STATE OF WASHINGTON June 2018

Grays Harbor Fall Chum Abundance and Distribution, 2017

by Amy R. Edwards and Mara S. Zimmerman

Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 18-09

Grays Harbor Fall Chum Abundance and Distribution, 2017

Washington Department of Fish and Wildlife

Amy R. Edwards
Region 6 Fish Management
48 Devonshire Rd, Montesano WA 98563

Mara S. Zimmerman
Fish Science Division
1111 Washington St SE, Olympia WA 98501

June 2018

Acknowledgements

We would like to thank our surveyors for collecting data and samples: Garrett Moulton, Frank Staller, Justin Miller, Valerie Miranda, Sebastian Ford, Stephanie Lewis, Megan Tuttle, Michael Sinclair, Curt Holt, Mike Scharpf, Kim Figlar-Barnes, Nick Vanbuskirk, Craig Loften, Oliver Crew, Brian Barry, Chris Mattoon, Danielle Williams, and Jesse Guidon. We would like to thank our volunteers for helping conduct supplemental surveys: Sara Ashcraft, Kyle Vandegraaf, Eric Walther, and Hamish Stevenson. Thanks also to Eric Walther with help in designing new upper extent protocol. Special thanks to Curt Holt, and Mike Scharpf for information on prior knowledge of the basin and for comments to the draft. We would also like to thank Quinault Division of Natural Resources (QDNR), Steve Franks and Joel Jaquez for information on Chum in Grays Harbor, and Devin West for the Bingham Creek trap data. Thanks also to Kim Figlar-Barnes and Adam Rehfeld, who reconciled and input data. We would also like to thank Weyerhaeuser Corporation, Green Diamond Resource Company and other private land owners for allowing access permission to survey on their property.

This work was funded by the Washington State Legislature and designated for study, analysis, and implementation of flood control projects in the Chehalis River Basin. Project funding was administered by the Washington State Recreation Conservation Office.

Recommended citation:

Edwards, A.R and M.S. Zimmerman. 2018. Grays Harbor Fall Chum Abundance and Distribution, 2017. Washington Department of Fish and Wildlife. Olympia, Washington. FPA 18-09.

Table of Contents

List of Tables

List of Figures

Executive Summary

Background

The goals of this project are to improve estimates of Grays Harbor Fall Chum spawner abundance and describe the distribution and spawning habitats of this species throughout the sub-basins of Grays Harbor. Washington Department of Fish and Wildlife (WDFW) and the Aquatic Species Enhancement Plan Technical Committee of the Chehalis Basin Strategy (Aquatic Species Enhancement Plan Technical Committee 2014) identified abundance, distribution, and key spawning habitats of Grays Harbor Fall Chum salmon as key information gaps in the Chehalis River basin. The gap occurs because the existing methodology for estimating Chum spawner abundance, developed in the 1980s, is based on surveys of spawning habitat that have substantially changed or degraded over time and on a spawning distribution for Chum that requires additional documentation.

In 2015, a pilot study identified which sub-basins within the Chehalis River basin contained Chum, developed a survey frame within the Wynoochee and Satsop sub-basins, and identified index reaches within those sub-basins with high densities of Chum spawners. In 2016, a new survey design was developed and implemented. The new survey design resulted in an overall abundance estimate of 55,000 to 56,000 Chum within the tributaries of the Satsop and Wynoochee sub-basins and the main stems of the Satsop sub-basin, but was not successful in completing an estimate for the main stem of the Wynoochee sub-basin due to poor survey conditions throughout the season. Our 2016 estimates from the Wynoochee and Satsop sub-basins only were equivalent to those derived by the existing methodology for the <u>entire</u> Grays Harbor Chum spawning distribution. However, several inconsistencies with the 2016 data collection were identified for improvement to ensure quality of the final estimate. These findings justified the purpose of this study as well as further efforts to improve information on Grays Harbor Chum spawner abundance and distribution.

Methods

Data collected for this study include distribution inside versus outside index reaches, area-under-the-curve estimates within index reaches, carcass tagging estimates of abundance in select index reaches, survey life estimates, and total spawner abundance on Chum salmon. Distribution inside versus outside index reaches was based on live counts during a one-time survey conducted throughout the Chum survey frame during the peak spawning period. Area-under-the-curve estimates within the index reaches were based on live counts obtained during weekly surveys. Carcass tagging estimates of abundance were based on a Jolly-Seber abundance estimator for open populations. Survey life was calculated in selected index reaches from the combination of area-under-the-curve and carcass tagging estimates of abundance. The index reaches selected to estimate survey life represented variable stream size classes – side channel, small/medium, and large – defined a priori for the purpose of analysis. Abundance in all index reaches was based on area-under-the-curve calculations and the survey life of the corresponding stream size classification. Total spawner abundance was the abundance in index reaches expanded by the proportion of spawning that occurred inside versus outside index reaches. Live count data used in the analysis were partitioned between 'spawners' (i.e., actively spawning) and 'holders' (i.e., holding in pools and potentially passing through the spawning area) to ensure we understood the sensitivity of the final estimate to these two different types of live counts. This distinction will be important when considering how to apply the results of this work to historical live counts from the index reaches. In 2017, we continued focus in the Wynoochee and Satsop sub-basins and implemented several changes to the data collection protocol to ensure the quality of the final abundance estimates.

