Agenda Item F.3.a
Supplemental SRKW Workgroup Report 1
September 2019

Pacific Fishery Management Council Salmon Fishery Management Plan Impacts to Southern Resident Killer Whales

Draft Risk Assessment

Pacific Fishery Management Council

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CONTENTS

1 INTRODUCTION

This report is a product of the Pacific Fishery Management Council's (PFMC or Council) ad-hoc Southern Resident Killer Whale (SRKW) Workgroup which was tasked with reassessing the effects of Council-area ocean salmon fisheries on SRKW. We first provide a brief overview of the background context, workshop process, and the role of the SRKW Workgroup. Then we assess the current status of the SRKWs, followed by describing the interactions known to occur between SRKW and salmon fisheries, leading to a general description of the Pacific Coast Salmon Fishery Management Plan (FMP), and then we attempt to assess how reductions in prey through implementing the FMP may affect SRKW demographics.

1.1 Background

SRKW are listed as endangered under the Endangered Species Act (ESA) (70 FR 69903). Multiple actions along the west coast are active in conserving and recovering SRKW, particularly to address three threats to the whales that were identified in the SRKW Recovery Plan (NMFS 2008): prey limitation, vessel traffic and noise, and chemical contaminants. Fisheries affect the whales primarily through removing prey. The Council uses provisions of the FMP, to make recommendations to NMFS for implementing salmon fisheries in Federal waters (3-200 nautical miles) off the coast of Washington, Oregon, and California. The effects on SRKW of implementing the FMP, i.e., prey removal and the potential for interaction between fishing gear and vessels, were last consulted under the ESA per Section 7(a)(2) by NMFS in 2009 (NMFS 2009). That consultation described the effects on the amount of prey available to SRKW and the potential for interactions between fishing gear and vessels. In that opinion, NMFS concluded Council fisheries did not jeopardize the survival and recovery of SRKW.

Since the 2009 consultation was completed, new information is available on SRKW and their relationship to salmon prey species, and in March of 2019, NMFS announced plans to reinitiate consultation on the implementation of the FMP, for which it did on April 12, 2019. Subsequently, at its April 2019 meeting, the Council formed the ad-hoc SRKW workgroup (SRKWW or Workgroup) to reassess the effects of Council-area ocean salmon fisheries on the Chinook salmon prey base of SRKW, and depending on the results, develop a long-term approach that may include proposed conservation measure(s) or management tool(s) that limit PFMC fishery impacts to prey availability for SRKW relative to implementing the FMP.

The Workgroup met numerous times during the course of 2019 in order to develop the risk assessment approach contained in this report, and all meetings were open to the public. A detailed list of Workgroup meetings and presentations can be found online at: https://www.fisheries.noaa.gov/west-coast/southern-resident-killer-whales-and-fisheries-interaction-workgroup

1.2 Purpose and Need

Chinook salmon, the whales' primary prey, are important to SRKW survival and recovery. Any activities that affect the abundance of Chinook salmon available to SRKW have the potential to impact the survival and population growth of the whales. Fisheries can reduce the prey available to the whales and in some cases can interfere directly with their feeding. Insufficient prey can impact their energetics (causing them to search more for fewer prey), health (decreasing their body condition), and reproduction (reducing fecundity and calf survival).

NMFS consulted on the effects of Council fisheries under the ESA in 2009 and concluded that annual management recommendations developed according to the PFMC's Pacific Coast Salmon FMP and its associated amendments, were not likely to jeopardize the continued existence of the SRKW Distinct Population Segment (DPS) or adversely modify its critical habitat. Given new information is available on SRKW and their prey since 2009 and potentially the effects of the fisheries on the whales, NMFS has re-initiated ESA consultation on the Council fisheries, and asked for the Council's assistance in assessing the effects of implementing the FMP in 2019 and beyond. In cooperation, the Council appointed a workgroup with membership including representatives from West Coast tribes; the states of California, Oregon, Washington, and Idaho; the PFMC; and NMFS' West Coast Region, Northwest Fisheries Science Center, and Southwest Fisheries Science Center.

The purpose the Council tasked the workgroup with was to reassess the effects of PFMC ocean salmon fisheries on SRKW and if needed, develop a long-term approach that may include proposed conservation measure(s) or management tool(s) that limit PFMC fishery impacts to Chinook salmon prey availability for SRKW relative to implementing the FMP. The need is that the workgroup's findings will inform NMFS' ESA consultation and biological opinion, wherein NMFS will determine whether the fisheries jeopardize the continued existence of SRKWs in light of new information about the whales' dependence on West Coast Chinook salmon stocks.

Specifically, the Workgroup collected and summarized information related to:

- overlap between PFMC salmon fisheries and SRKW;
- information the Council's Salmon Technical Team (STT) developed in 2019 regarding which Chinook salmon stocks that are priorities for the whales also contribute to PFMC-area salmon fisheries (see Agenda Item D.8.a, Supplemental STT Report 2 from the Council's 2019 March meeting); and
- analyses for prior salmon fishery/SRKW evaluations.

The Workgroup was also instructed to recommend (if needed based on the risk assessment) conservation measures or management tools to limit PFMC fishery impacts on Chinook salmon prey availability for SRKW.

The workgroup is focused exclusively on addressing the impacts of PFMC-area ocean salmon fisheries through tools or conservation measures that apply to those fisheries. Considerations of other fisheries or other threats to SRKW are outside the scope of the reinitiated consultation, which is limited to the salmon fisheries as implemented under the FMP. NMFS considers other activities in the action area as part of the environmental baseline in the consultation. In addition, the NMFS West Coast Region and its partners are addressing the broader suite of threats separately.

1.3 NMFS Recovery Plan Guidance

Working with its federal, state, tribal, and local partners, NMFS published a recovery plan for SRKW in January 2008 (NMFS 2008). The plan provides a road map to recovery and there is considerable uncertainty about which threats (prey abundance and quality, noise, and contaminants) may be responsible for the decline in the SRKW population, or which is the most important to address for recovery. The plan lays out an adaptive management approach and a recovery strategy that addresses each of the potential threats based on the best available science.

The recovery program outlines links from management actions to an active research program to fill data gaps and a monitoring program to assess effectiveness. Feedback from research and monitoring will provide the information necessary to refine ongoing actions and develop and prioritize new actions. For actions that affect prey abundance, (e.g., salmon), NMFS identified near-term priorities of ongoing restoration efforts for depleted salmon populations in order to:

- Rebuild depleted populations of salmon and other prey to ensure an adequate food base for recovery of SRKWs.
- Support salmon restoration efforts in the region
- Support regional restoration efforts for other prey species
- Use NMFS authorities under the ESA and the Magnuson Stevens Act (MSA) to protect prey habitat, regulate harvest, and operate hatcheries.

Healthy SRKW populations are dependent on adequate prey levels. Reductions in prey availability may force SRKWs to spend more time foraging and might lead to reduced reproductive rates and higher mortality rates.

2 STATUS OF THE SPECIES

The SRKW DPS, composed of J, K, and L pods, was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). A 5-year review under the ESA completed in 2016 concluded that SRKWs should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2016).

The limiting factors described in the final recovery plan included reduced prey availability and quality, high levels of contaminants from pollution, and disturbances from vessels and sound (NMFS 2008). This section summarizes the status of SRKWs throughout their range and summarizes information taken largely from the recovery plan (NMFS 2008), recent 5-year review (NMFS 2016), as well as newly available data.

2.1 Abundance, Productivity, and Trends

SRKW are a long-lived species, sexual maturity occurs at age 10 (review in NMFS (2008)). Females produce a small number of surviving calves (n < 10, but generally fewer) over the course of their reproductive life span (Bain 1990; Olesiuk et al. 1990). Compared to Northern Resident killer whales (NRKWs), which are a resident killer whale population with a sympatric geographic distribution ranging from coastal waters of Washington State and British Columbia north to Southeast Alaska, SRKW females appear to have reduced fecundity (Ward et al. 2013; Vélez-Espino et al. 2014).

Recent aerial imagery corroborates previous notions that SRKWs are thought to have a higher than expected rates of reproductive failure. As can be seen by aerial photogrammetry images collected[1], SRKWs that are pregnant develop pronounced increased width at mid body. The gestation period is about 17 months. Robeck et al. 2016 estimated a mean gestation of 532 ± 3.1 days and Duffield et al. 1995 estimated a mean gestation of 517 ± 20 days. Validation based on pregnant whales in captivity and wild whales that gave birth has shown that aerial images can reliably detect pregnancy by about 9 months. Photogrammetry data have shown that ~68 percent of the detected late stage pregnancies (pooled across 10 years) do not produce a documented calf. Notably, K pod hasn't produced a surviving calf since 2011. A recent study indicated pregnancy hormones (progesterone and testosterone) can be detected in SRKW feces and have indicated several miscarriages, particularly in late pregnancy (Wasser et al. 2017).

Since the early 1970s, annual censuses in the Salish Sea using photo-identification techniques have occurred (Bigg et al. 1976; Balcomb et al. 1980; Center for Whale Research, unpubl. data). The surveys are typically performed from May to October, when all three pods tend to reside near the San Juan Islands, and are considered complete censuses of the entire population. The population was at its lowest known abundance in the early 1970s following live-captures for aquaria display. The abundance since the annual censuses began peaked in 1995 followed by an almost 20 percent decline from 1995-2001 (from 98 whales in 1995 to 81 whales in 2001). In 2014 and 2015, the

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[1] Presentation on May 23, 2019, to the SRKW Ad Hoc Workgroup: "Photogrammetry to monitor growth and body condition". This work is a collaboration with NOAA SWFSC and SR3 (a non-profit research and animal welfare group based in Seattle). The time series has also had key contributions from the Center for Whale Research on San Juan Island, and the Vancouver Aquarium.

SRKW population increased from 78 to 81 as a result of multiple successful pregnancies that occurred in 2013 and 2014. At present, the SRKW population has declined to near historically low levels (Figure 1). As of August 2019, the population is 73 whales (2 calves were born and three whales died since the 2018 census).

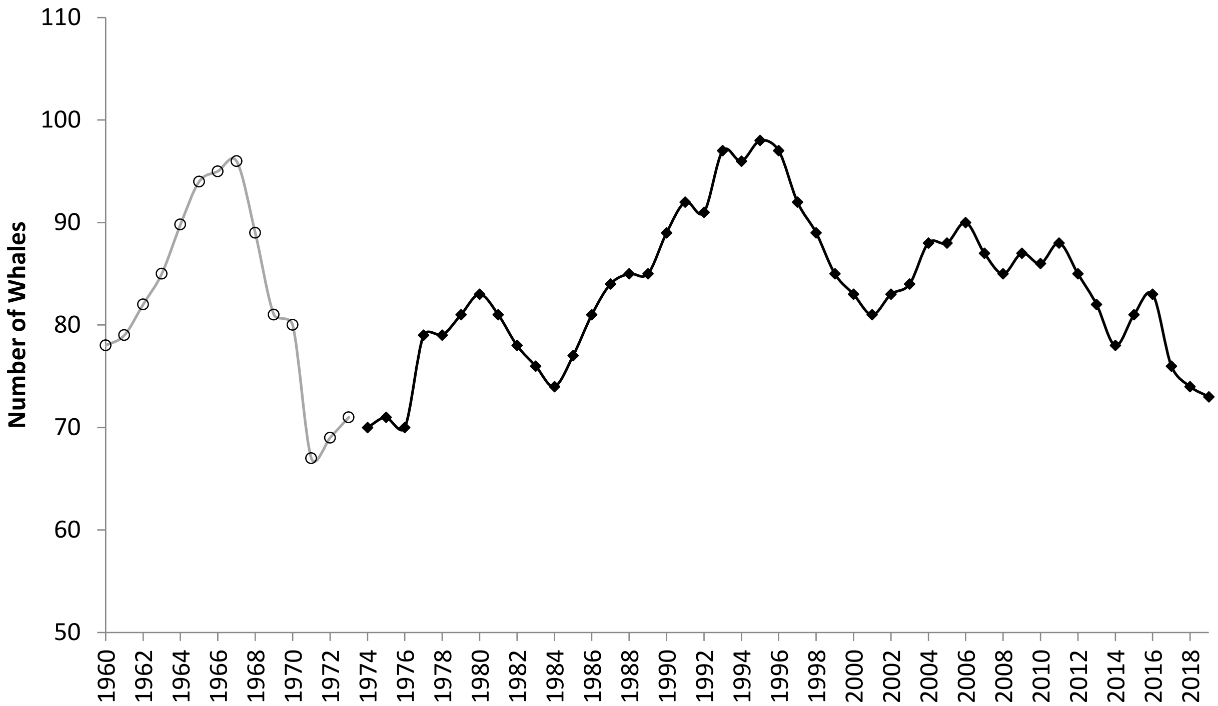

Figure 1. Population size and trend of Southern Resident killer whales, 1960-2019. Data from 1960-1973 (open circles, gray line) are number projections from the matrix model of Olesiuk et al. (1990). Data from 1974-2019 (diamonds, black line) were obtained through photo-identification surveys of the three pods (J, K, and L) in this community and were provided by the Center for Whale Research (unpublished data) and NMFS (2008). Data for these years represent the number of whales present at the end of each calendar year.

There are several demographic factors of the SRKW population that are cause for concern, namely (1) reduced fecundity, (2) a skewed sex ratio toward male births in recent years, (3) a lack of calf production from certain components of the population (K pod, other groups), (4) a small number of adult males acting as sires (Ford et al. 2018) and (5) an overall small number of individuals in the population (review in NMFS 2008). Based on an updated pedigree from new genetic data, many of the offspring in recent years were sired by two fathers, meaning that less than 30 individuals make up the effective reproducing portion of the population. Because a small number of males were identified as the fathers of many offspring, a smaller number may be sufficient to support population growth than was previously thought (Ford et al. 2011; Ford et al. 2018). Inbreeding may be common amongst this small population, with a recent study by Ford et al. (2018) finding several offspring resulting from matings between parents and their own offspring. However, the fitness effects of this inbreeding remain unclear and is an effort of ongoing research (Ford et al. 2018).

The previously published historical abundance of SRKW is 140 animals (NMFS 2008). This estimate (~140) was generated as the number of whales killed or removed for public display in the 1960s and 1970s (summed over all years) added to the remaining population at the time the captures ended. Because of the summed captures over all years, this estimate is likely an upper bound of the population size prior to removals.

The NWFSC continues to evaluate changes in fecundity and mortality rates, and has updated population viability analyses conducted for the 2004 Status Review for Southern Resident Killer Whales and the 2011 science panel review of the effects of salmon fisheries (Krahn et al. 2004; Hilborn et al. 2012; Ward et al. 2013). Following from that work, the data now suggests a downward trend in population growth projected over the next 50 years. As the model projects out over a longer time frame (50 years) there is increased uncertainty around the estimates. The downward trend is in part due to the changing age and sex structure of the population, and will occur more frequently if the fecundity rates are lower (as in 2016) compared to the recent past (2011-2016) (Figure 2, NMFS 2016).

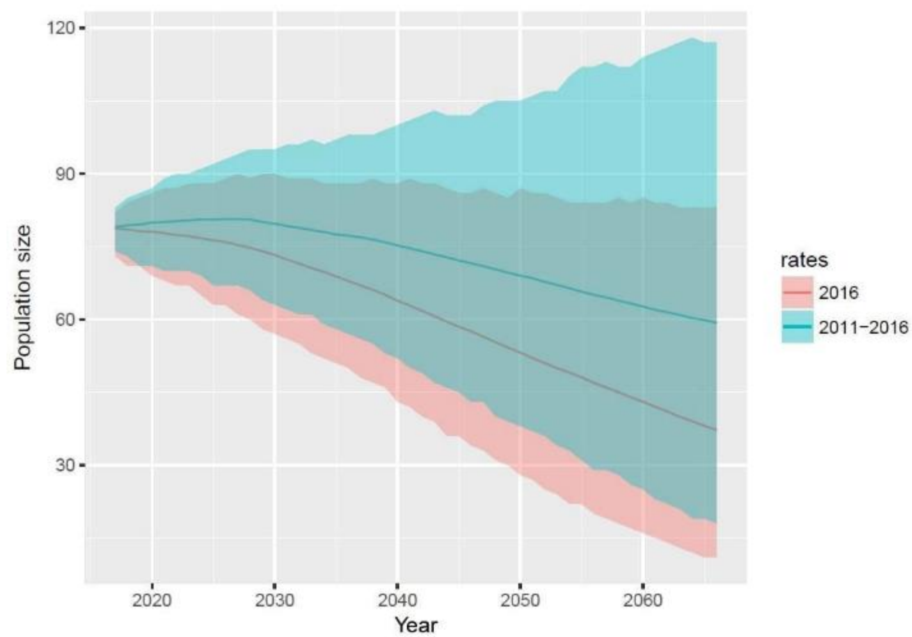

Figure 2. Southern Resident killer whale population size projections from 2016 to 2066 using 2 scenarios: (1) projections using demographic rates held at 2016 levels, and (2) projections using demographic rates from 2011 to 2016. The pink line represents the projection assuming future rates are similar to those in 2016, whereas the blue represents the scenario with future rates being similar to 2011 to 2016 (NMFS 2016).

