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1 Abstract

The ocean fishery consultation standard for threatened California Coastal Chinook (CC-Chinook) salmon is specified as a cap on the preseason-projected age-4 ocean harvest rate for Klamath River fall Chinook (KRFC). Since the listing of the CC-Chinook Evolutionarily Significant Unit (ESU) under the federal Endangered Species Act in 1999, this consultation standard has frequently constrained ocean salmon fisheries in California and Oregon. Low levels of spawner and ocean fishery data have precluded development of a CC-Chinook-specific management strategy and necessitated use of the KRFC proxy. The purpose of this Technical Memorandum is to examine the spawner escapement and ocean fishery data that currently exist for CC-Chinook and address questions regarding whether there is now potential for the development of an alternative ocean fishery management strategy. At the current time, sufficient data do not exist to derive ESU-level estimates of spawner escapement. Recently collected genetic stock identification data from the ocean commercial fishery has allowed for inference about the ocean spatial distribution for CC-Chinook, yet these and other ocean fishery data are not sufficient for estimating total CC-Chinook ocean harvest. The current data are not sufficient to perform cohort reconstructions. Until more comprehensive spawner escapement and ocean fishery data are available, few prospects exist for developing management strategies that are based directly on CC-Chinook data.

2 Introduction

The California Coastal Chinook (CC-Chinook) salmon Evolutionarily Significant Unit (ESU) comprises all populations of Chinook salmon between (and including) Redwood Creek (Humboldt County) and the Russian River (Sonoma County), California (Figure 1). CC-Chinook were listed as threatened under the Endangered Species Act in 1999 (64 FR 50394, 1999), and their listing status has been reaffirmed in two subsequent status reviews (Good et al., 2005; Williams et al., 2011).

Owing to limited freshwater escapement and ocean catch data, a proxy ocean harvest rate limit has been used to control the effect of ocean fisheries on populations within this ESU. This proxy, a maximum preseason-projected[1] Klamath River fall Chinook (KRFC) age-4 ocean harvest rate of 0.17, was defined as part of the Reasonable and Prudent Alternative for the 2000 Biological Opinion (NMFS, 2000). This maximum ocean harvest rate was subsequently reduced to 0.16 based on modifications to the KRFC cohort reconstruction model (KRTAT, 2002). Since the 2000 Biological Opinion, the CC-Chinook consultation standard has frequently constrained ocean fisheries in California and Oregon.

Because of the importance of this ESU to the annual configuration of ocean fisheries, there has been interest in evaluating whether alternative assessment and management approaches are feasible. In this report, we review the current information available for the CC-Chinook salmon ESU. We begin with a review of the justification given for the threatened status of CC-Chinook and the extent of the available freshwater data. The ocean fishery consultation history and available ocean fishery data are then reviewed. Finally, we examine the feasibility of developing an alternative management approach for CC-Chinook, given the data currently available.

[1]The term "preseason-projected" refers to a quantity forecast prior to the fishery and/or spawning escapement. The term "postseason-estimated" refers to a quantity estimated after the fishery and/or spawning escapement.

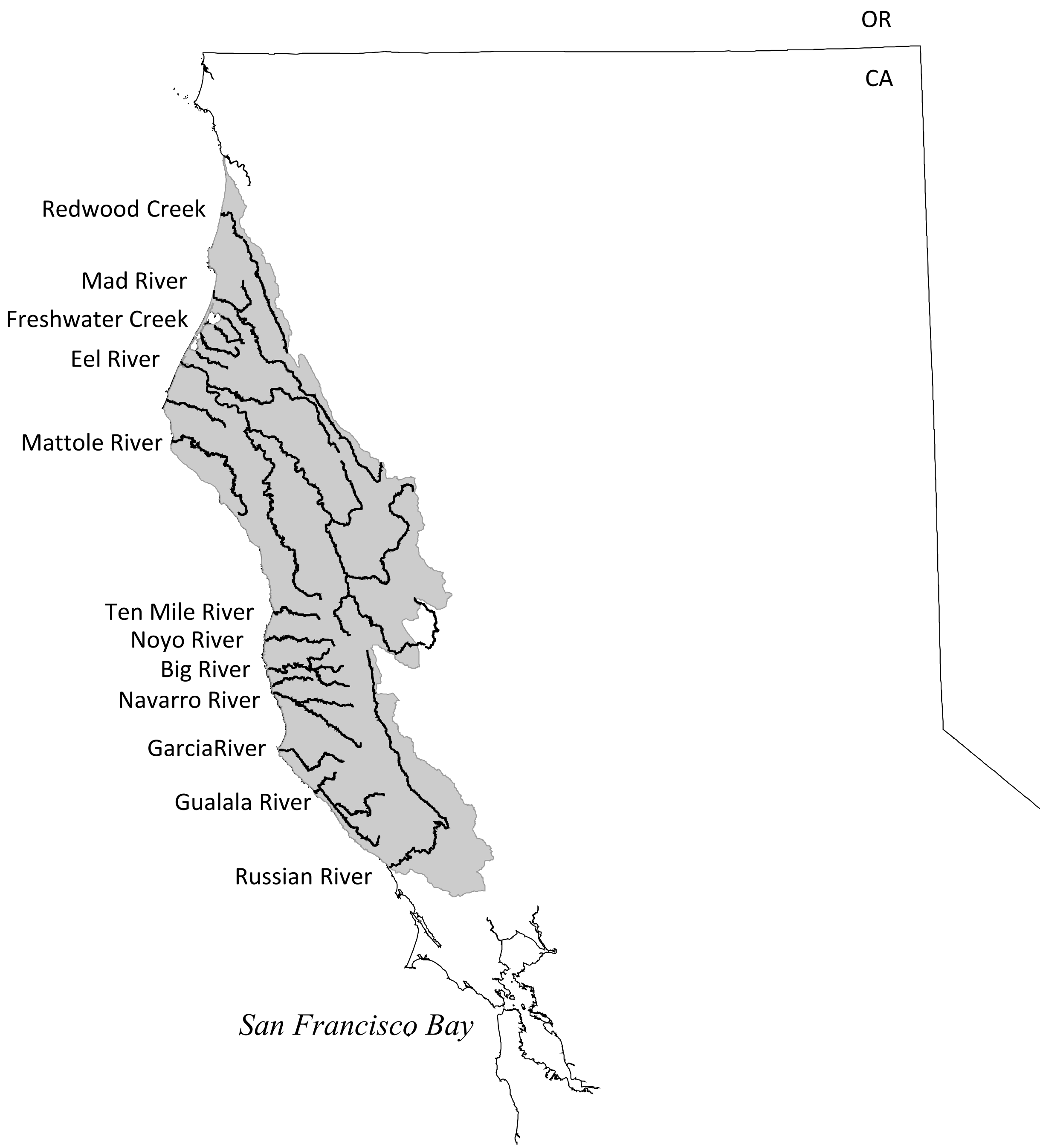

Figure 1. Map of the California Coastal Chinook ESU (shaded grey area) and major watersheds. Areas upstream from impassible dams are not included in the ESU and lie outside the shaded area.