Results

- **Distribution inside versus outside index reaches:** In the Wynoochee tributaries, 92-93% of Chum spawning occurred within the index reaches with the highest densities observed in Schafer and Neil creeks. In the Wynoochee main stem, 10-11% of Chum spawning occurred within the index reaches with the highest densities of Chum observed between river miles 29.1 and 39.5. In the Satsop tributaries, 44-45% of Chum spawning occurred within the index reaches with the highest densities of spawning observed in Decker Creek. In the Satsop main stem, 70-69% of Chum spawning occurred within the index reaches with the highest densities observed between river mile 12.4 and 14.7. The range in proportions represents the range in values provided by the different types of live counts (spawners only versus total live).
- **Area-under-the-curve in index reaches:** In the Wynoochee sub-basin, fish-day calculations summed across 8 index reaches ranged between 24,656 (spawners only) and 32,211 (total live counts). In the Satsop sub-basin, fish-day calculations summed across 16 index reaches ranged between 49,086 (spawners only) and 55,384 (total live counts).
- **Abundance in carcass tagging index reaches:** Chum spawner abundance was estimated to be 186 (173-208 95% C.I.) in the side channel index (Satsop Tributary 0462), 721 (605-885 95% C.I.) in the medium stream channel index (Schafer Creek) and 3,408 (2,402-4,755 95% C.I.) in the large stream channel index (EF Satsop River).
- **Survey life:** In this study, survey life represented BOTH the number of days a live Chum is present AND the observer efficiency within an index reach. For the side channel index (Satsop Tributary 0462), survey life was 8.98 days (±0.43) using counts of spawners only and total lives. The estimate did not differ by count type because no ‘holders’ were observed in the side channel index. For the medium stream channel index (Schafer Creek), survey life was 9.00 days (±0.93) with spawners only and 12.50 days (±1.30) with total live counts. For the large stream channel index (EF Satsop River), survey life was 1.52 days (±0.31) for spawners only and 1.83 days (±0.37) for total live counts.
- **Abundance in all index reaches:** In the Wynoochee sub-basin, abundance within the 8 index reaches was estimated between 2,780 (spawners only) and 2,606 (total live counts). In the Satsop sub-basin, abundance within the 16 index reaches was estimated between 8,631 (spawners only) and 8,329 (total live counts).
- **Spawner abundance:** The 2017 Chum spawner abundance for the Wynoochee sub-basin was estimated to be 16,728 (±1,422) using spawner only counts and 13,852 (±1,084) using total live counts. Chum spawner abundance for the Satsop sub-basin was estimated to be 15,161 (±806) using spawner counts only and 14,460 (±791) using total live counts.

Conclusions

The overall estimates of Chum spawner abundance differed slightly based on the type of counts (spawners only, total live counts including spawners and holders) used for analysis. However, our estimates were consistently higher than those derived using the existing methodology for Grays Harbor Chum. All together, we estimated a 2017 Chum spawner abundance of approximately 28,000 to 32,000 fish for the sub-basins included in our study. Our estimate in the Satsop and Wynoochee sub-basins alone was 9,000 to 13,000 fish more than the number of spawners estimated for the entire Grays Harbor basin using the existing methodology (n = 18,627). Similar to our findings in 2016, these results suggest that the existing methodology likely underestimates the abundance of Grays Harbor Chum salmon.

Tributary estimates for the Wynoochee and Satsop sub-basins were derived in both 2016 and 2017. The 2017 tributary estimates were 80-83% lower in the Wynoochee and 45-51% lower in the Satsop than the 2016 tributary estimates. In addition to differences in abundance, flow regimes in 2017 varied from 2016. The fall of 2016 was characterized by high flows by mid-October that were maintained throughout the spawning reason whereas the fall of 2017 had lower sustained flows until mid-November when the river flows increased. The difference in flows did not greatly affect distribution in the Satsop sub-basin where tributary and main stem estimates were available for both years. Chum spawners using tributaries of the Satsop sub-basin were 46-53% of the total sub-basin estimate in 2016 and 48-51% of the total sub-basin estimate in 2017. A corresponding comparison for spawning distribution in the Wynoochee sub-basin was not available due to the lack of information from main stem areas in 2016.

Survey life estimates have a far greater influence on the final abundance than the type of live counts. In this study, survey life represented BOTH the number of days a live Chum was present AND the observer efficiency within an index reach. Estimates of survey life in 2016 and 2017 ranged between 5.7 and 12.5 days, with a much lower estimate of 1.52 days in the large stream channel index (EF Satsop River) in 2017. The low value in the EF Satsop River was likely influenced by low observer efficiency as surveyors consistently encountered low visibility and high angler activity in this index reach (and throughout the main stem Satsop survey reaches). Additional years of study are needed to better understand the variability in survey life and the consequences of this variability for the final estimates of Chum spawner abundance.

