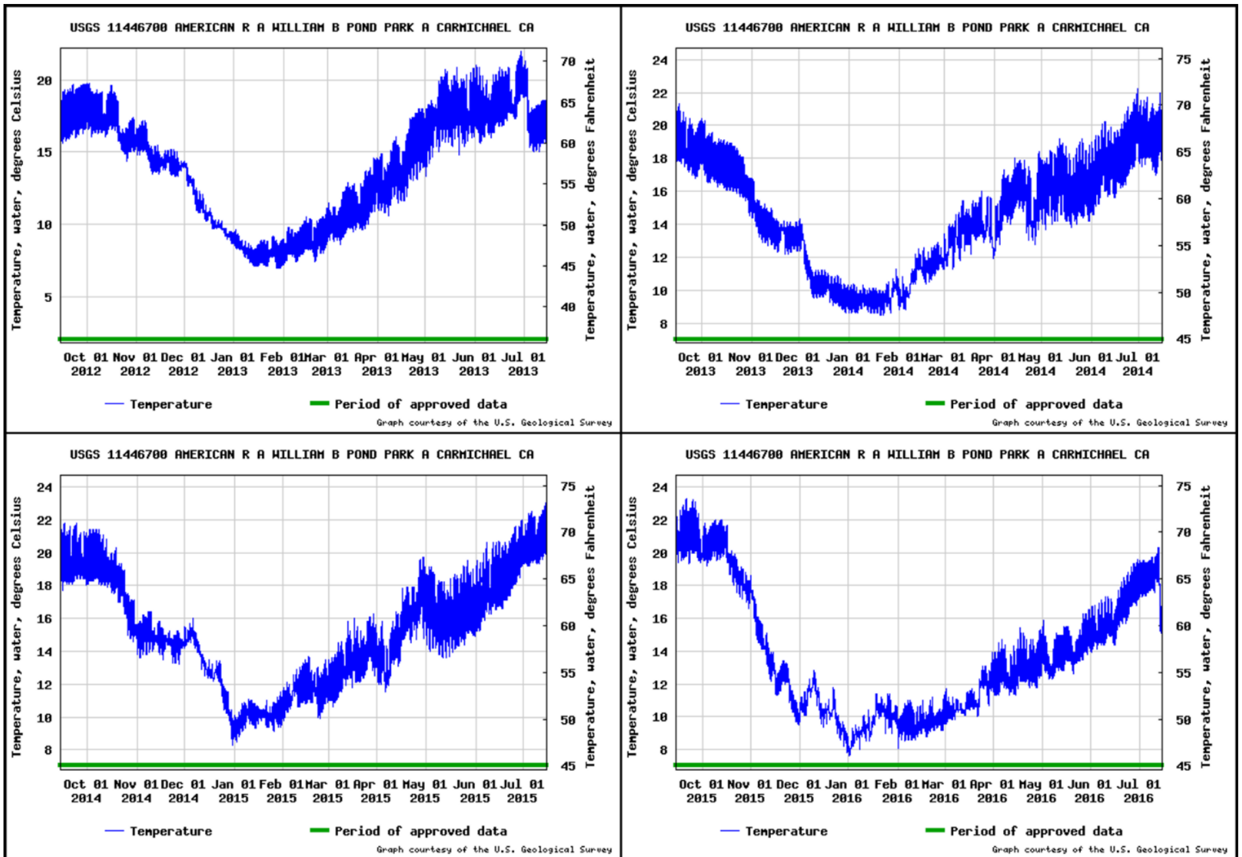

Figure 3.1.1.3.a. American River water temperatures (°C on the left axis, °F on the right axis) during the incubation, rearing, and outmigration periods for brood years 2012-2015. Data was obtained from the USGS gauge at William B. Pond Park near Carmichael, California.

As mentioned above, temperature impacts can be expressed in a variety of ways. Though direct measures of temperature impacts are often difficult to quantitatively assess, it is likely that adult pre-spawn mortality, and direct egg and embryo mortality, substantially decreased juvenile production in the LAR during 2013 through 2015. Additional flow-related impacts likely exacerbated temperature-related reductions in juvenile production (see section 3.1.7: *Other relevant factors*). To evaluate pre-spawn mortality on the American River, female SRFC carcasses encountered during the escapement survey were qualitatively checked for the presence of eggs. The level of egg retention was determined by inspecting the abdominal cavity. Females are assumed to be unspawned if >70% of eggs are present, partially spawned if 30-70% of eggs are present, or spawned if <30% of eggs are present. Figure 3.1.1.3.b shows a trend from 2013 through 2015 where the majority of female carcasses encountered during the first 2-3 weeks of the survey (last two weeks of October and first week of November) were unspawned transitioning to fully spawned as the season progressed. As population density, temperatures, habitat availability, and other factors can influence pre-spawn mortality, it is difficult to correlate observed pre-spawn mortality with water temperatures alone. Regardless of cause, however, all years evaluated show a reduction in potential juvenile production due to pre-spawn mortality. As 2013 had the largest adult escapement to the LAR and 2014 had the warmest water temperatures during the time period in question (2013-2015), it is likely that these were contributing factors to the observed pre-spawn mortality during those years.

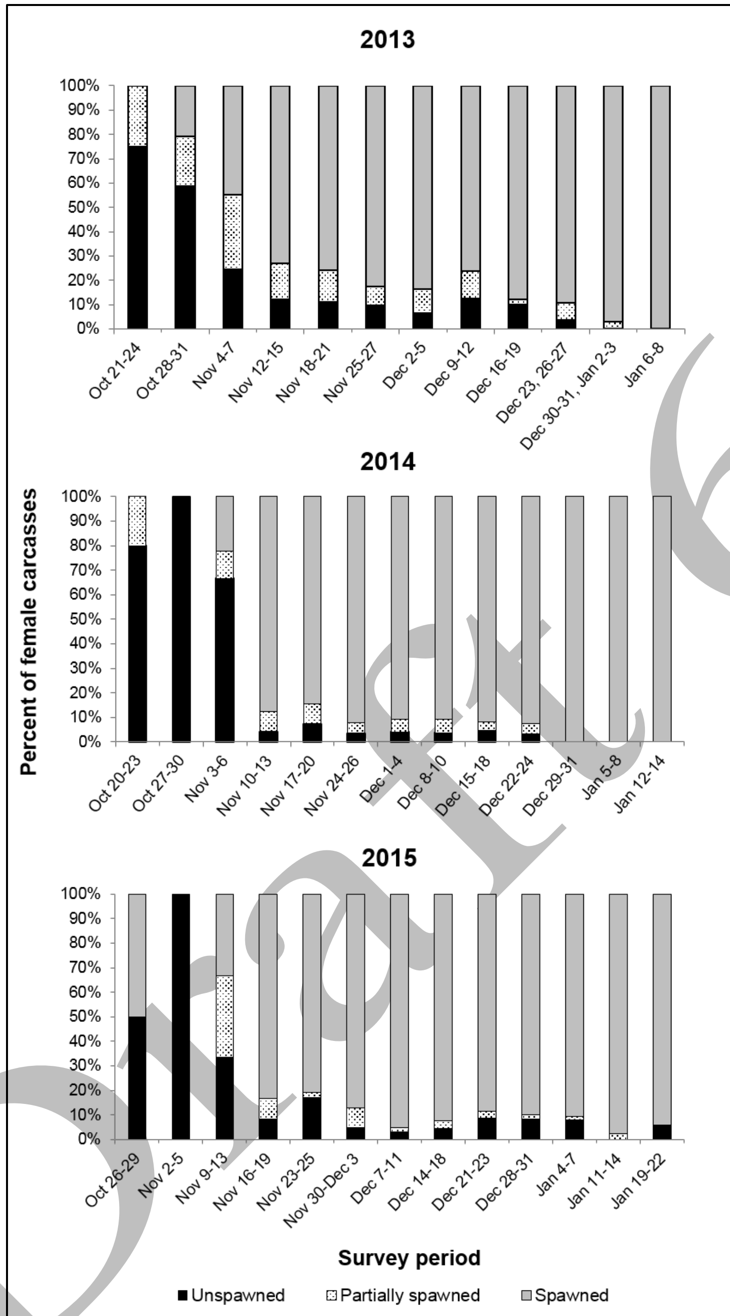

Figure 3.1.1.3.b. Estimated proportions of unspawned (>70% of eggs present), partially spawned (30-70% of eggs present), and spawned (<30% of eggs present) female SRFC carcasses in the American River natural area surveys during the 2013-2015 spawning seasons.

3.1.2 Parental spawner abundance

For the 2012-2014 critical broods, parental spawner escapement to hatcheries and natural areas was near or above the average over years 1970-2017 and well above the S_{MSY} of 122,000 adults (see Table B-1 in PFMC 2018b).

Estimates of the number of female spawners above Red Bluff Diversion Dam (RBDD) are reported in Voss and Poytress (2017). Excluding the 2002 and 2003 high escapement years, the average number of female spawners above RBDD has been 24,400 fish (Figure 3.1.2.a). The number of female spawners in brood years 2012-2014 were above this average, ranging from 32,600 to 39,400 across these brood years.

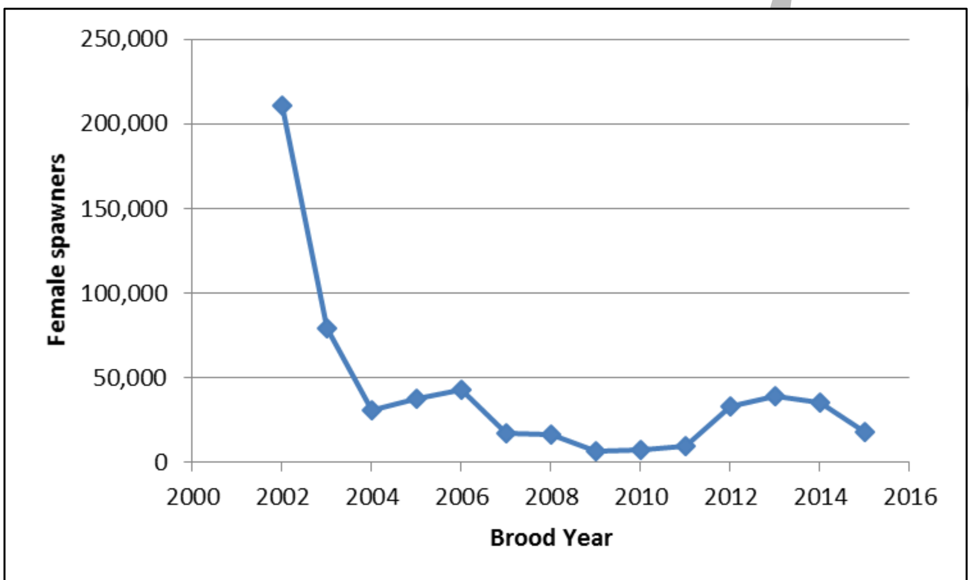

Figure 3.1.2.a. Estimates of the number of female spawners above RBDD (from Voss and Poytress 2017).

The CDFW RBFO annually estimates the population of mainstem SRFC spawning from Princeton Ferry (RM 164) to Keswick Dam (RM 302). This estimate is based on a carcass survey conducted from Balls Ferry (RM 276) to Keswick Dam and aerial redd counts from Balls Ferry to Princeton Ferry. In addition to a total population estimate, the RBFO annually estimates the proportion of natural-origin versus hatchery-origin SRFC in the population. This estimate is based on examination of fresh carcasses on the carcass survey. All fresh carcasses are examined for an adipose fin clip, which indicates a hatchery-origin fish. Coded-wire tags (CWTs) recovered from these carcasses are then read and a hatchery fish expansion is conducted using specific CWT expansions based on the percentage of juveniles tagged with each CWT code recovered. These data have been available for the 2011 spawning population onward, following initiation of the Central Valley Constant Fractional Marking program in 2006. Table 3.1.2.b presents total estimated SRFC population estimates, and estimated proportions of hatchery- versus natural-origin fish for years 2011 through 2017.

Table 3.1.2.b. Total estimated Sacramento River fall Chinook natural area spawner estimates and estimated proportions of stray hatchery-origin verses natural-origin fish, 2011 - 2017.

	Natural Area Spawners			Percent
Year	Natural-origin	Hatchery-origin	Total	Hatchery-origin
2011	7,296	4,296	11,592	37%
2012	6,900	21,801	28,701	76%
2013	25,312	14,772	40,084	37%
2014	15,624	19,390	35,014	55%
2015	**8,738**	**19,921**	**28,659**	**70%**
2016	**2,646**	**1,643**	**4,289**	**38%**
2017	**1,338**	**414**	**1,752**	**24%**
2011-2014 avg.	13,783	15,065	28,848	51%
2015-2017 avg.	4,241	7,326	11,567	44%

3.1.3 Juvenile Production Estimates

Since 2002, USFWS has used screw traps attached to RBDD to estimate juvenile SRFC passage (Voss and Poytress 2017). These estimates represent a fry-equivalent juvenile production index (JPI) that provides a useful measure of juvenile productivity above RBDD (Figure 3.1.3.a). Across brood years 2002-2015, the average JPI has been 18.5 million fry. Brood years 2012 and 2013 were well-above average, but brood year 2014 was the lowest value recorded for the JPI.

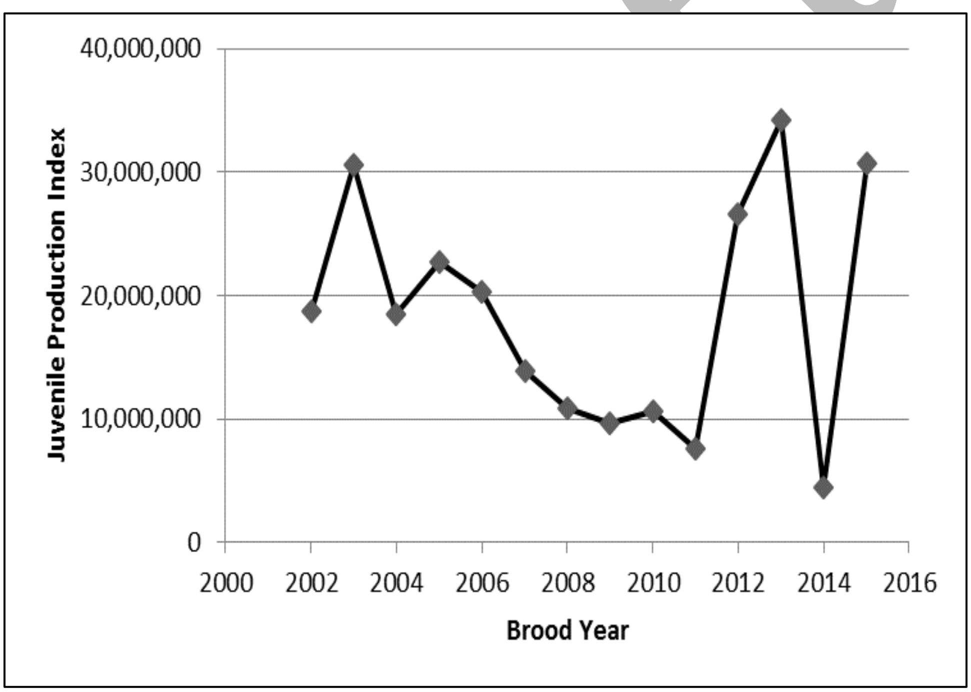

Figure 3.1.3.a. Fry-equivalent Juvenile Production Index estimates of SRFC production above RBDD across brood years 2002-2015 (Voss and Poytress 2017).