3 ESU status

In an initial review of biological and ecological information for West Coast Chinook salmon, the Biological Review Team (BRT) identified 11 new Chinook salmon ESUs (three Columbia River Chinook salmon ESUs had previously been described), including what was termed the Southern Oregon and California Coastal Chinook ESU (Myers et al., 1998). This putative ESU encompassed coastal Chinook salmon populations south of Cape Blanco, Oregon, including the populations in the Klamath Basin downstream of the confluence of the Klamath and Trinity Rivers (Upper Klamath/Trinity Chinook is a separate ESU). The BRT unanimously concluded that Southern Oregon and California Coastal Chinook ESU, which included the present-day CC-Chinook ESU, was likely to become at risk of extinction in the foreseeable future and noted that very sparse data existed for coastal rivers south of the Klamath Basin (Myers et al., 1998). However, the National Marine Fisheries Service (NMFS) delayed its final ruling on listing, citing substantial scientific uncertainty surrounding appropriate ESU boundaries (NMFS, 1999).

In a subsequent status review (NMFS, 1999), the BRT split the Southern Oregon and California Coastal Chinook ESU into two separate ESUs, with the southern ESU becoming the present day CC-Chinook ESU. This status review of the new CC-Chinook ESU led to the 1999 listing under the ESA as threatened (64 FR 50394, 1999). Since the initial listing, two 5-year status reviews have reaffirmed the threatened status of CC-Chinook (Good et al., 2005; Williams et al., 2011). Good et al. (2005) concluded that CC-Chinook are likely to become endangered and Williams et al. (2011) concluded that new information since the previous status review does not appear to suggest a change in extinction risk.

The concerns of the BRT at the time of the initial listing still applied at the time of the most recent 5-year status review. These concerns included, but were not limited to, (1) evidence pointing to low population size relative to historical abundance, (2) mixed trends in the limited abundance indices available, (3) apparent extirpation of many populations in the southern portion of the ESU between the Mattole and Russian rivers, (4) the loss of the spring-run diversity type, and (5) the low levels of information about abundance, productivity, and distribution (Williams et al., 2011).

4 Available spawner data

A common theme in the ESA status determinations for CC-Chinook salmon is the sparseness of spawner abundance data. There is a lack of adult spawner estimates spanning 3-4 generations for any of the populations, which prevents application of the viability criteria developed for this ESU (Spence et al., 2008). Additionally, the lack of historical population abundance estimates is a major uncertainty. Chinook salmon are periodically observed in many mid-sized watersheds (i.e., Big River, Ten Mile River, Noyo River, Navarro River, Garcia River, and Gualala River) in the region between Cape Mendocino and the Russian River (Spence et al., 2008). However, these watersheds currently do not appear to support persistent populations, and there remains substantial uncertainty about whether they did historically (Bjorkstedt et al., 2005). The paucity of historical evidence may reflect in part the fact that substantial modification of habitats due to logging, splash-damming, and other forestry-related activities had already taken place by the late 1800s (Spence et al., 2008). A summary of data sources evaluated in the most recent 5-year status review (Williams et al., 2011) is provided in Table 1. In some cases, where the data for these populations are published in the Pacific Fishery Management Council (PFMC) annual Review of Ocean Fisheries report (PFMC, 2012b), more recent abundance information is noted. We do not attempt to exhaustively describe all freshwater CC-Chinook data sources; more detailed information can be found in Myers et al. (1998), NMFS (2000), Good et al. (2005), NMFS (2005), Spence et al. (2008), Williams et al. (2011), and individual survey reports.

Care must be taken when interpreting the spawner data currently available for CC-Chinook salmon. Many of the sampling programs are confined to small portions of the spawning habitat available to a given population (e.g., Sproul Creek, Tomki Creek), and more extensive examinations indicate that substantial spawning occurs outside of these survey reaches (see e.g., Harris and Thompson, 2009). Some estimates (e.g., Tomki Creek, Van Arsdale Station) are likely influenced by flow, such that in low-flow situations fish tend to spawn downstream of the sampling areas (Boydstun and McDonald, 2005); thus, spawner numbers in these limited areas depend partially on hydrography and are not necessarily a true index of the number of spawners in the system.

Table 1. California Coastal Chinook freshwater data sources examined in the most recent 5-year status review (Williams et al., 2011). Populations are as defined by Bjorkstedt et al. (2005) and modified by Spence et al. (2008).

Location	Population	Data
Prairie Creek	Redwood Creek	Estimates of spawner abundance have been made for Prairie Creek since 1998 using area under the curve methods. Estimates have declined over time from maximum values of approximately 500 fish to low values of well below 100 fish.
Canon Creek	Mad River	An index of abundance made by maximum live/dead counts has been performed since 1981. Interannual survey effort has been variable, ranging from 1-10 surveys per year. Counts range from 10s to 100s of fish. The long-term trend was slightly positive at the time of the most recent 5-year status review; however, counts have generally declined since 2005.
Freshwater Creek	Humboldt Bay	Partial counts have been made at a weir since 1994. These counts are considered partial because fish may pass the weir uncounted during high flow events and jacks may pass through the weir without being counted. The counts exhibit a decline, with only two Chinook counted in both 2008 and 2009.
Sproul Creek	Lower Eel River	An index of abundance made by maximum live/dead counts has been performed since 1970s. Interannual survey effort has been variable, ranging from 1-10 surveys per year. Williams et al. (2011) report a slight positive trend in short term, while the long-term trend is negative. Reported counts are in the 10s to 100s of fish for recent years.
Tomki Creek	Upper Eel River	Maximum live/dead counts began in the 1970s. Beginning in the 2000-2001 run year, run-size estimates made from index sites have been made and owing to the change in methodology estimates before and after the change are not comparable. Counts appear to be influenced by mainstem flows, which are partially regulated by dam releases. In times of low flow, few Chinook may enter Tomki Creek and instead spawn in the mainstem Eel River. Recent estimates are on the order of 10s to 100s of fish.
Van Arsdale Station	Upper Eel River	Counts made at a fish counting facility at Van Arsdale Dam, which is located toward the upper end of the available spawning area of the Eel River. Dam counts are likely affected by flow; during years of low flow fish tend to spawn below the counting station. Mandated increases in minimum flow releases from Cape Horn Dam began in 2004. Counts made at Van Arsdale have appeared to increase since the mid-1990s. Total counts for the 2011-2012 return year were approximately 2,400 Chinook, approximately half of which were jacks. This represents the highest observed count at this station. Historically, most counts have been below 1000 fish.
Mattole River	Mattole River	The Mattole Salmon Group has conducted spawner surveys since 1994-1995, resulting in an estimated redd index. The most recent 5-year status review indicates that there has been a slight downward trend in the redd index since 1994.
Russian River	Russian River	Counts at a video weir have been made since 2000. Some spawning is known to occur in areas below the weir (Chase et al., 2007), though the number of spawners is not estimated. The most recent 5-year review reported a non-significant negative trend, but counts have increased over the past three years.