Introduction

The Aquatic Species Enhancement Plan Technical Committee of the Chehalis Basin Strategy (Aquatic Species Enhancement Plan Technical Committee 2014) identified a gap in knowledge of Chum abundance, distribution, and spawning habitats as a necessary area of study within the sub-basins of Grays Harbor. Established Chum populations typically spawn in large aggregations and deliver annual pulses of marine derived nutrients that increase the productivity of the freshwater ecosystem (Naiman et al. 2002). As a result, improved understanding of Chum abundance, distribution, and spawning habitat will contribute to restoration planning activities. Improved information on Chum abundance will also provide critical information needed by the Washington Department of Fish and Wildlife (WDFW) and their co-managers for fisheries management in the sub-basins of Grays Harbor.

Grays Harbor includes the Chehalis River and its sub-basins as well as the Humptulips River and other tributaries draining directly into the Grays Harbor estuary. Most Chum spawning occurs in the mainstem Humptulips, Hoquiam, Wishkah, Wynoochee, and Satsop rivers and their tributaries. Additional spawning is observed in Black River, Cloquallum Creek and other smaller main stem tributaries, as well as in the south harbor tributaries, such as Elk and Johns rivers. Grays Harbor Chum are included as two populations in the WDFW Salmon Stock Inventory (SaSI) database - Humptulips Chum and Chehalis Chum (WDFW 2002). The Humptulips population included Humptulips River and its tributaries and the Chehalis population included tributaries of the Chehalis River from the Black River (upstream) to the Hoquiam River (downstream). The 2002 SaSI report noted no genetic difference between Chum in the Humptulips and Satsop rivers, but maintained separate assignment due to geographic separation of the rivers. In 2015, WDFW initiated further evaluation of Grays Harbor Chum that resulted in combining the two SaSI populations. This change was based on existing management criteria that used single escapement goal for the combined populations.

The existing methodology for estimating spawner abundance of Chum was developed by WDFW almost four decades ago (1977). At this time, the entirety of the known Chum distribution was evaluated and fish were enumerated by survey reach. Additional information collected by regional biologists included a quantitative (area) and a qualitative (poor, fair, good, excellent) assessment of spawning habitat in each tributary or river. The method for estimating spawner abundance was based on four index reaches that covered 0.68% of the total miles in the identified spawning distribution and were assumed to comprise 10.8% of the total spawner abundance for the watershed (J. Linth, Washington Department of Fish and Wildlife; Table 1). Since this time, the four long-term Chum index reaches have been surveyed annually by WDFW, including one index reach in the Humptulips sub-basin and three index reaches in the Satsop sub-basin. Stevens Creek from river mile (RM) 4.5 to 6.2 (Humptulips sub-basin) is a medium-sized tributary located four river miles upstream of Humptulips hatchery. The three Satsop index reaches are small slough and side-channel areas. Creamer Slough and Schafer Slough are located near each other on the East Fork (EF) Satsop River. Due to channel migration over time, the original Schafer Slough is now a section of the EF Satsop River proper and is 0.4 RM in length. River migration also changed the location of Creamer Slough by creating a small, separate channel of water that extends from Creamer Slough to the EF Satsop River. This channel connecting to the EF Satsop River is currently surveyed as a supplemental survey while the original reach has remained 0.3 RM in length. Maple Glen is located on Decker Creek near RM 1.1 and is 0.3 RM in length.

Table 1. Fish densities and abundance of Grays Harbor Fall Chum in each of the four long-term index reaches that correspond to a population abundance (escapement goal) of 21,000 Chum. Fish per mile is the count of live and dead fish during peak spawning.

Survey Reach	Sub-basin	'Goal' Fish/Mile	Reach Length	'Goal' Abundance	% Population
Stevens Creek	Humptulips	647	1.7	1,100	5.24%
Creamer Slough	Satsop	1,950	0.3	585	2.79%
Maple Glen	Satsop	1,050	0.3	315	1.50%
Schafer Slough	Satsop	888	0.4	266	1.27%

The current method for estimating Chum spawner abundance relates counts of live and dead fish during peak spawning in the four index reaches with the "goal fish per mile" in these reaches. On an annual basis, the abundance of Grays Harbor chum salmon is based on the ratio of fish counts per mile to the "goal fish per mile" in the four index reaches applied to the spawning escapement goal of 21,000 spawners (e.g., ratio greater than one will result in total spawner escapement greater than 21,000). This method assumes that the index reaches comprise 10.8% of the total spawning population. The "goal fish per mile" was derived from counts in a year when Chum spawner escapement was assumed to be 21,000 spawners (escapement goal for the population). Unfortunately, the methodology used to derive the 21,000 spawners was not retained and the basis of this number as the escapement goal was not documented. The current methodology includes a number of assumptions that require additional validation or are known to be violated in some cases:

