Methods and data behind the SRKW priority stock analysis Factor 3 (overlap with whales)

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Motivation

This document is intended to describe how to use existing, published estimates of Chinook salmon distribution to approximate salmon and Southern Resident Killer Whales spatio-temporal overlap in the ocean.

To address spatio-temporal overlap, we first need to define the temporal and spatial scales of use for combining information from Chinook salmon and SRKW. The objective of this document is to summarize the scales used and justifications for those choices.

Seasons

In general, SRKW (J, K, and L pods) inhabit the waters of the Salish Sea (Strait of Juan de Fuca, Strait of Georgia, Puget Sound) during the summer months (June/July - September/October, NMFS 2006; Hauser et al. 2007). The whales may also frequent coastal waters particularly off Washington and Vancouver Island (Ford et al. 2000; Hanson et al. 2017). During the winter and spring months (November – April), K and L pods typically occur along the outer coastal waters of British Columbia and southeast Alaska (west coast Vancouver Island), Washington (Cape Flattery to the Columbia River mouth), Oregon, and California (as far south as Monterey Bay), whereas J pod mostly occurs within the Salish Sea (including Puget Sound, northern Strait of Georgia, and the western entrance to the Strait of Juan de Fuca).

Chinook salmon have complicated and varied life-histories that are thought to be a factor in variable ocean distributions. The primary drivers of ocean distribution for Chinook salmon are the river of origin and the run type which corresponds to the season in which Chinook salmon enter their river of origin before spawning. Multiple run types frequently co-occur within a single river system and so at the very least, the division of seasons needs to reflect the timing of spawning migrations for different run types. Available information for fall-run Chinook salmon also suggests that ocean distributions shift outside of spawning migration times (e.g. Healey 1991, Shelton et al. 2019).

To accommodate this variation in SRKW and Chinook salmon, we divided the year into four seasons of uneven duration (described in Shelton et al. 2019). We defined spring as April-May, summer as June-July, fall as August-October, and winter as November-March. These breaks reflect, approximately, the division of Chinook salmon run timing and correspond to predictable patterns of SRKW occupancy of interior and coastal waters. Future work could consider alternate season breaks if desired.

Spatial definitions

While SRKW visit a wide range of habitats from California to Alaska, available information suggests they inhabit core areas within the Salish Sea and along the outside coasts of Washington and Oregon. Based on satellite tag data and acoustic detections, the area between the Columbia river mouth and Cape Flattery, Washington appears to be of particular importance to SRKW.

We mapped SRKW abundances into five broad areas for determining salmon abundance, defining the five regions as 1) Salish Sea, 2) Cape Falcon, Oregon north to the Canadian border (noted as coastal Washington), 3) Cape Falcon to Cape Mendocino (Oregon and Northern California), and 4) Cape Mendocino, CA to Point Sur, California, and 5) Southwest Vancouver Island, Canada. We considered areas north of southwest Vancouver Island (including Alaska) to be less important for SRKW.

<u>Methods for addressing the focal question</u>

Do the fish from each origin region / hatchery overlap with SRKW in the ocean?

a. Spatial - seasonal patterns

We defined important areas for SRKW above. Salmon ocean distributions are a function of many factors including origin river, run type, and season. Climate factors also likely play an important role in determining ocean distribution (e.g. Myers et al. 2007), but for this exercise, we assume no variability in ocean distribution of a given stock among years. In general, our knowledge about ocean distributions in the winter months is substantially more uncertain than other times of the year (as the majority of CWT recoveries occur in summer and fall, during commercial fishing seasons). Coastwide, very few fisheries occur in the ocean during the winter months and therefore the sampling rate of Chinook salmon is very low.

For fall run Chinook salmon (including some summer-fall runs) we rely on a recently published study to describe the proportional distribution of fall run stocks in the ocean (Shelton et al. 2019). Shelton et al. (2019) uses 17 spatial regions and the four seasons outlined above (April-May, summer as June-July, fall as August-October, and winter as November-March). We consolidate these 17 regions into the five SRKW areas described above. Note that because of limited data available during winter months, this model assumes that spring and winter month distributions are identical (November – March). Other management models, such as FRAM, use similarly broad groupings of months in winter where recoveries are sparse.