Video counts have been compromised by turbidity (e.g., Russian River; Chase et al., 2007). Accuracy of weir counts has been reduced during high flow events when the weir is overtopped (e.g., Freshwater Creek). Changes in methodology have occurred over the years in some cases (e.g., Tomki Creek), which makes comparisons across different periods of the time series untenable. The Eel River watershed contains the largest amount of Chinook spawning habitat in the ESU, yet only a small fraction of the habitat is surveyed. The ability to draw inferences about the status of Eel River Chinook was summarized by Williams et al. (2011, p.25): "Until more exhaustive and spatially representative surveys of the available habitat are done on a consistent basis, the status of Chinook salmon in these watersheds will remain highly uncertain." At the current time, it appears that the video counts made on the Russian River are the only satisfactory index of total spawner abundance for any population in the CC-Chinook ESU (Chase et al., 2007; Williams et al., 2011). In sum, the low quality and quantity of spawner data in the CC-Chinook ESU strongly hinder status assessment both for individual populations and the ESU as a whole.

New spawner abundance data may become available in the future with implementation of the California Coastal Salmonid Monitoring Plan (CMP; Adams et al., 2011). The CMP outlines sampling strategies and methods designed to estimate population-level abundance, as well as abundance at larger spatial scales. Additionally, the CMP calls for the establishment of Life-Cycle Monitoring Stations (LCMs), which will enable estimation of total adult abundance as well as outmigrant smolt abundance from selected watersheds. Intensive monitoring of adult return and smolt outmigrant abundance can allow for estimation of both freshwater and marine survival (Adams et al., 2011). However, it remains unclear if LCMs can or will be established in rivers supporting Chinook populations of sufficient size to produce robust estimates of freshwater or marine survival. Implementation of systematic adult spawner surveys has been initiated across portions of the CC-Chinook ESU (Gallagher et al., 2010; Ricker, 2011), and one LCM has been established in a watershed that supports a small Chinook salmon population (Freshwater Creek). However, it is unclear when funding will be available to fully implement both the coast-wide adult spawner survey and LCM elements of the CMP.

5 Ocean fishery consultation history

The 2000 Biological Opinion established the CC-Chinook consultation standard consisting of a maximum preseason-projected KRFC age-4 ocean harvest rate of 0.17 (NMFS, 2000). The harvest rate cap was reduced to 0.16 shortly thereafter owing to modifications made to the KRFC cohort reconstruction model (KRTAT, 2002). Currently, the maximum preseason-projected KRFC age-4 ocean harvest rate of 0.16 remains the ocean fishery consultation standard. The justification provided for this consultation standard and the outcome from a 2005 reinitiation of consultation (NMFS, 2005) are described below.

Reductions in ocean salmon fisheries as a result of KRFC harvest allocations and Sacramento River winter Chinook conservation concerns occurred prior to the development of the CC-Chinook consultation standard in 2000. In 1993, establishment of 50:50 sharing of the tribal and non-tribal allowable harvest of KRFC permanently constrained ocean fisheries that impact the stock. In particular, commercial fisheries in the Klamath Management Zone (the combined KO and KC management areas) and Fort Bragg (FB) were sharply reduced (see Figure 2 for a map of ocean fishery management areas). In 1996, the first constraints on ocean fisheries to protect Sacramento River winter Chinook were introduced, which resulted in reduced fishing effort south of Point Arena, California. Because CC-Chinook are thought to have an ocean distribution somewhat intermediate to KRFC and Central Valley Chinook (NMFS, 2000), it was inferred that harvest rates on CC-Chinook declined as a result of these ocean fishery constraints. Furthermore, it was concluded that KRFC ocean harvest rates should be comparable to CC-Chinook total harvest rates because there is no legal river harvest of CC-Chinook and their ocean distributions likely have substantial overlap.

The combined constraints to ocean fisheries resulting from KRFC tribal/non-tribal sharing and Sacramento River winter Chinook conservation concerns since 1996 led to a focus on the fisheries that occurred between 1996 and 1999 when developing the CC-Chinook consultation standard. In this four-year time period, the maximum postseason-estimated KRFC age-4 ocean harvest rate estimate was 0.17 (range: 0.11–0.17). This result, coupled with limited information suggesting