Since 1995, CDFW has used rotary screw traps at Knights Landing to track emigrating juvenile SRFC passage into the Sacramento-San Joaquin Delta. Passage estimates for the Knights Landing screw traps followed similar trends to those observed at RBDD for brood year 2013 through 2016 outmigrants, with a substantial reduction in passage observed for brood year 2014 (Table 3.1.3.a). Data for brood year 2012 were not available.

Table 3.1.3.a. Juvenile SRFC passage estimates at Knights Landing for brood years 2013 -2016.

Brood Year	Smolts (in millions)
2013	25.8
2014	3.2
2015	19.7
2016	11.4

3.1.4 Disease

In addition to influencing pre-spawn mortality and available temperature suitable spawning habitat, elevated temperatures and stable low reservoir releases in the Feather River have likely contributed to disease infectivity and disease contraction in juvenile SRFC. Since 2012, pathogens *Ceratonova shasta* (*C. shasta*) and *Parvicapsula minibicornis* (*P. minibicornis*) have been monitored by USFWS in collaboration with CDWR and CDFW. Between 2012 and 2016 (January-May), a pattern of *C. shasta* and *P. minibicornis* infectivity was observed and likely affected a large proportion of the emigrating population. *C. shasta* was detected in 35 percent, 58 percent, and 46 percent of the juveniles collected in spring of 2014, 2015, and 2016, respectively (Foott 2014, Foott et el. 2016, Foott and Imrie 2016).

As referenced above, warm water releases from the Thermalito Afterbay river outlet (RM 59) frequently result in temperatures that exceed optimal spawning temperatures for SRFC in October downstream of the outlet. This likely compresses adult spawners into available temperature suitable spawning habitat upstream of the outlet at least for a portion of the spawning window. Pathology data suggested a zone of high infectivity was likely present in the high flow channel downstream of the Afterbay river outlet (Foott 2014). In both 2015 and 2016 a zone of high *C. shasta* infectivity was present beginning near the confluence of RM 59 and extended downstream to at least RM 45, according to reports provided by USFWS California-Nevada Fish Health Center (Foott et al. 2016, Foott and Imrie 2016).

It is reasonable to assume that if a majority of adults spawn in the low flow channel (upstream of RM 59), and their progeny must emigrate through a zone of high *C. shasta* infectivity, then in-river juvenile production would be severely reduced. For brood years 2012 through 2015, passage estimates within the high flow channel (RM 45.8) were substantially lower than estimates of passage at the low flow channel rotary screw trap at RM 61 (Table 3.1.4.a). These data suggest that the emigrating juvenile populations of brood years 2012-2015 were reduced by an average of 48 percent in only 15 miles of habitat. While some loss due to predation and other causes would be expected between the two sampling locations, the magnitude of loss suggests that disease severely reduced in-river production in the Feather River and that there was no appreciable spawning downstream of RM 61. If successful spawning occurred downstream of RM 61 during 2012 through 2015, it did not occur in sufficient magnitude to offset the observed losses. It is worthwhile noting that in spring of 2018 (brood year 2017), only 1.9 million juveniles were estimated to have passed the low flow channel rotary screw trap (RM 61). This is the lowest passage estimate during the 2012-2018 period and suggests that short-term stock rebuilding may need to rely more heavily on hatchery production than natural production from the Feather River.

It is generally accepted that in order to develop an infectious zone the following factors need to coincide: low velocity, unvaried flows in close proximity to spawning areas (myxospore input), and temperatures above 12-15° C. It is also worth noting that due to reoccurring pathogen issues documented on the Feather River, pulse flows similar to those mandated on the Klamath River (*HVT v. NMFS* 2017) may be prudent to help with stock rebuilding and maintenance.

Table 3.1.4.a. Sacramento River fall Chinook juvenile passage estimates in the Feather River and the estimated mortality during downstream migration, brood years 2011-2015.

Brood Year	Juvenile Passage Estimate at River Mile 61.0	Juvenile Passage Estimate at River Mile 45.8	Percent Reduction
2011	9,902,393	9,271,622	6%
2012	26,254,553	13,871,128	47%
2013	27,645,796	23,888,112	14%
2014	19,087,391	7,516,495	61%
2015	10,025,589	2,994,935	70%

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 abundances 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[1] 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 RBDD and the JPI estimates calculated from RBDD passage provide the necessary components for examining the stock-recruitment relationship for the Sacramento River and its tributaries upstream of RBDD (Figure 3.1.5.a). The Ricker stock-recruitment function that was fit to these data indicated that the juvenile production index increases with increased spawner abundance with maximum average juvenile production at approximately 80,000 female spawners, that there was a moderate amount of density-dependence at higher spawner abundances, and that there was a relatively low amount of density-independent variation.

[1] Residuals are the differences between the observed $\log_e$ (recruits/spawners) and the predicted $\log_e$ (recruits/spawners) from the stock-recruitment relationship. In this application, recruits are the Juvenile Production Index and spawners are the number of female spawners.

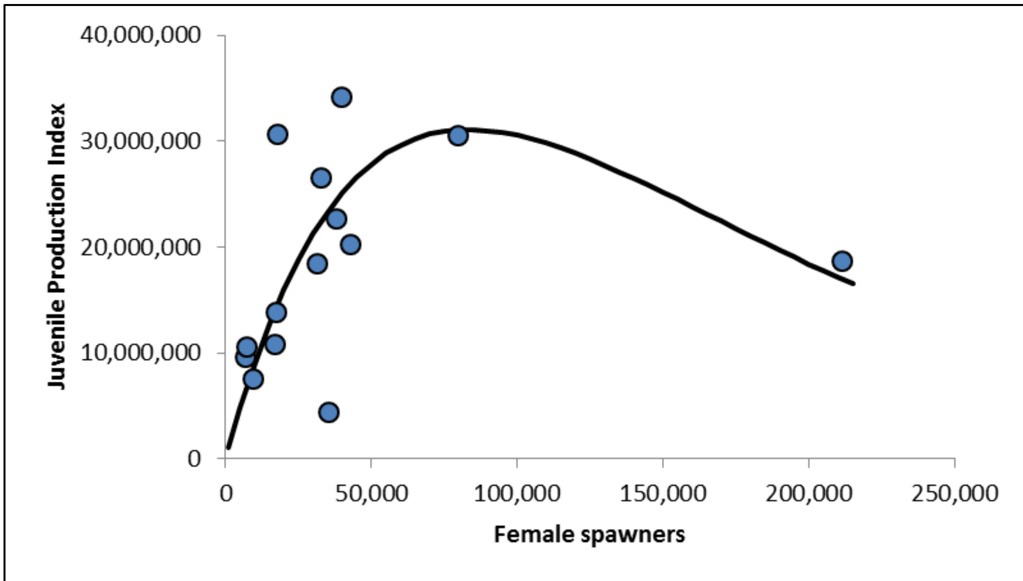

Figure 3.1.5.a. Estimates of the number of the total number of female spawners above RBDD and the fry-equivalent juvenile production index for brood years 2002-2015. The line represents the Ricker stock-recruitment function that was fit to the data.

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 SRFC data indicated that brood years 2012 and 2013 had slightly higher-than-expected recruitment given female spawner abundance, but brood year 2014 had dramatically lower-than-expected recruitment given the number of female spawners that year (Figure 3.1.5.b).

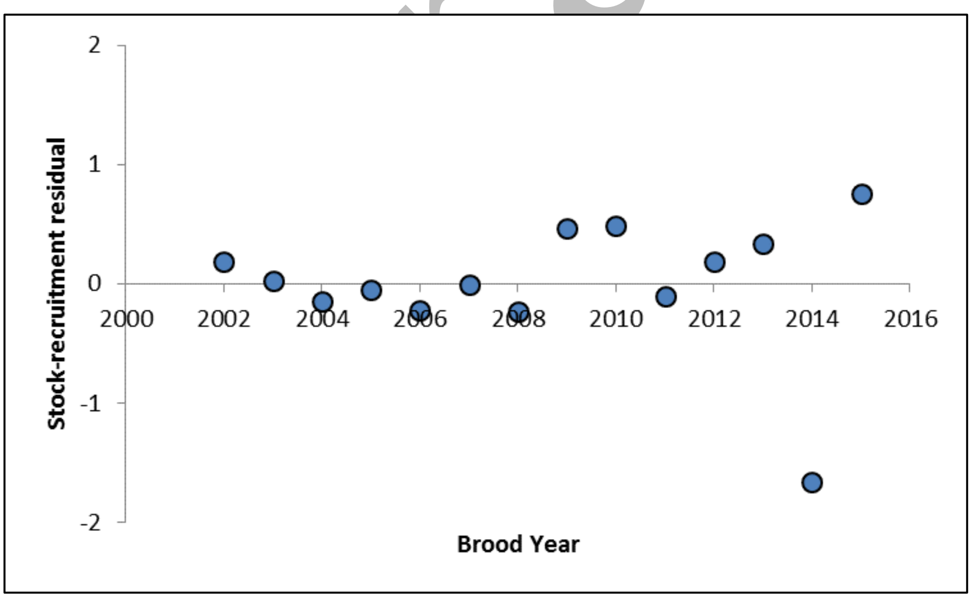

Figure 3.1.5.b Residuals from the fitted stock-recruitment relationship by brood year for the Sacramento River above RBDD.

3.1.6 Hatchery production

As described earlier, hatchery production of SRFC comes from Coleman National Fish Hatchery (CNFH), operated by USFWS, and from Feather River Hatchery (FRH) and Nimbus Fish Hatchery (NFH), operated by CDFW. Table 3.1.6.a shows the total number of SRFC smolts released annually from each hatchery for brood years 2000-2014. For all three facilities, annual release numbers during the brood years that contributed to the overfished status were lower than the 2000-2011 averages. While CNFH and NFH released on average 800-900 thousand fewer smolts during the critical years, the difference was much greater at FRH with an average of 2.8 million fewer smolts released. CNFH is located on Battle Creek, a tributary near the upper limit of anadromy in the mainstem, and smolts are typically released directly into the creek. However, in response to severe drought conditions in the Sacramento River, brood years 2013 and 2014 had 62 percent and 100 percent of their smolts, respectively, trucked to the delta and released into net pens (Figure 3.1.6.a). At FRH, all of the fall-run production is trucked (or sometimes barged) and released into net pens in the delta and San Pablo/San Francisco Bay, as well as coastal net pens located in Half Moon Bay and Santa Cruz. NFH is located on the American River, upstream of the city of Sacramento. While a portion of the production at NFH is always trucked to the delta or bay and released into net pens, brood years 2013 and 2014 were entirely trucked, again due to extreme drought conditions in-river.

More detailed information on hatchery operations during the critical years, release strategies, and the effects of hatchery straying is forthcoming.

Table 3.1.6.a. Numbers of SRFC smolts released from Coleman National Fish Hatchery (on Battle Creek), Feather River Hatchery, and Nimbus Fish Hatchery (on the American River) for the 2000-2014 broods.

Brood Year	Coleman National Fish Hatchery	Feather River Hatchery	Nimbus Fish Hatchery	Total SRFC Smolts Released
2000	12,664,580	5,036,622	4,375,806	22,077,008
2001	11,318,028	6,743,911	4,222,082	22,284,021
2002	14,018,806	8,137,445	4,361,300	26,517,551
2003	13,101,565	8,549,876	4,578,400	26,229,841
2004	11,854,153	8,996,680	4,570,000	25,420,833
2005	13,355,345	10,347,148	3,002,600	26,705,093
2006	12,316,193	9,785,968	6,130,383	28,232,544
2007	12,699,100	10,148,313	6,931,264	29,778,677
2008	14,021,126	8,351,309	4,194,887	26,567,322
2009	11,569,461	9,719,123	4,612,769	25,901,353
2010	12,709,391	10,552,142	4,855,599	28,117,132
2011	12,508,161	10,012,097	4,805,043	27,325,301
2012	**11,875,014**	**6,952,929**	**4,012,500**	**22,840,443**
2013	**11,780,007**	**6,632,534**	**3,587,565**	**22,000,106**
2014	**11,846,951**	**4,578,358**	**3,932,549**	**20,357,858**
2000-2011 avg.	12,677,992	8,865,053	4,720,011	26,263,056
2012-2014 avg.	11,833,991	6,054,607	3,844,205	21,732,802

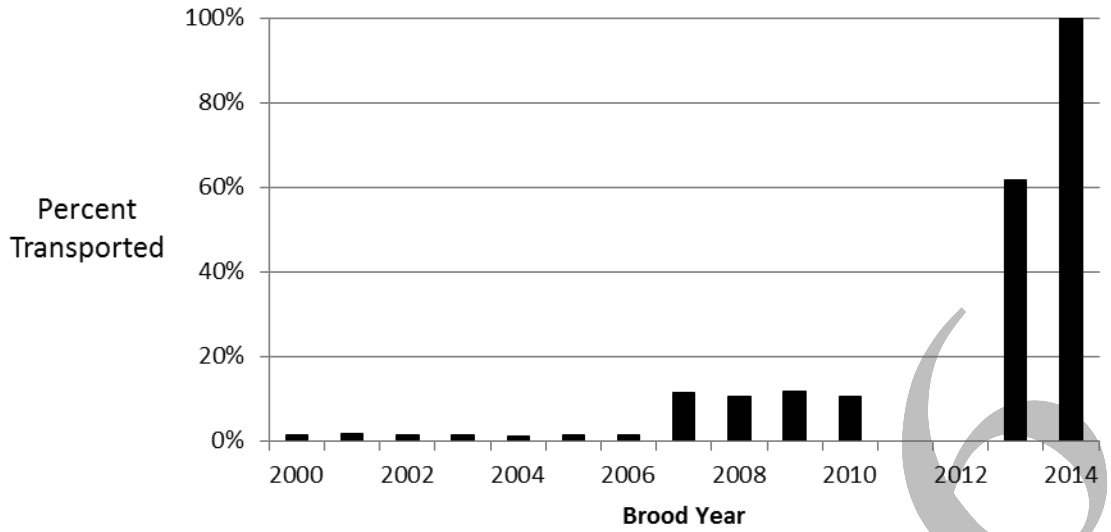

Figure 3.1.6.a. Percentages of the total annual SRFC releases from Coleman National Fish Hatchery that were transported to net pens via truck prior to release, brood years 2000-2014.

3.1.7 Other relevant factors

Drought actions and regulatory oversight of state and federal water project operations
On January 17, 2014, California Governor Jerry Brown issued a Drought Emergency Proclamation that directed the State Water Resources Control Board (Water Board) to consider petitions to modify established requirements for reservoir releases or diversion limitations and implement a water quality control plan (see Water Board Decision-1641). As a result, Temporary Urgency Change Petitions (TUCPs) and other associated actions were filed by CDWR and the U.S. Bureau of Reclamation (USBR) in 2014, 2015, and 2016 (see https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/).