For spring runs there are very few estimates of ocean distribution and most of the estimates are not defined seasonally. For example, Weitkamp (2010) provides information on ocean distribution for a number of spring run stocks based on the proportion of coded wire tag (CWT) recoveries in different ocean areas, but these proportions include information from a broad range of years and from recoveries in all seasons, and are confounded by differences in fishing effort. In general, information from high seas tagging, genetic stock identification, and coded wire tag recoveries suggest that spring run Chinook salmon tend to have a more northerly distribution (Weitkamp 2010, Satterthwaite et al. 2013, Satterthwaite and O'Farrell 2018) and more offshore distribution (Healey 1991, Bracis 2010) than fall run Chinook from the same river, though this appears to vary to some degree among rivers. Because of these offshore distributions and earlier return migration, spring Chinook generally have less encounters with directed Chinook fisheries.

In the absence of data to the contrary, we assume that proximate stocks are more similar in ocean distribution than physically distant stocks - i.e., stocks from southeast Alaskan rivers have a more similar ocean distribution with one another than with Californian stocks.

In general, the approach we used for approximating ocean distribution when direct information was not available is as follows:

1) We assume spring stocks are concentrated in front of their river mouths in the spring more than they would be other times of the year for their spawning migration into the river. Spring

and winter distributions represent times in which some components of the spring-run stocks should be engaging in spawning migrations. To approximate the proportion of the population that should be near the river mouth during the spring, we looked at the spatial distribution of fall Chinook salmon stocks during the fall (their spawning season) in Shelton et al. (2019). We calculated the average proportion of each stock in ocean areas directly adjacent to the origin river mouth. For example, for Columbia river stocks, we summed the fraction of the population in the northern Oregon, Columbia, and Washington coastal regions. Across all origin regions examined in Shelton et al. (2019), on average 52% (range 27-74%) of the fish population was estimated to be proximate to the river mouth (within 1-2 spatial boxes defined at the scale of Shelton et al. 2019, see their Table S1.3 for the locations corresponding to river entry for each stock) during the fall season. So we use 50% as a reasonable approximation for the fraction of spring Chinook proximate to river mouths in winter and spring.

2) In some cases, primarily for Chinook salmon originating in Oregon and California, more than 50% of the fall stock is estimated to be near the river mouth year round and there is auxiliary information supporting similar distributions between fall and spring run types (see below). In such cases we used the values from the fall run fish directly as proxies for the spring run distributions. The unique winter run from the California Central Valley is a special case described below.
3) We explored other available data sources such information on the spatial distribution of mortalities from indicator stock used by the Pacific Salmon Commission to determine if our proposed distributions were consistent with available information. Each section below contains a brief discussion of information consulted for each stock and proposed distributions. For some stocks, available information is very sparse and proposed distributions reflect this uncertainty.
4) The proportional distribution values presented below are approximate and logical but they are not precise. We present ranges of values rather than point estimates when appropriate to emphasize this uncertainty. The ocean distribution estimates are particularly uncertain for spring Chinook salmon stocks. To use the same scoring system for all run types, we do not use the point estimates for distributions presented below directly but convert them into categorical bins to reflect a range of occurrence values (rare to common; see Scoring below). Small to moderate changes to distribution values would be consistent with the uncertainty about spring run distributions in particular.

Scoring

Spatio-temporal overlap

We used the following criteria to score each Chinook salmon stock. We defined area-seasons as follow and assigned weights to each. Higher weights correspond to higher priority areas and seasons:

1. Proportion of population in WA coast in Winter / Spring; weight = 0.5
2. Proportion of population in WA coast in Summer / Fall; weight = 0.5
3. Proportion of population in Salish Sea in Winter / Spring; weight = 0.5
4. Proportion of population in Salish Sea in Summer / Fall; weight = 0.5
5. Proportion of population along Southwest Coast of Vancouver Island in Winter / Spring; weight = 0.5
6. Proportion of population in OR / N.CA coast in Winter / Spring; weight = 0.25
7. Proportion of population in CA coast in Winter / Spring ; weight = 0.25

For each spatial area - season component, we awarded scores of 0, 1, or 2 to each population as follows.

Proportion ≥ 0.25 : 2 point
0.25 > Proportion ≥ 0.05 : 1 point
Proportion < 0.05 : 0 point

For example, this means that a common run (i.e. a run with an ocean distribution proportion greater than 0.25) in a high priority area would receive 1 point (2*0.5=1).

We then multiplied each score by the associated weight and summed across the five area-seasons to calculate a score for the stock. Using these seven area-season categories and associated weights, a given population could score greater than 3 points. We normalized the scores such that the maximum observed score was equal to 3 (if this factor was the only metric included in the ranking, this normalization would not be necessary).