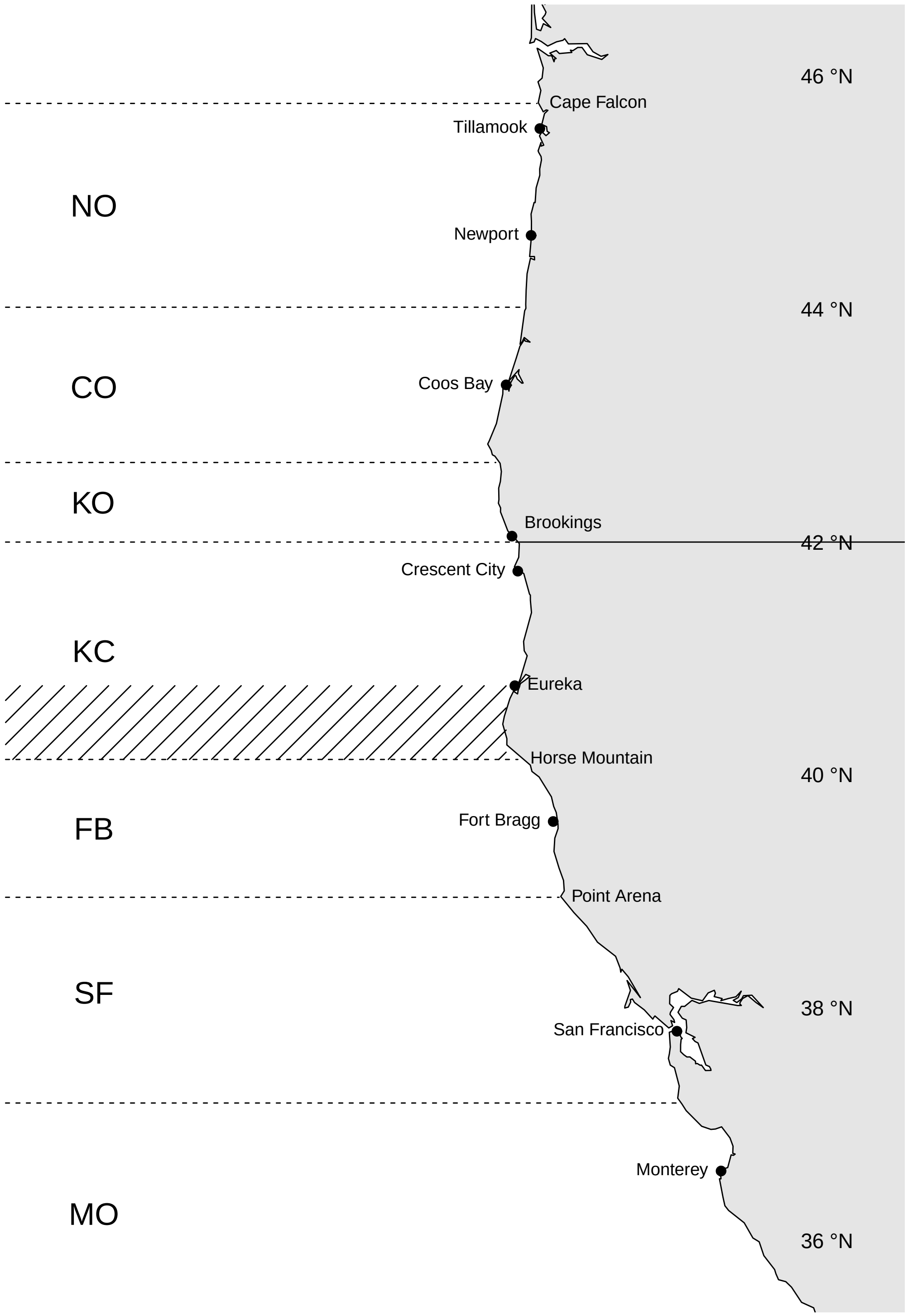

Figure 2. Map of the seven ocean fishery management areas, as well as major ports and landmarks, for the area south of Cape Falcon, Oregon. The area from Humboldt South Jetty (Eureka) to Horse Mountain, denoted by the striped area has been closed to commercial salmon fishing since 1992. The KO and KC management areas comprise the Klamath Management Zone.

that spawner abundance of some CC-Chinook populations had improved since 1996, suggested that ocean fisheries operated at the 1996–1999 scale were sufficient to allow for persistence of CC-Chinook when they are at low abundance (NMFS, 2000). This cap on the preseason-projected KRFC age-4 ocean harvest rate was also justified by the concern that in years of high KRFC abundance, the preseason-projected age-4 ocean harvest rate could otherwise exceed 0.20, while still meeting the KRFC spawner escapement objective. Such a scenario would likely result in increased CC-Chinook ocean harvest rates if there were expansion of fishing in California north of Point Arena.

In addition to limiting the preseason-projected age-4 ocean harvest rate of KRFC, the Reasonable and Prudent Alternative in the 2000 Biological Opinion stipulated that (1) NMFS must continue to evaluate the KRFC harvest rate as an indicator of the harvest rate on CC-Chinook and (2) NMFS shall cooperate with the states and PFMC to ensure that ocean fisheries are monitored and sampled for stock composition, including coded-wire tags (CWTs) and other biological information (NMFS, 2000).

In 2005, a reinitiation of consultation was undertaken as a result of a very high KRFC age-4 ocean harvest rate estimated postseason for 2004 ocean salmon fisheries (NMFS, 2005). Although the CC-Chinook consultation standard specifies the cap on the preseason-projected KRFC age-4 ocean harvest rate of 0.16, and the Klamath Ocean Harvest Model (KOHM) projected harvest rate in 2004 was 0.15, the postseason estimate of the rate in 2004 was 0.52. As a result of the preseason projection being exceeded by such a large amount, an effort to determine the causes of this overage was undertaken. This analysis identified the primary cause to be underpredicted contact-rates-per-unit-effort in the KOHM (NMFS, 2005). The 2005 consultation therefore specified that the PFMC and Salmon Technical Team would modify the KOHM for the 2006 season to more heavily weight recent-year contact-rate-per-unit effort estimates for forecasting purposes. In practice, this led to using data from 2003 forward for making contact-rate-per-unit-effort predictions for the commercial fishery in the FB, San Francisco (SF), and Monterey (MO) management areas (PFMC, 2006). This practice of using data from 2003 forward for forecasting contact-rates-per-unit-effort in the KOHM for the commercial salmon fishery in those areas continues through the present time.

Since the 2006 season, large differences between preseason and postseason values of the KRFC age-4 ocean harvest rate have not been observed, and postseason estimates have ranged between zero and 0.21 (see PFMC, 2012a, Table II-4).

6 Available ocean data

Sparse data from the sampling of ocean fisheries exist for CC-Chinook. The data that do exist include CWT recoveries from ocean fisheries and genetic stock identification (GSI) data from ocean fisheries and ocean sampling in times and areas closed to fishing.

Marking and tagging with CWTs has occurred sporadically for various populations of CC-Chinook since the late 1970s. The 2000 Biological Opinion made use of limited CWT recoveries from fish released in the Eel River basin to infer ocean distribution relative to KRFC and Central Valley Chinook raised at Coleman National Fish Hatchery (NMFS, 2000). This analysis examined the proportion of sample-expanded tag recoveries for KRFC, CC-Chinook, and Central Valley Chinook by ocean management area. While the analysis of these CWT recoveries did not account for differential levels of fishing effort expended in each management area, or examine within year (i.e., monthly) differences in the spatial distribution of CWT recoveries, inferences were made about the distribution of CC-Chinook relative to the other stocks. The analysis suggested a distribution of Eel River Chinook that was more southerly than KRFC, and more northerly than Central Valley Chinook. As a result, it was inferred that recent reductions (at that time) in the ocean harvest rate of KRFC and fishery constraints south of Point Arena to protect Sacramento River Winter Chinook resulted in a reduction in the ocean harvest rates on CC-Chinook. The change in ocean harvest rates was inferred as it could not be directly estimated owing to the paucity of spawner escapement data and river CWT recoveries. Since the 2000 Biological Opinion, very few tagged CC-Chinook have been released. A query of the Regional Mark Processing Center (RMPC) CWT database revealed that eight CWT release groups, ranging in size from 2,300 to 73,000, were released between brood years 2000 and 2002, and none thereafter. Few CWTs have been recovered since calendar year 2000; the RMPC database contains records for 287 ocean recoveries and zero freshwater recoveries. The two hatcheries that most recently marked, tagged, and released CC-Chinook are Mad River Hatchery and Warm Springs Hatchery (Russian River). Neither hatchery currently produces Chinook salmon.