- **Assumption 1: The proportion of spawners in the long-term index reaches versus the entire population was accurately determined at the time they were derived.** This assumption cannot be evaluated because the data used to derive these proportions are not currently available.
- **Assumption 2: The proportion of spawning that occurs in the long-term index reaches was developed from an accurate (unbiased) estimate of spawner abundance at the watershed scale.** The expansion of peak live and dead counts in the index reaches to a population estimate of abundance relies on an accurate estimate of population abundance. Detailed methods used to arrive at a spawner abundance of 21,000 Chum associated with peak counts ("goal fish per mile") in the index reaches are not available but are unlikely to have been obtained using an unbiased study design. Regional WDFW staff indicated that this number was likely qualitative and based on the assumption that the watershed had met its escapement goal of 21,000 Chum in the year(s) that the "goal fish per mile" was established for the index reach. The escapement goal for the watershed itself is "based on a relationship between Grays Harbor and Willapa Bay production as measured by long-term catch data. This relationship was applied to the escapement goal for Willapa Bay streams." (Rick Brix, WDF memo, circa 1978 or 1979).
- **Assumption 3: Spawner distribution has not changed over time such that a constant proportion of Chum salmon spawn in the long-term index reaches relative to the entire watershed** (Table 1). There are many reasons to suspect that spawner distribution would change over a 40-year time frame. On an annual basis, fall stream flows influence fish access to many of the off channel spawning areas resulting in variable access to spawning habitat on an annual basis. Furthermore, river processes result in channel creation and abandonment that change the available patches of spawning habitat over time (I.J. Schlosser 1991; Anderson et al 2006). Local habitat conditions are also modified by natural processes such as beaver activity, as well as anthropogenic influences on the landscape. All of these local disturbances are known to occur across the landscape encompassing Chum distribution. For example, the surveyed length of the

Stevens Creek index reach (in the Humptulips basin) differed between the 1980s survey and the current reach making the fish per mile information inconsistent with earlier calculations.

- **Assumption 4: The quality of spawning habitat in the long-term index reaches and the connectivity of these reaches to the main stem river has not changed over time.** Substantial habitat changes are known to have occurred over time in the three index reaches in the Satsop sub-basin. "Creamer Slough" is a manufactured spawning channel that is no longer maintained and has experienced degradation of spawning habitat over time. The slough channel itself has changed over the years as the EF Satsop River channel has migrated. There is now a section called "Creamer Slough A" that joins the EF Satsop River to "Creamer Slough". During low flow conditions, a gravel lens near the mouth can restrict fish access. "Maple Glen" is a spring-fed channel; the main channel of Decker Creek shifted thus creating a back water channel upstream to Maple Glen with beaver dam blockages along its length. WDFW must actively maintain this channel by permitted deterrence of beaver activity, but access is especially limited in low water years. Even when adult spawners access the channel, the habitat has degraded over time with increasing abundance of silt that likely interferes with the egg incubation and fry emergence. "Schafer Side-channel" was a WDFW engineered Chum spawning channel, created in 1980, that has not existed in its original form since the EF Satsop River began flowing through the side-channel in 1995. Although Chum continue to spawn in this reach, the available spawning habitat has changed dramatically.

The Grays Harbor Fall Chum project was initiated in 2015 with funding from the Washington State legislature associated with the Chehalis Basin Strategy. A pilot study in 2015 established the survey frame and identified reaches with high densities of Chum spawners that could be used for further study (Ashcraft et al. 2017). Continued work in 2016 developed updated methods to estimate Chum spawner abundance and implemented these methods in the Wynoochee and Satsop sub-basins. The updated methodology incorporated data collected from established index reaches set up for Chum estimation and for Coho and Chinook estimation (where Chum data were also collected).

Results from 2016 suggested that the existing methodology may underestimate the true abundance of Grays Harbor Chum salmon. In 2016, we estimated a Chum spawner abundance of approximately 55,000 to 56,000 fish for the Satsop sub-basin and a portion of the Wynoochee sub-basin. Our 2016 estimate in these sub-basins only was nearly equivalent to the number of spawners estimated for the entire Grays Harbor basin using the existing methodology (n = 62,800). However, further confirmation of this conclusion was needed as the 2016 implementation of the updated methodology had several inconsistencies and uncertainties. After completing the analysis and final report for the 2016 return, we decided to return to the Wynoochee and Satsop sub-basins for the 2017 fall salmon season to re-implement the updated methodology and address specific uncertainties with the 2016 estimates. Areas for improvement that included:

1. Develop and implement a consistent sub-sampling strategy when field crews encounter high numbers of carcasses that cannot be sampled and tagged in their entirety within the available daylight hours. When sampling and tagging of all carcasses is not feasible, representative sub-sampling will ensure that unbiased estimates of abundance can be obtained.
2. Increase the coverage of potential spawning habitat surveyed during peak spawn period. Improved information of Chum spawning distribution is especially needed in the mainstem sections of each sub-basin in order to more accurately reflect Chum spawning distribution inside and outside the index reaches.
3. Collect live count data in a consistent manner across all field teams surveying AUC and CMR index reaches. Live counts should be split between 'spawners' and 'holders' as several of the

analysis steps are potentially sensitive to this distinction and this sensitivity needs to be understood with respect to applying the updated methodology to historical data.