Brief descriptions of ocean distributions for Chinook salmon stocks arising from California to Southeast Alaska in the context of Southern Resident Killer Whales.

For all sections below, reference to mortalities taken from the Pacific Salmon Commission's Chinook Technical Committee (CTC; PSC 2018b) represent the proportion of fishing mortalities occurring in particular spatial areas. For the calculation of this proportion, the denominator includes the total number of recoveries in fisheries and in escapement. These proportions are an indicator of the occurrence and, potentially, the relative prevalence of particular stocks along the coast; larger proportions are likely (but are not necessarily) positively related to higher densities. They should not be directly interpreted as estimates of ocean distribution; observed proportional mortalities are affected the spatial distribution of the stock as well as by a variety of other factors including the intensity and seasonal timing of fisheries.

In the descriptions below, when discussion proportional ocean distributions we use the word "common" to designate ocean distribution proportions greater the 0.25, "moderate" to describe proportions in the range of 0.05 to 0.25, and "rare" for values below 0.05.

Spring and summer stocks from Central British Columbia, Northern British Columbia, and Alaska

Northern stocks are expected to play a minimal role in determining Chinook salmon abundance in SRKW areas. In the CTC models, for example, CWT tags from Alaska stocks (Taku, Unuk, Stikine, Chilkat) had zero recoveries in any WCVI, Washington, or Oregon fishery. Among central and northern British Columbia stocks, the Atnarko river Chinook salmon (indicator stock for central BC) were observed rarely in both southern BC fisheries (<0.3% mortalities across all years) and WCVI fisheries (<1%) and almost never in sport or troll fisheries in Washington of Oregon (PSC 2018b). Similarly, fish from the Skeena river (indicator stock for northern BC; Kitsumkalum river) were had estimated mortalities of less than 0.1% for WCVI fisheries and <0.1% for Washington and Oregon fisheries. CWT recoveries from Kitsumaklum were only observed in Washington in one year since 1983. As a result, we assert that Chinook salmon stocks from central BC and north do not contribute meaningfully to the Salish Sea, Washington Coastal or other areas identified as SRKW habitat (PSC 2018b).

Fall stocks from the West Coast of Vancouver Island.

These stocks are dominated by the Robertson Creek Hatchery, but include a natural production from natural populations and a few smaller hatchery populations. They are largely detected in waters north of the SRKW areas.

Data from the CTC shows that mortalities for these stocks are predominantly in SE Alaska fisheries (15% or more) and Northern BC (generally between 5 and 10%). There are lower proportion of mortalities observed along the west coast of Vancouver Island (~1-3%) and in southern BC (~2-6%). There are occasional (<1%) mortalities in fisheries in Puget Sound and US waters north of Cape Falcon, OR.

Distribution of Fall run stocks from the West Coast of Vancouver Island from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall

California	0.01	0	0
Oregon – Northern Cal.	0.02	0	0
Washington - Columbia	0.01	0.01	0.03
Salish Sea	0.02	0.03	0.07
SWVI	0.04	0.04	0.18

Spring and Summer stocks from the Fraser river

Fraser Spring

Fraser spring (Nicola river CTC mortality data; PSC 2018b) are rare (<1%) in SE Alaska fisheries, slightly more common in NBC fisheries (0.1 to 2%), and more common in S. BC fisheries (~3-5%). These Fraser spring Chinook also occur in the north of Cape Falcon troll (1-3%) and in Puget Sound sport fisheries (~ 2%) where catches likely occur early in the year (before June).

Fraser spring (Dome Creek CTC mortality data; PSC 2018b) are rare (<1% in SEAK fisheries), slightly more common in NBC fisheries (on average 0.1 to 2% but highly variable among years), most common in S. BC fisheries (~8-15%). These stocks occur in N of Cape Falcon troll (~1%) and in Puget sound sport (~1 percent) where catches might occur early in the year (before June).

Weitkamp (2010) shows broadly similar patterns to the CTC data. It is based on Spius Creek, Fraser above Hope (a mix of different release locations). If anything, Weitkamp (2010) suggests a larger proportion in the Salish Sea than the CTC data and more Salish Sea representation than the Fraser Summer stocks.

Fraser Summer

Fraser summer (Lower Shuswap CTC mortality data; PSC 2018b) commonly occur (8-17%) in SEAK fisheries, are slightly less common in NBC fisheries (5-17% or so), occur in 3-5% for WCVI fisheries, and are even less common in S. BC fisheries (~1-6%). These stocks occur in N Falcon troll rarely (<1%) and in Puget sound net and sport (~1-2%).