Efforts to collect GSI data have increased in recent years. GSI can allow for genetic-based estimates of the stock of origin for fish sampled in ocean fisheries. For CC-Chinook, GSI methods are able to discriminate between Eel River and Russian River fish with a high degree of confidence, with other populations within the ESU likely to be assigned to the Eel River population (Carlos Garza, NMFS Southwest Fisheries Science Center, personal communication). GSI data were collected by the commercial salmon fleet along much of the California and Oregon coast for 2010–2012. The 2010 GSI project sampled nearly all months and management areas south of Cape Falcon, Oregon, both during the course of regular commercial fisheries and as non-retention sampling in months and areas closed to commercial fishing. The age composition of the 2010 samples from Oregon and California was estimated by reading scales (see Kormos et al., 2011, for California age structure estimates). The 2011 GSI sampling project was conducted only during months and areas open to commercial fishing and age composition was estimated only for the Oregon samples. Data collection in 2012 recently concluded and analysis is underway. The data generated from the 2010 and 2011 GSI projects have yielded estimates of the contribution rate of CC-Chinook to the sampled catch (or fish sampled and released in the case of non-retention sampling) at fine spatiotemporal scales. However, there are some potential limitations to the inferences that can be derived from these data. For example, it is unclear how well GSI data collected during non-retention sampling can be expected to represent the harvest stock composition that would have resulted from normal, retention fishing. Secondly, these data are only from the commercial fishery, which has less spatiotemporal coverage along the coast than the recreational fishery. Nonetheless, these data have been used in a comparison of size-at-age and spatial distributions of CC-Chinook and Klamath Chinook (Satterthwaite et al., In prep.). A summary of these spatial distribution results is provided in Section 7.5.

A relatively small amount of GSI data exists from ocean fisheries prior to 2010. GSI sampling on small temporal and spatial scales has occurred in California and Oregon, and test fisheries have occurred in California (Winans et al., 2001). Tissue samples were collected by California recreational fishery port samplers from 1998 to 2002, but these data have not yet been analyzed.

7 Feasibility of alternative fishery management strategies

The ability to devise a new management strategy for CC-Chinook that is not based on the KRFC proxy depends on the freshwater and ocean data available, as well as the information content of those data. Some salmon stocks are managed using an abundance-based approach, where allowable exploitation rates are specified by recent or forecast abundance (see section 3.3.6 of PFMC, 2012, for examples). To employ such a strategy, estimates or forecasts of abundance are needed, and it must be possible to produce a postseason estimate of the exploitation rate for evaluation purposes. Here we examine, given the data context, the ability to estimate and forecast important metrics such as spawner escapement, ocean harvest, ocean abundance, exploitation rates, and suitable exploitation rates for ocean fisheries.

7.1 Can total escapement of CC-Chinook be estimated?

Aggregate escapement estimates for the CC-Chinook ESU cannot be made owing to relatively low levels of sampling and a lack of randomized sample site selection across the available spawning habitat. For those areas that are sampled, measures of escapement are nearly all confined to indices of relative abundance, some of questionable quality, and they therefore do not provide population- or region-level estimates of total escapement (Williams et al., 2011). At the individual population level, the video counts made on the Russian River potentially provide an estimate of Russian River escapement, although the amount of spawning downstream of the video counting station is not estimated.

7.2 Can ocean harvest of CC-Chinook be directly estimated?

Stock proportions are estimable from GSI data, and the product of local stock proportions and local total catch could yield an estimate of total CC-Chinook harvest. Uncertainty in total CC-

Chinook catch arising from genetic assignment and sampling uncertainty can be quantified using the methods described in Satterthwaite et al. (In prep.), which have been incorporated into the computer program gsi_sim[2]. However, expanding stock proportions from a genotyped subsample to estimate total CC-Chinook harvest requires that the genotyped subsample is representative of the fishery management stratum harvest as a whole. Thus, the fishermen who participate in GSI sampling must be fully representative of the fleet, in terms of where and how they fish, or the GSI samples need to be collected via a comprehensive dockside sampling scheme similar to that currently employed for CWTs.

While GSI data can, in theory, allow for estimation of CC-Chinook ocean harvest in an adequately sampled management stratum, estimates of total ocean catch cannot be made from the data currently available. The estimation of total catch would require stock proportion estimates from all month/area/fishery strata within the CC-Chinook range. These GSI data do not currently exist. The low proportion of CC-Chinook expected in many strata (Winans et al., 2001) adds to the difficulty, as small proportions are difficult to estimate with adequate precision unless sample sizes are impractically large (Allen et al., In prep.).

7.3 Can a cohort reconstruction be completed for CC-Chinook?

Cohort reconstructions allow for the estimation of abundance, maturation rates, harvest, harvest rates, and many other metrics used to assess stock status and the effect of fisheries on a population (Hilborn and Walters, 1992; O'Farrell et al., 2012). The basic method for cohort reconstruction is the sequential rebuilding of abundance from the end of a cohort's life, when abundance is zero, to an earlier age, usually prior to recruitment to ocean fisheries, by accounting for removals due to fishing, natural mortality, and maturation. Most commonly, the core data used for cohort reconstructions are CWT recoveries (properly expanded for nonexhaustive sampling and, in some cases, the fraction of fish released with marks and tags) from freshwater escapement surveys, river harvest surveys, and ocean harvest surveys. However, CWT data are not strictly necessary so long

[2]`http://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=12964`

as the core information requirements of cohort reconstruction are met. Here we evaluate whether the data currently available for CC-Chinook satisfy these requirements.

Freshwater data requirements for cohort reconstruction include age-specific escapement and river harvest data. For CC-Chinook, age-specific escapement data do not exist. As noted in Section 7.1, total escapement cannot be estimated from the current data, and there has been no known effort to estimate age structure. There are no records of freshwater CWT recoveries in the RMPC CWT database. Freshwater harvest of CC-Chinook is prohibited. Thus, because age-specific escapement data do not exist for CC-Chinook, the freshwater data requirements for cohort reconstruction are not met.