CDWR and USBR requested that the Water Board consider modifying requirements of USBR's and CDWR's water right permits to enable changes in operations, and requested concurrence under federal biological opinions for the state and federal water projects. Petitions requested reduced delta outflow requirements to increase reservoir storage, along with associated modifications to delta water quality standards. In addition, TUCPs requested greater flexibility in CDWR and USBR operations of the Delta Cross Channel (DCC) gates to ensure freshwater supplies were maintained and to minimize salinity intrusion from San Francisco Bay. It was widely recognized that some of the requested modifications to standards and requirements could pose risks to fisheries resources. In response to these concerns, a drought operations plan was developed in 2014 to maximize regulatory flexibility to allow for swift adjustments in response to changes in the weather and environment to help bolster water supplies when possible while minimizing impacts to fish and wildlife (USBR and CDWR 2014). The 2014 plan called for increased monitoring in order to respond to the needs of state and federally listed fish species, and included a matrix of triggers for DCC gate operations to prevent entrainment of ESA-listed Sacramento River winter Chinook (SRWC) and Central Valley spring Chinook into the interior delta. Entrainment into the interior delta has been shown to slow emigration and increase loss rates of salmonids (USBR and CDWR 2014).

SRFC have evolved with and are adapted to high spring flows associated with snow melt. Drought conditions in 2013 through 2015 resulted in reduced reservoir releases affecting fall temperatures and spawning habitat availability, and also influenced conditions during juvenile outmigration. Reduced winter and spring flows resulted in elevated temperatures within emigration corridors, decreased food availability, increased energetic expenditure during emigration associated with slow water velocities, and increased risk of predation and disease contraction. The 2013-2015 drought likely impacted juvenile SRFC in several ways resulting in decreased recruitment to ocean fisheries and subsequent adult escapement. As SRFC are not state or federally listed, drought operations plans and triggers were not designed to be particularly protective of this stock. This extended to SRFC hatchery production and resulted in altered release strategies. For example, USFWS developed an alternate release plan for CNFH fall-run production which modified standard release strategies if downstream temperatures exceed certain thresholds and the DCC gates are open (USFWS 2014). Similar drought release strategies were developed for NFH. In both cases, thresholds were met in 2014 and all fall-run production was released into net pens in the delta or San Francisco Bay. While these actions may have improved survival of juveniles to ocean entry and increased recruitment to the ocean fisheries, they also drastically increased straying of returning adults. In the case of CNFH fall-run production, the rate of adult straying in fall of 2017 was high and the hatchery was unable to meet its production goal. This will likely influence the SRFC stock rebuilding timeline.

3.2 Marine Survival

3.2.1 Review of ocean conditions

The California Current Large Marine Ecosystem, in which SRFC 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 SRFC. 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).

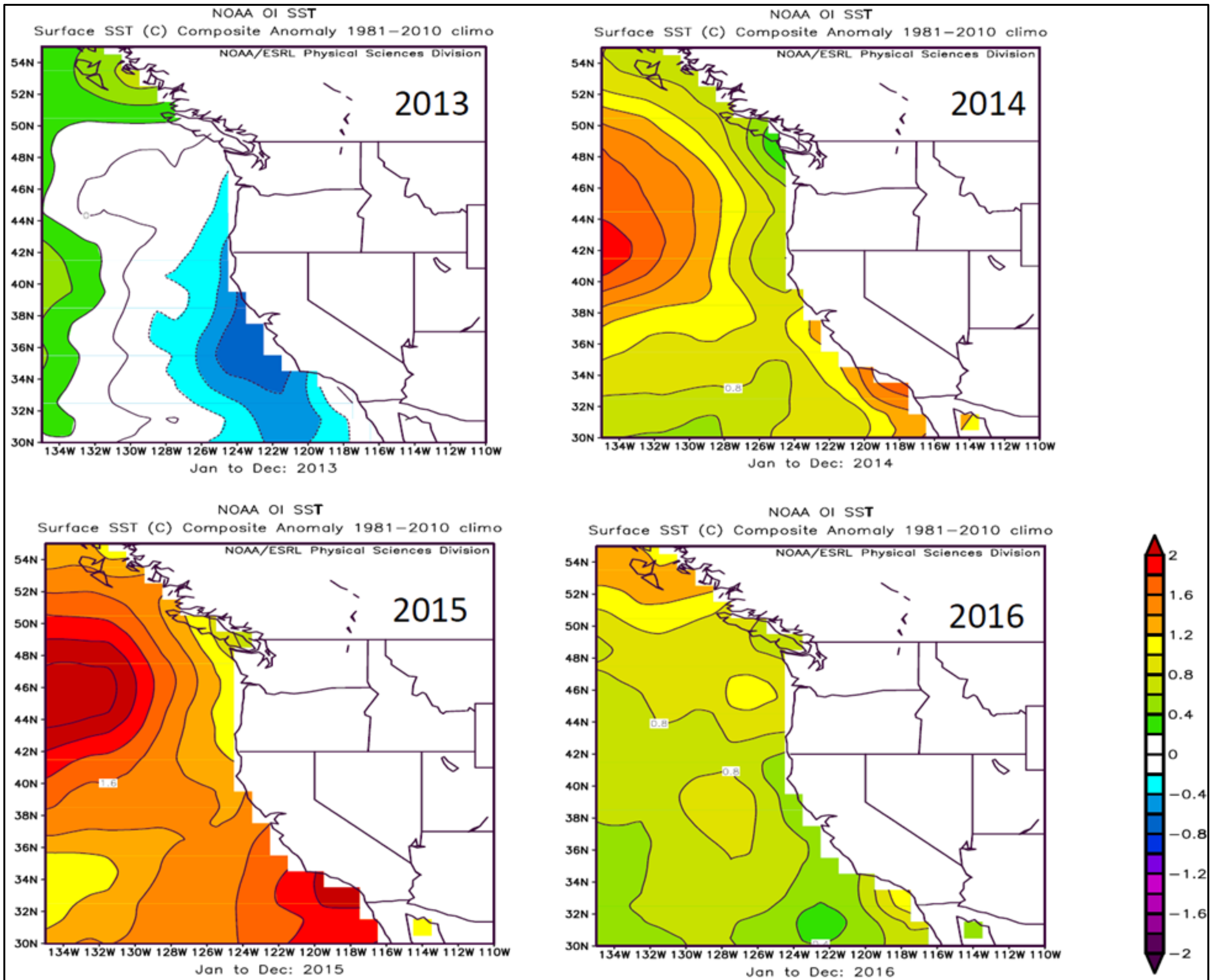

Figure 3.2.1.a. Annual sea surface temperature anomalies for years 2013-2016 (Nathan Mantua, NMFS, personal communication).

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.

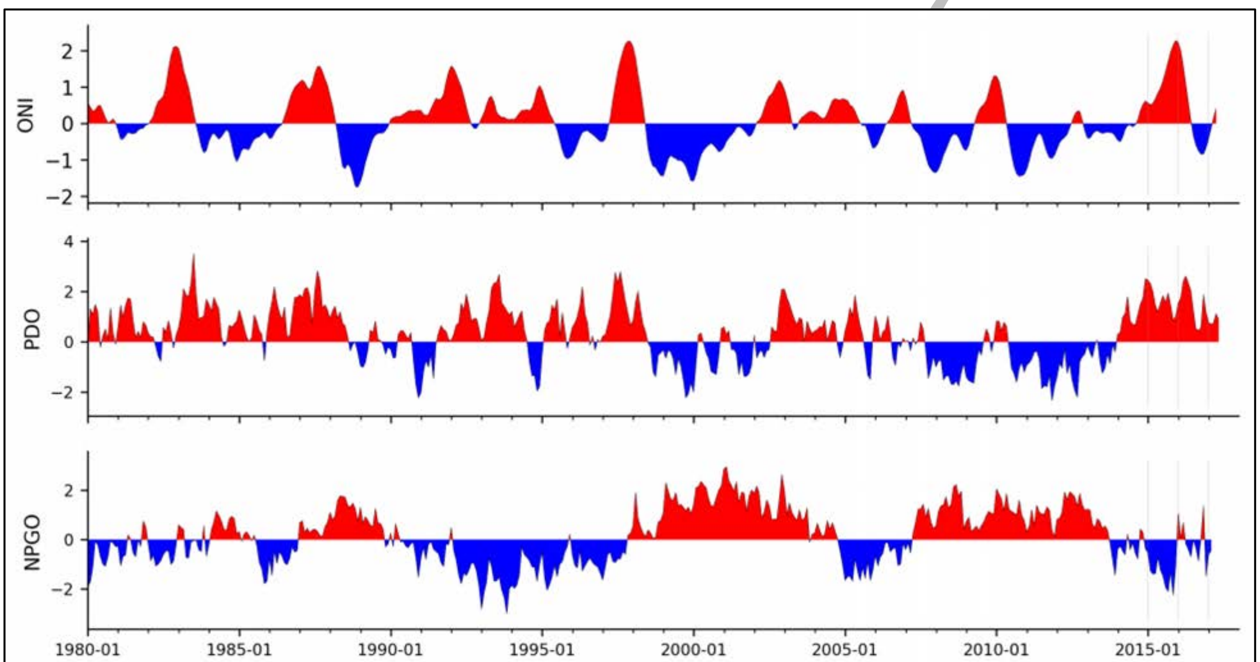

Figure 3.2.1.b. Time series for three ocean climate indices relevant to productivity of the California Current: the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), and the North Pacific Gyre Oscillation (NPGO). Tick marks represent January values (Figure reproduced from Wells et al.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

Local-scale ocean conditions relevant to SRFC 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 brood year 2012. 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.

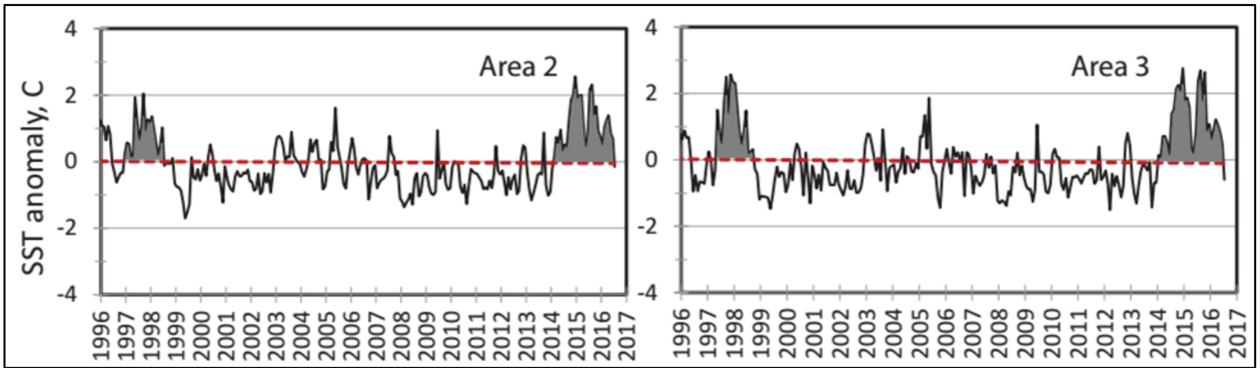

Figure 3.2.1.c. Anomalies of monthly mean sea-surface temperature in offshore (Area 2) and coastal (Area 3) areas off central California between Trinidad and Pt. Conception. Anomalies were calculated relative to the long-term (1981-2016) mean monthly values. The shaded areas correspond to the anomalies 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 SRFC are the CUI values for 36° N (just south of Monterey Bay) and 39° N (just north of Point Arena). 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.

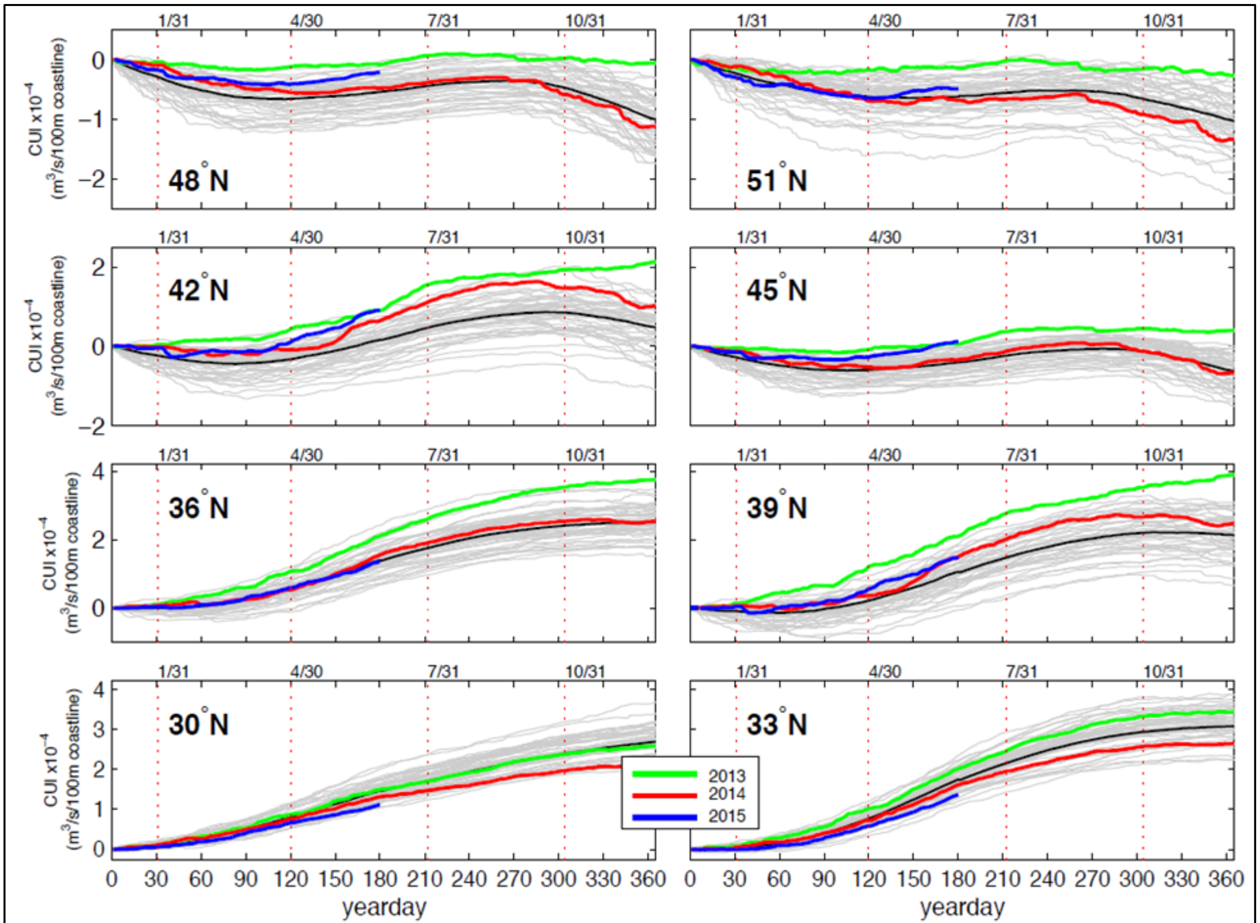

Figure 3.2.1.d. Plots of the Cumulative Upwelling Index (CUI) by latitude. The black line is the mean from 1967-2011 and grey lines are years 1967-2013. Years 2013-2015 are represented by the colored lines defined in the legend. Figure reproduced from Leising et al. (2015).

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).