To explore potential demographic projections, Lacy et al. (2017) constructed a SRKW population viability assessment that considered sub-lethal effects and the cumulative impacts of multiple threats (contaminants, acoustic disturbance, and prey abundance). They found that over the range of scenarios tested, using previously reported correlations of demographic rates with Chinook abundance to parameterize their model, the effects of prey abundance on fecundity and survival had the largest impact on the population growth rate. A delisting criterion for the SRKW DPS is that the population exhibit an average growth rate of 2.3 percent for 28 years (NMFS 2008). Lacy et al. (2017) suggested that reducing the acoustic disturbance in half and increasing annual coast wide Chinook abundance by 15 percent would allow the population to meet this delisting criterion.

Because of this population's small abundance, it is also susceptible to increased risks of demographic stochasticity – randomness in the pattern of births and deaths among individuals in a population. Several other sources of stochasticity can affect small populations and contribute to variance in a population's growth and increased extinction risk. Other sources include environmental stochasticity, or fluctuations in the environment that drive fluctuations in birth and death rates, and demographic heterogeneity, or variation in birth or death rates of individuals because of differences in their individual fitness (including sexual determinations). In combination, these and other sources of random variation combine to amplify the probability of extinction, known as the extinction vortex (Gilpin and Michael 1986; Fagan and Holmes 2006; Melbourne and Hastings 2008). The larger the population size, the greater the buffer against stochastic events and genetic risks. In light of the current small population size and declining status, these conditions reinforce the need to promote immediate population growth.

Population growth is also important because of the influence of demographic and individual heterogeneity on a population's long-term viability. Population-wide distribution of lifetime reproductive success can be highly variable, such that some individuals produce more offspring than others to subsequent generations, and male variance in reproductive success can be greater than that of females (e.g. Clutton-Brock 1988; Hochachka 2006). For long-lived vertebrates such as killer whales, some females in the population might contribute less than the number of offspring required to maintain a constant population size (n = 2), while others might produce more offspring. The smaller the population, the more weight an individual's reproductive success has on the population's growth or decline (Coulson et al. 2006). For example, from 2010 through July 2019, only 15 of the 28 reproductive aged females successfully reproduced, resulting in 16 calves. There were an additional 10 documented non-viable calves, and likely more undocumented, born during this period (CWR unpubl. data). This further illustrates the risk of demographic stochasticity for a small population like SRKWs – the smaller a population, the greater the chance that random variation will result in too few successful individuals to maintain the population.

2.2 Geographic Range and Distribution

SRKWs occur throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as Southeast Alaska (NMFS 2008; Carretta et al. 2019) (Figure 3). SRKW are highly mobile and can travel up to approximately 86 miles in a single day (Erickson 1978; Baird 2000), with seasonal movements likely tied to the migration of their primary prey, salmon. During the spring, summer, and fall months, SRKWs have typically spent a substantial amount of time in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Ford et al. 2000; Krahn et al. 2002; Hauser et al. 2007). During fall and early winter, SRKWs, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum, coho, and Chinook salmon runs (Osborne 1999; Hanson et al. 2010; Ford et al. 2016). Although seasonal movements are generally predictable, there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall, with late arrivals and fewer days present in recent years (Hanson and Emmons 2010; The Whale Museum unpubl. data).

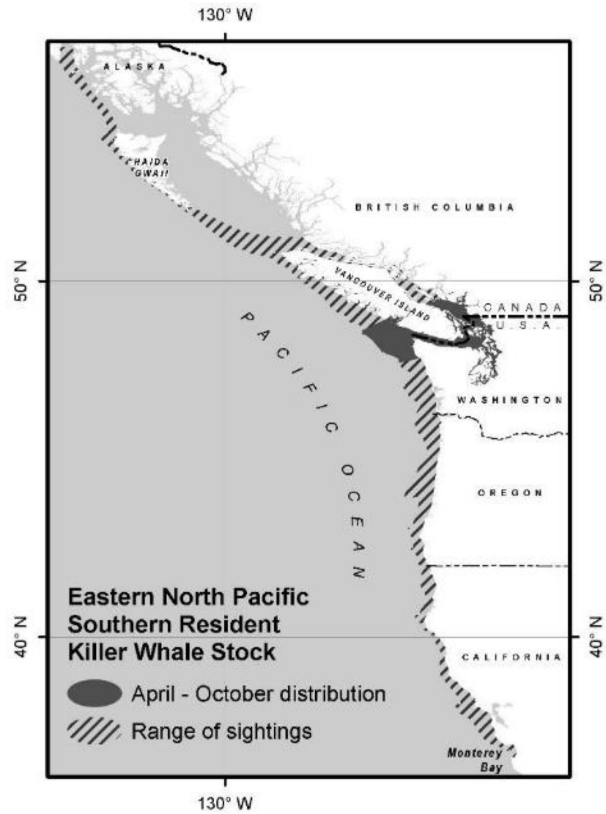

Figure 3. Geographic range of Southern Resident killer whales (reprinted from Carretta et al. 2019).

SRKWs distribution and forging areas in winter months is less known. Research is on-going to address this. Hanson et al. (2017) used remotely deployable tags and acoustic recorders to further understand SRKW movements and occurrence patterns. Hanson et al. (2018) integrated opportunistic visual sightings with results from a state-space movement model to fill in the detection gaps in the acoustic detections of SRKWs in coastal waters over a 4-year period when satellite tags were not deployed. From 2012-2016 they deployed satellite-linked tags on eight male SRKW (three tags on J pod members, two on K pod, and three on L pod) in Puget Sound or in the coastal waters of Washington and Oregon (Table 1). These telemetry tags transmitted multiple locations per day and were used to assess winter movements and occurrences of SRKW (identified as a priority area of research in Hilborn et al. 2012). Additionally, passive acoustic recorders were deployed in areas thought to be of frequent use by SRKWs to assess their seasonal uses of these areas via the recording of stereotypic calls of the SRKW. The recorders were deployed off the coasts of California, Oregon and Washington in most years since 2006 (Figure 4; Hanson et al. 2013). The acoustic monitoring detected SRKW 131 times at up to 7 locations from 2006-2011 (Hanson et al. 2013). The number of sites off the Washington coast was increased from 7 to 17 in the fall of 2014 to better understand the residency of SRKWs in this area (Figure 5; Hanson et al. 2017).

Table 1. Satellite-linked tags deployed on Southern resident killer whales 2012-2016 (Hanson et al. 2018).

Whale ID	Pod association	Date of tagging	Duration of signal contact (days)
J26	J	20 Feb. 2012	3
L87	J	26 Dec. 2013	31
J27	J	28 Dec. 2014	49
K25	K	29 Dec. 2012	96
L88	L	8 Mar. 2013	8
L84	L	17 Feb. 2015	93
K33	K	31 Dec. 2015	48
L95	L	23 Feb. 2016	3

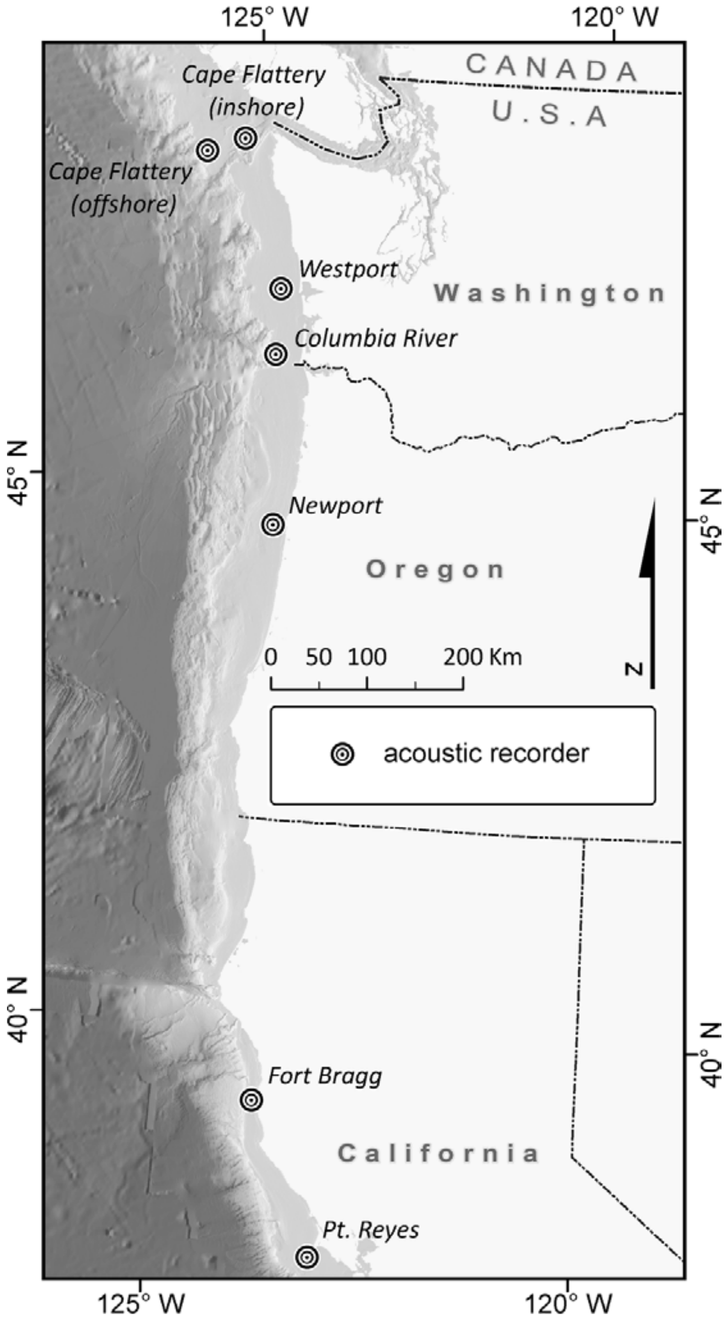

Figure 4. Deployment locations of acoustic recorders on the U.S. west coast from 2006 to 2011 (Hanson et al. 2013).

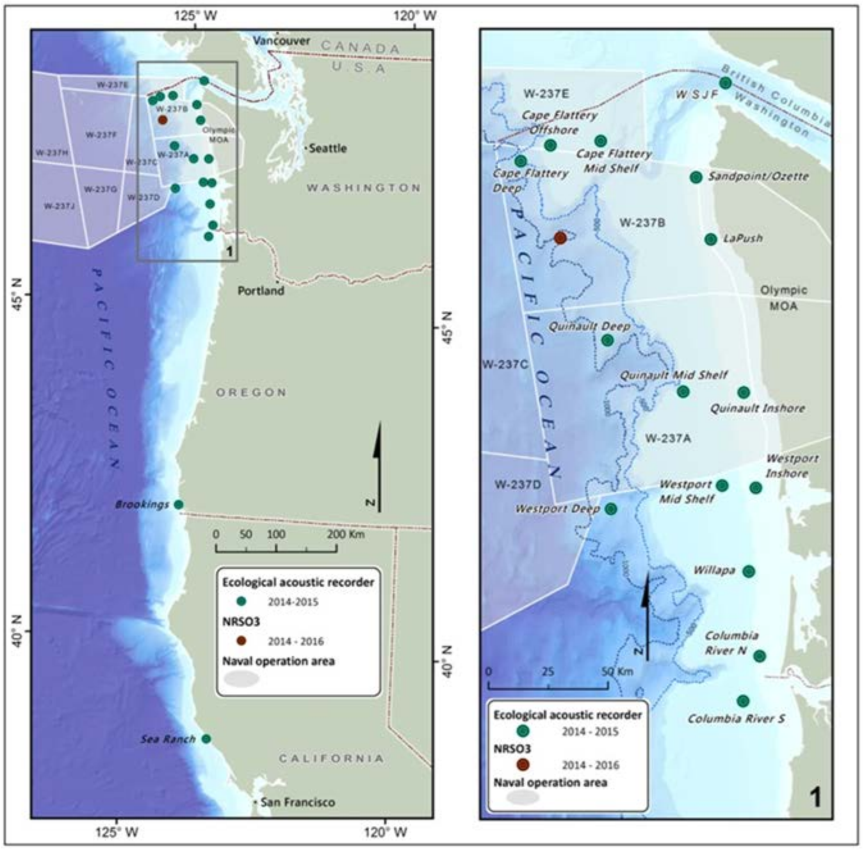

Figure 5. Locations of passive acoustic recorders deployed beginning in the fall of 2014 (Hanson et al. 2017).

The satellite tags resulted in 323 days of monitoring with deployment durations from late December to mid-May. The winter locations of the tagged whales included inland and coastal waters. The inland waters range occurs across the entire Salish Sea, from the northern end of the Strait of Georgia and Puget Sound, and coastal waters from central west coast of Vancouver Island, British Columbia to northern California. J pod had high use areas in the northern Strait of Georgia and the west entrance to the Strait of Juan de Fuca. K/L pods occurred almost exclusively on the continental shelf during December to mid-May, primarily on the Washington coast, with a continuous high use area between Grays Harbor and the Columbia River and off Westport (Hanson et al. 2017, 2018). Approximately 95 percent of the SRKW locations were within 34 km of the shore and 50 percent of these were within 10 km of the coast. Only 5 percent of locations were greater than 34 km away from the coast, but no locations exceeded 75 km. Most locations were in waters less than 100m in depth.

Between 2011 and 2016, the SRKWs were acoustically detected 246 times (Hanson et al. 2018). There were acoustic detections off Washington coast in all months of the year, with greater than 2.4 detections per month from January through June with a peak of 4.7 detections per month in both March and April (Hanson et al. 2017), indicating that the SRKW may be present in Washington coastal waters at nearly any time of year, and in other coastal waters more often than previously believed. . High use areas for the SRKW in winter are primarily located in three areas 1) the Washington coast, particularly between Grays Harbor and the mouth of the Columbia River (primarily for K/L pods); 2) the west entrance to the Strait of Juan de Fuca (primarily for J pod); and 3) the northern Strait of Georgia (primarily for J pod). It is important to note that this study was designed to assess spatial use off Washington coast and thus the effort was higher (i.e. the number of recorders increased from 7 to 17 in this area, see Figure 5) compared to off Oregon and California.

In a recent study, researchers collected data using an autonomous acoustic recorder deployed at Swiftsure Bank from August 2009 to July 2011 to assess how this area is used by Northern Resident and Southern Resident killer whales (Figure 6, Rivera et al. 2019).

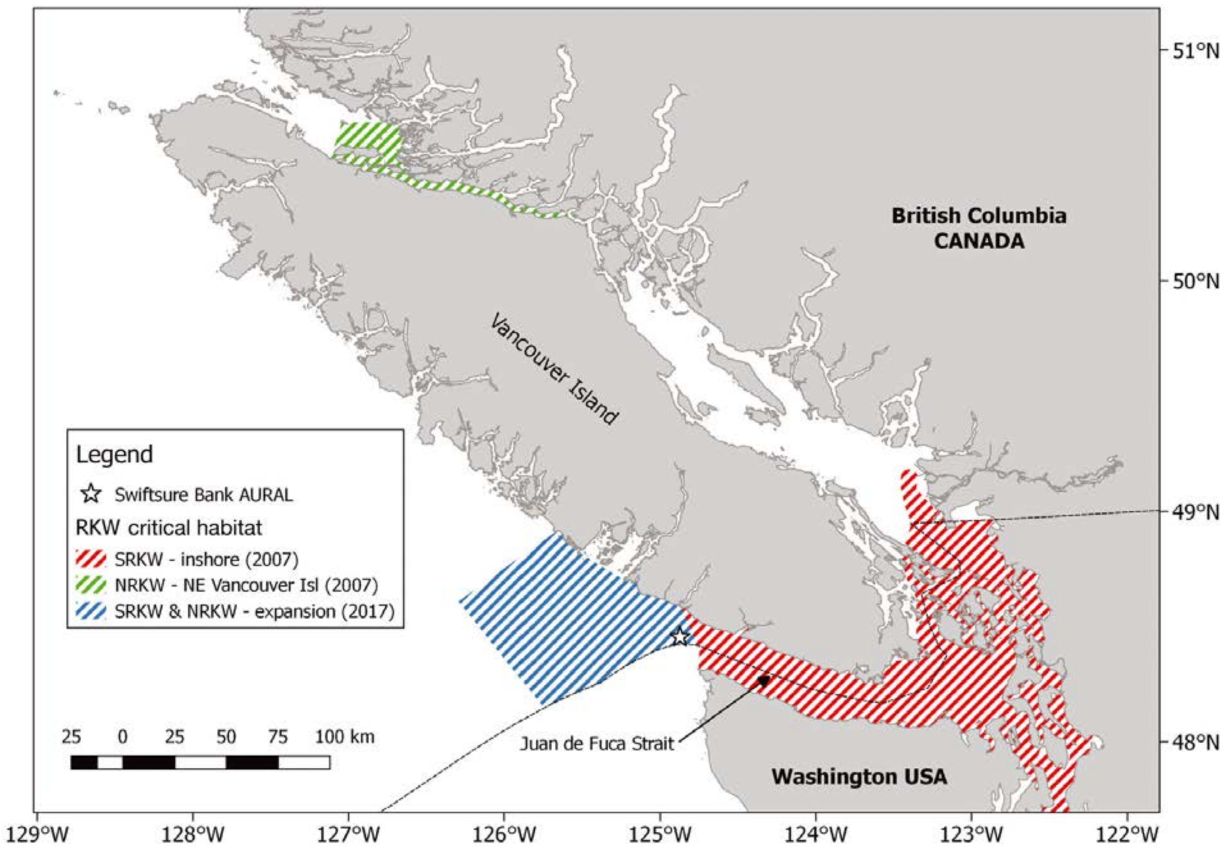

Figure 6. Swiftsure Bank study site off the coast of British Columbia, Canada (Riera et al. 2019).