The ocean data required for cohort reconstruction is age-specific harvest. Minimal CWT data exist, and the release of marked and tagged CC-Chinook ceased after the 2002 brood year. GSI has the potential to identify CC-Chinook in the ocean harvest, but to date no estimates of total CC-Chinook ocean harvest exist. Furthermore, minimal information exists on the age structure of ocean-harvested fish identified as CC-Chinook via GSI. To meet the ocean data requirements for cohort reconstruction, recreational and commercial fisheries would both need a carefully planned sampling scheme to generate estimates of total harvest for each of the stocks identifiable by GSI. These harvest estimates would also need to be age-specific, likely requiring extensive scale-aging and careful consideration of the resultant uncertainties. These harvest estimates would need to be combined with estimates of escapement for the same stock units identifiable by GSI; i.e., a cohort reconstruction could not proceed if ocean harvest was identified to the level of the ESU (or "reporting group") while escapement was measured for only a single river.

Ocean harvest, maturation rates, and other vital rates can be estimated from cohort reconstructions performed on untagged, natural populations (i.e., CC-Chinook) if a suitable CWT indicator stock exists. To perform natural-origin cohort reconstructions in this manner, age-specific river return estimates for the natural population and information from reconstructed cohorts of the CWT indicator stock are needed. Assuming equality in the ocean fishery contact or exploitation rates between the CWT indicator stock and the natural population, natural-origin cohort reconstructions proceed using the natural population's age-specific river return estimates and the ocean fishery contact or exploitation rate estimates borrowed from the indicator stock. For example, cohort reconstructions of natural-origin KRFC are performed using ocean fishery contact rates estimated from reconstructed hatchery-origin KRFC release groups coupled with age-specific natural-origin KRFC river return estimates (Mohr, 2006). For CC-Chinook, within-ESU indicator stocks do not exist because marking and tagging of CC-Chinook no longer occurs. Other neighboring stocks with CWT programs, such as KRFC and Central Valley Chinook stocks, are not likely to be appropriate indicator stocks for CC-Chinook because of differences in marine stock distributions (see Section 7.5 for more information on the ocean distribution of CC-Chinook). Furthermore, age-specific river return data are not available for CC-Chinook.

Therefore, owing to both freshwater and ocean data deficiencies, cohort reconstructions cannot be performed for CC-Chinook at the current time, and as a result estimation of abundance, exploitation rates, and maturation rates is hindered. Moreover, without a time series of historical abundance estimates, preseason forecasting of abundance using traditional methods (i.e., sibling regressions) is also not possible at the current time.

7.4 Can an abundance index for CC-Chinook be estimated?

The minimum data requirements for cohort reconstruction are not met by many West Coast salmon stocks. However, in some cases, the data do allow for the estimation of an abundance index and a crude exploitation rate based on the ratio of total catch to the sum of total catch and total escapement (Hankin and Healey, 1986). For example, the Sacramento Index (SI) has been used for assessment of Sacramento River fall Chinook, and the forecast SI is used to define annual exploitation rate targets or limits for that stock (O'Farrell et al., In prep.). The SI is defined as the sum of total escapement, total ocean harvest, and total river harvest.

For CC-Chinook, the lack of total escapement and ocean harvest data currently precludes the estimation of an abundance index for the entire ESU. A more realistic goal might be to estimate an abundance index for an indicator population within the ESU. A leading candidate would be the Russian River population, which appears to have the most complete estimate of annual escapement and can be identified in ocean fisheries with GSI methods. However, ocean catch of Russian

River Chinook would need to be estimated using GSI-derived stock proportions collected from all months/areas/fisheries. Because Russian River Chinook make up only a fraction of CC-Chinook abundance, estimating the proportion of Russian River Chinook in the ocean harvest would require even larger sample sizes for acceptable precision than for the aggregate CC-Chinook ESU.

Estimates of catch in all months/areas/fisheries currently do not exist. As a result, the extent and resolution of ocean catch data precludes estimation of an abundance index (analogous to the SI) for any of the populations within the CC-Chinook ESU.

7.5 Can abundance of CC-Chinook be inferred from other stocks?

Equivalent (or approximately so) estimates of catch-per-unit-effort (CPUE) for two or more stocks in a month/fishery stratum would suggest similar local abundance if the following conditions are met. First, the stocks would need to have equal catchability. Second, the fishing fleet should not differentially capture one stock over another (i.e., the fleet would randomly sample the aggregate local abundance). If these conditions were met, similarity in local CPUE would indicate similarity in local abundance. However, this would not necessarily imply similarity in total ocean abundance between these stocks. More information regarding the spatial distributions of the stocks at sea would be needed to make such an inference. For example, if the distributions of the stocks were identical, then CPUE similarities may imply similar abundance. If the distributions were not identical, differences in fishing effort in space and time could lead to misleading inferences with regard to abundance. To illustrate this point, consider the following hypothetical scenario. A similar CPUE is estimated for Klamath Chinook and CC-Chinook in FB for August, while KC is closed to fishing and sampling. If the above assumptions hold and distributions were identical, this result would correctly imply a similar ocean abundance for these stocks. If, however, the underlying spatial distribution of Klamath Chinook results in the bulk of their abundance being located in KC and the bulk of CC-Chinook abundance located in the FB management area, a similar CPUE between the stocks for FB in August would indicate that the Klamath stock is much more abundant. Inferring similar abundance from similar local CPUE would therefore draw an incorrect conclusion.

Differences in estimated Klamath Chinook and CC-Chinook ocean spatial distributions have been identified from an analysis of contacts per unit effort based on GSI data from 2010 and 2011. Satterthwaite et al. (In prep.) found that contacts per unit effort were similarly distributed for Klamath Chinook and CC-Chinook early in the year (analysis possible only in 2010), but late in the year (July or August) contacts per unit effort were relatively higher for CC-Chinook in the FB area and for Klamath Chinook in the KC area (this pattern held qualitatively in both 2010 and 2011). The comparison was confounded by the closure of the area between Humboldt South Jetty and Horse Mountain, an area that has been closed to commercial salmon fishing since the early 1990s, largely for the purpose of protecting CC-Chinook populations. This result must be interpreted with caution since it is limited to two years' data, and likely more complicated patterns would emerge in time. We might expect a high concentration of CC-Chinook in the closed area as spawners return to the Eel and Mattole rivers with mouths in that area but cannot test this hypothesis directly with the data at hand. The GSI-based estimates of CC-Chinook spatial distributions made in Satterthwaite et al. (In prep.) are not inconsistent with the CWT-based inferences made for CC-Chinook in NMFS (2000), despite the differences in data and methods used.