Objectives

The overall goals of the Grays Harbor Fall Chum project are to improve estimates of spawner abundance and describe the distribution of Chum in the Grays Harbor basin. The overall objectives are to:

- Derive unbiased Chum spawner abundance estimates in the Grays Harbor sub-basins that include a measure of precision,
- Determine the distribution of Chum spawning within Grays Harbor sub-basins including upper and lower extent of their spawning distribution,
- Derive parameters (e.g., survey residence time, index area expansions) needed to update estimates from historically collected count data, and
- Provide an updated methodology that can be implemented in future years.

The objectives for the **2017 field survey season** were to:

- Implement study design in Wynoochee and Satsop sub-basins of the Grays Harbor Chum salmon population,
- Update the survey frame for each sub-basin, Wynoochee and Satsop, and document the upper limit of occurrence (ULO) of spawning and potential barriers to Chum,
- Conduct surveys throughout the entire survey frame in each sub-basin during the peak spawn time and collect count data on live and dead Chum inside and outside index reaches,
- Conduct surveys on a weekly basis within established (AUC) index reaches for Chinook, Chum, and Coho and collect count data on live and dead Chum salmon, and
- Implement live counts and carcass mark-recapture study concurrently on a weekly basis within additional (CMR) index reaches selected in each sub-basin.

Methods

Study Design

The study design included index and supplemental reaches (Table 2). Index reaches were surveyed every week starting in October through December. Supplemental reaches were surveyed once during the peak spawn time in each sub-basin. Index reaches were divided into area-under-the-curve (AUC) and carcass-mark-recapture (CMR) indexes. Data collected in AUC index reaches included live counts Chum salmon whereas data collected in CMR index reaches included live counts and carcass tagging. We estimated the abundance of Chum in index reaches and expanded this estimate to the total spawning population using peak count ratios in the index versus supplemental reaches. Trap counts from the Satsop sub-basin were added to result in a final Chum abundance estimate.

Table 2. Surveys conducted for Chum salmon in the Wynoochee and Satsop rivers, 2017.

Survey	Type	Frequency	Count Data	Biological Data
AUC (AUC only)	Index	Weekly (Oct – Dec)	Lives, Carcasses	Sex, Scales
CMR (AUC and Carcass Mark-Recapture)	Index	Weekly (Oct – Dec)	Lives, Carcasses, Carcass Tag Recaptures	Sex, Length
Peak Count	Supplemental	Once (early to mid-Nov)	Lives, Carcasses	---
Trap – 100% capture trap	Weir Count	Daily or Weekly (Oct – Dec)	Lives	---

Study Area

The study was conducted on the Wynoochee and Satsop main stems and their tributaries. Both of these rivers are right bank tributaries to the Chehalis River with headwaters in the Olympic mountains. The Wynoochee River enters the Chehalis main stem at RM 13.0, and the Satsop River enters the Chehalis main stem at RM 20.2 and is located east and upriver from the Wynoochee River.

The Wynoochee River has a drainage area of 218 square miles with a main stem over 60 miles long. The Wynoochee Dam is located at RM 49.9 and regulates the flow for the Wynoochee River. The dam was built in 1972 for flood control, industrial water storage, and water irrigation, and in 1994 Tacoma Power added a hydroelectric powerhouse. The reservoir (Wynoochee Lake) created by the dam is 4.4 miles long and has a drainage area of 41.0 square miles. A fish trap located at RM 47.9 operated by Tacoma Power transports Chinook, Coho, and winter-run Steelhead above the trap and above Wynoochee Lake. No Chum have been captured at this facility indicating current Chum distribution is entirely below the dam location. From its mouth to about RM 21.0, the Wynoochee River is surrounded by mostly privately owned land (i.e., farms, forest, residential) with some public access points. From RM 21.0 to 45.0 the river is primarily surrounded by privately owned timber farms, with WDFW game fields and private property interspersed. Between RM 39.5 and 42.9 the river is confined to a gorge with high flow velocities and drop chutes. From RM 45.0 upstream there is a combination of privately owned timber farms and national forest lands. There is no Chum hatchery program in the Wynoochee basin.

The Satsop River has a watershed drainage area of 291 square miles and comprised of three main forks: West Fork (WF) Satsop River, Middle Fork (MF) Satsop River, and East Fork (EF) Satsop. The WF Satsop River and MF Satsop River are rain fed watersheds, while the EF Satsop River is a spring fed watershed. The lower Satsop River is surrounded by private property mostly consisting of farmland. At RM 6.3, the Satsop River splits into the WF Satsop River and EF Satsop River. The mainstem of the WF Satsop River is 41.3 RM long and mostly surrounded by privately owned tree farms. The MF Satsop River joins the EF Satsop River at RM 11.0, is 32.0 RM long, and mostly surrounded by privately owned tree farms. The EF Satsop River extends northeast from the confluence of the WF Satsop and is 28.6 RM long.