Fraser summer (Middle Shuswap CTC mortality data; PSC 2018b) occur in a small sample size of years (post 2011). They commonly occur (7-8%) in SEAK fisheries and NBC fisheries (~9%), less so (~3%) for WCVI fisheries, and are common in S. BC fisheries (~10%). These stocks show up in North of Falcon troll rarely (1%) and not in Puget sound net and sport.

Weitkamp (2010) shows broadly similar patterns to the CTC data based on the Quesnel, Clearwater, Eagle, and Shushwap Rivers.

Fall run information from the Fraser river and Strait of Georgia (Shelton et al. 2019) during non-spawning seasons

Fall run Chinook salmon are estimated to have ~30% of their population in the Salish Sea in the spring and summer (non-spawning times) and about 18% (spring) and 9% (summer) in the Washington Coast and Columbia regions. They are considered very uncommon in northern Oregon and areas south (~1.5% total for OR and N. CA, < 0.5% CA Coast).

Distribution of Fall run stocks from the Fraser river and Strait of Georgia from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall

California	0	0	0
Oregon – Northern Cal.	0	0.02	0.02
Washington - Columbia	0.18	0.09	0.08
Salish Sea	0.30	0.33	0.35
SWVI	0.09	0.08	0.05

Proposed proportional distribution of Fraser and Strait of Georgia spring and summer Chinook salmon in Salish sea (Strait of Georgia and Puget Sound) and the US coast north of Cape Falcon. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Spring	*>0.25*	*0.05-0.25*	*<0.05*	*0.05-0.25*	*<0.05*	*<0.05*	*0.05-0.25*
Summer	*0.05-0.25*	*>0.25*	*0.05-0.25*	*<0.05*	*0.05-0.25*	*<0.05*	*0.05-0.25*

Proposed proportional distribution in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Spring	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*
Summer	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*

Spring and summer stocks from Puget Sound, and the Strait of Juan de Fuca

Spring Stocks

Nooksack spring (Yearling and Fingerling) CTC mortalities (PSC 2018b) are most common in WCVI troll and sport (5-25%), occur commonly in S. BC sport (8-15%) somewhat more rare in SEAK troll (3-5%). These stocks are rare in WA coast troll (<1%).

Skagit spring CTC mortalities (PSC 2018b). These are virtually the same as Nooksack, with slightly less catch in SEAK.

White River spring (Yearling) CTC mortalities (PSC 2018b) are observed most commonly in the Puget Sound sport fishery (~5-15%) and in small numbers in the WCVI troll catch (1%).

Weitkamp (2010) includes two spring runs from Puget Sound: Marblemount and Kendall Creek. Both stocks appear to have recovery patterns broadly similar to fall stocks from Puget Sound with a preponderance of recoveries in Puget Sound and the Strait of Georgia.

Based on these recoveries, we believe that these stocks are rare from the Washington coast south during the summer and fall seasons but at a moderate level along the Washington coast during the winter and spring. They are proposed to be common in the Salish Sea and moderately common in SWVI in during the winter and spring.

Summer Stocks

There is no information about summer CTC catches.

Summer stocks (Wallace River) look virtually identical to Puget Sound fall stocks in Weitkamp (2010). The division between summer and fall stocks in Puget Sound is not clear and it may be appropriate to treat summer and fall stocks as equivalent. They were assigned to be common during the summer and moderately common in Puget Sound during the fall.

Fall run information from the Puget Sound (Shelton et al. 2019) during non-spawning seasons.

Fall run Puget Sound Chinook salmon are estimated to have ~30% of their population in the Salish Sea in the spring and summer (non-spawning times) and about 35% (spring) and 19% (summer) in the WA Coast region. In summer, Puget Sound fall Chinook have about 3% and 1% in the OR coast and CA coast, respectively. In winter both areas are estimated to be 0.5%. In fall, the proportions are ~4% (OR – Northern CA) and ~1% (CA coast).