In sum, there is potential for evaluating relative local ocean abundance of KRFC and CC-Chinook with CPUE data, and such data currently exist from the GSI sampling program in 2010 and 2011. However, CPUE data must be interpreted cautiously when inferring relative, range-wide abundance because of uncertainty in differences in catchability and spatial distributions. If such problems could be resolved, and more data become available, relative CPUE measures could be used to make inferences about stock abundance. However, it seems unlikely that this approach could be useful for fishery management. The CPUE data necessary to infer CC-Chinook abundance would come from the fishery, and the bulk of the fishery occurs after the preseason fishery planning process. Relative CPUE measures from fisheries conducted the previous fall (September–November) could be investigated, though interpretation of these data is likely problematic because of the potential for run-timing differences between KRFC and CC-Chinook. Peak river mouth return of KRFC occurs around September 1 (O'Farrell et al., 2010), while CC-Chinook may only be able to enter certain natal rivers after the first large winter storms, which typically arrive in

November (Bjorkstedt et al., 2005).

If abundance of CC-Chinook and other stocks (i.e, KRFC, SRFC) are highly correlated, then preseason forecasts of the more data-rich stocks could potentially be used to infer relative abundance of CC-Chinook. The only CC-Chinook data series judged to be of adequate quality to represent total escapement is from the Russian River. Examination of the pairwise relationships between Russian River video counts and river mouth return estimates of adult KRFC, age-4 KRFC, and SRFC indicate low correlation (Figure 3). For these comparisons, river mouth returns for KRFC and SRFC were compared to the Russian River escapement estimates because the Russian River population is not subject to river fisheries and, assuming little river natural mortality, the river mouth return and escapement values should be comparable. Ignoring the correlation between adult and age-4 KRFC, the highest correlation exists between the Russian River and SRFC, although this correlation coefficient was not statistically significant ($p = 0.098$). The Russian River lies at the southern end of the CC-Chinook ESU and is the most proximate CC-Chinook population to Central Valley Chinook stocks; a lower correlation with SRFC might be expected for other CC-Chinook populations. The relatively low correlation between KRFC or SRFC and the Russian River population suggests that using KRFC or SRFC abundance forecasts to infer abundance of CC-Chinook would be problematic.

7.6 What is an appropriate exploitation rate for CC-Chinook?

While we have addressed questions about the estimation of exploitation rates, of perhaps equal or greater importance is the question of what exploitation rate is appropriate for the CC-Chinook ESU. Estimation of a stock-recruitment relationship can allow for estimation of stock productivity, which defines the exploitation rates that maximize yield, allow for population persistence, or promote recovery.

Sufficient data do not exist for estimating a stock-recruitment relationship at the ESU- or population-level, again due to the lack of sufficient escapement and ocean harvest information. Future data generated from LCMs may assist in the estimation of appropriate exploitation rates, although these data are not currently available and many years of data will be necessary before stock-

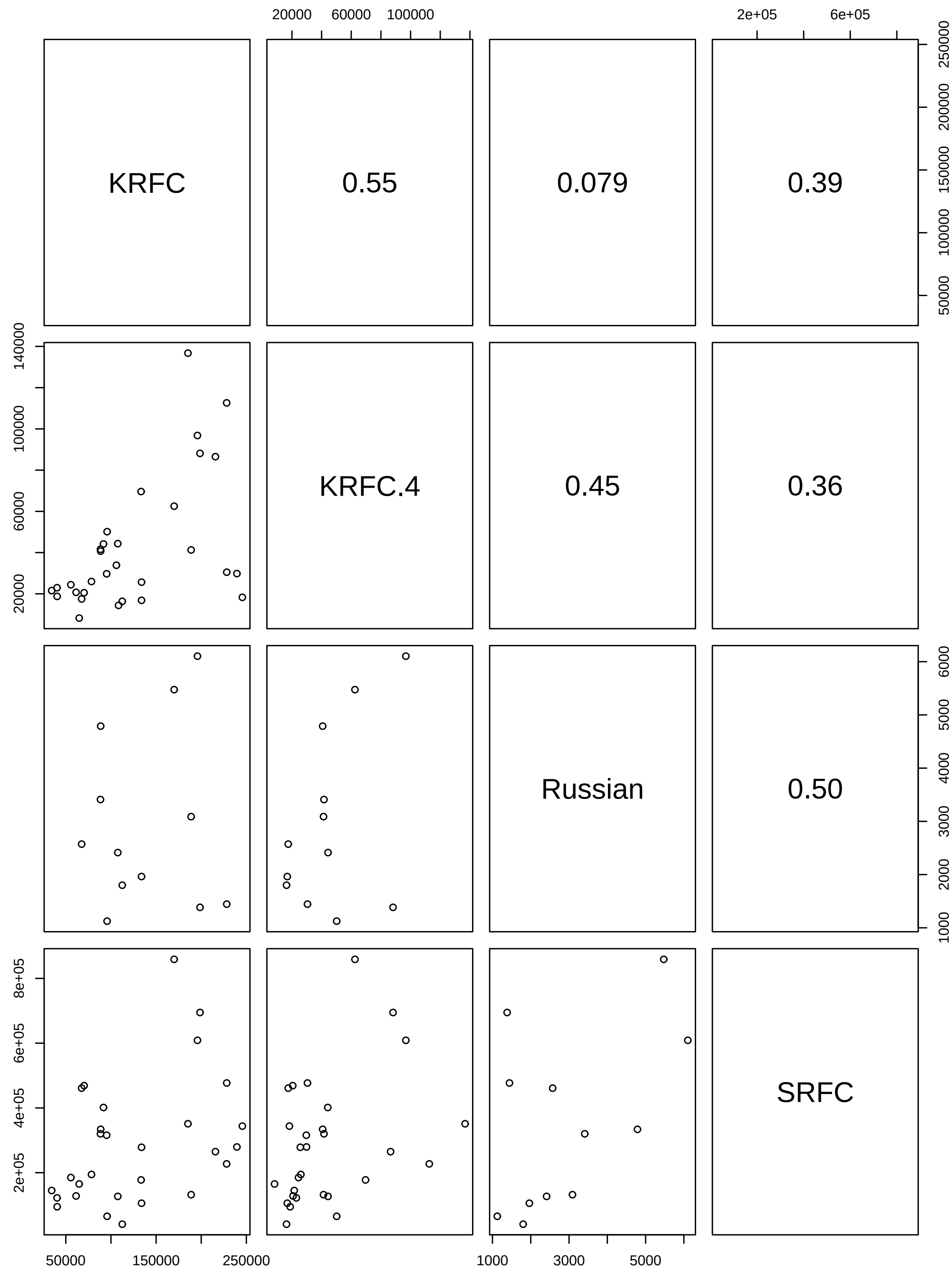

Figure 3. Pairwise comparisons between Russian River escapement estimates and river return estimates for Klamath River fall Chinook (KRFC) and Sacramento River fall Chinook (SRFC). Correlation coefficients appear above the diagonal. KRFC denotes adult (age 3–5) river return and KRFC.4 denotes age-4 river return.