SRKW were detected on 163 days with 175 encounters (see Figure 7 for number of days of acoustic detections for each month). All three pods were detected at least once per month except for J pod in January and November and L pod in March. K and L pods were heard more often during the summer (87 percent of calls and 89 percent of calls, respectively, between May and September). J pod was heard most often during winter and spring (76 percent of calls during December and February through May; Riera et al. 2019). K pod had the longest encounters in June, with 87 percent of encounters longer than 2 hours occurring between June and September. L pod had the longest encounters in May, with 79 percent of encounters longer than two hours occurring during the summer (May through September). The longest J pod encounters were during winter, with 72 percent of encounters longer than 2 hours occurring between December and May (Riera et al. 2019).

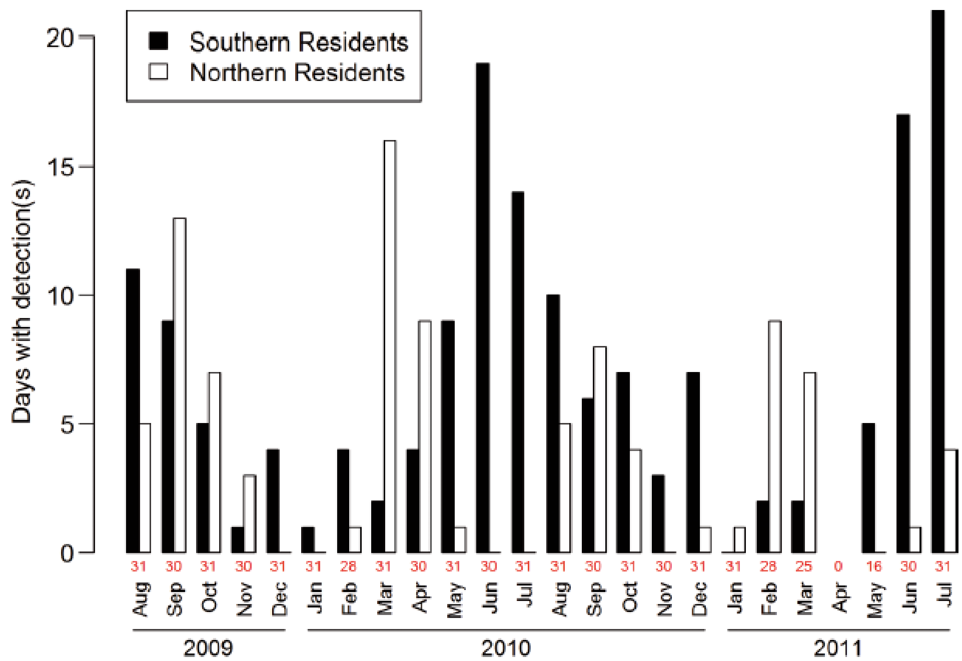

Figure 7. Number of days with acoustic detections of SRKWs at Swiftsure Bank from August 2009 – July 2011). Red numbers indicate days of effort. (Riera et al. 2019).

2.3 Limiting Factors and Threats

Several factors identified in the recovery plan for SRKW may be limiting recovery. These are quantity and quality of prey, toxic chemicals that accumulate in top predators, impacts from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting together to impact SRKWs. Modeling exercises have attempted to identify which threats are most significant to survival and recovery (e.g. Lacy et al. 2017) and available data suggest that all of the threats are potential limiting factors (NMFS 2008).

2.3.1 Quantity and Quality of Prey

SRKWs have been documented to consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998; Ford et al. 2000; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016), but salmon are identified as their primary prey. SRKWs are the subject of ongoing research, the majority of which has occurred in inland waters of Washington State and British Columbia, Canada during summer months and includes direct observation, scale and tissue sampling of prey remains, and fecal sampling. The diet data indicate that SRKWs are consuming mostly larger (i.e., older) Chinook salmon. Chinook salmon is their primary prey despite the much lower abundance in comparison to other salmonids in some areas and during certain time periods. Factors of potential importance include the species' large size, high fat and energy content, and year-round occurrence in the SRKWs' geographic range. Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (kilocalorie/kilogram (kcal/kg)) (O'Neill et al. 2014). For example, in order for a SRKW to obtain the total energy value of one adult Chinook salmon, they would need to consume approximately 2.7 coho, 3.1 chum, 3.1 sockeye, or 6.4 pink salmon (O'Neill et al. 2014). Research suggests that SRKWs are capable of detecting, localizing, and recognizing Chinook salmon through their ability to distinguish Chinook echo structure as different from other salmon (Au et al. 2010).

May - September

Scale and tissue sampling from May to September in inland waters of Washington and British Columbia, Canada indicate that the SRKW's diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90 percent) (Hanson et al. 2010; Ford et al. 2016). Genetic analysis of the Hanson et al. (2010) samples from 2006-2010 indicate that when SRKW are in inland waters from May to September, they primarily consume Chinook stocks that originate from the Fraser River (including Upper Fraser, Mid Fraser, Lower Fraser, North Thompson, South Thompson and Lower Thompson), and to a lesser extent consume stocks from Puget Sound (North and South Puget Sound) and Central British Columbia Coast and West and East Vancouver Island. This is not unexpected as all of these stocks are returning to streams proximal to these inland waters during this timeframe.

DNA quantification methods are also used to estimate the proportion of different prey species in the diet from fecal samples (Deagle et al. 2005). Recently, Ford et al. (2016) confirmed the importance of Chinook salmon to SRKWs in the early to mid-summer months (May-August) using DNA sequencing from SRKW feces collected in inland waters of Washington and British Columbia. Salmon and steelhead made up to 98 percent of the inferred diet, of which almost 80 percent were Chinook salmon. Coho salmon and steelhead are also found in the diet in inland waters of Washington and British Columbia in spring and fall months when Chinook salmon are less abundant. Specifically, coho salmon contribute to over 40 percent of the diet in September in inland waters, which is evidence of prey shifting at the end of summer towards coho salmon (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016). Less than 3 percent each of chum salmon, sockeye salmon, and steelhead were observed in fecal DNA samples collected in the summer months (May through September) in inland waters.

October - December

Prey remains and fecal samples collected in inland waters during October through December indicate Chinook and chum salmon are primary contributors of the whale's diet during this time (NWFSC unpublished data). Diet data for coastal waters is limited (Figure 8).

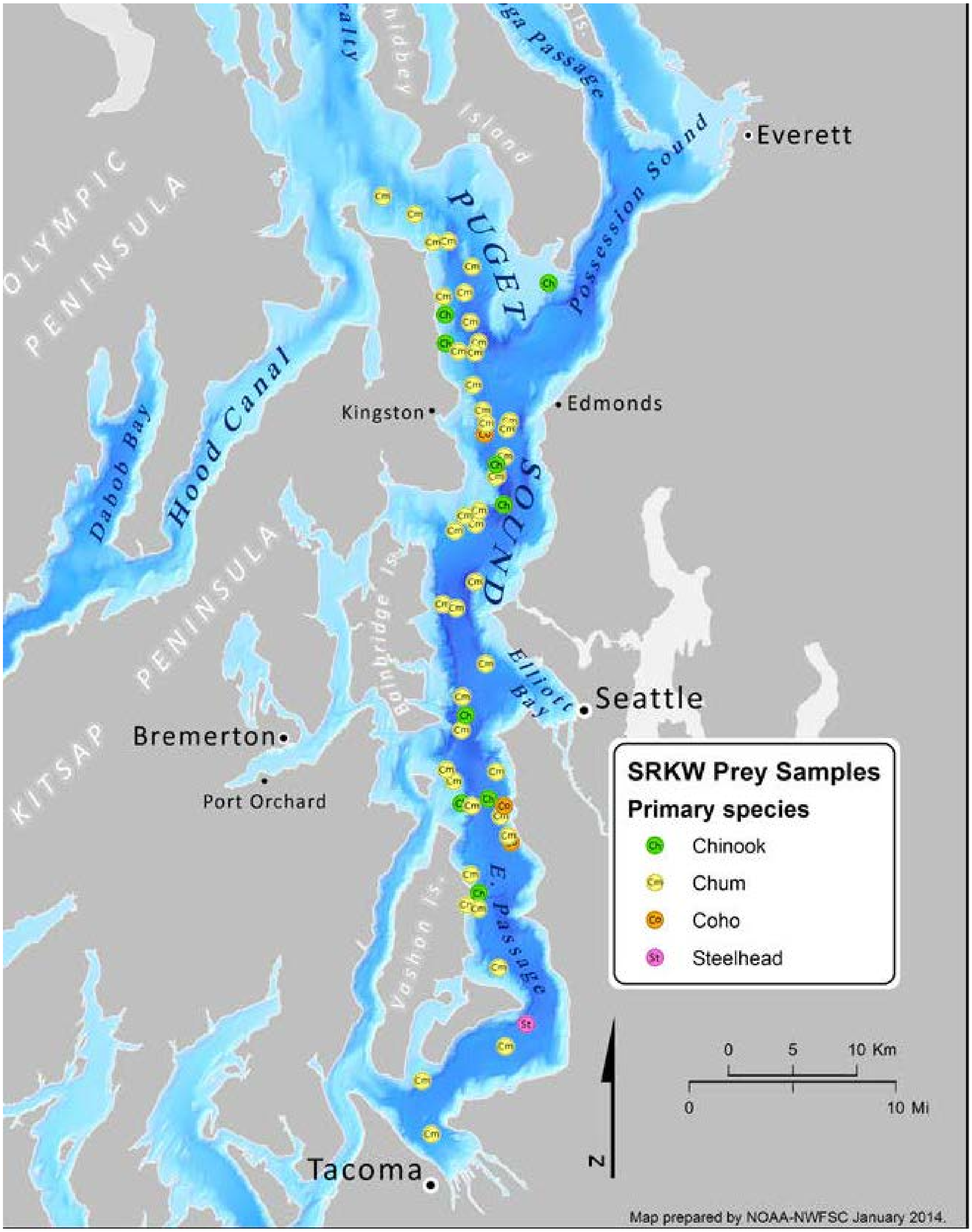

Figure 8. Locations of SRKW predation events by prey species in Puget Sound between October and December (NWFSC unpubl. data)

January – April

Observations of SRKWs overlapping with salmon runs (Wiles 2004; Zamon et al. 2007) and collection of prey and fecal samples have also occurred in coastal waters in the winter and spring months. Although fewer predation events have been observed and less fecal samples collected in coastal waters, recent data indicate that salmon, and Chinook salmon in particular, remains an important dietary component when the SRKWs occur in outer coastal waters during these timeframes. Prior to 2013, only three prey samples for SRKW on the U.S. outer coast had been collected (Hanson et al. in prep). From 2013 to 2016, satellite tags were used to locate and follow the whales to obtain predation and fecal samples. A total of 55 samples were collected from northern California to northern Washington (Figure 9). Results of the 55 available prey samples indicate that, as is the case in inland waters, Chinook are the primary species detected in diet samples on the outer coast, although steelhead, chum, lingcod, and halibut were also detected in samples. The occurrence of K and L pods off the Columbia River in March suggests the importance of Columbia River spring runs of Chinook salmon in their diet (Hanson et al. 2013). Chinook genetic stock identification from samples collected in winter and spring in coastal waters from California through Washington included 12 U.S. west coast stocks, and over half the Chinook salmon consumed originated in the Columbia River (Ward, May 23, 2019; Agenda Item B.3; Figure 8). Columbia River, Central Valley, Puget Sound, and Fraser River Chinook salmon collectively comprised over 90 percent of the 55 diet samples collected for SRKW's in coastal areas (Ward, May 23, 2019; Agenda Item B.3).

Most of the Chinook prey samples opportunistically collected in coastal waters were determined to have originated from the Columbia River basin, including Lower Columbia Spring, Middle Columbia Tule, and Upper Columbia Summer/Fall. In general, we would expect to find these stocks given the diet sample locations (Figure 8). However, the Chinook stocks included fish from as far north as the Taku River (Alaska and British Columbia stocks) and as far south as the Central Valley California (Ward, May 23, 2019; Agenda Item B.3).

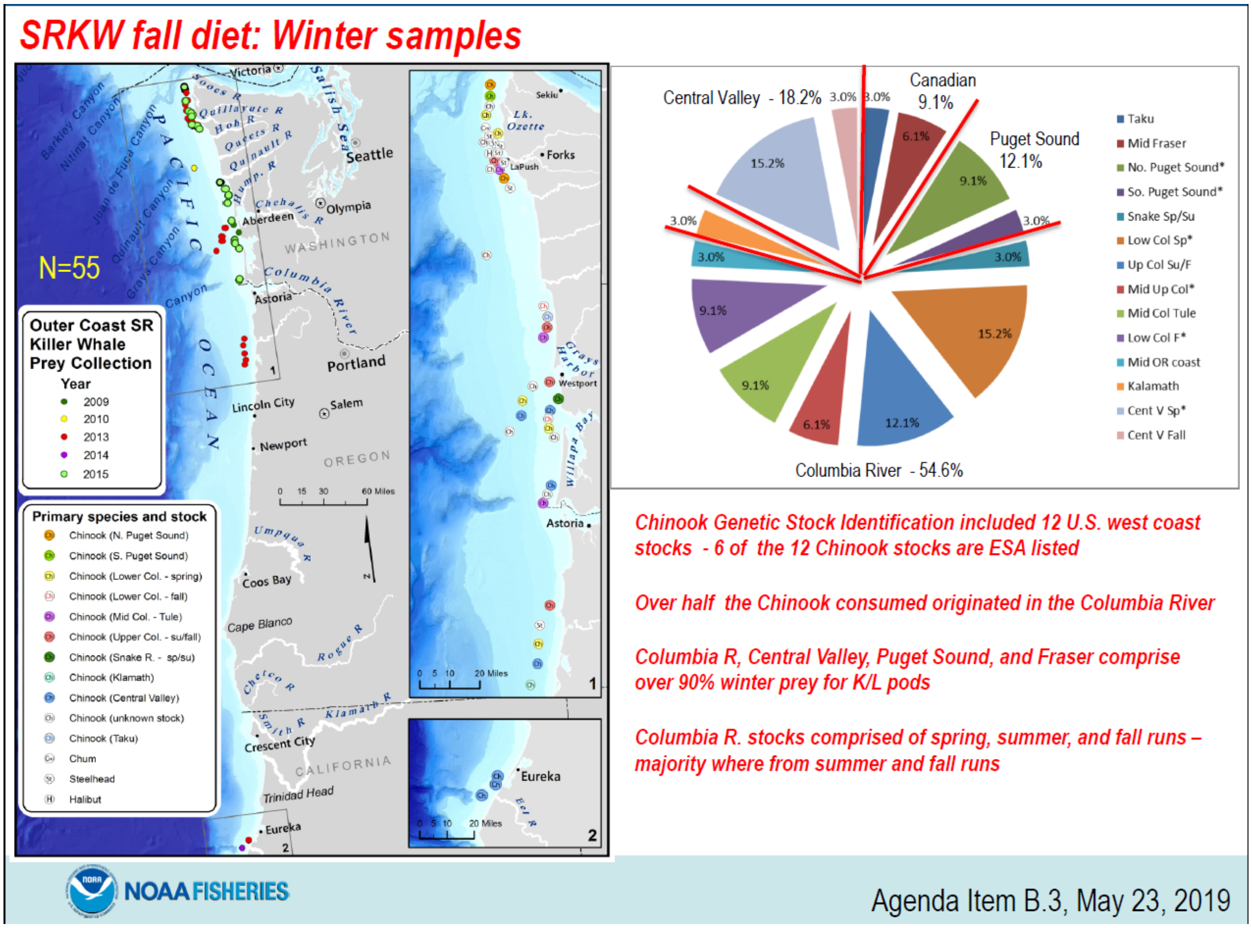

Figure 9. Location and species for scale/tissue samples collected from Southern Resident killer whale predation events in outer coastal waters[2]

In general, over the past decade, some Chinook salmon stocks within the range of the SRKWs have had relatively high abundance (e.g. Washington (WA)/Oregon (OR) coastal stocks, some Columbia River stocks) compared to the previous decade, whereas other stocks originating in the more northern and southern ends of the whales' range (e.g. most Fraser stocks, Northern and Central British Columbia (B.C.) stocks, Georgia Strait, Puget Sound, and Central Valley) have declined. There are many factors that affect the abundance, productivity, spatial structure, and diversity of Chinook salmon and thus affect prey availability for the whales. Human impacts and limiting factors come from multiple sources, including hydropower development, habitat degradation, hatchery effects, fishery management decisions, and ecological factors, including predation and environmental variability. Changing ocean conditions driven by climate change is also expected to influence ocean survival and distribution of Chinook and other Pacific salmon, affecting the prey available to SRKWs.