There are two hatchery facilities (both release Chum) located on the EF Satsop River: Satsop Springs Hatchery (SSH) is operated by the Chehalis Basin Task Force (at RM 14.7) and Bingham Creek Hatchery (BCH), operated by WDFW (at RM 17.5). An average of 200,000 Chum were released on an annual basis from each facility over the past ten years (Table 3). These two hatcheries have been working together for the past eight years; BCH started releasing Chum in 2008. Chum broodstock are collected at the SSH spawning channel or by hook and line methods within the EF Satsop River. They are spawned and the fertilized eggs are transported, incubated and raised at BCH. Once they are of size, the fry are split between hatcheries and released. Hatchery Chum fry are not marked to distinguish from wild Chum as their small size at release is not suitable for external marking.

There are passage barriers with associated adult fish traps in the EF Satsop River area: one is a barrier dam located at RM 17.5 on the EF Satsop River and one is a weir located at RM 0.9 on Bingham Creek. The barrier dam with fish ladder on the EF Satsop River is located at BCH and used to capture returning salmonids. WDFW operates a creek spanning weir and adult fish trap located on Bingham Creek, which is used for a life cycle monitoring study of wild Coho and Steelhead. Both facilities pass all captured Chum upstream, along with all other wild salmonids. The EF Satsop River is surrounded by privately owned tree farms above BCH, and private and public property below BCH.

Table 3. Number of hatchery Chum released from Bingham Creek Hatchery (BCH) and Satsop Springs Hatchery (SSH) in the Satsop sub-basin, 2007-2018. Numbers were obtained from the Regional Mark Information System (http://www.rmpc.org/)

	Number of hatchery Chum released at each facility		
Release Year	**BCH**	**SSH**	**Total[a]**
2007	0	198,300	198,300
2008	0	197,800	197,800
2009	130,100	0	130,100
2010	193,800	325,000	518,800
2011	188,700	338,400	527,100
2012	198,100	0	198,100
2013	203,800	201,800	405,600
2014	128,700	200,000	328,700
2015	197,700	136,700	334,400
2016	181,500	152,000	333,500
2017	210,200	214,700	424,900
2018	194,400	155,900	350,300
Average	**182,700**	**211,767**	**311,075**

[a] Total = BCH + SSH

Survey Frame

The survey frame included the entire known distribution of Chum within each sub-basin (Table 2). Information used to generate the survey frame included a pilot study in 2015 which identified areas of high Chum spawning densities, local knowledge of WDFW Fish Management District 17 and the Quinault Division of Natural Resources (QDNR) staff, WDFW SalmonScape (http://apps.wdfw.wa.gov/salmonscape/map.html) , and the WRIA stream catalog salmon use classification (Phinney and Bucknell 1975). Where no other information was available, we relied on results of a WDFW assessment of Chum spawning habitat conducted in the late 1970's (WDFW unpublished data). Based on this information, a survey frame for this study was established in 2016 (Ashcraft et al. 2017) and continued for the 2017 surveys.

The survey frame was divided into foot and boat strata based on the way in which surveyors could access the river. Foot strata were determined by the ability of a surveyor to survey most to all of the stream by foot. The surveyor might have had to avoid a few deep pools, or survey from the bank for a portion of the reach, but for the most part was able to walk the reach wearing chest waders. Reaches that were too large and unsafe to walk were surveyed as boat strata. Boat strata were determined by the need to float the reach due to numerous deep pools or channels with spawning riffles throughout the reach. If the reach was too wide, two pontoons/rafts were used to survey side by side so that the entire width of the reach was surveyed.

Selection of Index Reaches

Index reaches were surveyed using either the Area-Under-the-Curve (AUC) and/or the Carcass-Mark-Recapture (CMR) methods. Details of each method are provided in sections below.

There were a total of 29 planned AUC index reaches in 2017, although five were dropped from analysis due to low or inconsistent time series of spawner counts (data from these reaches were included as peak counts only, see Results). Surveys of the AUC index reaches were conducted by WDFW District 17 Fish Management Staff (WDFW D17 FMS) as part of their annual stock monitoring program in the Chehalis River basin. AUC index reaches were the long-term ‘Chum’ index reaches on the Satsop River (Creamer Slough, Maple Glen, Schafer Slough) and long-term ‘Chinook and Coho’ index reaches on both the Satsop and Wynoochee rivers (Appendix A-1). These indexes were included in this study because they will allow information gained on Chum to be applied to historical data from these reaches. An additional four AUC reaches were added to the list of established reaches and surveyed by WDFW Chum Project staff in 2017 (Appendix A-1). These additional four reaches were identified to have high densities of Chum spawners in the 2016 survey year (Ashcraft et al. 2017).