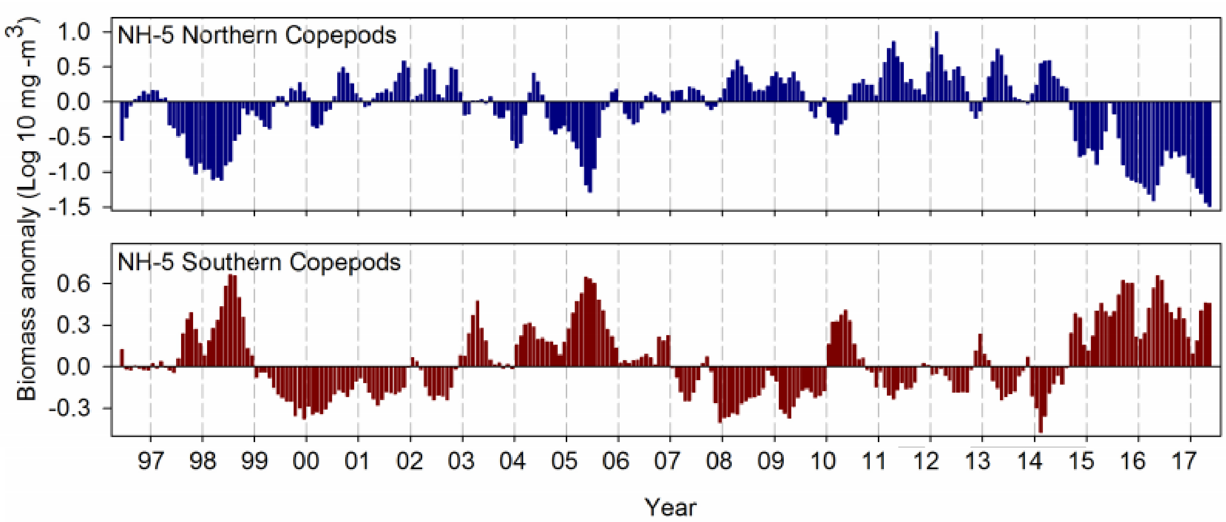

Figure 3.2.1.e. Time series plots of northern and southern copepod biomass anomalies in coastal Oregon waters, measured along the Newport Hydrographic Line. Figure reproduced from Wells et al. (2017).

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 2013-2014, which would correspond to the outmigration years for brood year 2012-2013 SRFC. The biomass of salmon-favored ichthyoplankton increased substantially in 2015, with major contributions from rockfish and anchovy (Figure 3.2.1.f). 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. While SRFC adults are caught in ocean fisheries up to and north of Newport, OR, it is unclear how relevant the zooplankton results for Newport and Trinidad, and the ichthyoplankton results for Newport, might be for juvenile SRFC entering the ocean in the Gulf of the Farallons.

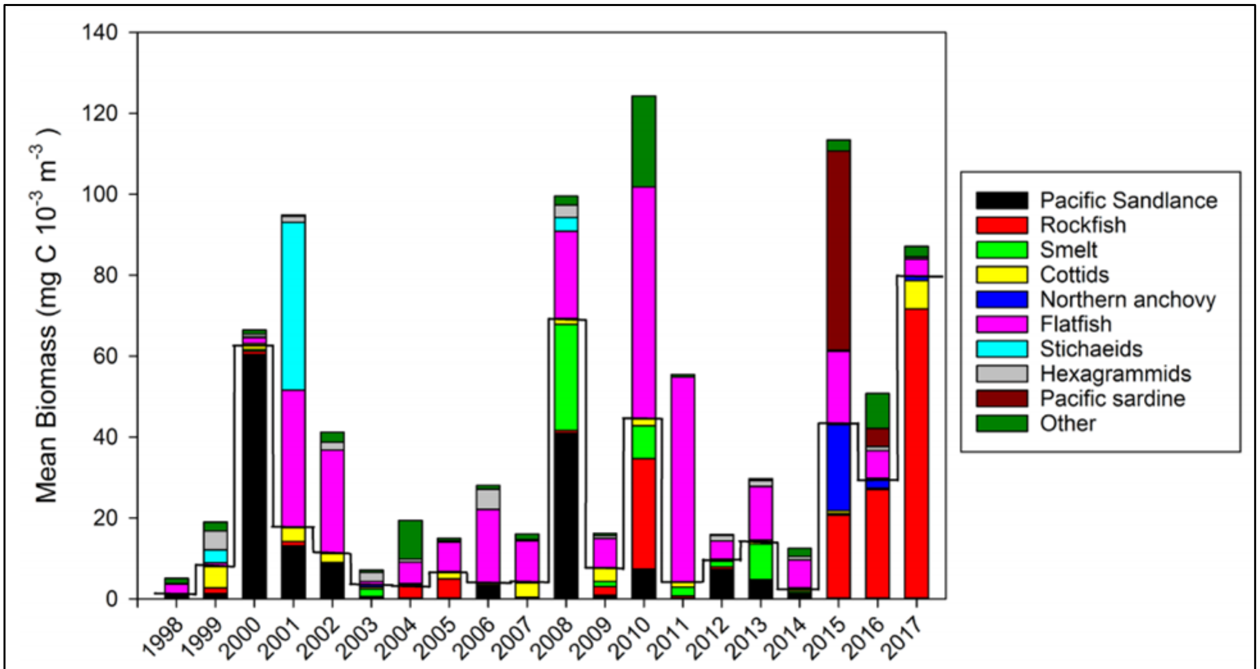

Figure 3.2.1.f. Annual mean biomass of five important juvenile salmon prey taxa (below solid line) and five other larval fish taxa (above solid line) collected during winter (January-March) along the Newport Hydrographic Line, 9-46 km off the coast of Oregon. Figure reproduced from Wells et al. (2017).

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 Auklets from California to British Columbia that occurred in 2014-2015. To the north, the biomass of lipid-poor, southern copepods was identified as the most supported predictor of this event. In central California, mortalities were dominated by young-of-the-year birds, which were surmised to be from the breeding colonies on the Farallon Islands.

For the years of primary interest with regard to the SRFC overfished status (outmigration years 2013-2015), indicators of ocean productivity and feeding conditions for salmon were highly dynamic. Outmigration year 2013 was characterized by generally cool SSTs in the California Current, relatively high biomass of northern copepods at off Newport, OR, and moderate levels of ichthyoplankton biomass for species known to be important prey for juvenile salmon. Upwelling indices were above average, 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 latitude 36^{o} N to latitude 48^{o} N, upwelling generally remained at average or above average levels. Late in 2014, SSTs warmed and the copepod assemblage off Newport, OR 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 planktivorous seabird, Cassin's auklet, 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 latitude 36^{o} N to latitude 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 yet a relatively high salmon-favorable ichthyoplankton biomass was observed in 2015 at Newport.

In summary, for the critical brood years of 2012-2014, outmigrating juvenile SRFC encountered a wide range of ocean conditions. The earliest brood encountered generally cool, productive conditions in the California Current that could be characterized as favorable for salmon survival. An abrupt transition occurred in 2014; however, with rapid warming which resulted in record high SSTs in 2015, the development of a very strong ENSO event in 2015, and most large-scale indicators pointing toward low productivity in the California current from mid-2014 through 2016.

3.3 Harvest Impacts

3.3.1 Ocean fisheries

SRFC are the largest contributing stock in California and Oregon ocean salmon fisheries (O'Farrell et al. 2013). SRFC are primarily contacted between Cape Falcon, Oregon and Pt. Conception, California, with contact rates generally higher closer to San Francisco Bay, which connects the Sacramento River to the ocean. This includes the major management areas of Northern Oregon (Cape Falcon to Florence south jetty[2]), Central Oregon (Florence south jetty to Humbug Mt.), the Oregon Klamath Management Zone (KMZ) (Humbug Mt. to the OR/CA border), the California KMZ (OR/CA border to Horse Mt.), Fort Bragg (Horse Mt. to Pt. Arena), San Francisco (Pt. Arena to Pigeon Pt.), Monterey North (Pigeon Pt. to Pt. Sur), and Monterey South (Pt. Sur to the U.S./Mexico border). Both commercial and recreational ocean salmon fisheries typically occur in all of these areas. The commercial fishery generally receives a larger share of the projected ocean 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. When SRFC abundance is projected to be low and it is a constraining stock, fisheries in areas closer to San Francisco Bay (i.e., San Francisco, Fort Bragg, and both Monterey areas) are the most affected. However, SRFC was not a constraining stock in any season during 2015-2017. Rather, ocean fisheries south of Cape Falcon

[2] 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.

were primarily constrained by Klamath River fall Chinook (KRFC), and areas south of Pt. Arena were also constrained by endangered SRWC.

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 the U.S./Mexico border. In general, seasons progressively became more restrictive between 2015 and 2017, largely due to a steep downward trajectory in preseason KRFC abundances, but also to protect 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 often some of the late-summer/fall quotas are 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 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 comprised of various blocks of open time between May and September. In 2015, this area had a relatively wide open season, but it was curtailed back 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 a small fishery centered around the Golden Gate 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 both Monterey areas, seasons are highly 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 in Monterey North and slightly less in Monterey South, and the 2016 and 2017 seasons were limited to two months in both areas.

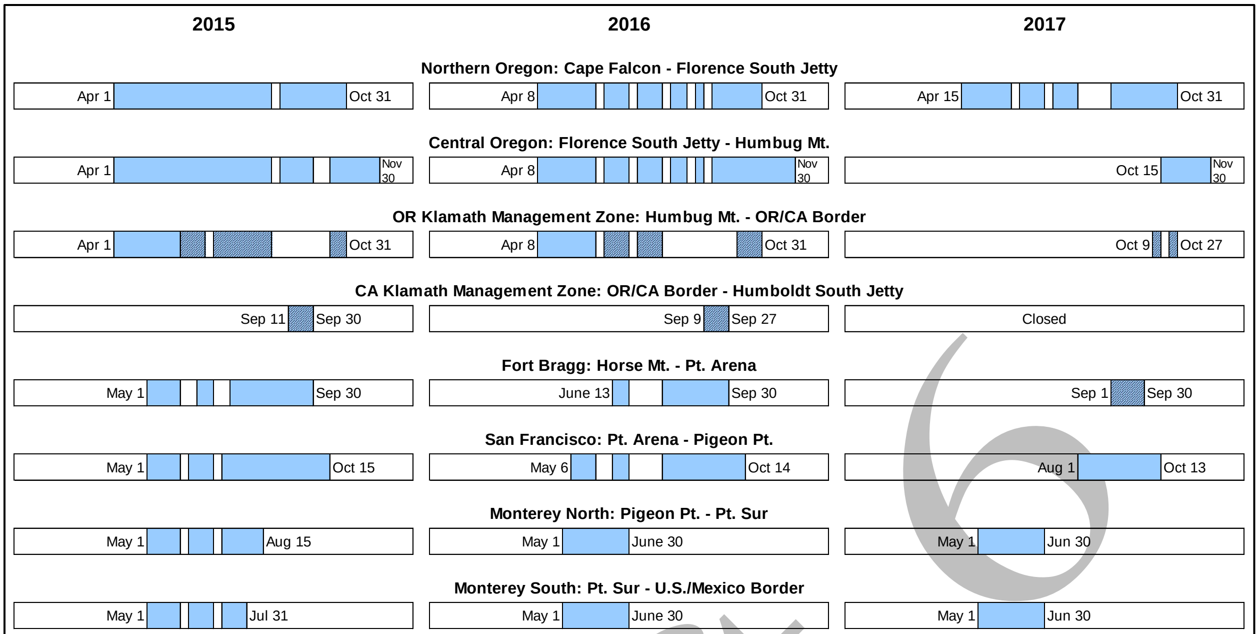

Figure 3.3.1.a. The general commercial ocean season structure for all management areas between Cape Falcon and the U.S./Mexico border during 2015-2017, with the first and last open days of the season displayed. Open periods shown with a diagonal pattern were operated under quota systems.

Recreational Ocean Seasons

Figure 3.3.1.b illustrates the general season structures of the 2015-2017 recreational ocean salmon fisheries between Cape Falcon and the U.S./Mexico border. As mentioned above, KRFC was the primary constraining stock during those years. The recreational fishery has relatively lower impacts on KRFC, so season reductions when KRFC is limiting are mostly confined to the KMZ, although Fort Bragg was majorly 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. There is also usually a November state-water-only fishery centered around the Elk River mouth in the Central Oregon area. 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. There is also usually a state-water-only fishery centered around the Chetco River mouth in the Oregon KMZ during early-October. 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 those 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 both Monterey areas, seasons are highly 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 in Monterey North ended in early-September, and the 2016 and 2017 seasons only continued through mid-July. In Monterey South, the 2015 season ended in mid-July, and the 2016 and 2017 seasons only continued through May.

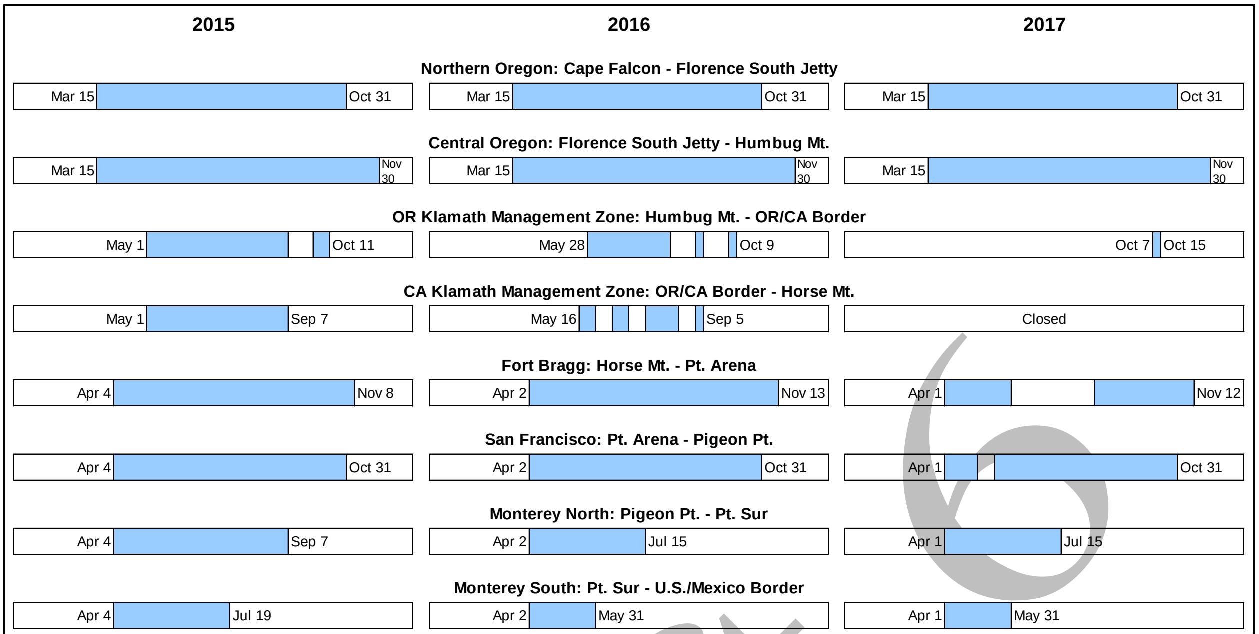

Figure 3.3.1.b. The general recreational ocean season structure for all management areas between Cape Falcon and the U.S./Mexico border during 2015-2017, with the first and last open days of the season displayed.

Adult Harvest

Table 3.3.1.a displays historical adult SRFC harvest levels. For ocean harvest, the year (t) represents September 1 in the prior year (t-1) through August 31 (t). The commercial fleet harvested approximately 100,000 adult SRFC during the 2015 season, a relatively low number, and only about two-thirds and one-third that amount in 2016 and 2017, respectively. The average commercial harvest of adult SRFC during 2015-2017 was only 20 percent of the long-term average. In the recreational ocean fishery, harvest of adult SRFC increased each season during those three years, but even in 2017 the harvest was less than one-third of the long-term average. The average number of adult SRFC harvested by recreational ocean anglers during 2015-2017 was only 25 percent of the long-term average. At no point during 2015-2017 did ocean harvest of adult SRFC approach the long-term average.