recruitment relationships are estimable. Hence, at present, the productivity of the CC-Chinook ESU is unknown and, as a consequence, appropriate exploitation rates can not be determined for the ESU or its constituent populations.

8 Discussion

Many of the data quantity and quality issues that have hindered status reviews of the CC-Chinook ESU leave few options for the development of alternative fishery management strategies. The current consultation standard, which relies on the preseason-projected age-4 ocean harvest rate for the proxy KRFC stock, was developed because of the data limitations that exist for CC-Chinook. Since the development of that consultation standard, more GSI data from the ocean commercial fishery have been collected and analyzed. Results from analysis of these data (Satterthwaite et al., In prep.) are consistent with the results described in NMFS (2000), which suggested that Eel River Chinook have an ocean distribution between that of KRFC and Central Valley Chinook stocks. Aside from these recent GSI data, few other new data have become available for CC-Chinook.

The paucity of data available for CC-Chinook contrasts with other ESUs or stocks that are managed under a framework where the allowable exploitation rate can vary with stock abundance. For example, an abundance-based management approach was recently adopted for threatened Lower Columbia River tule fall Chinook (LCR tules). The existence of a long time series of hatchery-origin CWT indicator stocks, considered representative of LCR tules, allowed for the development and implementation of this new management strategy (Ad Hoc Tule Chinook Work Group, 2011). Aggregate hatchery stock run sizes were demonstrated to be correlated with LCR tule run size, as indexed by natural spawner escapement, suggesting that the hatchery stock-based run size forecasts would serve as a reasonable proxy for LCR tules. Furthermore, exploitation rates can be estimated for representative hatchery indicator tag groups, allowing for postseason evaluation of the harvest policy. The data available for LCR tules that enable the abundance-based management approach are not available for CC-Chinook.

While the results of this evaluation indicate that the current data leave few options for the development of an alternative fishery management strategy, more work needs to be performed to identify new sources of data that would enable future changes in CC-Chinook management. We identify some potential alternatives for improving the data richness of CC-Chinook in a manner that would be informative for fisheries assessment and management.

Implementation of the CMP would undoubtedly improve escapement estimates for populations within the CC-Chinook ESU, and better escapement estimates would improve status determinations. More complete escapement estimates would also allow for better inference regarding correlations between CC-Chinook and neighboring stocks. However, improved escapement estimates alone would not be sufficient for the development of an alternative fishery management strategy. Thus, implementation of the CMP would be only one component of a future strategy aimed at better assessment and management of CC-Chinook.

Establishment of an indicator population, or populations, for the CC-Chinook ESU might allow for development of alternative fishery management approaches. The data collected for the indicator stock(s) must be sufficient to conduct cohort analysis, which would allow for both the postseason estimation of exploitation rates and the estimation of appropriate, sustainable exploitation rates for CC-Chinook. As described in section 7.3, the basic data requirements for cohort analysis are age-specific escapement and harvest. Age-specific escapement for some populations might be estimable if the CMP were implemented and collection of data allowing for age structure estimation were prioritized. The estimation of age-specific ocean harvest for these corresponding populations is likely to be more difficult.

The use of GSI data to estimate age-specific harvest for use in cohort analysis of an indicator population is problematic. Comprehensive dockside sampling of all ocean fisheries south of Cape Falcon for tissue samples (for genetic assignment) and scales (for age assignment) would need to be undertaken. The GSI reporting group would need to match the indicator population so that genetic assignments only pertained to the indicator population monitored in freshwater. This may be possible for the Russian River but does not appear to be possible for the other populations in the ESU because it is thought that they assign to an inclusive “Eel River” reporting group (Carlos Garza, NMFS Southwest Fisheries Science Center, personal communication). Furthermore, there are likely to be problems associated with having sufficient power to estimate the expected small stock proportions of the harvest for an indicator stock that represents a potentially small fraction of the total ESU ocean harvest.

More study should be given to the feasibility of establishing one or more tagged indicator populations for the ESU. It may be possible to mark and CWT naturally-produced juvenile Chinook, perhaps at suitably located LCM sites. However, it is unclear whether a sufficient number of natural-origin juveniles could be marked and tagged with a CWT to allow for cohort reconstructions. We know of no examples of natural-production CWT programs that have been operated at a large enough scale to allow for credible cohort reconstructions, yet the feasibility of performing large-scale natural-origin marking and tagging should be further investigated. Consideration could be given to the re-establishment of a Chinook CWT program at hatcheries located within the ESU. Genetic parental-based tagging of an indicator population may also deserve further study to evaluate its suitability for cohort reconstructions (Hankin et al., 2005; California Hatchery Scientific Review Group, 2012). Hankin et al. (2005) note that sampling sufficient natural-area spawners may be difficult, and a parental-based tagging approach is most effective when a large proportion of spawners can be sampled and included in the parental database. Use of parental-based tagging data for cohort reconstructions would also require comprehensive ocean fishery tissue sampling as described for GSI.

Finally, care would need to be taken when choosing appropriate indicator stocks. While the Russian River population currently has the best estimate of total escapement, questions remain regarding how well the population would serve as an indicator for the entire ESU. Differences between Russian River and Eel River Chinook ocean distributions have not been estimated, yet the potential for such differences exists as a result of the distance separating the populations. The vulnerability of Russian River Chinook to ocean fisheries may also differ from that of other populations in the ESU. The Russian River mouth is located within the SF fishery management area while the other rivers in the ESU enter the ocean in the FB or KC management areas. Relative to SF, commercial fisheries in these more northern management areas are typically much more constrained. Maturation rates and/or size-at-age may differ, which would also affect vulnerability to fisheries. Establishment of an indicator population for the northern portion of the ESU, potentially the Eel River or a component of it, and a southern indicator population at the Russian River may be warranted.

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