[2] Ward presentation on May 23, 2019; Agenda Item B.3

In an effort to prioritize recovery efforts to increase the whales' prey base, NMFS and WDFW developed a report identifying the Chinook salmon stocks thought to be of most importance to the health of the SRKW populations along the West Coast (NOAA and WDFW 2018)[3]. Scientists and managers from the U.S. and Canada reviewed the model at a workshop sponsored by the National Fish and Wildlife Foundation (NFWF). Since the development of the list, the NFWF has cited the priority list in requests for proposals. The draft priority list was also shared at the Task Force established by Washington Governor Inlsee. The priority stock report was created using observations of Chinook salmon stocks found in scat and prey scale/tissue samples, and by estimating the spatial and temporal overlap with Chinook salmon stocks ranging from Southeast Alaska (SEAK) to California (CA). The report gave higher priority to salmon runs that support the SRKWs during times of the year when the SRKWs' body condition is more likely reduced (October through May) and when Chinook salmon may be less available, such as in winter months. The analysis also placed higher priority on Chinook populations observed in the SRKW diet samples as being more important to the health of the whales. The Workgroup reviewed the priority prey list and modified it to reflect error checking and also revised salmon distributions that were suggested for a few stocks by workgroup members (Table 2 is a summary of those stock descriptions). However, because the list was developed to help prioritize salmon recovery actions and was not developed to describe or assess prey availability along the coast, the Workgroup decided to instead develop a quantitative method to assess available abundances of Chinook stocks, which is described in Section 6 of this document.

[3] https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/recovery/srkw_priority_chinook_stocks_conceptual_model_report___list_22june2018.pdf

Table 2. Summary of the priority Chinook salmon stocks (adapted from NOAA and WDFW (2018), updated based on error checking and revised distribution estimates provided by workgroup members).

Priority	ESU/Stock Group	Run Type	Rivers or Stocks in Group
1	North Puget Sound South Puget Sound	Fall	Nooksack, Elwha, Dungeness, Skagit, Stillaguamish, Snohomish, Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal Systems
2	Lower Columbia Strait of Georgia	Fall	Fall Tules and Fall Brights (Cowlitz, Kalama, Clackamas, Lewis, others), Lower Strait (Cowichan, Nanaimo), Upper Strait (Klinaklini, Wakeman, others), Fraser (Harrison)
3	Middle Columbia	Fall	Fall Brights
4	Upper Columbia & Snake Fraser Lower Columbia	Fall Spring Spring	Upriver Brights, Spring 1.3 (Upper Pitt, Birkenhead; Mid & Upper Fraser; North and South Thompson) and Spring 1.2 (Thompson, Louis Creek, Bessette Creak); Lewis, Cowlitz, Kalama, Big White Salmon
5	Snake River Northern Puget Sound	Spring/summer Spring	Snake, Salmon, Clearwater, Nooksack, Elwha, Dungeness, Skagit (Stillaguamish, Snohomish)
6	Washington Coast	Spring and Fall	Hoh, Queets, Quillayute, Grays Harbor
7	Central Valley	Fall and late Fall Spring	Sacramento, San Joaquin Sacramento and tributaries
8	Middle/Upper Columbia	Spring/Summer	Columbia, Yakima, Wenatchee, Methow, Okanagan
9	Fraser	Summer	Summer 0.3 (South Thompson, Lower Fraser, Shuswap, Adams, Little River, Maria Slough) and Summer 1.3 (Nechako, Chilko, Quesnel, Clearwater River)

Priority	ESU/Stock Group	Run Type	Rivers or Stocks in Group
10	Klamath River	Fall and Spring	Upper Klamath, and Trinity
11	Upper Willamette	Spring	Willamette
12	South Puget Sound	Spring	Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal systems
13	West Coast Vancouver Island	Fall	Robertson Creek, WCVI Wild
14	North/Central Oregon Coast	Fall	Northern (Siuslaw, Nehalem, Siletz) and Central (Coos, Elk, Coquille, Umpqua)
15	Southern OR & Northern CA Coastal	Fall and Spring	Rogue, Chetco, Smith, Lower Klamath, Mad, Eel, Russian
16	Central Valley	Winter	Sacramento and tributaries

Currently, hatchery production is a significant component of the salmon prey base returning to watersheds within the range of SRKWs (Barnett-Johnson et al. 2007; NMFS 2008). The release of hatchery fish has not been identified as a threat to the survival or persistence of SRKWs. It is possible that hatchery produced fish may benefit this endangered population of whales in the short term by enhancing prey availability to SRKWs and hatchery fish often contribute significantly to the salmon stocks consumed (Hanson et al. 2010). Currently, hatchery fish play a mitigation role of helping sustain prey numbers while other, longer term, recovery actions for natural fish are underway.

2.3.2 Nutritional Limitation and Body Condition

When prey is scarce or in low density, SRKWs likely spend more time foraging than when prey is plentiful or in high density. Increased energy expenditure and prey limitation can cause poor body condition and nutritional stress. Nutritional stress is the condition of being unable to acquire adequate energy and nutrients from prey resources and as a chronic condition, can lead to reduced body size of individuals and to lower reproductive and survival rates in a population (Trites and Donnelly 2003). During periods of nutritional stress and poor body condition, cetaceans lose adipose tissue behind the cranium, displaying a condition known as “peanut-head” in extreme cases (Pettis et al. 2004; Bradford et al. 2012; Joblon et al. 2014). Between 1994 and 2008, 13 SRKWs were observed from boats to have a pronounced “peanut-head”; and all but two subsequently died (Durban et al. 2009; Center for Whale Research unpublished data). None of the whales that died were subsequently recovered, and therefore definitive cause of death could not be identified. Both females and males across a range of ages were found in poor body condition.

Since 2008, NOAA’s Southwest Fishery Science Center (SWFSC) and SR[3], a response rehabilitation and research center, has used aerial photogrammetry to assess the body condition and health of SRKWs, initially in collaboration with the Center for Whale Research and with the Vancouver Aquarium. Aerial photogrammetry studies have provided finer resolution for detecting poor condition, even before it manifests in “peanut-head” that is observable from boats. Annual aerial surveys of the population from 2013-2017 (with exception of 2014) have detected declines in condition before the death of seven SRKWs (L52 and J8 as reported in Fearnbach et al. (2018); J14, J2, J28, J54, and J52 as reported in Durban et al. (2017)), including five of the six most recent mortalities (Trites and Rosen 2018). These data have provided evidence of a general decline in SRKW body condition since 2008, and documented members of J pod being in poorer body condition in May compared to September (at least in 2016 and 2017) (Trites and Rosen 2018). Other pods could not be reliably photographed in both seasonal periods.

Body condition in whales can be influenced by a number of factors, including prey availability or limitation, increased search or traveling time to find prey, disease, physiological or life history status, and variability over seasons or across years. Previous scientific review investigating nutritional stress as a cause of poor body condition for SRKW concluded “Unless a large fraction of the population experienced poor condition in a particular year, and there was ancillary information suggesting a shortage of prey in that same year, malnutrition remains only one of several possible causes of poor condition” (Hilborn et al. 2012). Body condition data collected to date has documented declines in condition for some animals in some pods and these occurrences have been scattered across demographic and social groups (Fearnbach et al. 2018).

It is possible that poor nutrition could contribute to mortality through a variety of mechanisms. To exhibit how this is possible, we reference studies that have demonstrated the effects of energetic stress (caused by incremental increases in energy expenditures or incremental reductions in available energy) on adult females and juveniles, which have been studied extensively (e.g., adult females: Gamel et al. (2005), Schaefer (1996), Daan et al. (1996), juveniles: Trites and Donnelly (2003)). Small, incremental increases in energy demands should have the same effect on an animal's energy budget as small, incremental reductions in available energy, such as one would expect from reductions in prey. Ford and Ellis (2006) report that SRKWs engage in prey sharing about 76 percent of the time. Prey sharing presumably would distribute more evenly the effects of prey limitation across individuals of the population than would otherwise be the case (i.e., if the most successful foragers did not share with other individuals).

2.3.3 Toxic Chemicals

Various adverse health effects in humans, laboratory animals, and wildlife have been associated with exposures to persistent pollutants. These pollutants have the ability to cause endocrine disruption, reproductive disruption or failure, immunotoxicity, neurotoxicity, neurobehavioral disruption, and cancer (Reijnders 1986; Subramanian et al. 1987; de Swart et al. 1996; Bonefeld-Jørgensen et al. 2001; Reddy et al. 2001; Schwacke et al. 2002; Darnerud 2003; Legler and Brouwer 2003; Viberg et al. 2003; Ylitalo et al. 2005; Fonnum et al. 2006; Darnerud 2008; Legler 2008). SRKWs are exposed to a mixture of pollutants, some of which may interact synergistically and enhance toxicity, influencing their health. Relatively high levels of these pollutants have been measured in blubber biopsy samples from SRKWs compared to other resident killer whales in the North Pacific (Ross et al. 2000; Krahn et al. 2007; Krahn et al. 2009; Lawson et al. in prep), and more recently, these pollutants were measured in fecal samples collected from SRKWs providing another potential opportunity to evaluate exposure to these pollutants (Lundin et al. 2016a; Lundin et al. 2016b).

SRKWs are exposed to persistent pollutants primarily through their diet. For example, Chinook salmon contain higher levels of some persistent pollutants than other salmon species, but only limited information is available for pollutant levels in Chinook salmon (Krahn et al. 2007; O'Neill and West 2009; Veldhoen et al. 2010; Mongillo et al. 2016). These harmful pollutants, through consumption of prey species that contain these pollutants, are stored in the SRKW's blubber and can later be released; when the pollutants are released, they are redistributed to other tissues when the SRKWs metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of other reasons. The release of pollutants can also occur during gestation or lactation. Once the pollutants mobilize in to circulation, they have the potential to cause a toxic response. Therefore, nutritional stress from reduced Chinook salmon populations may act synergistically with high pollutant levels in SRKWs and result in adverse health effects.

2.3.4 Disturbance from Vessels and Sound

Vessels have the potential to affect SRKWs through the physical presence and activity of the vessel, increased underwater sound levels generated by boat engines, or a combination of these factors. Vessel strikes are rare, but do occur and can result in injury or mortality (Gaydos and

Raverty 2007). In addition to vessels, underwater sound can be generated by a variety of other human activities, such as dredging, drilling, construction, seismic testing, and sonar (Richardson et al. 1995; Gordon and Moscrop 1996; National Research Council 2003). Impacts from these sources can range from serious injury and mortality to changes in behavior. In other cetaceans, hormonal changes indicative of stress have been recorded in response to intense sound exposure (Romano et al. 2003). Chronic stress is known to induce harmful physiological conditions including lowered immune function, in terrestrial mammals and likely does so in cetaceans (Gordon and Moscrop 1996).

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. While in inland waters of Washington and British Columbia, SRKWs are the principal target species for the commercial whale watch industry (Hoyt 2001; O'Connor et al. 2009) and encounter a variety of other vessels in their urban environment (e.g., recreational, fishing, ferries, military, shipping). Several main threats from vessels include direct vessel strikes, the masking of echolocation and communication signals by anthropogenic sound, and behavioral changes (NMFS 2008). There is a growing body of evidence documenting effects from vessels on small cetaceans and other marine mammals. Research has shown that SRKWs spend more time traveling and performing surface active behaviors and less time foraging in the presence of all vessel types, including kayaks, and that noise from motoring vessels up to 400 meters away has the potential to affect the echolocation abilities of foraging whales (Holt 2008; Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2010). Individual energy balance may be impacted when vessels are present because of the combined increase in energetic costs resulting from changes in whale activity with the decrease in prey consumption resulting from reduced foraging opportunities (Williams et al. 2006; Lusseau et al. 2009; Noren et al. 2009; Noren et al. 2012).

At the time of the SRKWs' listing under the ESA, NMFS reviewed existing protections for the whales and developed recovery actions, including vessel regulations, to address the threat of vessels to SRKWs. NMFS concluded it was necessary and advisable to adopt regulations to protect SRKWs from disturbance and sound associated with vessels, to support recovery of SRKWs. Federal vessel regulations were established in 2011 to prohibit vessels from approaching SRKWs within 200 yards and from parking in the path of SRKWs within 400 yards. These regulations apply to all vessels in inland waters of Washington State with exemptions to maintain safe navigation and for government vessels in the course of official duties, ships in the shipping lanes, research vessels under permit, and vessels lawfully engaged in commercial or treaty Indian fishing that are actively setting, retrieving, or closely tending fishing gear (76 FR 20870, April, 14, 2011).

In the final rule, NMFS committed to reviewing the vessel regulations to evaluate effectiveness, and also to study the impact of the regulations on the viability of the local whale watch industry. In December 2017, NMFS completed a technical memorandum evaluating the effectiveness of regulations adopted in 2011 to help protect endangered SRKWs from the impacts of vessel traffic and noise (Ferrara et al. 2017). In the assessment, Ferrara et al. (2017) used five measures: education and outreach efforts, enforcement, vessel compliance, biological effectiveness, and economic impacts. For each measure, the trends and observations in the five years leading up to the regulations (2006-2010) were compared to the trends and observations in the five years following the regulations (2011-2015). The memo finds that some indicators suggested the regulations have benefited SRKWs by reducing impacts without causing economic harm to the commercial whale-watching industry or local communities, whereas some indicators suggested that vessel impacts continue and that some risks may have increased. The authors also find room for improvement in terms of increasing awareness and enforcement of the regulations, which would help improve compliance and further reduce biological impacts to the whales.

2.3.5 Oil Spills

In the Northwest, SRKWs are the most vulnerable marine mammal population to the risks imposed by an oil spill due to their small population size, strong site fidelity to areas with high oil spill risk, large group size, late reproductive maturity, low reproductive rate, and specialized diet, among other attributes (Jarvela Rosenberger et al. 2017). Oil spills have occurred in the range of SRKWs in the past, and there is potential for spills in the future. Oil can be discharged into the marine environment in any number of ways, including shipping accidents, refineries and associated production facilities, and pipelines. Despite many improvements in spill prevention since the late 1980s, much of the region inhabited by SRKWs remains at risk from serious spills because of the heavy volume of shipping traffic and proximity to petroleum refining centers.

Repeated ingestion of petroleum hydrocarbons by killer whales likely causes adverse effects; however, long-term consequences are poorly understood. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion and disease, pneumonia, liver disorders, neurological damage, adrenal toxicity, reduced reproductive rates, and changes in immune function (Schwacke et al. 2013; Venn-Watson et al. 2015; de Guise et al. 2017; Kellar et al. 2017), potentially death and long-term effects on population viability (Matkin et al. 2008; Ziccardi et al. 2015). For example, 122 cetaceans stranded or were reported dead within 5 months following the Deepwater Horizon spill in the Gulf of Mexico (Ziccardi et al. 2015). An additional 785 cetaceans were found stranded from November 2010 to June 2013, which was declared an Unusual Mortality Event (Ziccardi et al. 2015). In addition, oil spills have the potential to adversely impact habitat and prey populations, and, therefore, may adversely affect SRKWs by reducing food availability.

3 SRKW AND CHINOOK SALMON FISHERIES

Here we provide a basic description of the relationship between SRKWs and Chinook salmon and a summary of the history of fisheries impacts analyses on SRKWs.

3.1.1 Relationship between SRKW and Chinook salmon

There are several challenges to characterizing the relationship between SRKW and Chinook salmon and uncertainty remains. The results of statistical models are sensitive to which animals and which years are used (e.g. only data after 1976 versus only data after 1980), whether Chinook salmon is included as a covariate on survival or fecundity (and which lag time is used), or the Chinook abundance indices (e.g. CTC, FRAM, etc.) used. Largely, attempts to compare the relative importance of any specific Chinook salmon stocks or stock groups using the strengths of these statistical relationships have not produced clear distinctions as to which are most influential and most Chinook salmon abundance indices are highly correlated with each other. It is also possible that different Chinook salmon populations may be more important in different years and that the relative importance of specific Chinook salmon stocks in the SRKWs' diet changes over time. If anything, large aggregations of Chinook salmon stocks that reflect abundance on a coast-wide scale appear to be equally or better correlated with SRKW vital rates than smaller aggregations of Chinook salmon stocks, or specific stocks such as Chinook salmon originating from the Fraser River that have been positively identified as key sources of prey for SRKWs during certain times of the year in specific areas (see Hilborn et al. 2012; Ward et al. 2013). For example, several studies in the past have found correlations between Chinook salmon abundance indices and SRKW demographic rates at a coarse coast wide scale (Ford et al. 2005; Ford et al. 2009; Ward et al. 2009; Ward et al. 2013). Although these studies examined different demographic responses related to different Chinook aggregate abundance indices, they all found significant positive relationships (high Chinook abundance coupled with high SRKW fecundity or survival). However, these correlations have weakened with the addition of data from recent years

There are numerous challenges to identifying statistically robust relationships. Demographic stochasticity can create year-to-year variation in measured demographic rates that mask underlying probabilities or rates. Effects of demographic stochasticity are particularly pronounced because SRKWs have a small population size (not many births or deaths in a year to correlate with salmon abundance). These whales are long-lived, thus changes in mortality rates across years are relatively small, making it more challenging to detect statistically-significant changes in mortality rates. Effects of prey abundance on demographic performance across years is confounded with changes in other primary threats (disturbance from vessels and sound and high levels of toxic pollutants) that can also influence demographic rates. There are substantial uncertainties in the annual Chinook salmon abundance estimates being used to predict SRKW performance, and there is currently no single widely-accepted metric for prey abundance and accessibility to the whales. These challenges may mask our ability to accurately predict the relationship between SRKW demographic rates and Chinook salmon abundance.