Table 3.3.1.a. Harvest and abundance indices for adult Sacramento River fall Chinook in thousands of fish. Bold values indicate years which resulted in the overfished status. Table modified from Table II-1 in PFMC (2018c).

	SRFC Ocean Harvest South of Cape Falcon[a/]						
Year (t)	Troll	Sport	Non-Ret[b/]	Total	River Harvest	Sacramento Index (SI)[c/]	Exploitation Rate (%)[d/]
1983	246.6	86.3	0.0	332.9	18.0	461.1	76
1984	266.2	87.0	0.0	353.1	25.9	538.1	70
1985	355.5	158.9	0.0	514.4	39.1	792.8	70
1986	619.0	137.5	0.0	756.4	39.2	1,035.7	77
1987	686.1	173.1	0.0	859.2	31.8	1,086.1	82
1988	1,163.2	188.3	0.0	1,351.5	37.1	1,616.1	86
1989	602.8	157.1	0.0	759.9	24.9	937.3	84
1990	507.3	150.4	0.0	657.8	17.2	780.0	87
1991	300.1	89.6	0.0	389.7	26.0 [e/]	534.6	78
1992	233.3	69.4	0.0	302.8	13.3 [e/]	397.6	79
1993	342.8	115.3	0.0	458.1	27.7 [e/]	623.2	78
1994	303.5	168.8	0.0	472.3	28.9 [e/]	666.7	75
1995	730.7	390.4	0.0	1,121.0	48.2	1,464.6	80
1996	426.8	157.0	0.0	583.8	49.2	934.7	68
1997	579.7	210.3	0.0	790.0	56.3	1,191.1	71
1998	292.3	114.0	0.0	406.3	69.8 [e/]	722.1	66
1999	289.1	76.2	0.0	365.3	68.9 [e/]	834.0	52
2000	421.8	152.8	0.0	574.6	59.5 [e/]	1,051.6	60
2001	284.4	93.4	0.0	377.9	97.4	1,072.0	44
2002	447.7	184.0	0.0	631.7	89.2 [e/]	1,490.8	48
2003	501.6	106.4	0.0	608.0	85.4	1,216.3	57
2004	621.8	212.6	0.0	834.5	46.8	1,168.2	75
2005	367.9	127.0	0.0	494.9	64.6	955.5	59
2006	149.9	107.7	0.0	257.7	44.9	577.6	52
2007	120.0	32.0	0.0	152.0	14.3 [e/]	257.7	65
2008	3.2	0.9	0.0	4.1	0.1 [e/]	69.6	6
2009	0.0	0.2	0.1	0.3	0.0 [e/]	41.1	1
2010	11.2	11.4	0.3	22.8	2.5 [e/]	149.6	17
2011	46.6	22.8	0.0	69.4	17.4 [e/]	206.1	42
2012	182.9	93.3	0.3	276.5	62.2 [e/]	624.2	54
2013	290.7	114.4	0.0	405.1	55.5 [e/]	866.8	53
2014	240.5	62.4	0.0	302.9	35.7 [e/]	551.1	61
2015	**100.0**	**24.4**	**0.0**	**124.4**	**16.9** [e/]	**254.2**	**56**
2016	**62.9**	**28.9**	**0.0**	**91.8**	**23.9** [e/]	**205.3**	**56**
2017[f/]	**38.8**	**31.7**	**0.0**	**70.5**	**25.0** [e/]	**140.0**	**68**
1983-2017 avg.	338.2	112.5	0.0	450.7	38.9	729.0	62
2015-2017 avg.	67.2	28.3	0.0	95.5	21.9	199.8	60

a/ Ocean harvest for the period September 1 (t-1) through August 31 (t).
b/ Mortalities estimated from non-retention ocean fisheries (e.g., coho-only fisheries, non-retention GSI sampling). In 2008, there were 37 estimated mortalities as a result of non-retention fisheries that have been rounded to 0 in this table.
c/ The SI is the sum of (1) SRFC ocean fishery harvest south of Cape Falcon between September 1 and August 31, (2) SRFC impacts from non-retention ocean fisheries when they occur, (3) the recreational harvest of SRFC in the Sacramento River Basin, and (4) the SRFC spawner escapement.
d/ Total ocean harvest, non-retention ocean fishery mortalities, and river harvest of SRFC as a percentage of the SI.
e/ Estimates derived from CDFW Sacramento River Basin angler survey. Estimates not marked with a footnote are inferred from escapement data and the mean river harvest rate estimate.
f/ Preliminary.

3.3.2 In-river fisheries

Fishery area and seasons

Sport fishing for SRFC in the Sacramento Basin occurs on the Sacramento River from the Carquinez Strait near Vallejo, CA upstream to the Deschutes Road Bridge, just downstream from Redding, CA (Table 3.3.2.a). The lowermost fishing area includes Suisun Bay and adjacent channels representing portions of the western Sacramento-San Joaquin Delta, and the North and South forks of the Mokelumne River and adjacent sloughs, which represent portions of the central Delta. Fishing also occurs on the American and Feather rivers, the largest tributaries to the Sacramento River. Currently, over 400 miles of river and delta channels are available for the inland sport fishery. It is important to note that the Mokelumne River is not a tributary of the Sacramento River, and thus harvest in this river is not included when calculating the SI.

The open season for salmon fishing is designed to focus harvest on SRFC and Sacramento River late-fall Chinook, including production from both natural spawning areas and hatcheries. The general season is five months long and runs from July 16 through December 16. Minor exceptions to this season occur in select areas of the system, to avoid contact with listed Central Valley spring Chinook and SRWC in some areas, and to provide additional fishing opportunity for late-arriving SRFC in other areas.

Daily bag and possession limits

The daily bag limit for Chinook salmon in the Sacramento Basin has been two salmon per day for most of at least the last 70 years of the management history of this stock. Exceptions included a liberalization to three salmon per day on the Feather and American rivers during the mid-2000s in response to exceptionally high escapements on those rivers during 2001-2003. No harvest was allowed during the complete fishery closure on SRFC during 2008 and 2009. There was a bag limit of one salmon per day in 2010 as the stock recovered, followed by a return to the two salmon per day bag limit in 2011, which continued, along with a possession limit of four salmon, through the 2017 season. In response to the overfished status of the stock, the daily bag and possession limits for the 2018 season are one and two salmon, respectively.

Sampling design

The Chinook salmon sport fishery in the Sacramento Basin is monitored by CDFW’s Central Valley Angler Survey (Survey). Currently, the Chinook salmon fishing area described above is divided into 25 survey sections (Table 3.3.2.a). A stratified, random sampling design, based on Smith (1950) and Wixom et al. (1995), is used to estimate salmon angling effort, catch, and harvest in each survey section. Each survey section is sampled four weekdays and four weekend days per month, each day selected randomly. Weekdays and weekend days constitute separate temporal strata given that angling effort is generally much higher on weekend days than on weekdays.

Table 3.3.2.a. Survey section codes and descriptions for river and delta sections surveyed by the Central Valley Angler Survey during the 2017 Chinook salmon sport fishery season in the Sacramento River system.

Section No.	Section Description
Sacramento River and Western Delta	
1	Carquinez Bridge to Rio Vista Bridge
1.1	Suisun Bay, Suisun Cutoff to Middle Grounds
1.2	Southhampton Bay from Benicia State Recreation Area to First Street Pier
2	Rio Vista Bridge to mouth of American River
3	American River to Knights Landing (Hwy. 113 Bridge)
4	Knights Landing to Colusa State Park
5	Colusa to Hamilton City (Hwy. 32 Bridge)
6	Hamilton City to Red Bluff Diversion Dam
7	Red Bluff Diversion Dam to Balls Ferry Boat Ramp
7.1	Barge Hole at the confluence of Battle Creek and Sacramento River
8	Balls Ferry Boat Ramp to Deschutes Road Bridge
American River	
9	Discovery Park to the interstate 80 Bridge
10	Interstate 80 Bridge to lower point of Sailor Bar peninsula
10.1	Hazel Avenue Bridge to Nimbus Dam (aka: Nimbus Basin)[a/]
10.2	Lower point of Sailor Bar peninsula to USGS cable lines adjacent to Nimbus Hatchery
Feather River	
11.1	Verona to Shanghai Rapids
11.2	Shanghai Rapids to Sunset Pumps
12	Palm Avenue Riffle to Thermalito Afterbay Outlet
12.1	Thermalito Afterbay Outlet
12.2	Sunset Pumps to Palm Avenue Riffle
Mokelumne River (Central Delta)	
16	South Fork, from the confluence with the San Joaquin to the confluence with the Cosumnes River
16.1	Beaver Slough (tributary to the South Fork Mokelumne River)
16.2	Hog Slough (tributary to the South Fork Mokelumne River)
16.3	Sycamore Slough (tributary to the South Fork Mokelumne River)
17	North Fork, from the confluence with the South Fork to the point of divergence from the mainstem

[a/] Nimbus Basin is closed to all fishing, effective March 1, 2018.

Survey components include roving counts, roving interviews, and access point interviews, as described below. Roving counts and access point interviews are used to estimate total fishing effort, while roving interviews are used to estimate catch per unit effort (CPUE) as catch/hour. Access point interviews are used to collect data for construction of effort distribution models, comparatively evaluate catch rates as derived from roving and access point interviews, and to gather completed angler trip data. Effort distribution models provide the proportion of whole-day fishing effort that is represented by an angler count made during two single hours of the fishing day.

Data collection

Primary data collection occurs from propeller-driven boats, jet-powered boats, drift boats, and kayaks, depending upon the physical characteristics of a given survey section. On each survey day in a given section, a high-speed pass is made through the section, during which all anglers are counted, thus comprising a roving count. Data collected during the roving count include time of observation, location by river mile, number of boats, number of boat anglers, and the number of shore anglers.

With completion of the first roving count of anglers, a second pass is made traveling back through the section to conduct roving interviews and a second roving count of anglers. Data collected during each interview include location by river mile, time of interview, fishing method, number of hours fished, number of anglers in the group, target species, zip code, whether the trip was completed, and the number of fish kept and released by species, including the time salmon were caught, as applicable.

Access point interviews are conducted at heavily used launch and shore fishing locations and are scheduled to encompass all hours of a virtual day to be used in the effort distribution model for that survey section, month, and day-type stratum (weekday or weekend day). Data collection from angler interviews occurs as described above for roving interviews.

Descriptions of fishery performance, both historically and during the years that led to the overfished status, are forthcoming.

3.4 Assessment and management

3.4.1 Overview

The Sacramento Harvest Model (SHM) is a model used by the PFMC during the annual season setting process to forecast the escapement of SRFC as a function of the SI forecast and ocean and river fishery management measures. The model is defined as

$$\mathrm{E} = \mathrm{SI}(1 - \mathrm{i_o})(1 - \mathrm{i_r}), \qquad (1)$$

where E is the forecast escapement, SI is the forecast Sacramento Index, i_o is the forecast ocean fishery impact rate, and i_r is the forecast river fishery impact rate (Mohr and O'Farrell 2014). For Chinook retention fisheries, the impact rates in Equation (1) are equivalent to harvest rates.

To assess the roles of assessment and fisheries management on escapement in 2015, 2016, and 2017, we examined whether SRFC 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 Equation (1) to assess how relative errors in the SHM components affected escapement projections in 2015-2017.

3.4.2 Performance

If no fishing mortality occurred on SRFC in 2015, 2016, and 2017, and escapement was assumed equal to the postseason estimate of the SI, escapement in each year would have exceeded the MSST of 91,500 and the S_{MSY} of 122,000 hatchery and natural-area adults. The stock would not be classified as overfished as the geometric mean of escapement absent fishing for 2015-2017 equals 194,048.

Using postseason estimates of the SI (i.e., assuming no SI forecast error) and imposing the exploitation rate defined by the control rule given the postseason estimates of the SI (i.e., assuming no fishery implementation error), the stock would not be overfished as the geometric mean of projected escapement would be 116,047. Projected escapements under this scenario equaled 122,000, 122,000, and 104,998, in 2015, 2016, and 2017, respectively.

Table 3.4.2.a displays preseason forecasts (pre) and postseason estimates (post) for the SI, survival rates $1 - i_o$ and $1 - i_r$, and SRFC escapement.

Table 3.4.2.a. Preseason forecasts (pre) and postseason estimates (post) of Sacramento Harvest Model (SHM) components for years 2015-2017. The Sacramento Index is denoted by SI and ocean and river survival rates are denoted by $(1 - i_o)$ and $(1 - i_r)$, respectively. E represents hatchery and natural-area escapement.

Year	Type	SI	$1-i_o$	$1 - i_r$	E
2015	pre	651,985	0.61	0.86	341,017
	post	254,240	0.51	0.87	112,947
	post/pre	0.39	0.84	1.01	0.33
2016	pre	299,609	0.59	0.86	151,129
	post	205,289	0.55	0.79	89,674
	post/pre	0.69	0.94	0.92	0.59
2017	pre	230,700	0.67	0.86	133,242
	post	139,997	0.50	0.64	44,574
	post/pre	0.61	0.74	0.75	0.33

In 2015, the postseason estimate of escapement was 0.33 of the predicted value, and this difference was largely the result of over-forecasting the SI (post/pre = 0.39). The ocean survival rate $(1 - i_o)$, was lower than predicted (post/pre = 0.84); this was mostly attributed to under-predicting the ocean harvest rate for the commercial fishery (the ocean recreational fishery was well predicted). The river survival rate $(1 - i_r)$ was well predicted (post/pre = 1.01).

In 2016, the postseason estimate of escapement was 0.59 of the predicted value, and this difference was also largely the result of over-forecasting the SI (post/pre = 0.69). However, both the ocean survival rate and the river survival rate were lower than predicted which also contributed to the difference in predicted versus observed escapement.

In 2017, the postseason estimate of escapement was 0.33 of the predicted value, and this difference again was primarily the result of over-forecasting the SI (post/pre = 0.61). The ocean survival rate was lower than predicted, owing primarily to under-predicting the ocean harvest rate in the recreational fishery. The river survival rate was substantially over-predicted as well.

The SI was over-forecasted in each of the three years contributing to the overfished status, and substantially so in 2015. These errors occurred despite relatively large reductions in the SI forecasts for 2016 and 2017 resulting from the autocorrelated error component in the SI forecast model (see PFMC 2016b, 2017). The downward correction in the SI forecast was appropriate in these years, but was not of sufficient magnitude to produce accurate forecasts.

Under-prediction of both ocean and river impact rates contributed to escapement shortfalls as well. In 2016, a modification to the data range used to forecast commercial fishery impact rates in the SHM was implemented in response to serial under-predictions of these rates (see PFMC 2016c, Appendix A, for a description of this modification). The result of this modification was to increase the predicted impact rates per unit of fishing effort in the commercial fishery, and commercial fishery impact rates in 2016 and 2017 were relatively well predicted. No such modification was needed at the time for the recreational ocean or river fisheries because they had been well forecast.