There were a total of nine planned CMR index reaches in 2017, although two were dropped from the analysis (included as AUC reaches only) due to low carcass recoveries (see Results). Surveys in the CMR index reaches were conducted by WDFW Chum Project staff. CMR reaches were selected based on past knowledge of Chum abundance within the study areas (long-term salmon reaches surveyed by QDNR and WDFW, 2015 pilot study, WRIA catalog salmon use classification, SalmonScape distribution, and WDFW 1980’s Chum habitat assessment). CMR index reaches were of variable stream size (Appendix A-2) and were known to have Chum spawner numbers that exceeded several hundred fish to ensure there would be enough carcasses for the CMR methodology. The top and bottom of the reach were chosen as points where there was unlikely to be spawning activity in order to help reduce movement of carcasses into and out of the CMR reach. For instance, we looked for reaches with little spawning habitat directly above and below the top and bottom extent of the reach.

Data Collection

Habitat Characteristics of Index Reaches

Habitat metrics were collected from each index reach (CMR, AUC) in mid-September to early October. In 2016, habitat data were collected in CMR indexes only and the information was expanded to CMR and AUC index reaches in 2017. The purpose of the habitat data was to provide information on environmental covariates that may be associated with survey life. ‘Survey life’ parameter (described in the section below) was a critical parameter in the final estimation of Chum abundance that may differ by stream size because variables such as stream flow, predator access, and visibility are likely to differ between smaller and larger stream channels.

Habitat metrics for all CMR and AUC indexes included average bankfull width (BFW) and average wetted width (WW). Additional habitat data in CMR index reaches included average thalweg depth (TD), maximum depth (MD) and residual depth (RD). Bankfull width (BFW) is the width of the dominant channel formed by a recurring flow. Thalweg depth (TD) is the deepest part of the river channel. The maximum depth (MD) was measured at the deepest point in the reach. Residual depth

(RD), a depth measure independent of flow, was calculated at each pool by subtracting the pool tail depth from the max pool depth.

Habitat measurements were made in 10 habitat units equally spaced downstream from the top point of the index. Measurements were equally spaced along a section of the index reach that was 20 times the length of the mean channel width (MCW) at the top of the index reach. The MCW selected for spacing was calculated from the average of three MCWs at the top of the index reach. Surveyors measured the wetted channel width at the top of the index reach again after walking upstream and downstream a distance equivalent to the first wetted channel width measurement. In some cases, the entire survey reach was too short to divide into 10 habitat units for measurement. In these cases, measurements were obtained from at least three locations in the reaches under 0.3 RM (e.g. side-channels).

Each index reach was assigned a size classification (side-channel, small, medium, large) based on proximity to the mainstem channel and BFW measures. 'Side-channels' were the smallest classification with a BFW of 8 meters or less that were located off of a main stem river and thought to be breached during high water events in the fall. 'Small' index reaches had BFW between 8 and 15 meters and were generally secondary or tertiary tributaries. 'Medium' index reaches had BFW of 15 to 20 meters and were directly connected to the mainstem. 'Large' index reaches had BFW of 60 m or greater and were mainstem river sections.

General Survey Methods

Surveyors were equipped with all necessary gear to safely conduct surveys and to ensure accurate counts, including polarized glasses and a brimmed hat to eliminate glare and increase in-stream visibility. Environmental data collected during each survey included water clarity, stream flow, riffle and pool visibility, direction surveyed, and weather. Water clarity was visually estimated as depth in feet the surveyor could see in the water column at the deepest point in the survey reach. Stream flow was recorded based on a qualitative 1 to 5 scale, where 1 indicates low flow/height and 5 indicates high flow/height for the reach. Riffle and pool visibility are separate, subjective measurements to indicate how well a fish could be seen spawning on a riffle/pool on a qualitative 1-5 scale, where 1 is excellent visibility and 5 is poor visibility for the reach. The direction being surveyed was either upstream or downstream. All boat strata were surveyed downstream. Most foot strata (86%) were also surveyed downstream; foot strata surveyed upstream were because of available access points or to determine upper extent/limit for distribution. The weather conditions were recorded as sunny/clear, cloudy/overcast, rain, or snow to indicate potential environmental factors impacting surveys.

Surveyors were trained to accurately identify live and dead Chum, Chinook, Coho, and Steelhead which are holding and/or spawning during the same period with the same streams. Chum spawning is observed from the mid-October to mid-December based on QDNR and WDFW long-term surveyed reaches. Spawning Chum are identified by their olive green coloration with unique calico coloration (vertical bars along sides), white tips on the ventral and anal fins, the head shape of the males (large heads with large jaws), large canine-like teeth, no spotting on dorsal or tail, and narrow caudal peduncle. Females and some males can display a horizontal black stripe instead of the vertical bars. Chum are typically smaller than Chinook and larger than Coho. Chum holding in pools with Chinook and Coho can be identified by their darker coloration, but are hard to enumerate depending on the number of individuals in the pool. The surveyor made an estimate of the total number of Chum based on his/her observation of the activity in the pool. Redds were not used for the CMR analysis but were counted and tracked within the AUC reaches when possible.