Distribution of Fall run stocks from Puget Sound from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0	0.01	0.01
Oregon – Northern Cal.	0.01	0.03	0.04
Washington - Columbia	0.35	0.19	0.18
Salish Sea	0.30	0.32	0.30
SWVI	0.20	0.18	0.17

Proposed proportional distribution in Puget Sound spring Chinook salmon in the Salish Sea (Strait of Georgia and Puget Sound) and the US coast north of Cape Falcon. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Spring	*>0.25*	*0.05-0.25*	*<0.05*	*0.05-0.25*	*<0.05*	*<0.05*	*0.05-0.25*

Summer	*0.05-0.25*	*>0.25*	*0.05-0.25*	*0.05-0.25*	*0.05-0.25*	*<0.05*	*0.05-0.25*

Proposed proportional distributions for use in proportional distribution in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Spring	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*
Summer	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*

Spring stocks from coastal Washington

No CTC data is available for spring coastal stocks.

Weitkamp (2010) provides information on Sol Duc river springs (stock #45). Relative to other WA coast fall run stocks it has a larger proportional representation in the SWVI, NWVI, and PUSO regions but recoveries of this stock are quite low.

Information about the spatial distribution of spring stocks from this region is particularly sparse. Available information from fall runs suggest this stock is largely distributed in northern BC and Alaska during non-spawning months. Therefore, we provide a proposed distribution that reflects common occurrence in the Washington coast in the winter-spring with moderate occurrence in adjacent regions during these spawning periods.

<u>Fall run information from the Washington coast (Shelton et al. 2019) during non-spawning seasons.</u>

Fall run Washington coastal Chinook salmon are estimated to have about 2-3% of their population in the Salish Sea in the spring and summer (non-spawning times) and about 6% (both spring and summer) in the Washington Coast and Columbia regions. For more southern areas (OR – Northern CA and CA coasts), the estimated contribution of Washington coast fish is small but non-trivial (5% and 2% and in winter-spring, 1.5% and 1% in summer, 1.7% and 0.8% in fall). The contribution of these stocks to WCVI is much larger, with 35% of the stock estimated to be in WCVI in winter-spring, 12% in summer, and 19% in fall.

Distribution of Fall run stocks from the Washington Coast from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.02	0.01	0.01
Oregon – Northern Cal.	0.05	0.01	0.02
Washington - Columbia	0.06	0.06	0.16

Salish Sea	0.03	0.02	0.06
SWVI	0.10	0.06	0.10

Proposed proportional distribution of coastal Washington spring Chinook salmon in the Salish Sea (Strait of Georgia and Puget Sound) and the US coast north of Cape Falcon. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Spring	*0.05-0.25*	*<0.05*	*<0.05*	*>0.25*	*0.05-0.25*	*0.05-0.25*	*0.05-0.25*

Proposed data for use in proportional distribution in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Spring	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*

Spring and summer stocks from the Columbia river basin

Lower Columbia Springs

Willamette springs (Willamette river hatchery) CTC ocean mortalities generally occur in the north (3-8% in SEAK, 1-6% NBC, 1-2% WCVI; almost all recoveries in the troll fishery). They are rare but present in S. BC, WA coast, OR coast, Puget Sound (mostly ~1% or less). They occur in large proportions in river catches (can be 20% or greater).

Weitkamp (2010) provides information on Cowlitz river springs which is similar to Cowlitz fall tules (and appears somewhat different from Willamette River spring Chinook).

Overall, we view these stocks as generally occurring in the far north (Alaska, BC) but making spawning migrations during the winter and spring to the mouth of the Columbia. As such we classify them as common along the Washington coast during the winter and spring and moderately common in nearby areas.

Upper Columbia Spring

No data presented in Weitkamp (2010) and there are no CTC mortality estimates.

Wahle et al. (1981) has very few marine recoveries of Upper Columbia Springs (Leavenworth hatchery). The rare recoveries appear to be distributed to the north broadly (Alaska, BC). Their absence in marine recoveries suggest that these stocks are likely particularly unavailable to fisheries, even relative to other spring run stocks. Perhaps this is due to particularly early migration timing of these stocks? Or possibly a very far north or very offshore distribution?

We assign them to be common along the Washington coast during the spring spawning migration and moderate in other seasons but rare in all other areas and seasons relevant for SRKW.

<u>Snake River Spring-Summers</u>

No data presented in Weitkamp (2010), and there are no CTC mortality estimates.

Wahle et al. (1981) has substantial numbers of marine recoveries of Snake River Spring-Summers (Lochsa, Kooskia, Rapid River, Hayden Creek, Pahsimeroi Pond, Decker Pond hatcheries). The recoveries appear to be evenly spread north and south of the Columbia river mouth with recoveries in CA, OR, WA, BC, and AK. But these recoveries were from a very early CWT studies and it is unclear from the document how much of the fisheries catch was sampled for CWT and so if this pattern of recoveries is biased by spatially varying sampling effort.