Since SRFC would not have been projected to be overfished (1) in the absence of fisheries in 2015-2017 and (2) under a scenario where fishing occurred but the level of fishing mortality was not influenced by assessment or management error, we conclude that aspects of the fishery assessment and management process contributed to the stock's overfished status. However, it is noted that the total exploitation rate, estimated postseason for 2015-2017, was well below the F_{MSY} level of 0.78 (PFMC 2018, Table II-1) and thus overfishing, as defined in the FMP, did not occur

3.5 Summary of potential causal factors

The critical broods of 2012-2014 resulted in well below average ocean abundance index values and adult spawner escapement in 2015-2017. Brood year 2014 appears to be the weakest of the critical broods as it was the primary contributor to the very low 2017 Sacramento Index postseason estimate and one of the lowest spawner escapement estimates on record. The record low escapement to the Upper Sacramento Basin in 2017 is particularly noteworthy.

Parental spawner levels for the critical broods were near or above average, and well above the S_{MSY} of 122,000 hatchery and natural-area adults. Brood year 2014 spawners in the upper Sacramento River experienced high temperatures and low flows that likely contributed to relatively high levels of pre-spawn mortality. High pre-spawn mortality was also noted in the Feather and American rivers, perhaps resulting from high water temperatures during the spawning period for the critical brood years. Juvenile production from the Sacramento Basin was very low, given the number of parental spawners, for brood year 2014. In the lower Sacramento River during the season of outmigration, temperatures were generally high, and flows low, for brood years 2013 and 2014.

A relatively cool, productive ocean was in place for brood year 2012 SRFC smolts entering the ocean in 2013. However, both basin- 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 conditions upon ocean entry that likely contributed to the low ocean abundance and escapement estimated for 2016 and 2017. The poor ocean conditions in 2014 and 2015 may have affected adult natural mortality for fish from brood year 2012, but we lack the data to directly evaluate this.
Assessment errors also contributed to low adult spawner escapement in 2015-2017. In each of these years, the Sacramento Index was over-forecast, sometimes substantially, which led to higher allowable exploitation rates than would be allowed if forecasts were very accurate. Furthermore, both ocean and river fishery mortality rates were underpredicted on several occasions. Because SRFC would not have been overfished in the absence of assessment and management error, we conclude that aspects of the fishery assessment and management process contributed to the stock's overfished status.

The relative contributions of individual factors that led to the overfished status cannot be determined given the existing data for SRFC. Yet, it is clear that some combination of river conditions, ocean conditions, and the assessment and management of salmon fisheries all contributed to the overfished status.

4.0 RECOMMENDATIONS FOR ACTION

4.1 Recommendation 1: Rebuilt Criterion

Consider the SRFC stock to be rebuilt when the 3-year geometric mean of hatchery and 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 salmon fisheries that impact SRFC until rebuilt status is achieved. We offer three alternative management strategies for consideration. The rebuilding time frame under each of the three Alternatives is not expected to exceed 10 years. The probability of achieving rebuilt status for years 1 through 10 is 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.

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

<ins>Alternative II.</ins> Status quo control rule with buffers added to maximum exploitation rates and escapement-based reference points until rebuilt status is achieved. Specifically:

Reduce the maximum allowable exploitation rate by 30 percent (to 49.0 percent), increase the S_{MSY} escapement level by 30 percent (to 158,600 hatchery and natural-area adult spawners), and maintain the current relationship between the reduced S_{MSY} and MSST (MSST = $0.75*S_{MSY}*1.30$).

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.

<ins>Alternative III.</ins> Suspend salmon-directed ocean fisheries in the area from Cape Falcon, OR south to the U.S./Mexico border 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 in-river 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 also serves to calculate 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, “fall” (September-December) ocean 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 SRFC. 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 4: Habitat Committee

This report has identified that habitat conditions contributed to escapement shortfalls and thus the overfished status determination. It is recommended that the Council direct the Habitat Committee 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, as described in the FMP. We also note that there are several habitat-related topics outlined, but not fully developed into recommendations, in Section 4.7: *Further recommendations*. The habitat-related topics in that section lie outside the expertise of the STT and thus assistance from the Habitat Committee is requested.

4.6 Analysis of Alternatives

The STT has developed a simple model to assess the probability of a stock achieving rebuilt status in each year following the overfished declaration. Future abundance is based on observed past abundance levels for the stock. 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 computation of the probability of rebuilt status by year. The model framework allows for evaluation of alternative rebuilding plans by specifying the rebuilding plans as alternative harvest control rules. The tool has some elements of a management strategy evaluation (MSE), but lacks an explicit biological operating model. This simplification is necessary because for many stocks data limitations do not allow for the development of full population dynamics models. Model structure, parameterization, and additional results are presented in Appendix B.

Figure 4.6.a displays the projected probability of achieving rebuilt status in year one through 10 of the rebuilding period for the three alternative rebuilding plans. Year one is assumed to be the

year following the stock meeting the criteria for overfished status. Thus, year one in Figure 4.6.a represents escapement year 2018. Under the no fishing alternative, the probability of achieving rebuilt status is greater than 0.7 in year one, while this probability is lower for the other two alternatives. The buffered control rule, Alternative II (Figure 4.6.b), has intermediate rebuilding probabilities in each year relative to the status quo control rule and no fishing. The results for all three alternatives converge near 1.0 at approximately years 5-6. The projected rebuilding time is defined as the number of years needed for the probability of achieving rebuilt status to exceed 0.50. Rebuilding times are projected to be three, two, and one years for Alternatives I, II, and III, respectively.

If there have been trends in productivity, future abundance may be more similar to recent abundance estimates than abundance estimates 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.

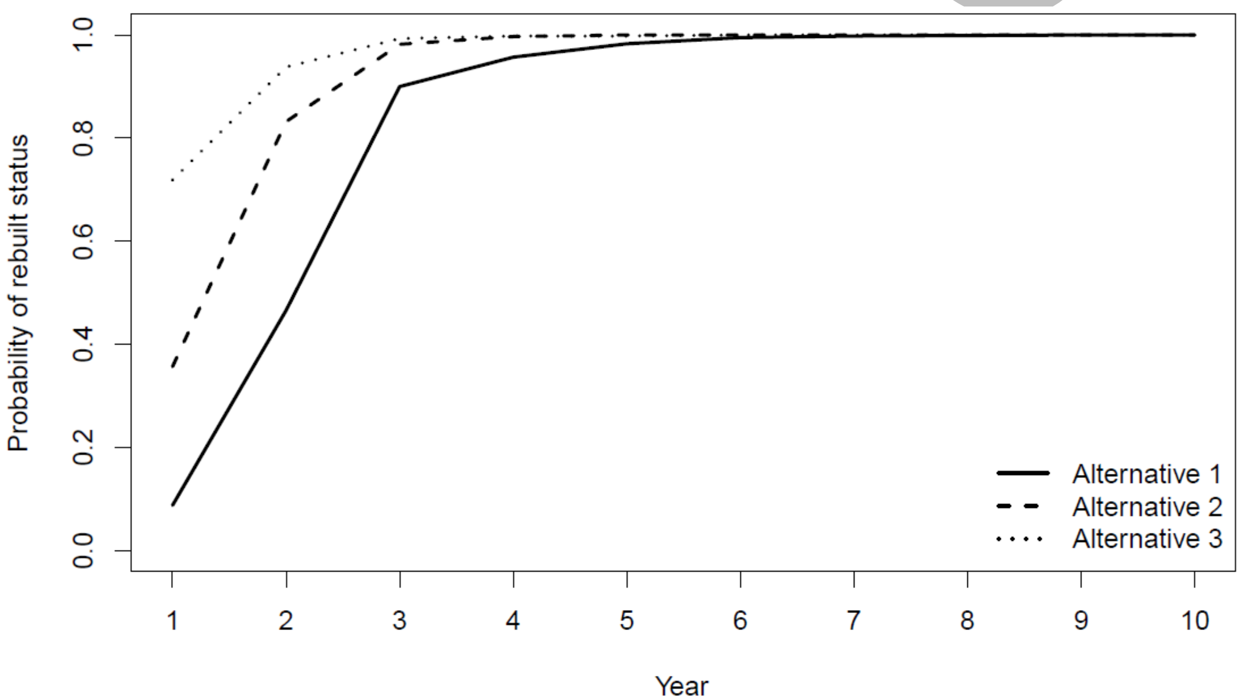

Figure 4.6.a. Projected probability of achieving rebuilt status by year under the three alternative rebuilding plans.

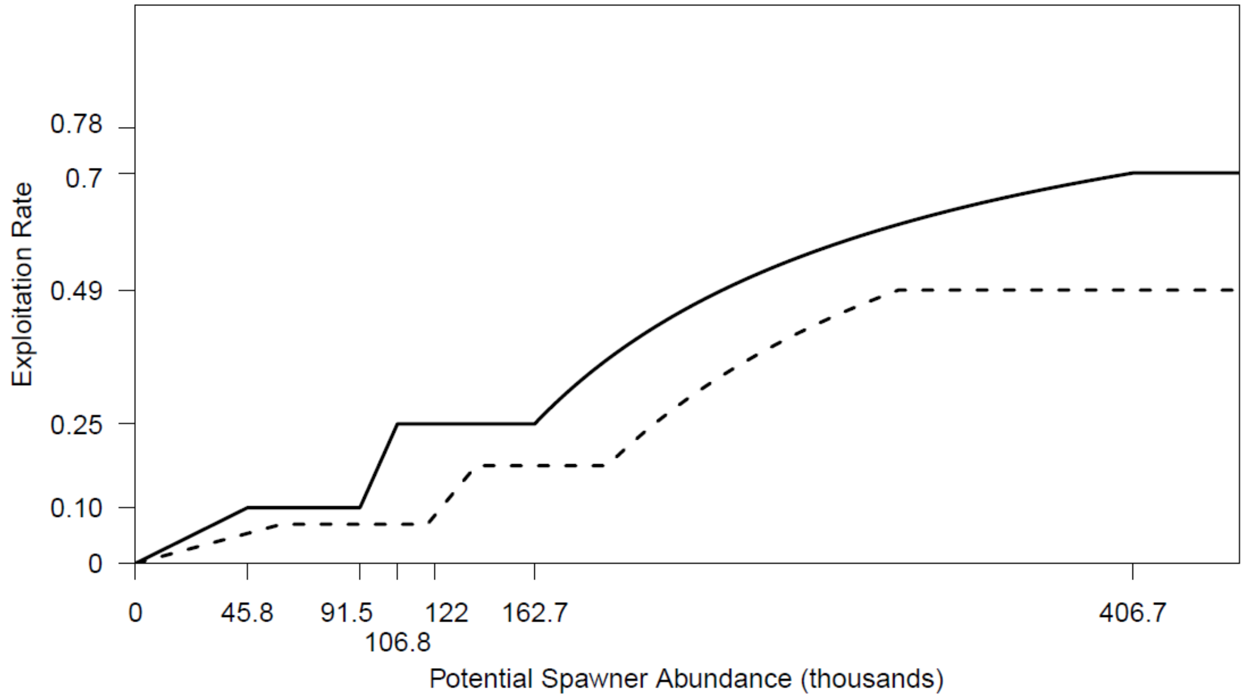

Figure 4.6.b. Control rules corresponding to Alternatives 1 (status quo, solid line) and 2 (buffered, dashed line).

4.7 Further recommendations

1. Reconsider the current conservation objective for SRFC. The goal range of 122,000-180,000 hatchery and natural-area adult spawners was adopted as a proxy for maximum sustainable yield in 1984, and much has changed in the Sacramento Basin since that time. Consideration should be given to estimating productivity of natural-area spawners and development of management objectives for this component of the SRFC stock, as has previously been recommended by CA HSRG (2012) and Lindley et al. (2009). Consideration should also be given to development of sub-basin specific escapement goals. For example, the analysis presented in section 3.1.5 suggests that juvenile production above Red Bluff Diversion Dam is maximized at escapement levels of approximately 80,000 females. Analyses such as this applied across other portions of the Sacramento Basin could be useful in the development of new conservation objectives.

2. Develop an age-structured stock assessment for the SRFC stock using cohort reconstruction methods. The data needed to perform this assessment are largely available. Cohort reconstruction methods allow for estimation of exploitation rates, maturation rates, and other metrics of interest for SRFC. Such an assessment can also contribute to an assessment of productivity for natural-area spawners, as mentioned in recommendation 1 above.

3. Develop age-structured abundance forecasts. If there is evidence for changes in maturation rates for SRFC, consider evaluating forecasting models that allow for non-stationary sibling relationships or models with environmental variables that could be used to predict changes in maturation rates. Such forecasts are feasible given reconstructed cohort

abundances. Forecasts of the aggregate-age Sacramento Index have regularly been higher that postseason estimates of the SI, sometimes substantially. While salmon abundance forecast error is commonly high, even when age-structured methods are employed, age-structured forecast methods may result in improved forecast performance for SRFC.

4. Develop an age-structured SRFC harvest model similar in structure to the Klamath Ocean Harvest Model (KOHM). Development of such a model is contingent on the implementation of an age-structured stock assessment, as described in Recommendation 2 above.

5. There were several issues identified during the development of this Rebuilding Plan that have yet to be fully evaluated and formed into recommendations. These topics include:
    a. Evaluate percent of unimpaired flow in February through June for major tributaries.
    b. Evaluate fall flow effects on redd dewatering.
    c. Evaluate fall Delta Cross Channel gate operations as they pertain to straying.
    d. Evaluate temperature control for the Feather and American rivers. Dam operations do not cover all spawning habitat.
    e. Examine changes in natural production over time in the Sacramento Basin. Recovery of natural populations slower than hatchery stocks and impacts to natural production likely to increase in the face of climate change.
    f. Incorporate age-2 river harvest in the forecasting of the SI.

5.0 SOCIO-ECONOMIC IMPACTS OF MANAGEMENT STRATEGY ALTERNATIVES

5.1 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 SRFC occur mainly in California and extending north into Oregon at least to Cape Falcon.

For purposes of describing the status quo economic situation, 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 representative of possible outcomes under the current status quo control rule. Data prior to 2004 is not used because that is the first year for which post-season coho FRAM estimates are available. There are currently five salmon rebuilding plans in development, including three Washington coho stocks, and it would simplify resulting management decisions if the economic analyses were comparable across all five plans.

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 from the combined non-tribal commercial troll and recreational salmon fisheries conducted in ocean areas averaged approximately $45.6 million during the period, ranging from $14.8 million in 2010 to $85.1 million in 2004.[3]

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). 2004 had the highest inflation-adjusted combined salmon fishery personal income impacts during the period overall and also 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 as it is anticipated to be relatively less affected by management changes in areas south of Cape Falcon to rebuild SRFC than the other Oregon and California port areas.

Although not included in these economic impact estimates, SRFC are also taken in recreational fisheries in the Sacramento River and its tributaries.

Provided that a sufficient likelihood of rebuilding is achieved during the allowable 10-year period under Status Quo (Alternative I), economic impacts under the two action alternatives (Alternatives II and III) are measured relative to the Status Quo fishery. The estimated timeframe needed to achieve rebuilt status (with a probability of at least 50 percent) under Status Quo exploitation rates is three years (Figure 4.6.a), during which time it is assumed the 2004-2016 inflation-adjusted average of $45.6 million per year in income from combined ocean commercial and recreational salmon fisheries would accrue in the affected communities south of Cape Falcon. By definition there would be no direct or indirect economic impact from the rebuilding plan under the Status Quo (no-action) alternative.

[3] It is important to note that income impact estimates for the two sectors (commercial and recreational) cannot be directly compared, as they are derived using different methodologies.