3.1.2 History of salmon fisheries impacts analyses

In 2011, an independent Science Panel (the Panel) reviewed the best available scientific information on the effects that salmon fisheries may have on SRKWs by reducing their prey (Hilborn et al. 2012). The Panel and workshop participants reviewed the ecology of the SRKWs, their feeding preferences, and their energy requirements. The participants examined the extent to which various salmon fisheries may reduce prey available to SRKWs, and the potential consequences to their survival and recovery. Following the independent science panel approach on the effects of salmon fisheries on SRKW, NMFS and partners have actively engaged in research and analyses to fill gaps and reduce uncertainties raised by the panel in their report. Below are the key points and conclusions in the Panel report (Hilborn et al. 2012), and we provide some updates based on scientific information that have become available since the Panel report.

- *Status of Southern Resident Killer Whales*

Key Point: The SRKW population has been observed to increase at an average rate of 0.71 percent per year, and would be expected to increase at about one percent per year in the long term if sex ratio at birth were 50:50.

Key Point: The panel believed that the existing delisting criterion of 2.3 percent growth rate is unlikely to be achieved given current (2012) circumstances or by reducing Chinook salmon fisheries. But if the total abundance continued to increase, a point will be reached where a reappraisal of their status would be likely.

The Panel examined the current knowledge of the SRKW population size, growth rates, and demography to: 1) assess current trends relative to historical trends in abundance; and 2) to evaluate the understanding of the current status of the population relative to recovery goals. The Panel examined the time period from 1974 to 2011 and found the population experienced a realized growth rate of 0.71 percent, from 67 individuals to 87 individuals. However, since 2011, the population has declined to 73 individuals and updated status information and population projections are summarized in the December 2016 ESA 5-year status review (NMFS 2016). As described in the Status of the Species and illustrated in Figure 2 the population is expected to decline over the next 50 years. However, we note there is increasing uncertainty as the projection extends beyond the first 10 years and with the small population size and number of births the model output can change with the birth of a small number of calves, particularly female calves.

During the workshop, the Vélez-Espino et al. demographic analysis was preliminary. More recently, Vélez-Espino et al. (2014) used data from 1987 to 2011 and estimated expected population growth rates are 0.91 percent annual decline for SRKWs (Figure 10). Furthermore, the estimated SRKW population size was expected to reach 75 individuals in a generation (which is considered 25 years), with an extinction risk of 49 percent and an expected minimum abundance of 15 during a 100-year period. The largest contributor to the variance in population growth rate was the survival of young reproductive females. Also the largest contributor to the uncertainty in population growth was the young reproductive female annual survival. Therefore, Vélez-Espino et al. (2014) suggest survival of young reproductive females has the largest influence on population growth and population growth variance. Additionally, as described in the Status section above, Lacy et al. (2017) suggested that reducing the acoustic disturbance by half and increasing annual coast wide Chinook abundance by 15 percent would allow the population to meet the delisting criterion.

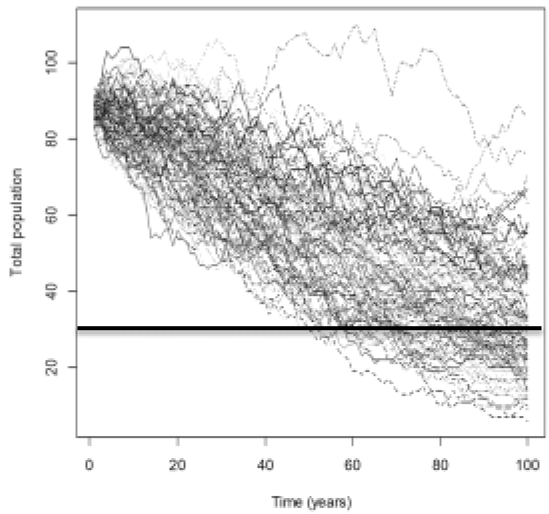

Figure 10. Projections of SRKW population size under demographic stochasticity and status quo conditions. Horizontal line shows a 30 individual quasi extinction threshold (Vélez-Espino et al. 2014).

- *SRKW Dependency on Chinook Salmon*

Key Point: The evidence for strong reliance on Chinook salmon in the summer is convincing, but it is also clear that SRKWs will switch to alternative, more abundant chum salmon when Chinook salmon of suitable size and quality are not readily available in the fall.

Key Point: Photographic evidence supports the assertion that poor condition, which is linked to mortality, and by implication to fecundity, may reflect nutritional stress. However, unless a large fraction of the population experienced poor condition in a particular year, and there was ancillary information suggesting a shortage of prey in that same year, malnutrition remains only one of several possible causes of poor condition.

The Panel report recognized SRKWs have a specialized diet of Chinook salmon from May to September which "means that it is biologically plausible for reduced Chinook salmon abundance to cause nutritional stress and impede recovery of the SRKW population." The report provides context with information on SRKW' distribution, diet (species and size selectivity), daily prey requirements, and nutritional stress (Hilborn et al. 2012). Despite logistical challenges, the Panel concluded that the diet data collected provide a reasonable indication of what SRKWs are eating in the summer in inland waters; however, winter diet was a major uncertainty. They concluded Chinook salmon appears to dominate their summer diet during this time period and in general larger Chinook salmon (4 and 5 year olds), however, smaller Chinook salmon may not be readily shared and thus could bias detecting their presence. Also fish swallowed at depth could go undetected at the surface. As discussed in the Status of the Species section above, (Ford et al. 2016) used fecal DNA analysis to confirm the results of previous studies conducted using other prey identification methods. These fecal samples are thought to be less biased than prey samples recovered from foraging events at the surface. Additional prey and fecal samples have been collected in the fall in Puget Sound, and in particular from K and L pods in coastal waters in winter and spring and J pod in the Northern Strait of Georgia in the winter.

The Panel considered the bioenergetic modeling approach (Noren 2011) consistent with models for other species and is a reasonable way to estimate the energy needs, and the numbers of fish that both NMFS and DFO estimate that the whales require are within reasonable limits. In contrast, forage ratios (the whales' bioenergetics needs compared to prey available) provide little insight into prey limitations and would require knowing the whale fitness/vital rates as a function of the supply and demand in order for the ratios to be useful. The Panel summarized that of 13 members of the population documented to be in poor condition at that time, all but two died, suggesting some SRKW have been nutritionally limited at certain times of the year. They suggested changes in social behavior may be a sensitive indicator of nutritional limitation.

- *Fisheries and Prey Availability*

Key Point: The maximum long-term increases in abundance of Chinook salmon that might theoretically be available to SRKW would be achieved by eliminating all ocean fishing (typically at least 20 percent increase in ocean abundance of age-4 and age-5 hatchery and wild fish due to elimination of ocean fishery interception of immature fish) and by maximizing recruitment through manipulation of freshwater exploitation rates to maximize recruitment (6 – 9 percent increase in recruitments of wild fish; no impact on hatchery fish).

The best potential for increased Chinook salmon abundance is restoration of freshwater habitat, reducing downstream migration mortality and a change in ocean conditions.

Key Point: The panel sees many potential reasons why not all foregone Chinook salmon catch would be available to SRKW, and is therefore skeptical that reduced Chinook salmon harvesting would have a large impact on the abundance of Chinook salmon available to SRKW.

- *Projected Future Status and Recovery*

Key Point: The statistical analysis by NMFS and DFO scientists are excellent, but the Panel believed considerable caution is warranted in interpreting the correlative results as confirming a linear causal relationship between Chinook salmon abundance and SRKW vital rates.

The Panel described a big picture of the historical vs. current abundances and marine distributions of Chinook salmon; recent trends in Chinook abundance and fisheries; and a description of the probable overlap of SRKW distribution with the distribution of salmon stocks. The Panel considered the results from the correlative approaches that linked Chinook salmon abundance and SRKW vital rates to be consistent with expected dynamics between a predator and its primary prey. The Panel response varied when asked about the strength of evidence that changes in Chinook salmon abundance cause or do not cause changes in SRKW vital rates from being in favor of a cause/effect relationship, rejecting except for one Chinook abundance index, or were unconvinced. The Panel suggested that the regression analyses conducted at the time seemed consistent with a conclusion that SRKW vital rates are more highly correlated with broad scale aggregated abundances of Chinook salmon that overlap with SRKW distribution in spring and late fall periods and potentially winter. However, they concluded a positive relationship between indices of Chinook salmon abundance and killer whale vital rates are probably more complicated than the simple linear relationships assumed. Given the regression results, and the likely higher density of salmon in the inland waters compared to coastal waters, the panel suggested the Chinook salmon that pass through the Salish Sea during the summer period do not directly limit the population growth. Instead, the panel suggested that coastal abundance of Chinook during non-summer months is probably more important for survival and reproduction.

- *<u>Estimating the Impact of Reducing Chinook Salmon Fisheries on SRKW</u>*

Key Point: The Panel was not confident that understanding of the interaction between Chinook salmon fisheries, other predators and SRKW vital rates, is sufficient to expect the model predictions of increased SRKWs to be accurate. The Panel expects the model predictions to overestimate the impact of reductions in Chinook salmon catch on SRKW.

The Panel agreed the methods presented at the workshop seem appropriate for assessing short-term impacts reduced fishing might have on ocean and terminal abundances of Chinook stocks. Using the Fisheries Regulation Assessment Model (FRAM), if exploitation rates were reduced to zero, there would be an expected increase in abundance (both ocean and terminal) of 18 – 25 percent. They emphasized this was assuming no competing risks of death[4], implying that this would not be the actual percent increase in abundance for SRKW based on other mortality, such as predation by other species. The Panel noted a 20 percent increase is likely the upper limit of abundance increase and that when Chinook salmon are at lower abundance levels or competing predators are at higher abundance levels, this percent increase would be smaller.

When asked what is the strength of evidence that changes in fisheries in the future would cause or would not cause changes in Chinook salmon abundance sufficient to affect SRKW vital rates, a couple of panelists suggested that any causal effect would be weak, another suggested that changes in fisheries harvest should only be considered for those salmon stocks for which a causal relationship has not been rejected. Lastly several Panel members suggested the impacts on SRKWs from changes to Chinook salmon fisheries would need to consider how this might increase availability of salmon to other predators (e.g. NRKWs and pinnipeds).

- *<u>The Conclusions of the Panel</u>*

The Panel believed that the estimated benefits of reducing Chinook salmon harvest in NMFS's recent analyses provide a maximum estimate of the benefits to SRKWs — and that the realized benefits would likely be lower and insufficient to increase growth rates to a level that meets existing SRKW delisting criteria in the foreseeable future. The Panel concluded that there is good evidence that Chinook salmon are a very important part of the diet of SRKWs and that there is good evidence, collected since 1994, that some SRKWs have been in poor condition and poor condition is associated with higher mortality rates. There is a statistical correlation between SRKW survival rates and some indices of Chinook salmon abundance. Based on those correlations, increases in Chinook salmon abundance would lead to higher survival rates, and therefore higher population growth rates of SRKWs. However, the effect is not linear as improvements in SRKW survival diminish at Chinook salmon abundance levels beyond the historical average. Using the

[4] The Panel had concerns how natural mortality (and predation on Chinook salmon by SRKW and NRKW) in the FRAM model structure was treated and suggested that a 'competing risks of death' framework that modeled the effects of fisheries and competing marine mammals on potential consumption of Chinook salmon by killer whales would be more informative.

statistical correlations, consistently positive SRKW growth rates can occur by avoiding extremely low Chinook salmon abundance levels observed in the 1970-80s and late-1990s.

Elimination of ocean fisheries for Chinook salmon would impact Chinook salmon abundance far less than the variations that have been seen since the 1970s. The Panel cautioned against overreliance on the correlative studies, and noted that the level of correlation is highly dependent on the choice of Chinook salmon abundance indicators, concluding the impact of reduced Chinook salmon harvest on future availability of Chinook salmon to SRKW is not clear.

4 PFMC SALMON FISHERIES (FMP DESCRIPTION)

The Pacific Coast Salmon FMP guides management of salmon fisheries in Federal waters (3-200 nautical miles) off the coast of Washington, Oregon, and California known as the Exclusive Economic Zone (EEZ). Salmon of U.S. and Canadian origin are included except when specific species are managed in those waters by another management entity with primary jurisdiction (i.e., sockeye and pink salmon by the Fraser River Panel of the Pacific Salmon Commission in the Fraser River Panel Area (U.S.) between 49°N latitude and 48°N latitude). The FMP covers the coast wide aggregate of natural and hatchery salmon encountered in ocean salmon fisheries, but only has management objectives and allocation provisions for Chinook or king salmon (*Oncorhynchus tshawytscha*), coho or silver salmon (*O. kisutch*), and pink salmon(*O. gorbuscha*). Catches of other salmon species are inconsequential (low hundreds of fish each year) to very rare (PFMC 2016). In the event this situation should change, management objectives for these species could be developed and incorporated by plan amendment. The incidental harvest of these salmon species can be allowed or restricted under existing federal fishery regulations.

Chinook and coho are the main species caught in Council-managed ocean salmon fisheries. In odd-numbered years, catches of pink salmon can also be significant, primarily off Washington and Oregon (PFMC 2018a).

The FMP also includes identification of essential fish habitat (EFH) for Chinook, coho, and pink salmon in ocean, estuary, and freshwater, and contains recommendations for measures to avoid or mitigate for impacts to salmon EFH (see PFMC 2016, Appendix A), and a description of the social and economic fishery characteristics (see PFMC 20126, Appendix B).

To the extent practicable, the Council has partitioned the coast wide aggregate of Chinook, coho, and pink salmon into various stock components and complexes with specific conservation objectives. A detailed listing of the individual stocks and stock complexes managed under the plan are provided in Tables 1-1, 1-2, and 1-3 (PMFC 2016). Stocks designated as hatchery stocks rely on artificial production exclusively, while those designated as natural stocks have at least some component of the stock that relies on natural production, although hatchery production and naturally spawning hatchery fish may contribute to abundance and spawning escapement estimates.

The FMP also contains allocation provisions to ensure that salmon resources are shared fairly among various user groups and regions. The FMP management framework allows fishing seasons to be set and managed in a fair and efficient manner. The Council's means of meeting the requirements of the MSA to achieve the optimum yield (OY) from the salmon fishery, meaning the amount of fish that will provide the greatest overall benefit to the Nation, is through maximum sustained yield (MSY), which is defined as the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions and fishery technological characteristics, and distribution of catch among fleets. The OY to be achieved for species covered by the FMP is the total salmon catch and mortality (expressed in numbers of fish) resulting from fisheries within the EEZ adjacent to the States of Washington, Oregon, and California, and in the waters of those states (including internal waters), and Idaho, that, to the greatest practical extent within pertinent legal constraints, fulfill the plan's conservation and harvest objectives.

Annually the Council recommends management measures to NMFS that achieve the stock conservation objectives for each stock or stock complex (see PFMC 2016, Chapter 3), while simultaneously seeking to fulfill, to the extent practicable, the harvest and allocation objectives (see PFMC 2016 Chapter 5) that reflect the Council's social and economic considerations. The level of total allowable harvest, the relative harvest levels in various management areas, and the species and stock composition of OY varies annually, depending on the relative abundance and distribution of the various stocks and contingencies in allocation formulas.

The Council's annual Review of Ocean Salmon Fisheries (stock assessment and fishery evaluation; SAFE) document and preseason reports (e.g., PFMC 2018a, 2018b, 2018c, and 2018d) assess and specify the present and historical range of harvests and harvest related mortalities that represent the OY.

4.1 Harvest Controls

Control rules are the metrics used to manage the harvest of stocks to achieve OY while preventing overfishing. Control rules specify the allowable harvest of stocks based on their abundance and are predicated on meeting conservation objectives in addition to relating those objectives to biological reference.

In relation to harvest control rules, the MSA provides an exception to the requirement for a FMP to specify ACLs and accountability measures (AMs) for stocks managed under an international agreement in which the U.S. participates. Pacific salmon stocks subject to fisheries in both the US and Canada are managed under the provisions of the Pacific Salmon Treaty (PST). Natural stocks managed under the provisions of the PST include: (1) Puget Sound pink salmon stocks, (2) most non-ESA-listed Chinook salmon stocks from the mid-Oregon coast to the US/Canada border, and (3) all non-ESA-listed coho stocks except Willapa Bay natural coho. For these stocks, the PST annually places overall limits on fishery impacts and allocates those impacts between the U.S. and Canada. It allows the U.S. and Canada to each manage their own fisheries to achieve domestic conservation and allocation priorities, while remaining within the overall limits determined under the PST. Because of these provisions of the PST, and the exception provided by the MSA, it is unnecessary for the FMP to specify ACLs or associated reference points for these stocks. The PST also includes measures of accountability which take effect if annual limits established under the Treaty are exceeded, and further reduce these limits in response to depressed stock status. However, it is still necessary to specify MSY reference points for these stocks.