This run is particularly complex with a large number of sub-stocks. We assign them to be common along the Washington coast during the spring spawning migration and during the summer months as they have an extended spawning migration. We suggest that they are moderately common in Oregon and N. California during the winter-spring and summer and moderate in other seasons but otherwise rare in all areas and seasons relevant for SRKW.

<u>Upper Columbia Summers</u>

Columbia upriver summers (Columbia River Summers) ocean mortalities from the CTC are 10-20% in SEAK, 2-8% in NBC, 2-16% in WCVI, 1-5% in WA Coast, 2-3% south of Falcon, and very rare in Puget Sound.

Weitkamp (2010) all suggest these general patterns with some occurrences south of Cape Falcon but most substantially north.

Wahle et al. (1981) does not explicitly discuss Columbia summer run stocks.

Therefore we propose to treat this stock as common in WA coast during the summer spawning migration.

<u>Fall run information on fall Chinook stocks from the Columbia basin (Shelton et al. 2019) during non-spawning seasons.</u>

Fall run lower Columbia Chinook salmon are estimated to have about 2.5% of their population in the Salish Sea in the spring and 5% in summer (non-spawning times) and about 37-41% (spring-summer) in the combined Washington Coast and Columbia regions. Northern CA - OR coast contains ~26% of these fish in spring (and 24% in summer) and CA coast has about 4% in spring and 6% in summer seasons.

Distribution of Fall run stocks from the lower Columbia River from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall

California	0.04	0.06	0.02
Oregon - Northern Cal.	0.26	0.24	0.24
Washington - Columbia	0.41	0.37	0.54
Salish Sea	0.03	0.05	0.03
SWVI	0.19	0.14	0.07

Fall run upper Columbia and Snake river Chinook salmon are estimated to have about 3-4% of their population in the Salish Sea in the spring and summer (non-spawning times) and about 30% (spring) and 24% in the combined WA Coast and Columbia regions. The Northern CA - OR coast contains 23% of these fish in spring, 14-15% in summer and fall. The CA coast has about 8% of these fish in spring, 4% in summer and a lower 1% in fall. An additional source for Upriver Bright Columbia Chinook salmon is Norris et al. 2000.

Distribution of Fall run stocks from the Upper Columbia and Snake river from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.08	0.04	0.01
Oregon – Northern Cal.	0.23	0.15	0.14
Washington - Columbia	0.3	0.24	0.43
Salish Sea	0.03	0.04	0.03
SWVI	0.18	0.14	0.08

Fall run middle Columbia Chinook salmon are broadly similar to upper Columbia and Snake populations but with a slightly more northerly distribution. For example, 45% of the Middle Columbia Chinook distribution is along California, Oregon, and Washington in spring (versus 61% for Upper Columbia and Snake populations), 30% of the distribution is in coastal California, Oregon, and Washington in summer (versus 42% for Upper Columbia and Snake populations) and 42% in fall (versus 58% for Upper Columbia and Snake populations).

Approximately 3-4% of Middle Columbia fish are distributed in the Salish Sea in all seasons. The majority of these fish are found in the Washington coast and Columbia regions (28% in winter-spring, 20% in summer and 32% in fall) and along Vancouver Island (26% in winter-spring, 20% in summer and 15% in fall). In contrast, the winter – spring distribution along the Northern California - Oregon region and California coasts are 15% and 3% respectively (9% and 2% in summer, 9% and 1% in fall).

Distribution of Fall run stocks from the Middle Columbia from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.03	0.02	0.01
Oregon – Northern Cal.	0.15	0.09	0.09
Washington - Columbia	0.28	0.20	0.32
Salish Sea	0.04	0.03	0.04
SWVI	0.14	0.11	0.07

Proportional distribution of Columbia river spring and summer Chinook salmon in the Salish Sea (Strait of Georgia and Puget Sound) and the US coast north of Cape Falcon. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Lower Columbia Spring	*<0.05*	*<0.05*	*<0.05*	*>0.25*	*0.05-0.25*	*0.05-0.25*	*0.05-0.25*
Upper Columbia Spring	*<0.05*	*<0.05*	*<0.05*	*>0.25*	*0.05-0.25*	*0.05-0.25*	*<0.05*
Upper Columbia Summers	*<0.05*	*<0.05*	*<0.05*	*0.05-0.25*	*>0.25*	*0.05-0.25*	*<0.05*
Snake River Spring-Summer	*<0.05*	*<0.05*	*<0.05*	*>0.25*	*>0.25*	*0.05-0.25*	*<0.05*