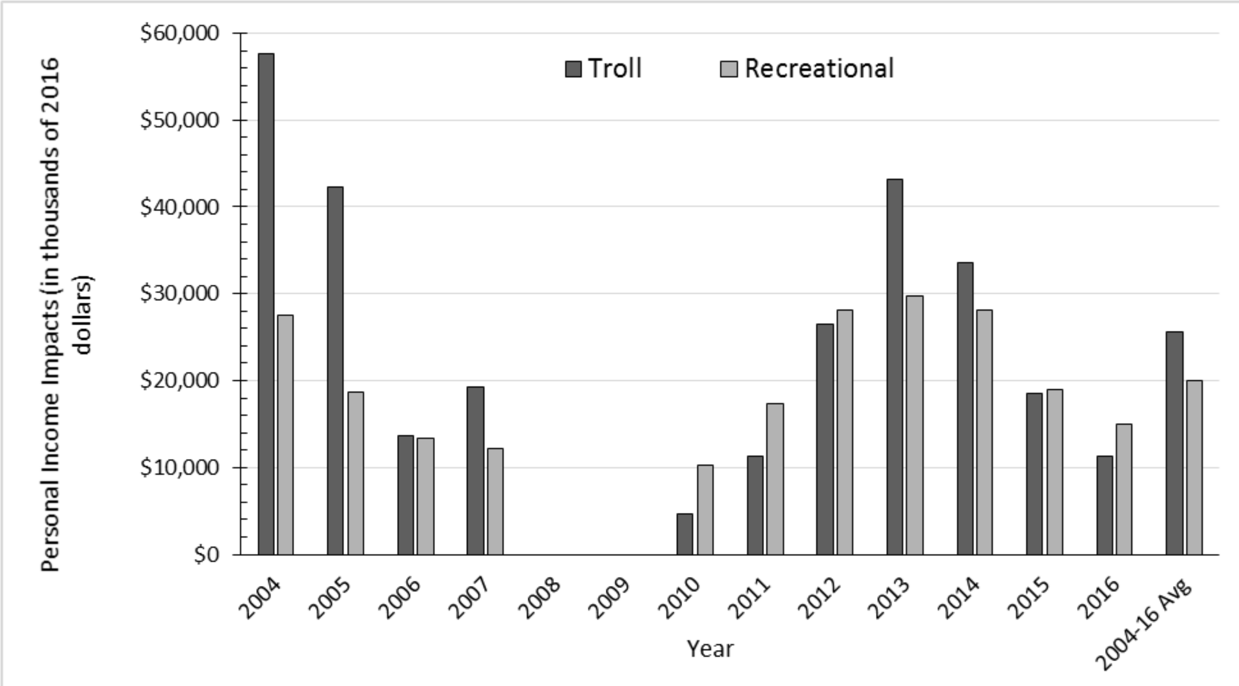

Figure 5.1.a. Estimates of total, aggregated personal income impacts in affected California and Oregon coastal communities south of Cape Falcon in thousands of real (inflation adjusted, 2016) dollars for the non-tribal commercial ocean troll and ocean recreational salmon fisheries.

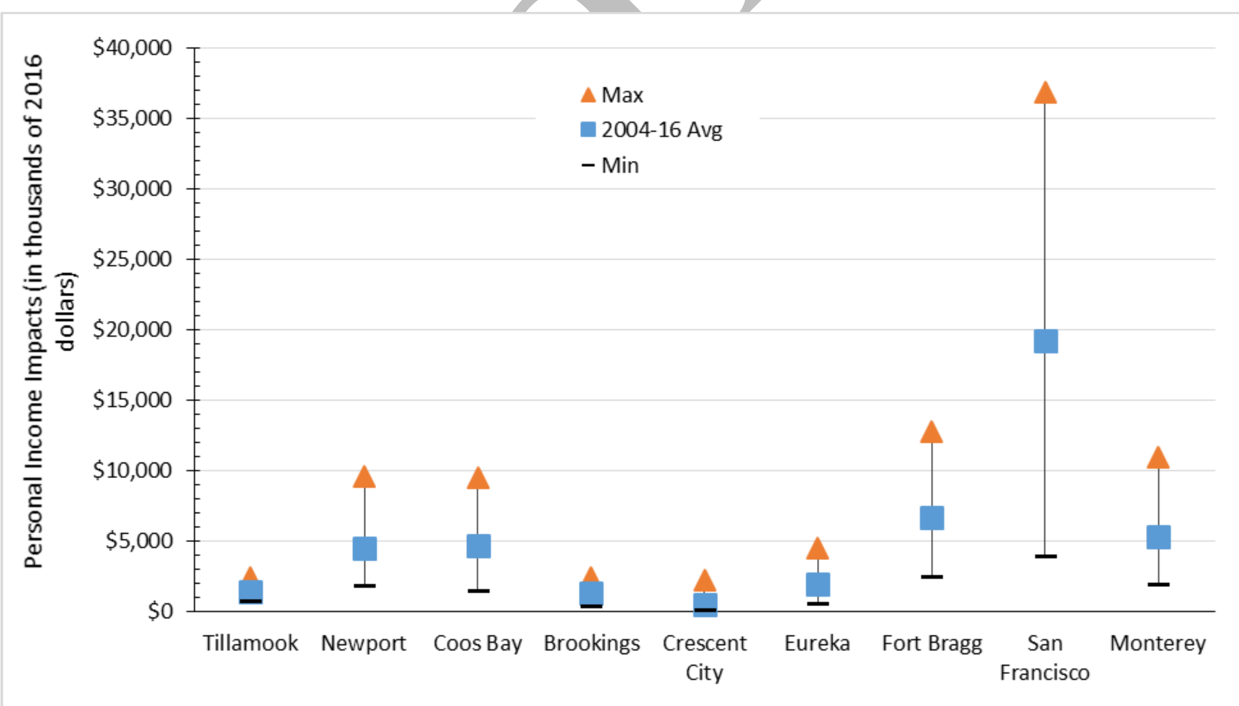

Figure 5.1.b. Estimates of personal income impacts by coastal community in thousands of real (inflation adjusted, 2016) dollars for the combined non-tribal commercial ocean troll and ocean recreational salmon fisheries in California and Oregon south of Cape Falcon.

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 II

Under Alternative II, rebuilding is estimated to occur after two years assuming an exploitation rate 30 percent lower than under Status Quo/Alternative I during that time. Compared with Status Quo/Alternative I, this would result in an overall income impact of negative (-) $9.1 million per year in coastal communities in the affected region over the three years it would take to rebuild under Status Quo.

5.3 Alternative III

Under Alternative III, rebuilding is estimated to occur after one year assuming an exploitation rate of zero during that time. Compared with Status Quo/Alternative I, this would result in an overall income impact of negative (-) $15.2 million per year in coastal communities in the affected region over the three years it would take to rebuild under Status Quo.

5.4 Note on Economic Impacts

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.

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 the National Environmental Policy Act (NEPA). The proposed action will have no impact on fish and fisheries other than salmon. The proposed action will affect commercial, recreational, and treaty tribal ocean salmon fisheries from Cape Falcon, Oregon to the U.S./Mexico border (as described in section 3.3.1, above).

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 2016a). 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 SRFC and KRFC. 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

{Analysis to be completed.}

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). Among the ESA-listed marine mammals, only the SRKW is known to interact with Pacific salmon or salmon fisheries, in that SRKW are known to prey on salmon. The range of SRKW in spring, summer, and fall includes the inland waterways of Washington state and the transboundary waters between the United States and Canada. In recent years, SRKW have been regularly spotted as far south as central California during the winter months (http://www.nmfs.noaa.gov/pr/species/mammals/whales/killerwhale.html) and their range is currently defined as extending as far south as Point Sur, California (Teresa Mongillo, pers. comm.[4]). In 2009 NMFS consulted on the effects of the ocean salmon fisheries on the SRKW and concluded that Council-managed salmon fisheries were not likely to jeopardize these whales. In

[4] Personal communication from T. Mongillo (NMFS) to P. Mundy (NMFS), email dated September 28, 2017.

the time since that consultation, there has been additional research on SRKW life history, feeding habits, fecundity, and mortality rates. This new information indicates that prey base, environmental contaminants, and disturbance by vessel traffic are among the factors that may affect the recovery of SRKW. NMFS is working with researchers from the U.S. and Canada to evaluate impacts of various human activities, including salmon fisheries, on the survival and recovery of SRKW. Until such time as sufficient information is developed to inform a new ESA consultation on the impacts of salmon fisheries on the survival and recovery of SRKW, NMFS is working on identifying and developing short-term management actions to improve Chinook salmon availability and reducing acoustic and vessel disturbance in key SRKW foraging areas. SRFC occur at the southern end of the SRKW range and it is not clear at this point how they contribute to the SRKW diet.

6.3.2 Environmental Consequences of Alternatives on Marine Mammals

{Analysis to be completed.}

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 6.4.1.a.

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 6.2.1.1), 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 the Alternatives on ESA-listed Salmon Stocks

{Analysis to be completed.}

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 the Alternatives on Non-target Fish Species

{Analysis to be completed.}

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 the Alternatives on Seabirds

{Analysis to be completed.}

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 the Alternatives on Habitat and Ecosystem Function
{Analysis to be completed.}

6.8 Cultural resources

6.8.1 Affected Environment
{Analysis to be completed.}

6.8.2 Environmental Consequences of the Alternatives on Cultural Resources
{Analysis to be completed.}

6.9 Cumulative Impacts
{To be developed}

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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 non-fishing 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. 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 Sacramento River fall Chinook (SRFC) salmon stock.

Methods

The methods described here are for a single replicate in one year.

The "known", true abundance (N) is determined by a random draw from the set of past abundance estimates. For SRFC, N corresponds to the Sacramento Index.

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

$$\widehat{N} \sim \text{Lognormal}[\log(N) - 0.5\sigma_{\log(\widehat{N})},\ \sigma_{\log(\widehat{N})}] \quad (1)$$

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

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

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

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

Projected adult spawner escapement E is thus

$$E = N \times (1 - F) \quad (3)$$

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

$$F \sim \text{Beta}(\alpha, \beta) \quad (4)$$

with parameters

$$\alpha = \frac{1 - \hat{F}(1 + \text{CV}_F^2)}{\text{CV}_F^2} \tag{5}$$

and

$$\beta = \frac{\frac{1}{\hat{F}} - 2 + \hat{F} + (\hat{F} - 1)\text{CV}_F^2}{\text{CV}_F^2}. \tag{6}$$

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 $\hat{E}$ are drawn from a lognormal distribution,

$$\hat{E} \sim \text{Lognormal}[\log(E) - 0.5\sigma_{\log(\hat{E})},\ \sigma_{\log(\hat{E})}] \tag{7}$$

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 (2).

The procedure described above is repeated for each year (years 1 through 10 following the overfished status determination), and each replicate.

A stock is assumed to be rebuilt when the geometric mean of $\hat{E}$ computed over the previous three years exceed 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 Sacramento River fall Chinook salmon (SRFC) presented here are the product of 1000 replicates for each of 10 years. The probability of being rebuilt in year *t* = 1 is the proportion of the 1000 simulations that resulted in the geometric mean of the estimated SRFC escapement in *t*-2 (89,674: the 2016 hatchery and natural-area escapement), the estimated escapement in *t*-1 (44,574: the 2017 hatchery and natural-area escapement), and the simulated escapement estimate in year *t* (2018) 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.

Figure 4.6.a in the body of the report displays the probability of achieving rebuilt status under three management strategies: (1) the status quo control rule, (2) a buffered control rule (Figure 4.6.b),

and (3) no fishing. For these simulations the following parameter values were assumed: $\text{CV}_{\hat{N}} = 0.2$, $\text{CV}_{\hat{E}} = 0.2$, and $\text{CV}_{F} = 0.1$. The parameter values were chosen because they produce reasonable 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 ($\text{CV}_{\hat{N}} = 0.6$), the escapement estimation error CV ($\text{CV}_{\hat{E}} = 0.5$), 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 for the status quo control rule. Overall, the probability of achieving rebuilt status by year is relatively insensitive to increased values of these parameters.

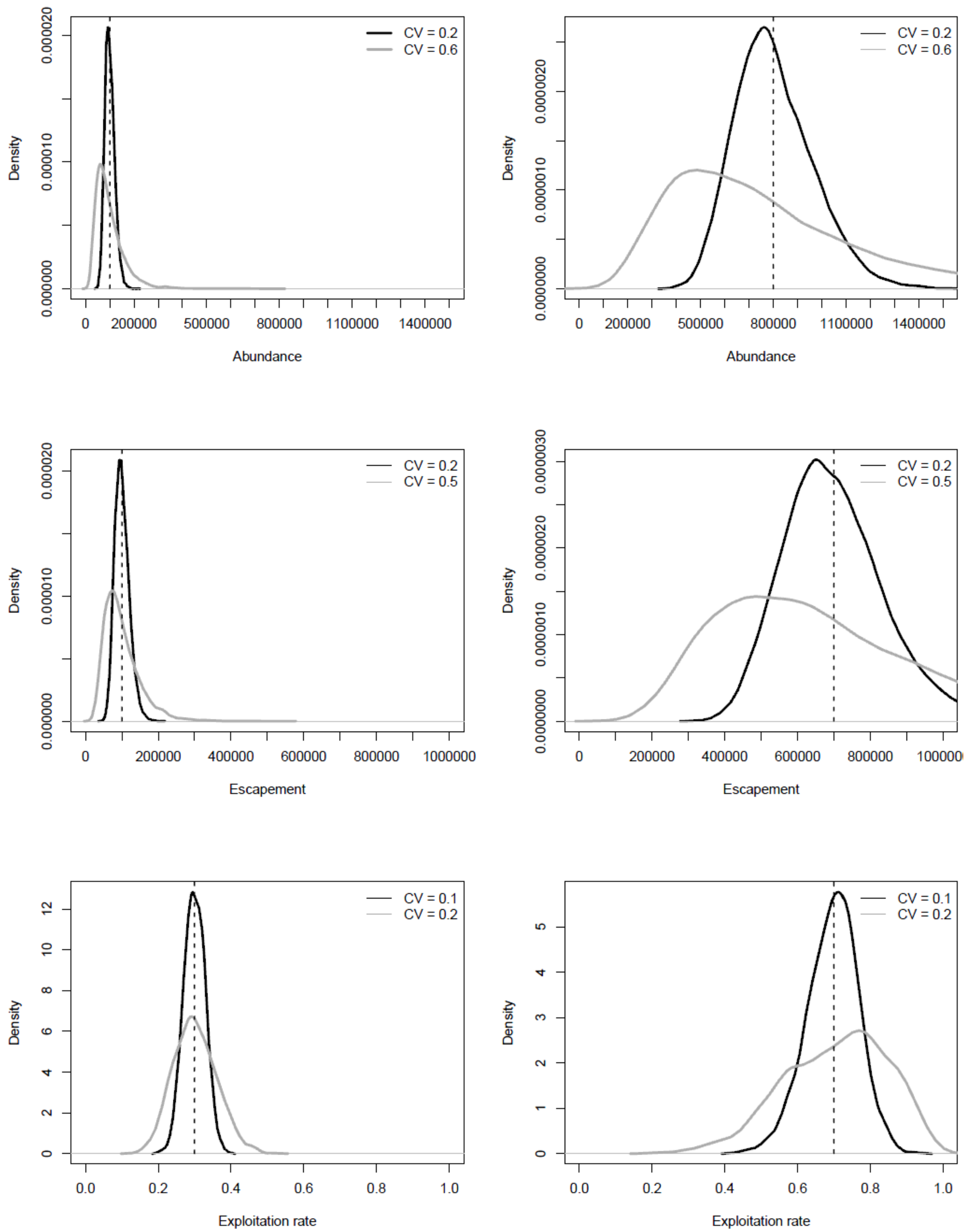

Figure 1. Distributions of the forecast abundance (top row), estimated escapement (middle row), and realized exploitation rate (bottom row) under different levels of known abundance, known escapement, and predicted exploitation rate. Known values are indicated by vertical dashed lines.