The ESA requires federal agencies whose actions may adversely affect listed salmon to consult with NMFS. Because NMFS implements ocean harvest regulations, it is both the action and consulting agency for actions taken under the FMP. To ensure there is no jeopardy, NMFS conducts ESA consultations with respect to the effects of ocean harvest on ESA-listed salmon stocks. In cases where the biological consultation results in a "no jeopardy" opinion, NMFS issues an incidental take statement which authorizes a limited amount of take of listed species that would otherwise be prohibited under the ESA. In cases where a "jeopardy" opinion is reached, NMFS develops reasonable and prudent alternatives to the proposed action which authorizes a limited amount of take.

The constraints on take authorized under incidental take statements and reasonable, prudent alternatives are collectively referred to as consultation standards in the FMP. These constraints take a variety of forms including FMP conservation objectives, limits on the time and area during which fisheries may be open, ceilings on fishery impact rates, and reductions from base period impact rates. NMFS may periodically revise consultation standards and the annual NMFS guidance letter reflects the most current information.

Because of the need to meet all control rules and consultation standards in each fishing year, Council salmon fisheries are managed under a “weak stock” approach. In order to meet all control rules and consultation standards for the weakest stocks in a given year, Council fisheries often forgo full use of available harvests for healthier stocks. As a result, it is a common case for stock-specific harvests for some stocks to be less than allowed under control rules or consultation standards due to status of co-occurring limiting stocks.

4.2 Overall Fishery Objectives

The following FMP objectives guide the Council in establishing fisheries against a framework of ecological, social, and economic considerations.

1. Establish ocean exploitation rates for commercial and recreational salmon fisheries that are consistent with requirements for stock conservation objectives and ACLs within Section 3, specified ESA consultation or recovery standards, or Council adopted rebuilding plans.
2. Fulfill obligations to provide for Indian harvest opportunity as provided in treaties with the U.S., as mandated by applicable decisions of the federal courts, and as specified in the October 4, 1993 opinion of the Solicitor, Department of Interior, with regard to federally recognized Indian fishing rights of Klamath River Tribes.
3. Maintain ocean salmon fishing seasons supporting the continuance of established recreational and commercial fisheries while meeting salmon harvest allocation objectives among ocean and inside recreational and commercial fisheries that are fair and equitable, and in which fishing interests shall equitably share the obligations of fulfilling any treaty or other legal requirements for harvest opportunities.[5]
4. Minimize fishery mortalities for those fish not landed from all ocean salmon fisheries as consistent with achieving OY and the bycatch management specifications of Section 3.5.
5. Manage and regulate fisheries so that the OY encompasses the quantity and value of food produced, the recreational value, and the social and economic values of the fisheries.
6. Develop fair and creative approaches to managing fishing effort and evaluate and apply effort management systems as appropriate to achieve these management objectives.
7. Support the enhancement of salmon stock abundance in conjunction with fishing effort management programs to facilitate economically viable and socially acceptable commercial, recreational, and tribal seasons.
8. Achieve long-term coordination with the member states of the Council, Indian tribes with federally recognized fishing rights, Canada, the North Pacific Fishery Management Council, Alaska, and other management entities which are responsible for salmon habitat or production. Manage consistent with the PST and other international treaty obligations.

[5] In its effort to maintain the continuance of established ocean fisheries, the Council includes consideration of maintaining established fishing communities. In addition, a significant factor in the Council’s allocation objectives in Section 5.3 is aimed at preserving the economic viability of local ports and/or specific coastal communities (e.g., recreational port allocations north of Cape Falcon). Chapter 6 in Appendix B and the tables it references provides additional specific information on the fishing communities.

9. In recommending seasons, to the extent practicable, promote the safety of human life at sea.

Harvest allocations are determined from a total allowable ocean harvest, which is maximized to the largest extent possible but still consistent with PST and treaty-Indian obligations, state fishery needs, and spawning escapement requirements, including consultation standards for stocks listed under the ESA. The Council makes every effort to establish seasons and gear requirements that provide troll and recreational fleets a reasonable opportunity to catch the available harvest. Procedures for determining allowable ocean harvest vary by species, fishery complexity, available data, and the state of development of predictive tools. These procedures have and will change over time to incorporate the best science. A number of management controls are available to manage the ocean fisheries each season, once the allowable ocean harvests and the basis for allocation among user groups have been determined. Stock management considerations also guide the Council for setting seasons within major subareas of the Pacific Coast (Figure 11).

Controls include management boundaries and seasons, quotas, minimum harvest lengths, fishing gear restrictions, area restrictions, landing limits, and recreational daily bag limits. Natural fluctuations in salmon abundance require that annual fishing periods, quotas, and bag limits be designed for the conditions of each year. What is suitable one year probably will not be suitable the next. New information on the fisheries and salmon stocks also may require other adjustments to the management measures. The Council assumes these ocean harvest controls also apply to territorial seas or any other areas in state waters specifically designated in the annual regulations. Details to the incorporation and use of these controls are contained in Chapter 6 of the FMP (PFMC 2016).

Successful management of the salmon fisheries requires considerable information on the fish stocks, the amount of effort for each fishery, the harvests by each fishery, the timing of those harvests, and other biological, social, and economic factors. Much of the information must come from the ocean fisheries; other data must come from inside fisheries, hatcheries, and spawning grounds. Some of this information needs to be collected and analyzed daily, whereas other types need to be collected and analyzed less frequently, i.e., once a year. In general, the information can be divided into that needed for inseason management and that needed for annual and long-term management. The methods for reporting, collecting, analyzing, and distributing information can be divided similarly. The description of the data needs, methods for obtaining inseason and annual long-term data, reporting requirements, and schedules for the Council's monitoring of the resource and the fisheries harvesting that resource are contained in Chapters 7 and 8 of the FMP (PMFC 2016).

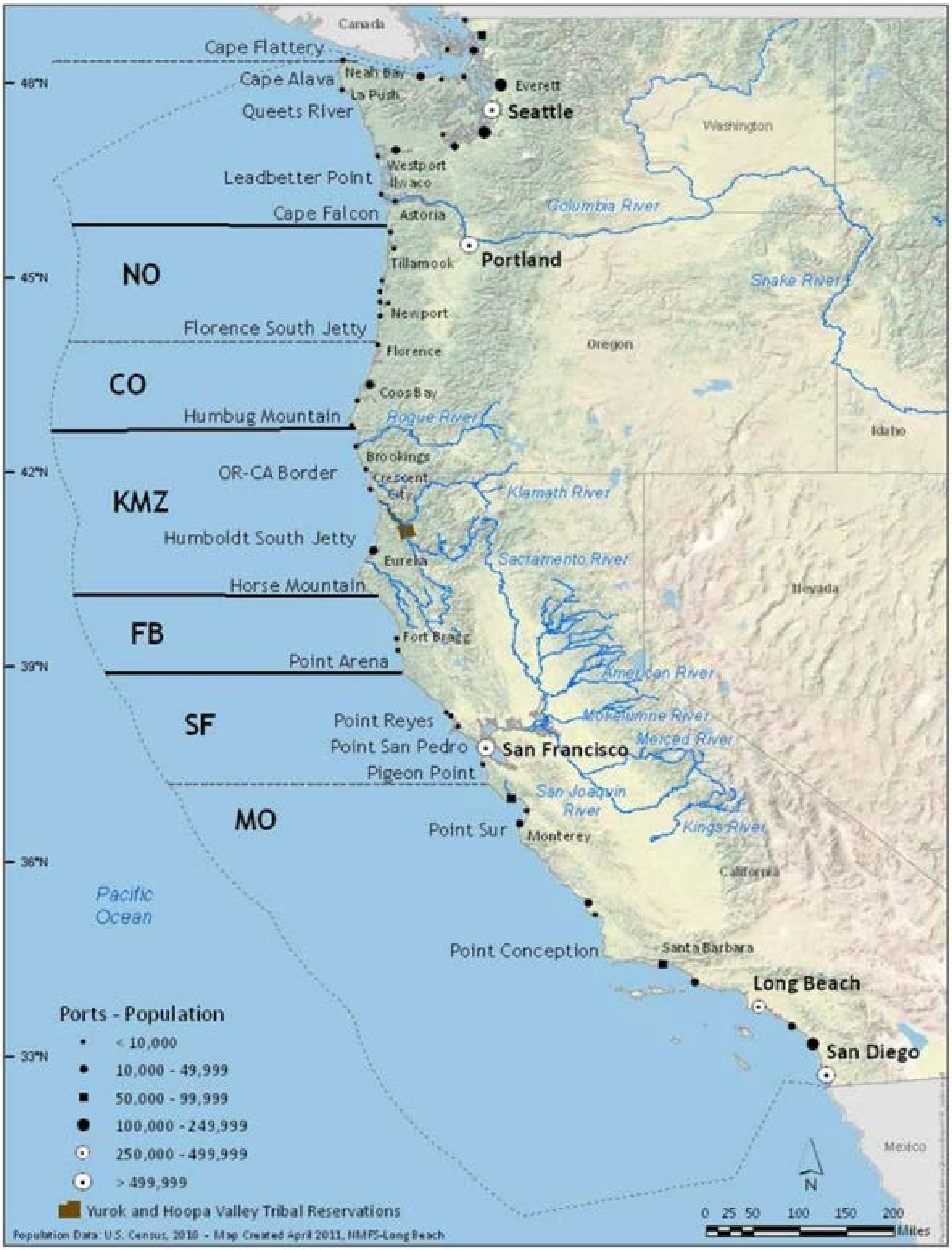

Figure 11. Major management boundaries in common use since 2000.

4.3 Schedule and Procedures for establishing annual management measures

The process for establishing annual or preseason management measures under the FMP contains a considerable amount of analysis, public input, and review. This is detailed in Chapter 9 (PFMC 2016). The actions by the Secretary of Commerce after receiving the preseason regulatory modification recommendations from the Council are limited to accepting or rejecting in total the Council's recommendations. If the Secretary rejects such recommendations he or she will so advise the Council as soon as possible of such action along with the basis for rejection, so that the Council can reconsider. Until such time as the Council and the Secretary can agree upon modifications to be made for the upcoming season, the previous year's regulations remain in effect. This procedure does not prevent the Secretary from exercising his or her authority under Sections 304(c) or 305(c) of the MSA and issuing emergency regulations as appropriate for the upcoming season. Inseason modifications of the regulations may be necessary under certain conditions to fulfill the Council's objectives and the process and procedures for doing so are detailed in Chapter 10 (PFMC 20126). Modifications not covered within the framework will require either an FMP amendment, rulemaking, or emergency Secretarial action. Depending on the required environmental analyses, the amendment process generally requires at least a year from the date of the initial development of the draft amendment by the Council. Emergency regulations may be promulgated without an FMP amendment. Details for both an FMP Amendment process and Emergency Regulations are detailed in Chapter 11 (PFMC 2016).

At the time of this draft, catch information and effort in ocean fisheries over the time series the Workgroup determined to use was still being compiled, and is expected to be incorporated in the final document.

4.4 Summary description of the 2009 biological opinion and 2019 assessment of fisheries impacts on SRKW

In the 2009 biological opinion on PFMC fisheries (NMFS 2009), NMFS compared prey potentially available to SRKW with and without the action and found that the fisheries will reduce prey available in some locations during some time periods. The analysis considered whether effects of that prey reduction may reduce the reproduction, numbers, or distribution of SRKW, pursuant to NMFS jeopardy standard. NMFS evaluated the potential effects of the FMP on SRKWs based on the reductions in prey resulting from a range of harvest scenarios that have been previously authorized, and considered likely in the future, under the FMP.

NMFS evaluated the potential short-term or annual effects as well as the long-term effects of prey reduction from the FMP. Short-term or annual effects of the FMP on prey availability were evaluated by: 1) the percent reduction in Chinook available with the action, and 2) the remaining prey base of Chinook with the action compared to the metabolic needs of the SRKWs. NMFS evaluated the potential for long-term effects on prey availability based on NMFS’ most recent conclusions for effects of the FMP on salmon and review of conservation objectives for individual Chinook stock groups affected by the action. The prey reduction was evaluated by time and area, among other factors, based on the available information to stratify the analysis.

Information on Chinook availability was based on FRAM model runs. FRAM provides year-specific ocean abundance estimates based on fishery data, escapement estimates, and assumptions about incidental and natural mortality from central California to Southeast Alaska. All Chinook stocks in the FRAM model travel through the range of SRKWs. FRAM includes most listed and non-listed Chinook stocks within the whales’ range, with notable exceptions including Alaska stocks, Upper Columbia River spring, Snake River summer/spring, Klamath River Chinook, Rogue River Chinook, Central Valley late-fall, winter, and spring runs, and fish from other rivers along the Southern Oregon and Northern California coasts. FRAM is a single-pool model that does not provide abundance estimates of Chinook within sub regions. However, by using catch distribution patterns from the FRAM base period (for the 2009 biological opinion the base period was 1979-1982) when fisheries were broadly distributed across time and area, a method was derived to estimate abundance at a regional scale for inland waters (Strait of Juan de Fuca, east to Georgia Strait in the north, and Puget Sound in the south), and coastal waters (all FRAM fishery regions except inland waters).

Regional abundance estimates were derived for two retrospective years that represented a range of high (2002) and low (2008) Chinook abundance and respective harvest levels. For both years, the estimates were specific to time periods in the FRAM model for an annual cycle: October to April, May to June, and July to September. The range of high and low years analyzed was expected to represent a reasonable range of abundance and harvest under the FMP in future years. In general, the percent reduction from fisheries is greater in good Chinook abundance years than in poor abundance years. The PFMC salmon fisheries were found to cause minimal or no prey reduction during the October to April time period, regardless of year or region and causes incrementally larger prey reductions during May to June and July to September when the majority of FMP fisheries occur. NMFS' opinions on effects of FMP fisheries on salmon also consider the effects of environmental variability on sustainability of salmon stocks (i.e., from ocean conditions or climate effects) and aim to maintain stocks at or above conservation objectives. Although in specific cases, for some years and stocks the conservation objectives are not met, overall NMFS determined that effects to the ESU still meet ESA compliance standards. When necessary to ensure that the FMP fisheries do not compromise ESA compliance, regulations for those fisheries have been adjusted to incorporate conservation measures that avoid jeopardy to listed salmonids. For example, in 2008 and 2009, poor performance of Chinook stocks in Central Valley, California were the impetus behind fisheries closures south of Cape Falcon, Oregon. As a result of the fishery closures the proposed action would not affect escapements of these stocks. However, while the salmon harvest is managed to meet objectives to promote recovery of salmon, NMFS was not able to evaluate if recovery levels identified for salmon ESUs are consistent with the prey needs and recovery objectives for SRKWs.

NMFS concluded in the 2009 biological opinion that the extent of take was not anticipated to appreciably reduce the survival and recovery of SRKWs. The amount of anticipated take would not increase the risk of mortality (i.e., and therefore would not rise to the level of serious injury or mortality), or hinder the reproductive success of any individual SRKW (NMFS 2009).

NMFS reinitiated consultation on the 2009 opinion in April, 2019. Pending completion of the reinitiated consultation, NMFS assessed the impact of 2019 PFMC salmon fisheries on SRKWs. NMFS considered all the information currently available to assess these impacts including: estimated percent reductions in overall Chinook salmon prey availability from the March 2019 Council's three fishery alternatives compared to past percent reductions; estimates of 2019 Chinook salmon abundance in coastal waters and inland waters derived using the Chinook FRAM as well as forecasts of Klamath River Fall Chinook and Sacramento River Fall Chinook based on the stock-specific models used for their management; Supplemental Salmon Technical Team Report 2; 2019 pre-season translated forecasts of abundance for each priority Chinook salmon prey stock that contributes to the Council salmon fisheries; and the contribution rates of the priority Chinook salmon prey stocks to total catch (both current predicted contribution and historical contribution) in the Council salmon fisheries.

For 2019, NMFS assessed the effects of the percent reductions to available Chinook salmon prey expected to result from the three fishery alternatives at the March Council meeting under consideration and considered this together with pre-season Chinook salmon abundance estimates for 2019 using FRAM and the two California stock-specific indices mentioned above (Agenda

Item F.1.e, Supplemental NMFS Report 1, April 2019). To put the reductions in context, the analysis involved comparing percent reductions in Chinook salmon prey availability from the fisheries and Chinook salmon abundance anticipated in 2019 to percent reductions and abundance for a retrospective time period (NMFS used 1992-2016 as the retrospective time period).

Overall, total percent reductions in prey availability in coastal waters anticipated from each fishing alternative considered by the Council for 2019 ranged from 7.1 percent in Alternative 3 to 9.9 percent in Alternative 1, which fall within the middle range (the range between the lower and upper quartile boundaries) of what was observed during the retrospective time period (1992 – 2016).