Proportional distribution of Columbia River spring and summer Chinook salmon in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Lower Columbia Spring	*0.05-0.25*	*<0.05*	*<0.05*	*0.05-0.25*	*<0.05*	*<0.05*
Upper Columbia Spring	*0.05-0.25*	*<0.05*	*<0.05*	*<0.05*	*<0.05*	*<0.05*

Upper Columbia Summers	*0.05-0.25*	*0.05-0.25*	*<0.05*	*<0.05*	*0.05-0.25*	*<0.05*
Snake River Spring-Summer	*0.05-0.25*	*0.05-0.25*	*0.05-0.25*	*0.05-0.25*	*<0.05*	*<0.05*

Fall run stocks from southern Oregon

Rogue River contains the numerically dominant Southern Oregon fall run stock (Myer et al 1998). Weitkamp et al. (2010) reported very similar patterns in CWT recoveries by area for Rogue fall versus Klamath/Trinity fall Chinook so we estimate distributions of Southern Oregon fall Chinook based on the Klamath/Trinity (NCA) results in Shelton et al. (2019). In general these stocks are restricted to the Oregon and California Coastal areas. These stocks occur rarely in WCVI (≤1% in all seasons), not at all in the Salish Sea, and have small contributions in the WA coast (4% in winter-spring, 3% for summer and fall). The largest proportion of these stocks are found off Northern California – Oregon coast, with 67% in winter-spring, 66% in summer and 81% of the stock occurring in this region in fall. Recoveries for Chetco River fish were skewed slightly north of this, but we considered Klamath tags more representative of the stock complex as a whole based on Rogue abundance and similarity to the Klamath.

For completeness, we also present estimates of ocean distribution derived largely from the Elk river in southern Oregon. The have a similar but slightly more northerly estimated distribution than the Klamath fall run.

Distribution of Fall run stocks from the Klamath River Fall Run stock used as a proxy for Southern Oregon (primarily Rogue fall) from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.27	0.30	0.15
Oregon – Northern Cal.	0.67	0.66	0.81
Washington - Columbia	0.04	0.03	0.03
Salish Sea	0	0	0
SWVI	0.01	0.01	0.00

Distribution of Fall run stocks from the smaller rivers in Southern Oregon from Shelton et al. 2019. These are largely derived from releases into the Elk river and represent a smaller number of fish than the Klamath or Rogue systems. Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.27	0.20	0.11
Oregon – Northern Cal.	0.75	0.68	0.82
Washington - Columbia	0.08	0.08	0.05

Salish Sea	0	0	0
SWVI	0.02	0.02	0.01

Spring stocks from southern Oregon

Weitkamp et al. (2010) reported very similar patterns in CWT recoveries by area for Rogue fall versus spring Chinook. Patterns in relative CPUE derived from GSI data in Bellinger et al. (2015) suggest that Rogue and Klamath Chinook (run timings combined) have more similar spatial distributions than do Rogue and Northern California/Southern Oregon Coast Chinook, so we used the Shelton et al. (2019) results for Klamath fall Chinook (NCA) to characterize Rogue River fish (both fall and spring) as well. Rogue River is numerically dominant among SOR Spring Chinook stocks (Myers et al. 1998, Shelton et al. 2019) so we used the NCA proxy for the Rogue to represent distribution for all SOR spring stocks.

Proportional distribution of Southern Oregon coast spring Chinook salmon in the Salish Sea and the Washington coast. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Southern Oregon Coast Spring	*0.00*	*0.00*	*0.00*	*0.04*	*0.03*	*0.03*	*0.01*

Proportional distribution of Southern Oregon coast spring Chinook salmon in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Southern Oregon Coast Spring	*0.67*	*0.66*	*0.81*	*0.27*	*0.30*	*0.15*

Fall and late fall stocks from California

We represent Central Valley Fall and Late Fall Chinook based on the Sacramento River (SFB) fall Chinook results in Shelton et al. (2019) and use the Shelton et al. (2019) Klamath/Trinity fall (NCA) results to represent fall run stocks from the Klamath Trinity and also from the Smith River (for which no direct distributional information is available) and for California Coastal Chinook from the Eel, Russian, Mad, and other smaller coastal streams between the Russian River and the Klamath River. GSI information (Satterthwaite et al. 2014) indicates broadly similar ocean distributions of Klamath and California Coastal Chinook. In general these stocks are mostly restricted to the coast off Oregon and California, although Central Valley stocks appear to extend slightly more into Washington Coastal waters despite their densest occurrence being south of the densest occurrence of Klamath/Trinity and California Coastal stocks.