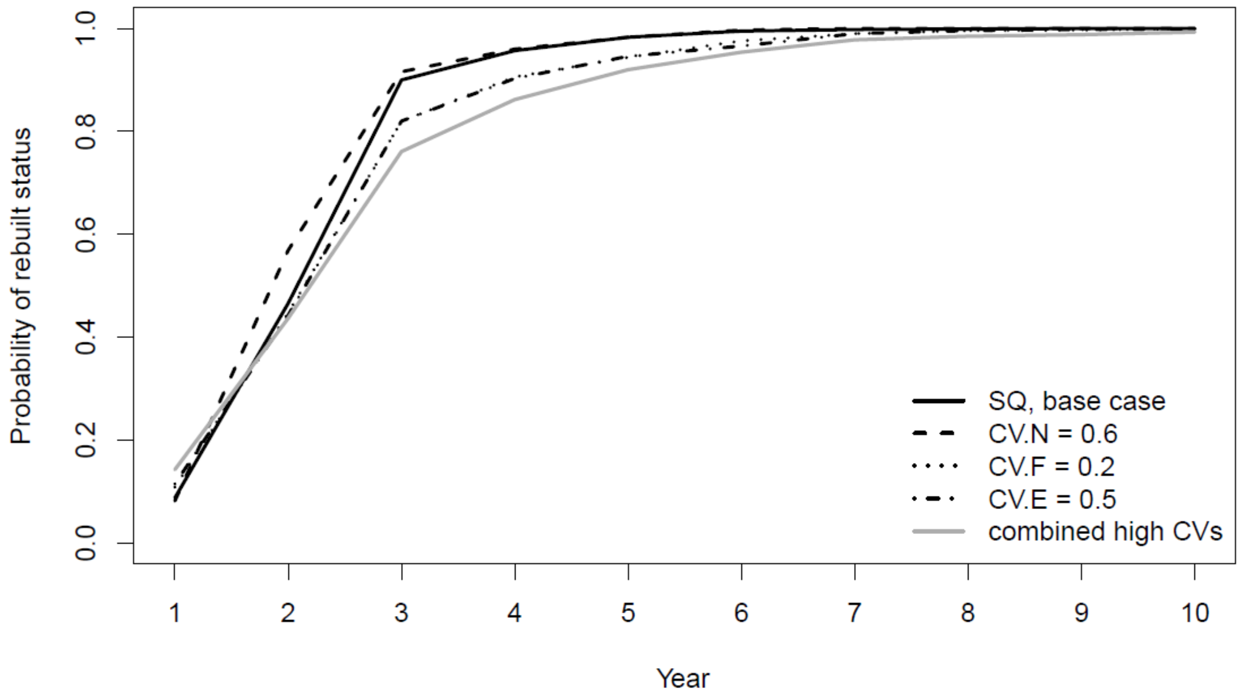

Figure 2. Probability of achieving rebuilt status in years 1 through 10, under the status quo control rule (Alternative 1) and under different parameter values.

Simulations were also performed assuming biased abundance forecasts, as the forecasted Sacramento Index (SI) has frequently exceeded the postseason estimate. Bias was incorporated by modifying the log-scale mean term in Equation (1) by adding the log of the observed ratio of the preseason forecast of the SI to the postseason estimate of the SI. Thus, the mean term in Equation (1) becomes $\log(N) - 0.5\sigma_{\log(\hat{N})} + \log(r)$, where r is a drawn (with replacement) from the set of 10 ratios of forecast to observed SI. On the arithmetic scale this ratio ranges from 3.54 to 0.78 and r > 1 in 8 of 10 years. Figure (3) displays the effect of including this bias in abundance forecasts for SRFC, given management under the status quo control rule. Positively biased forecasts (on average) result in slightly lower probabilities of achieving rebuilt status in the middle portion the rebuilding period, but results are similar in the beginning and end of the 10 year period.

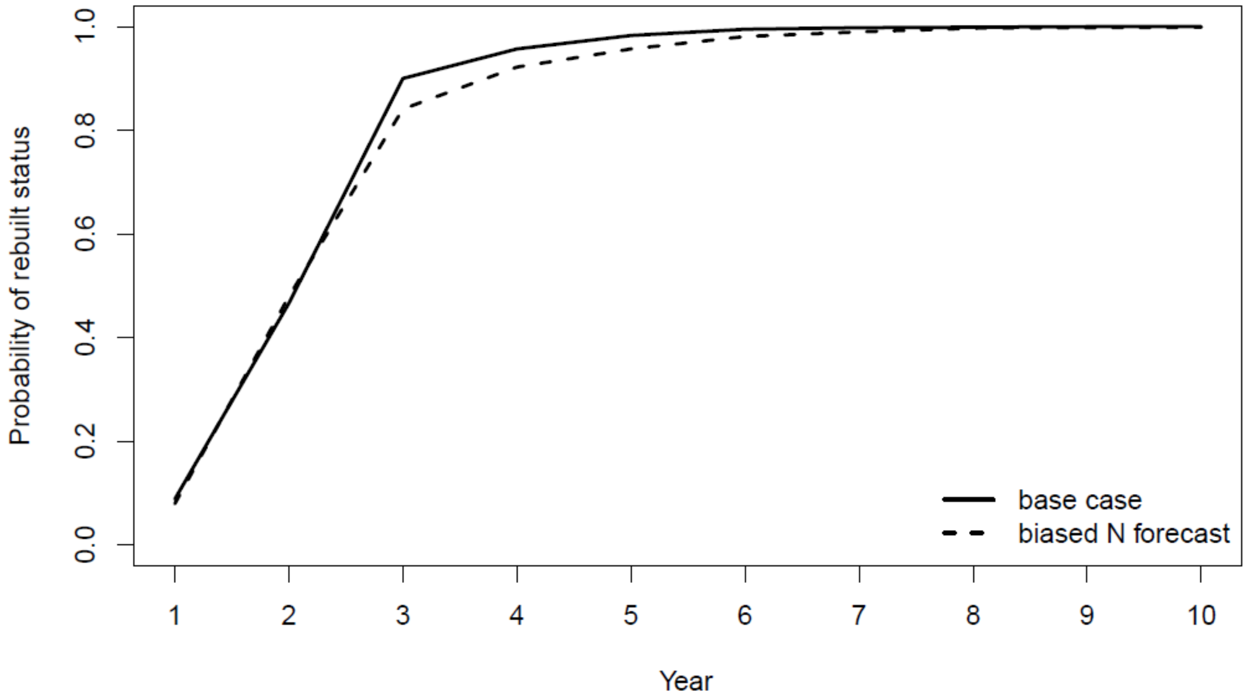

Figure 3. Probability of achieving rebuilt status under unbiased abundance forecasts and abundance forecasts that are on average biased high.

Finally, a "recent abundance" scenario was considered. There has been a downward trend in the SI over time, with two stock collapses in the relatively recent past (see Figure II-1 in PFMC 2018c). For the simulations described thus far, values of N have been drawn from the entire 1983-2017 set of SI values. For the recent abundance scenario, values of N were drawn from years a more contemporary set of years. Figure 4 displays results for the recent abundance scenario, using values of N from years 2014-2017, which can be compared to Figure 4.6.1. Unsurprisingly for SRFC, the probability of achieving rebuilt status is lower under all three alternatives when contemporary levels of abundance are assumed. It should be noted, however, that this result is highly sensitive to the choice of the range of years considered to be "recent". Using a year range of 2007-2017 results in a substantial reduction in the probability of achieving rebuilt status, relative to both the base case simulations, and simulations using the observed abundances in years 2004-2017 (Figure 5).

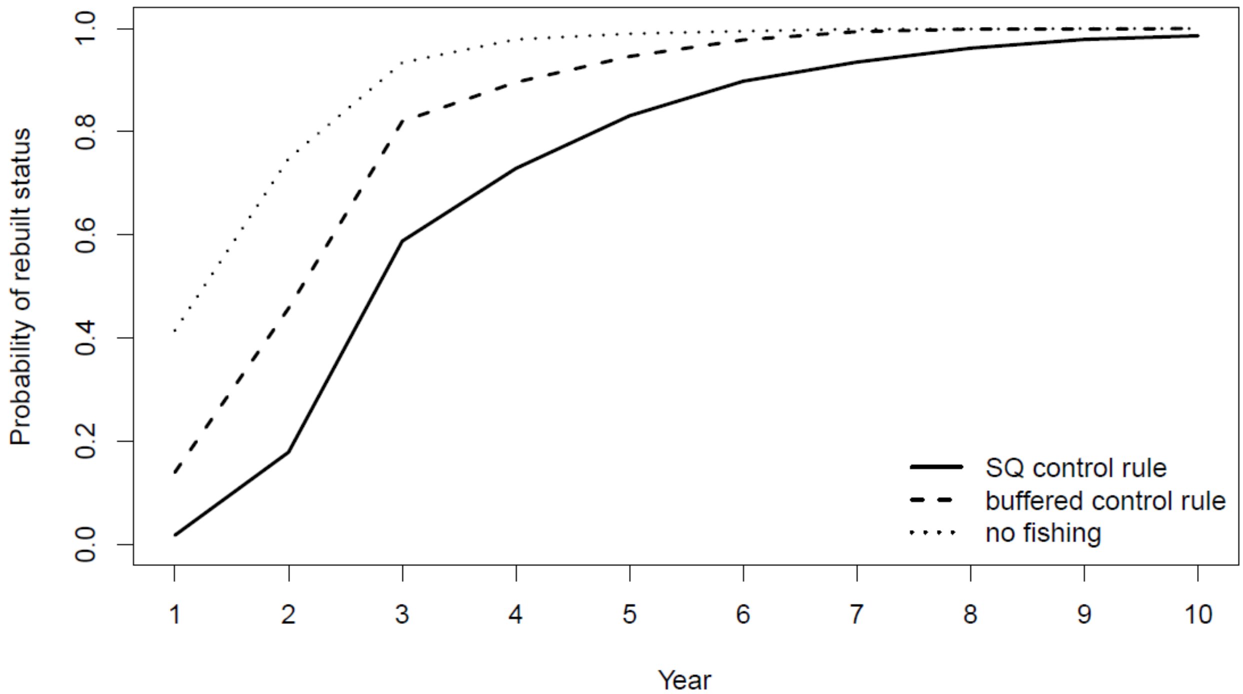

Figure 4. Probability of achieving rebuilt status in years 1 through 10, under the status quo control rule (Alternative 1), the buffered control rule (Alternative 2), and no fishing (Alternative 3), assuming recent SI values (2004-2017).

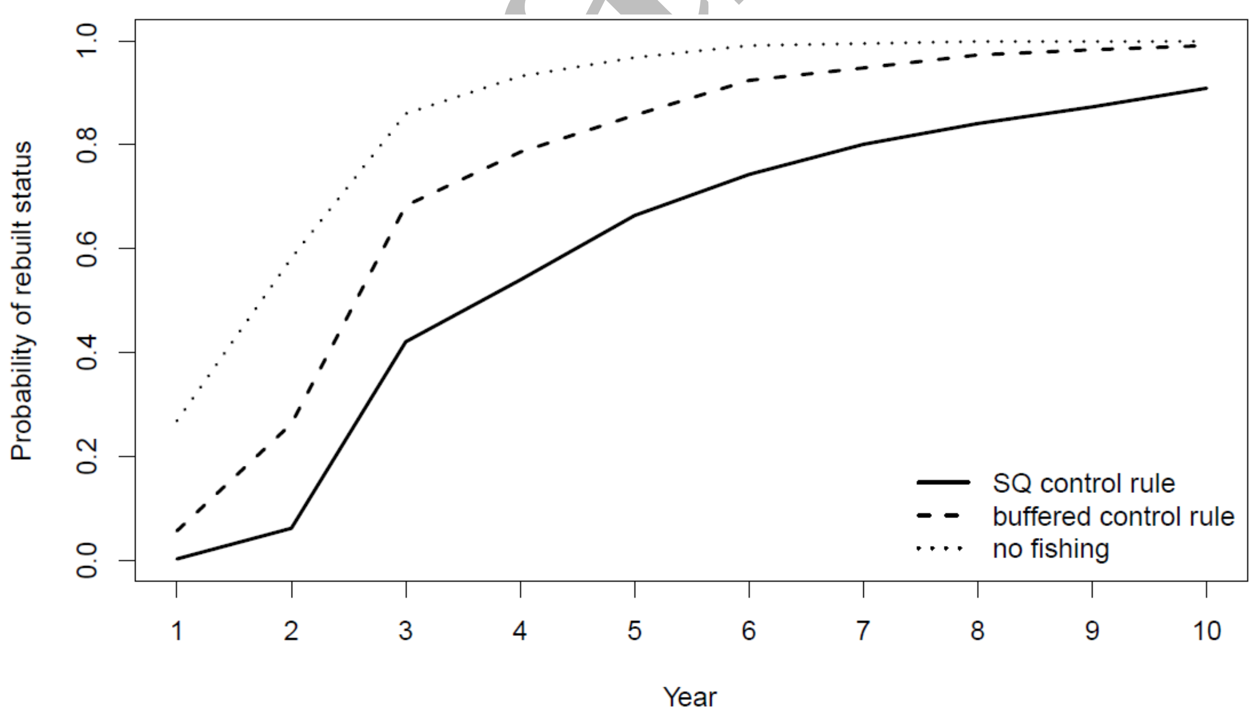

Figure 5. Probability of achieving rebuilt status in years 1 through 10, under the status quo control rule (Alternative 1), the buffered control rule (Alternative 2), and no fishing (Alternative 3), assuming recent SI values (2007-2017).

Discussion

This model was created to allow for a quantitative assessment of alternative rebuilding plans. It shares some attributes with MSE approaches, but lacks some important features. The model relies on random draws from past estimates of abundance to characterize future abundance. As such, autocorrelation in abundance is not modeled and there is no explicit population dynamics. Thus the model fails to capture multi-year increases or declines in abundance exhibited by SRFC and many other salmon stocks. 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 SRFC in ocean fisheries and thus the allowable exploitation rate is not able to be achieved. Rather, this 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 each year within a 10 year window for alternative rebuilding plans 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. Rebuilding periods could be much shorter (or longer) than these results suggest due to the vagaries of future production and fisheries.

APPENDIX C - DRAFT FINDING OF NO SIGNIFICANT IMPACT

Forthcoming.

APPENDIX D - PAST, PRESENT AND REASONABLY FORESEEABLE FUTURE IMPACTS

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 domoic 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 AGENGIES AND PERSONS CONSULTED

NMFS to provide.

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

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

NMFS to provide.

APPENDIX G - INITIAL REGULATORY FLEXIBILITY ANALYSIS

NMFS to provide.

APPENDIX H - NATIONAL STANDARDS ANALYSIS

NMFS to provide.

APPENDIX I - CONSISTENCY WITH OTHER APPLICABLE LAWS ANALYSIS

NMFS to provide. List should be similar for all 5 plans. Language may have slight differences among plans.

- 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