Pre-season coastal Chinook salmon abundance and inland Chinook salmon abundance were estimated to fall within a middle range of abundances estimated during the retrospective time period. Therefore, coastal and inland Chinook salmon abundances projected for 2019 were not in the low nor high quartiles for abundances compared to previous years. NMFS also assessed the forecasted pre-season abundances of the priority Chinook salmon prey stocks relative to past abundances during the same retrospective time period (1992 to 2016). Four priority stocks were anticipated to have relatively high Chinook salmon abundances (above the upper quartile boundaries) and ten stocks were anticipated to be within a middle range of abundances (i.e., neither substantially low nor high). Therefore, 2019 abundance estimates for 14 of the 16 priority prey stocks contributing to Council-area salmon fisheries were expected to be in the middle or upper quartiles of abundance when compared with the retrospective time period. Two priority Chinook salmon prey stocks, the lower Columbia River spring and the upper Willamette spring, have abundance estimates in the lowest quartile compared to the retrospective time period.

NMFS focused on these two priority stocks to help assess if the impacts of the 2019 Council area fisheries on these stocks would result in a level it deemed as unacceptable risk by increasing mortality or reducing fecundity of SRKWs because of the stocks' relatively low 2019 abundance compared to their abundances over the retrospective time period. The lower Columbia River spring stock is a low abundance stock but considered high priority because of its spatial and temporal overlap with the whales and because it has been observed in the whales' diet during the winter period when the whales have a higher likelihood of reduced body condition. However, the stock is a minor contributor to the catch composition of Council area salmon fisheries. Over the retrospective time period, this stock contributed to approximately 0.5 percent of the annual catch on average in Council Area fisheries (Figure 12). Of note, Figure 12 reflects proportional catches in fisheries as they occurred in a given year, and as a result it includes effects of changes in fisheries management as they may have occurred. For example, in 2009-2010, PFMC fisheries in areas South of Cape Falcon were either highly constrained or closed; as a result of that, the proportion of Central Valley and other more southerly stocks in the overall PFMC catch was very low, and proportions of stocks occurring in fishery areas that remained open were higher. In 2019, the percent contribution to the annual catch of the lower Columbia River spring Chinook stock under each alternative is estimated as 0.1 percent (Figure 12).

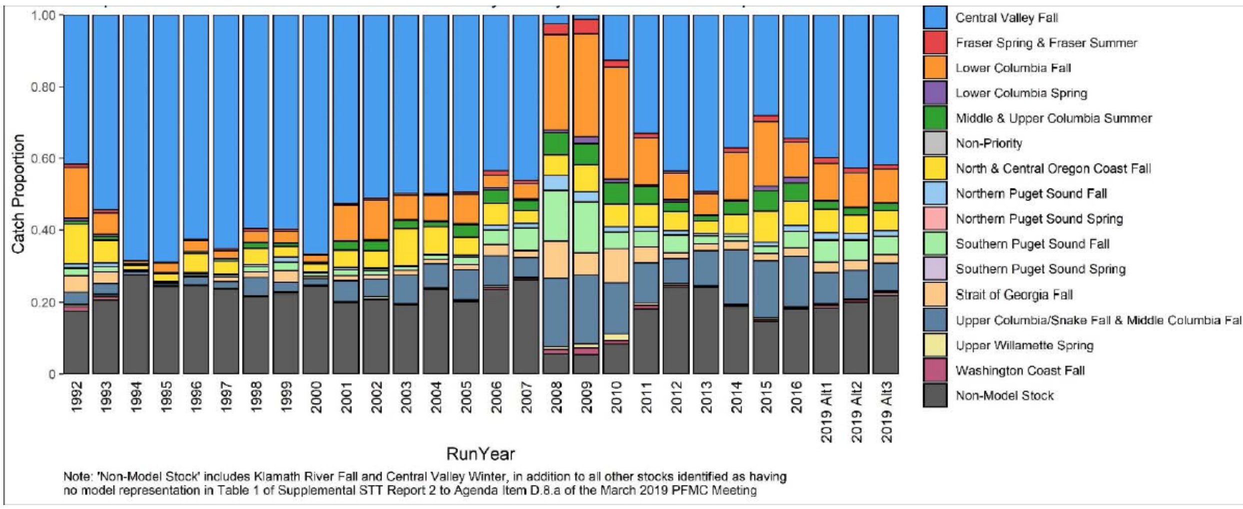

Figure 12. Composition of total Council Area Chinook salmon catch by Priority Chinook salmon stock group (Agenda Item F.1.e Supplemental NMFS Presentation 1, April 2019).

The upper Willamette spring Chinook salmon stock has not been observed in the diet of SRKWs, and thus is further down the priority prey list, but the stock does overlap in space and time with the whales. This stock is more abundant than the lower Columbia River spring Chinook salmon stock, but still considered relatively less abundant when compared to other priority Chinook salmon prey stocks, such as Southern Puget Sound fall, Lower Columbia River fall, and Strait of Georgia fall, among others. The expected contribution of the upper Willamette spring Chinook stock to the catch in 2019 is similar to the historical contribution of this stock to the Council salmon fisheries catch, which averaged less than 0.5 percent during the retrospective time period. Thus, although two priority stocks were anticipated to have low abundance relative to previous years, because of their low occurrence in Council fisheries, NMFS did not anticipate the Council fisheries would substantially reduce the availability of those priority Chinook salmon prey stocks to the whales. Furthermore, the overall forecast composition in 2019 contained a higher proportion of Chinook salmon stocks that are considered to be higher priority than the average composition in the retrospective time period.

5 Risk Assessment

The first stage of the risk assessment is built on the analyses of correlations between Chinook abundance and SRKW demography discussed by the 2012 Science Panel (Hilborn et al. 2012) and described by Ward et al. (2013), including more recent data on a broader range of SRKW demographic indices, and relating SRKW demography to estimates of aggregate adult Chinook abundance in specified times and locations. In contrast with earlier correlative studies, abundance aggregates were defined not on the basis of stocks, but on the basis of composite abundances in specific ocean areas based on distributions inferred from recent modeling efforts (Shelton et al. 2019). This analysis correlated past SRKW demographic performance with retrospective estimates of time- and area-specific Chinook abundance. For this part of the analysis, only the estimated Chinook abundance actually present in a particular time and area was of interest; no attempt was made to separate out the effects of production, natural mortality, or harvest in generating the realized abundances.

5.1 Methodology

5.1.1 Model Description

The models used analyze the statistical relationship between demographic indices of SRKW performance (see section 5.1.2) and retrospective estimates of adult (age 3 and older) ocean Chinook abundance at three time steps (October 1-April 30, May 1-June 30, and July 1-September 30) aggregated at various spatial scales and for fishery management years 1992-2016 (the fishery management year starts in the fall of the preceding year, so the first time step considered was October 1, 1991). When appropriate, we considered temporal lags between Chinook abundance and observed SRKW performance based on plausible physiological mechanisms linking food supply to future performance. For example, because killer whales have a gestation period of approximately 18 months, it may be important to consider Chinook indices in year *t*-1 as predictors of fecundity (Hilborn et al. 2012, Ward et al. 2009, Ward et al. 2013). We did not consider moving averages across multiple years.

Coast wide abundance estimates for most Chinook salmon stocks were generated using Chinook FRAM (MEW 2008). Abundance estimates for FRAM stocks are calculated using stock-specific terminal run size estimates by age and mark status provided by regional technical staff. Stock-specific terminal run sizes are then expanded by maturation rates, fishing mortality, and natural mortality estimates to derive a starting abundance. For additional details related to calculations of FRAM starting abundances, please refer to the Backwards FRAM documentation, available at https://github.com/dappdrd/PFMC_SRKW/blob/master/BkFRAM-May-2-2018.docx.

However, there are several Chinook stocks that are not modeled in FRAM. These stocks include those north of Vancouver Island, Hupp Springs, Coastal Springs, Tsoo-Yess Falls, Columbia Springs originating upriver of Bonneville, and all Chinook stocks originating south of Elk River, Oregon, with the exception of Sacramento Falls (Appendix A and B). Many of these stocks were relatively small in magnitude (e.g., Hupp Springs, Coastal Springs, and Tsoo-Yess) or were primarily outside of the core SRKW assessment area (e.g., stocks north of Vancouver Island). However, the SRKW workgroup determined that it was necessary to account for Sacramento Fall, Klamath Fall, and Rogue Fall stocks along with Upriver Columbia Springs using methods external to FRAM due to the likely spatial-temporal overlap of these stocks with SRKW and relatively large abundances of these stocks.

For Upriver Columbia Springs, terminal run size estimates were expanded to account for assumed ocean natural mortality to represent starting abundances. This stock aggregate has a unique pre-terminal catch distribution and typically experiences an exploitation rate less than one percent in all marine fisheries (coded wire tag analysis; 2000–2016). Given the very low rates of ocean exploitation, it is presumed that this stock aggregate either has a far north or offshore distribution. Therefore, Upriver Columbia Springs are most likely to be available to SRKW as they return to spawn.

For Chinook stocks originating south of the Elk River, we used abundance estimates for Sacramento River Fall Chinook (SRFC), Klamath River Fall Chinook (KRFC), and Rogue River Fall Chinook (RRFC) derived outside of Chinook FRAM. Although SRFC are included in FRAM as Sacramento Falls, they are not of primary interest North of Falcon and so we used an alternative model that more closely aligns with South of Falcon fisheries management conventions and models. For SRFC we used a modification of the Sacramento Index (O'Farrell et al. 2013) incorporating natural mortality and catch apportioned by month, for KRFC we used the same cohort reconstructions that inform the Klamath Ocean Harvest Model (KOHM; Mohr 2006), and for RRFC we adjusted the September 1 age-specific Rogue Ocean Production Index (ROPI) values (PFMC 2019) according to monthly ratios in age-specific KRFC abundance determined from cohort reconstructions. Additional details are available in Appendix A, and Appendix B discusses stocks for which abundance estimates are not available.

At each time step, coast wide ocean abundances were distributed among spatial boxes based on estimates of the proportion of each stock found in each area each season. For fall run stocks, proportional abundance in each management area was based on the results of Shelton et al. (2019). This is a state-space model that infers time- and area-specific ocean abundances of tagged fish from representative coded-wire tagged release groups using information on release size, time- and area-specific fishery catch and effort, and age structure of returning spawners. Individual FRAM stocks were matched up to units of analysis in the Shelton et al. model as described in Table 3. SRFC corresponds with Shelton et al.'s SFB stock and KRFC corresponds with NCA. Although the Rogue River is in Southern Oregon, the "SOR" results in Shelton et al. are for Chetco River fish. Spatial patterns in recoveries of Rogue River Chinook coded-wire tags (Weitkamp 2010) and genetically-identified fish (Bellinger et al. 2015, Satterthwaite et al. 2015) are more similar to Klamath River Chinook than to other Southern Oregon Chinook, so we apportioned RRFC spatially using NCA results. For spring run stocks, which lacked distribution estimates from Shelton et al., we followed the logic described in https://www.fisheries.noaa.gov/webdam/download/93036440, using point values of 0.02 to represent ranges of 0-0.05, 0.15 to represent ranges of 0.05-0.25, and 0.5 for areas directly adjacent to the river of origin.

Table 3. Mapping Chinook stocks used within the Shelton et al. model to the FRAM model stocks.

Stock (Shelton)	Stocks (FRAM)
Central Oregon	Mid Oregon Coast
Lower Columbia	Columbia River Oregon Hatchery Tule, Columbia River Washington Hatchery Tule, Lower Columbia River Wilds, Lower Columbia Naturals
Mid Columbia	Columbia River Bonneville Pool Hatchery
Northern Oregon	Oregon North Coast
Puget Sound	Nooksack/Samish, Skagit, Snohomish, Stillaguamish, Tulalip, Mid Puget Sound, University of Washington Accelerated, South Puget Sound, Hood Canal, Juan de Fuca Tributaries, Hoko
Southern Georgia Strait	Fraser Lates, Fraser Earlies, Lower Georgia Strait
Washington Coastal	Willapa Bay, Washington North Coast
West Coast Vancouver Island	West Coast Vancouver Island

We then aggregated individual spatial boxes and their corresponding abundances at three levels: The entire U.S. West Coast EEZ as a single unit, the West Coast EEZ split into two boxes north versus south of Cape Falcon, or the West Coast EEZ split into three boxes at Cape Falcon and at Horse Mountain, which are among the management area lines used in ocean fisheries management by the PFMC. We also calculated separate abundances for the Salish Sea (sum of PUSO and SGEO from Shelton et al. 2019) and Southwest Vancouver Island.

5.1.2 Demographic Indices Considered

The workgroup is assessing conservation risks of the fishery based on effects on to the following whale demographic indices: 1) SRKW survival rates, 2) SRKW fecundity (birth) rates, and 3) occurrence of "peanut-head" whales (a metric previously used as an index of extremely poor condition, Matkin et al. 20017), and 4) annual changes in SRKW abundance. A number of additional metrics were also discussed, but not ultimately included for a variety of reasons (questionable utility as indicators, few years of data, etc.). The list of these latter metrics included social cohesion (Parsons et al. 2009), occupancy of the Salish Sea (Olson et al. 2018), changes in body condition other than the occurrence of peanut-head whales (Fearnbach et al. 2018), hormone indicators of nutritional status (Wasser et al. 2017), indicators based on stable isotope data (Warlick et al., in review), diet diversity (Ford et al. 2016), and demographic parameters of Northern Resident killer whales (Olesiuk et al. 2005; Ford et al. 2009).

SRKW survival varies with age or stage of the whale (Olesiuk et al. 1990). Because some ages were uncertain (particularly older animals at the start of the survey), we modeled an effect of stage on survival so that we could compare survival standardized to a common stage across years (Hilborn et al. 2012; Ward et al. 2013). Similarly, fecundity varies with age so we modeled an effect of age on fecundity so that we could compare fecundity at a common age (set to age 20 because fecundity is thought to peak in the early 20s [Ward et al. 2009]).

5.1.3 Model Structure

Fecundity of individual female whales was modeled using logistic regression as a function of time-area specific Chinook abundance along with a quadratic function of age, allowing for fecundity peaking at an intermediate age. Whales that gave birth in the previous year were excluded due to the 18 month gestation period meaning they could not possibly give birth again the following year (Ward et al. 2013). We separately considered abundance in the current year, in the prior year, and two years prior to account for lagged effects.

Survival of individual whales was modeled using logistic regression as a function of time-area specific Chinook abundance and a categorical variable describing stage/sex (juvenile, young female, young male, old female, old male). For consistency, we used delineations that have been used previously (Ward et al. 2013).

The occurrence of whales with peanut-head each year as a function of area-specific Chinook abundance was modeled using Poisson GLM (Poisson family with log-link). Alternative approaches could include logistic regression, for example, but the number of whales with this condition is extremely small such that sample size precludes inclusion of covariates (age, sex) that might explain variation. Thus, all animals were assumed to have equal chances of developing the peanut head syndrome.

SRKW population trends were also considered as an assessment metric, represented as a binomial variable with 1 corresponding to population increases and 0 corresponding to population decreases. Periods of population increase and decrease were estimated by fitting a GAM (total SRKW population ~ year), with inflection points in the GAM representing changes in the direction of the population trend. Unlike fecundity, survival, or the occurrence of peanut head, correlations between Chinook abundance and SRKW population trends were not examined in isolation.

In addition, a cluster analysis using partitioning around medoids (PAM) was performed to explore possible associations between Chinook abundance and the SRKW population metrics (fecundity, survival, occurrence of peanut head, SRKW population trends). This analysis groups together years based on annual summary modeled (estimated) values for selected demographic variables (details on statistical smoothing available at https://www.fisheries.noaa.gov/webdam/download/94054344), optimizing the degree of association between the values of variables examined. For example, one group of years may be associated with high values for fecundity, survival, and SRKW population trends, but low values for the occurrence of peanut head syndrome. Local Chinook abundance can be considered in defining clusters, or after clusters of years of similar demographic performance are identified, we can explore whether clusters of years were similar with respect to various measures of Chinook abundance. For the cluster analysis, up to four groups were used to examine associations.

The code and statistical methodology used by the SRKW workgroup to perform all analyses is publicly available and can be accessed at: https://github.com/dappdrd/PFMC_SRKW.

5.1.4 Model Run Descriptions

Complete results can be obtained from https://dappdrd.shinyapps.io/SRKW_Chinook_Analysis/

To use the application and produce outputs:

1.) Go to it via website: https://dappdrd.shinyapps.io/SRKW_Chinook_Analysis/

2.) Input your email address.

3.) Send the input file to your email via the associated button (this may take a moment).

4.) Save the input file to your computer and then use the browse button on the application to select the input file.

5.) Press the “Begin Processing/Email Outputs” button to send an output file to your email (this may take a few minutes).

Interpreting the results:

1.) Each area-time step can be found as a tab in the output file. Time step 1 corresponds to October-April, time step 2 corresponds to May-June, time step 3 corresponds to July-September.

2.) Each graphic depicts the relationship between Chinook abundance and a SRKW population parameter. Each analysis was conducted as a logistic regression (or Poisson regression in the case of peanut-head). For fecundity analyses, age was included as a covariate and modeled as a quadratic. For the survival analysis, stage was included as a covariate. In order, the analyses are Chinook abundance versus fecundity (no lag; starting on row 2), survival rates (row 28), peanut head (row 54), fecundity (1 year lag; row 80), and fecundity (2 year lag; row 106).

3.) The model summaries are available to the left of each graphic. To determine if there is a statistically significant relationship between Chinook abundance on each population parameter, check the p-value for abundance in these sections. If the p-value is less than 0.05, that is the typical “cut-off” for determining that a relationship is statistically significant.