Distributional results for Klamath River Fall Run were reported for Southern Oregon Fall stocks, above. Like stocks from Southern Oregon and the Klamath River, stocks from the California Central Valley are minor contributors to the WCVI area and do not occur in the Salish Sea. The majority of this distribution is concentrated in California and the Oregon – Northern California regions (51% and 34% in winter-spring, 61% and 29% in summer, and 65% and 29% in fall).

Distribution of Fall run stocks from the California's Central Valley from Shelton et al. (2019). Estimates have been aggregated to regions and rounded to two decimal places.

Region	Winter - Spring	Summer	Fall
California	0.51	0.61	0.65
Oregon – Northern Cal.	0.34	0.29	0.29
Washington - Columbia	0.12	0.07	0.05
Salish Sea	0	0	0
SWVI	0.02	0.02	0.01

Spring and winter stocks from California

Comparisons of spatial patterns in the recovery of fall versus spring-run Central Valley Chinook salmon inferred from both CWT and GSI data were summarized by Satterthwaite et al. (2018). Although Central Valley spring Chinook appear distributed somewhat to the north compared to Central Valley fall, this difference is quite small on the spatial scale considered here, with both stocks appearing largely restricted south of Cape Falcon. Thus, we used the Central Valley Fall (SFB) distribution model results from Shelton et al. (2019) to characterize Central Valley spring distribution as well. Sacramento winter run appears highly restricted to the south (O'Farrell et al. 2012, Satterthwaite et al. 2013, Bellinger et al. 2015), and in fact PFMC management with respect Sacramento Winter Chinook only considers fisheries south of Point Arena, CA. CWT recoveries are exceedingly rare of Point Arena CA, but the northern extent of Sacramento Winter Chinook is difficult to define confidently because of the overall paucity of CWT recoveries and the confounding effects of fishing effort, minimum size limits, and sampling rate (Satterthwaite et al. 2013). The weight of evidence seems very strong that well over 75% of the ocean abundance of Sacramento Winter Chinook occurs south of Cape Mendocino and while seems likely that 95% is south of Point Mendocino, to be precautionary about the potential overlap with SRKW foraging range we assumed 5% of Sacramento Winter Chinook were in the Northern California/Southern Oregon Coast area in each season.

Satterthwaite and O'Farrell (2018) characterized small differences in the distributions of Klamath/Trinity fall versus spring Chinook in some months, while Weitkamp et al. (2010) reported very similar total CWT recoveries by area when aggregating across time. As these differences are small at the spatial scale considered here, we used Shelton et al. (2019) model results for Klamath/Trinity fall Chinook (NCA) to characterize Klamath/Trinity spring Chinook as well.

There are no known extant populations of California Coastal spring Chinook, but if populations were to be established, they would be assumed to be derived from nearby stocks such as the Klamath-Trinity system and have similar ocean distributions.

Proportional distribution of California winter and spring Chinook salmon in the Salish Sea (Strait of Georgia and Puget Sound) and the US coast north of Cape Falcon. Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	Salish Sea			*WA Coast*			*SWVI*
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*	*Winter-Spring*
Central Valley Spring	*0.00*	*0.00*	*0.00*	*0.12*	*0.07*	*0.05*	*0.02*
Central Valley Winter	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0*
Klamath/ Trinity Spring	*0.00*	*0.00*	*0.01*	*0.04*	*0.03*	*0.03*	*0.01*

Proportional distribution of California winter and spring Chinook salmon in the Oregon Coast (Cape Mendocino, CA to Cape Falcon, OR) and the California coast (Cape Mendocino, CA to Point Sur, CA). Months are defined as spring (April-May), summer (June-July), fall (August-October) and winter (November-March).

	OR Coast and N. CA			*Central CA Coast*		
	Winter-Spring	*Summer*	*Fall*	*Winter-Spring*	*Summer*	*Fall*
Central Valley Spring	*0.34*	*0.29*	*0.29*	*0.51*	*0.61*	*0.65*

Central Valley Winter	*0.05*	*0.05*	*0.05*	*0.95*	*0.95*	*0.95*
Klamath/ Trinity Spring	*0.67*	*0.66*	*0.81*	*0.27*	*0.30*	*0.15*

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