None of the fitted regressions met the typical criterion of $p<0.05$ that is often associated with “statistical significance”. A p-value of 0.05 means that given the level of variability in the data and the model assumptions, there is a five percent probability of seeing a relationship at least as strong as the one observed purely by chance under a null hypothesis of no effect. It should not be interpreted as the probability that there is or is not an effect in any particular case (Wasserstein and Lazar 2016). Rather, a small p-value means that it is unlikely that a pattern in the data at least as strong as the one seen would arise by chance, whereas a large p-value means that a pattern as strong as the one observed could easily have arisen by chance. It is still possible to occasionally get an apparently strong, but spurious relationship with a small p-value in the absence of a real effect, especially when conducting multiple tests. Conversely, especially when the data are noisy or confounding variables are not accounted for, it is possible for a real effect to be present despite the data having a pattern no more extreme than one that could be explained by chance alone (large p-value).

Given the lack of statistical significance, the results should be interpreted with caution. Nevertheless, in almost all cases the fitted relationships were of the expected sign (i.e. survival and fecundity increased with increasing Chinook abundance while occurrence of peanut-head decreased with increasing Chinook abundance). This was true in all cases excluding time lags and waters south of Cape Falcon.

Interpretation of the clustering analysis is still pending.

5.1.5 Effects of Fisheries

The Workgroup has yet to include the reduction in abundance of prey, by any of the stratifications used to try to correlate abundance to SRKW demographic indices. This information and step of the analysis is forthcoming and is expected to available during the Workgroup's October meeting.

5.1.6 Key Uncertainties

These include:

Uncertainty in Chinook salmon stock abundances

The uncertainty associated with Chinook salmon abundance forecasts in general is relatively well appreciated, but there is also substantial uncertainty in retrospective abundance estimates. Harvest and escapement estimates are themselves uncertain, but ocean abundance estimates depend further on unverified assumptions about natural mortality, constant adult natural mortality rates across years, mortality associated with fish caught but released, drop-off mortality, and bycatch mortality in other fisheries that are not accounted for in the management models. Additionally the FRAM model uses a "base period" to estimate fishing mortalities by stock, age, fishery, and time step. The current Chinook FRAM base period is represented by coded wire tag recoveries from fishing years 2007–2013. If stock distributions differ considerably from the 2007–2013 base period, fishery mortality estimates from the model will not reflect reality.

Uncertainty in Chinook stock distributions

The Shelton et al. (2019) distribution model is subject to uncertainty due to sampling error in harvest data, assumptions about natural mortality, assumptions about how catch per unit effort scales with local abundance (and the consistency of metrics of fishing effort across time and space), the assumption that stocks have the same spatial distribution every year, and the assumption that a subset of marked hatchery releases are representative of all releases from the corresponding stock and also representative of the natural-origin component of those stocks. The model published by Shelton et al. (2019) does not include data through 2016 as we used here, however, estimated distribution from that early period may be more precise because of higher sampling rates. Work is in progress to account for inter-annual variability in the Shelton et al. model, and to incorporate GSI information from both hatchery- and natural-origin fish, but no results were available in time to inform this analysis.

Additionally, a temporal mismatch exists between the Shelton et al., 2019 model and FRAM. FRAM abundances are based on three different time steps, corresponding to Winter (October through April), Early Summer (May through June), and Late Summer (July through September). However, time steps in Shelton et al., 2019 are offset by a month relative to the FRAM model, with Winter designated as November–May, Early Summer designated as June–July, and Late Summer designated as August–October. Although this mismatch causes a disconnect between the two models, the Shelton et al., 2019 model is believed by the workgroup to be the better model to characterize Chinook distribution, and future work will be explored to produce results from the Shelton model that are compatible with FRAM time steps.

Lack of information on Chinook distributions during winter

The model used to apportion Chinook abundance through space (Shelton et al. 2019) depends on coded-wire tag recoveries from ocean fisheries directly targeting Chinook salmon. Effort in these fisheries has been very limited or nonexistent in winter and early spring for most years (with several exceptions, including the 4B treaty troll fishery in Washington State near Neah Bay). Efforts are underway to include additional data sources (e.g., from salmon bycatch in trawl fisheries) to learn more about Chinook spatial distributions in the winter and early spring, but no results were available in time to inform this analysis.

Limited information on distribution for most spring-run Chinook stocks

Quantitative distribution estimates from Shelton et al. (2019) were only available for fall-run stocks. Efforts are underway to extend this model to spring-run stocks, but the generally lower catch rates and resultant smaller sample sizes pose a challenge. Ongoing efforts to share information across coded-wire tag, genetic stock identification, and trawl bycatch datasets should increase the statistical power and provide better insights about spring run distributions, although the seemingly more offshore distribution of some spring run stocks will pose an ongoing challenge to models based on fishery-dependent data. These results will have to be modeled at a coarser spatial resolution for instance, compared to fall stocks, because of significantly smaller sample sizes.

Effects of changes in Chinook salmon size and age structure

The utility of Chinook salmon as prey depends on more than their abundance alone. Older Chinook salmon are larger and thus provide more nutrition per fish than younger fish. In addition, Chinook salmon that mature at younger ages spend less time in the ocean and thus spend less time potentially available as prey, possibly meaning less food for SRKW per smolt entering the ocean. At the same time, returning spawners per smolt may be higher for younger fish that experience less cumulative mortality risk, potentially increasing the availability of Chinook salmon prey per smolt for SRKW specifically targeting aggregations of returning spawners near river mouths. It appears that both hatchery- and natural-origin Chinook salmon are becoming smaller and younger throughout most of the Pacific coast (Ohlberger et al. 2018).

Uncertainty in the distribution of SRKW

Much of the knowledge of SRKW distribution is based on sightings reported in the inland waters of the Salish Sea, especially in summer months (Olson et al. 2018; Hauser et al. 2006). The distribution year to year can be characterized as variable, and possibly subject to short term trends. Over the last several years, for example, many social groups of the SRKW population have not spent much time in inland waters during the summer relative to their historical occurrence (Olson et al. 2018). For non-summer months, sighting data is generally limited. Several satellite tags have been deployed on SRKW in winter months to characterize the winter distribution (Jan - Apr). Data from these deployments suggests that J pod appears to have a distribution in the Salish Sea, concentrated in the northern Strait of Georgia and western entrance to the Strait of Juan de Fuca (Hanson et al. 2018). However, J pod tag data is limited to an extremely small sample size (one tag deployed in February 2012 for three days; one tag deployed in December 2013 for 31 days; one tag deployed December 2014 for 49 days; Hanson et al. 2018) and additional data on the distribution of J pod during the winter would be beneficial. K and L pods are estimated to have a more frequent coastal distribution, with a seasonal concentration off the Columbia River, and Washington coast (Hanson et al. 2018). Distribution in spring and fall months has been characterized from acoustic recorders (Hanson et al. 2013) and additional analyses are being conducted to update these estimates.

Differential responses to changes in Chinook abundance among pods

J pod appears highly restricted to the Salish Sea relative to K and L pods that spend more time in coastal waters, thus it is likely that they would have differential responses to changes in the abundance of particular Chinook stocks compared to K and L. However, considerable statistical power is lost when analyzing one pod at a time due to lower sample sizes.

Uncertainty in the drivers of changes in the distribution of SRKW

Other than factors related to prey abundance, or phenology, it is unclear what drivers may influence SRKW distribution. Some have speculated that changes in the age structure of SRKW (particularly the loss of older animals) may alter future distributions, if historical knowledge is lost. It is unclear to what degree SRKW or other killer whales actively avoid vessels, or other populations of killer whales, however both of these may also influence distribution.

Uncertainty in the ability of SRKW to switch to alternative prey sources

The degree to which killer whales are able to or willing to switch to non-preferred prey sources (i.e., prey other than Chinook salmon) is also largely unknown, and likely variable depending on the time and location. Previous work from genetics has suggested that SRKW switch from Chinook to other salmon in fall months (particularly coho and chum salmon, Ford et al. 2016). Though a small number of samples have been collected, fecal samples collected in winter suggest a diet that is still more than 50% Chinook, but also includes contributions from groundfish (halibut, lingcod) and steelhead (Hanson et al. 2018). In addition to small sample sizes, the spatial location of these recent samples is confounded with season (e.g. few summer diet samples have been collected outside of the Salish Sea, and few winter diet samples have been collected in the Salish Sea). Diet data reflecting longer integration windows (bulk stable isotopes) have been analyzed recently, and suggests that there may be some year to year variability that may affect diet variation (e.g. Chinook salmon consumption may be higher when they are more abundant, and the contribution of Chinook salmon may be lower in years when coast wide abundance is low; Warlick et al. in review).

Patterns of temporal variation in competing threats

In addition to threats directly related to reduced prey (from Chinook salmon or other species), a number of threats have been previously identified as potential threats to SRKW. These include, but are not limited to: additional anthropogenic threats (contaminants in the food web, increased noise levels around vessels, risks of ship strikes, potential effects of oil spills, long term effects of habitat loss on salmon productivity and viability, long term effects of hatchery origin fish on natural production and viability), disease, ecosystem effects on reductions in salmon biomass (competition from other populations of fish-eating killer whales, and other marine mammals including seals and sea lions, long term reductions in Chinook salmon body size and age at maturity), inherent risks associated with small populations (inbreeding depression, demographic stochasticity, skewed sex ratios at birth with unknown causes), and behavioral risks (infanticide, Allee effects). To the extent that any of these factors vary across years, they will confound the effects of changes in Chinook salmon abundance, but they can only be included as model covariates if annual measurements are available, which by and large they are not.

Chinook salmon stocks whose abundances are not included in the modeling

North of Cape Falcon, non-modeled stocks include those north of Vancouver Island, Hupp Springs, Coastal Springs, and Tsoo-Yess Falls. Many of these stocks are relatively small in magnitude (e.g., Hupp Springs, Coastal Springs, Tsoo-Yess) or are present primarily outside of the core SRKW assessment area (e.g., stocks north of Vancouver Island).

South of Cape Falcon, it is likely that the two most important non-modeled stocks are Klamath-Trinity spring run (for which 1992-2016 adult river run sizes were on median 21 percent as large as the river run size of Klamath River Fall Chinook salmon) and California Coastal Chinook salmon (for which 0.23 genetically-identified fish were found for every 1 genetically-identified Klamath River Chinook during sampling of California recreational fisheries in 1998-2002 [Satterthwaite et al. 2015]). Rogue River Spring and Central Valley Spring Chinook might also be of particular value to SRKW due to their river return timing coincident with potential presence of SRKW in southern waters, but their run sizes are relatively small, with typical river run sizes less than 10 percent of the typical river run sizes of Klamath River Fall Chinook and Sacramento River Fall Chinook salmon, respectively. See Appendix A for further details on non-modeled stocks.

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APPENDIX A

Chinook salmon stocks excluded from the Assessment

The following details provide rationale for stocks which are known to occur in the EEZ, but for which the Council does either does not currently utilize models to account for these stocks, or in the specific case of Sacramento Winter Chinook, the stock's contribution to potential SRKW prey base was considered insubstantial. Although their abundance and distribution may affect SRKWs demographics, the Workgroup here provides the rationale for exclusion of these stocks:

• Sacramento Winter Chinook – Sacramento Winter Chinook escapement as a percentage of SRFC escapement had a median value of 1.3 percent for 1992-2016 (for this and the other Central Valley stock comparisons, 1992-2000 escapements were obtained from the CHINOOKPROD data set, obtained from the US Fish and Wildlife Service's Anadromous Fish Restoration Program [http://www.fws.gov/stockton/afrp, downloaded March 2011] and 2001-2016 escapements were obtained from PFMC 2019a). Sacramento Winter Chinook also have small body sizes, a primarily age-3 maturation rate, and have ocean distributions heavily concentrated south of Point Arena, CA (O'Farrell et al. 2012), all of which suggests they are unlikely to make substantial contributions as SRKW prey.

• Central Valley Spring Chinook – Central Valley Spring Chinook escapement as a percentage of SRFC escapement had a median value of 4.6 percent for 1992-2016. Note that the estimated Central Valley Spring Chinook escapement does not include spring run fish spawning in natural areas on the Feather River, which are included in the fall run escapement estimate and thus contribute to the SI modeled in Council fisheries.

•Other components of the Central Valley Fall Chinook Stock Complex (San Joaquin Fall and Sacramento Late-Fall Chinook) – Together escapement of these two as percentage of SRFC escapement had a median value of 6.4 percent for 1992-2016.

• Klamath River Spring Chinook – Adult river run size for Klamath River Spring Chinook as a percentage of adult river run size for KRFC had a median value of 21 percent for 1992-2016 (Klamath River Spring Chinook data from CDFW's "Current – 2017 Spring Chinook Megatable 1-Mar-2019.xlsx", KRFC data from PMFC 2019).

• California Coastal Chinook – Abundance of this stock is not well characterized. Genetic stock identification (GSI) sampling of California recreational ocean fisheries from 1998-2002 (Satterthwaite et al. 2015) suggested that 0.23 California Coastal Chinook were caught for each Klamath River Chinook (fall or spring run).

• Smith River Chinook – Abundance of this stock is not well characterized, but a few unpublished estimates suggest annual escapements on the order of 16,000 fish (Shelton et al. 2019), less than 20% of the median KRFC adult river run size for 1992-2016.

•Rogue River Spring Chinook – Terminal river returns are under 10,000 fish in most years (C. Kern ODFW pers. comm.), so mostly under 10 percent of the median KRFC adult river run size for 1992-2016.

• Other Southern Oregon Chinook stocks outside the Rogue River – Myers et al (1998) states that Rogue River fish are numerically dominant among these stocks.

Overall, we deemed it unlikely that excluding these less abundant stocks (all of which, with the exception of Sacramento Winter Chinook, lack vetted models for generating ocean abundance estimates, even retrospectively) would substantially affect the conclusions of later analyses relating SRKW performance to aggregate Chinook abundance. Further, again with the exception of Sacramento Winter Chinook, we do not have vetted abundance forecasts available for the excluded southern stocks, so we would have no way of evaluating their expected contribution to the SRKW prey base during preseason planning. Relative catch rates from genetic stock identification studies might be informative on relative ocean abundance for similarly distributed stocks, but sample sizes and spatio-temporal coverage are currently limited. Relative escapements or river run sizes might provide some indication of relative ocean abundances, but are confounded by differences in age structure, maturation schedules, natural mortality, and ocean fishing mortality.

Appendix A References

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APPENDIX B

Abundance models for southern stocks

For SRFC, we used a modification of the Sacramento Index (SI, O'Farrell et al. 2013) to characterize adult (ages 3 and older combined) ocean abundances through time. The SI is the sum of adult river run size and ocean harvest of SRFC south of Cape Falcon and serves to index abundance on September 1 of each management year (management years south of Cape Falcon run from September 1 to August 31). Note that the SI does not account for natural mortality, nor does it account for unharvested immature fish remaining in the ocean for another year, so it likely underestimates preseason ocean abundance. While we were not able to account for immature fish remaining in the ocean, we made new calculations that incorporate natural mortality. We assumed monthly adult natural mortality of m=0.0184, equivalent to 20 percent annual mortality. We then calculated August 1 ocean abundance N_8 as $N_8=R/(1-m)+H_8$ where R represents adult river run size and H_8 is adult ocean harvest of SRFC in August. For earlier months, $N_t=N_{t+1}/(1-m)+H_t$ (and for management years, month 12 precedes month 1). Our October 1 abundances do not match the SI values reported in PFMC 2019 Table II-1 both because our calculation reflects removals during September and because we adjust numbers upward throughout the year to account for natural mortality.

For KRFC, we used monthly age-specific (ages 3 and older) ocean abundance estimates produced by cohort reconstructions informing the Klamath Ocean Harvest Model (KOHM, Mohr 2006; September 1 values for ages 3 and 4 are available in PFMC 2019 Table II-3). Ratios between monthly age-specific abundance estimates in the KRFC cohort reconstruction reflect the combined effects of fisheries removals and assumed values of natural mortality.

For RRFC, we characterized age-specific September 1 ocean abundances using the ROPI (ROPI, PFMC 2019 Table II-7). The ROPI is calculated based on age-specific RRFC river run size, scaled up by age-specific ocean harvest rates estimated for KRFC and assumed natural mortality. Therefore, we assumed that age-specific values of RRFC abundance for later months would have the same ratio to the ROPI that monthly age-specific abundances for KRFC have to their corresponding September 1 estimates.

We estimated abundances on October 1, May 1, and July 1 for consistency with the seasonal breakpoints used in Chinook FRAM. SRKW appear most likely to be present in waters south of Cape Falcon during the winter and early spring (Hanson et al. 2018). Thus, fishery removals of Chinook during October could affect prey availability when SRKW are most likely to be present (ocean fisheries are closed during the winter). For SRFC, a maximum of three percent of the SI was harvested during October during the years 1992-2016, with annual median and mean of 0.9 percent and one percent, respectively. For KRFC, total reduction in adult abundance between October 1 and November 1 (reflecting both fisheries and assumed natural mortality) ranged from four to five percent with median five percent. Thus, it appears unlikely that accounting for October fishery removals would substantially change the results of later analyses.

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