Area-Under-the-Curve (AUC) Index Reaches

The purpose of the AUC index reaches was to obtain an estimate of fish-days for the selected AUC index reaches. The AUC method involved counts of live and dead Chum obtained in each AUC index reach between mid-October and early December. Surveys were conducted on a weekly basis unless weather conditions and/or stream flows made surveys impossible due to lack of visibility or safety concerns. Zero counts were obtained at the beginning and end of the data series. Live Chum were categorized as either holders or spawners. Holders were defined as fish that were not displaying spawning behavior, i.e., fish moving upstream, holding in pools. Spawners were defined as fish that were displaying spawning behavior on/near riffle areas, i.e. pairing up, actively digging. Several conversations between crew lead staff occurred before and during the beginning of the Chum spawning season to ensure spawner/holder classification was ubiquitous across all WDFW Chum Project and WDFW D17 FMS surveyors.

Biological sampling of Chum carcasses was conducted in a portion of the AUC index reaches (Table 2). The first twenty carcasses of each one hundred carcasses encountered were sampled once: the species was determined, the caudal/tail section was intact (not previously sampled), and had scales available for collection. If the carcass could not be identified by species, it was recorded as species not determined (SPND) and not sampled. If the carcass was identified as a Chum and the caudal/tail region was missing, the carcass was not sampled, and recorded as did not sample. If the carcass was identified as Chum and it had a cut tail, it was recorded as a dead Chum previously mark sampled. Sport-caught Chum that were left along the bank were not included in the dead count or biological samples.

Biological sampling included species identification, sex, length, and scales. Once biological sampling was complete, the tail was cut to identify that the carcass had been sampled. Further sampling (beyond 40/200) was conducted as time allowed. Therefore at least 40 Chum carcasses were sampled in reaches with more than 200 carcasses. Two scales were collected from the area posterior to the dorsal fin, anterior to the anal fin and above the lateral line, defined as the 'preferred area' by the WDFW Scale Aging Lab. Scales were mounted on adhesive scale cards with a unique identifier for each fish that was also written on the field data card. Age of each fish was determined by the WDFW Scale Ageing Lab.

Carcass Mark-Recapture (CMR) Index Reaches

The purpose of the CMR index reaches was to obtain simultaneous and independent estimates of fish-days and spawner abundance in order to derive estimates of survey life. Additional information on survey life calculations is provided in a later section of this report (see analytical methods). Live counts provided the estimate of fish-days and carcass mark-recapture provided the estimate of spawner abundance.

Similar to surveys in the AUC only index reaches, surveys in the CMR index reaches were conducted from mid-October through mid-December on a weekly basis unless weather conditions and/or stream flows made the survey impossible due to lack of visibility or safety concerns. Surveys began in October before Chum entered the study area (based on prior knowledge of the basin) and continued through mid to late December until no live Chum or taggable carcasses were observed for two consecutive weeks after the peak spawning period. Live and dead Chum were counted during each survey. Live Chum were categorized as holders or spawners, following the same method as used in the protocol outlined for AUC only index reaches.

Data collection in CMR indexes also included carcass condition as well as carcasses that were tagged and 'released', and tagged carcasses that were recaptured from a previous week. Carcass condition was assigned on a scale of 1 to 5 (Table 4). All Chum carcasses with an intact tail were counted and examined for a carcass tag by lifting each operculum to determine whether a plastic tag was stapled to the inside. Previous tag status was recorded for operculum on both sides of the carcasses (one for each operculum). Previous tag status was recorded as the tag number, not present (if the operculum was present but no tag), or unknown (if the operculum area was missing). If a carcass was not able to be examined due to its location in the channel (e.g., deep pool, pinned to a log jam in fast flows), then it was counted as an unknown species with unknown tail status, and was not included in the total counts of dead Chum. Chum carcasses with a cut tail were not included in the dead count, because they were counted previously.

Previously tagged carcasses were recorded as recaptures, their condition was scored, and their tails were cut to indicate whether they had been previously sampled. Untagged (maiden) carcasses were assigned as being in taggable or untaggable condition. Taggable condition meant that the carcass scored a 1, 2, or 3 on the qualitative scale (Table 4) and had both operculum attached. 'Untaggable' condition meant that the maiden carcass scored a 4 or 5 on the qualitative condition scale or was missing one of the two operculum.

Carcasses considered to be taggable has a square plastic tag with a four-digit number was stapled under the operculum on both sides of the fish. Each carcass had two tags (same number) and the placement of these tags under each operculum was not visible when looking at the carcass from a distance. Ensuring carcass tags were not visible helped reduce survey bias by necessitating each carcass was examined, and surveyors did not merely look for visibly tagged Chum. Surveyors measured the fork length in centimeters and designated sex as male, female or undetermined for each tagged carcass, then returned the carcass to the stream from where they were collected with their tails intact.

Carcasses considered untaggable (i.e., had one or both of the operculum missing, or had a carcasses condition of 4 or 5), were counted and assigned as male, female or unknown. Tails were cut prior to returning them to the stream to indicate that the fish had been investigated and counted.

A tagging rate was established for each CMR index reach to ensure survey completion during daylight hours. The tagging rate was selected at the beginning of the survey by the field lead based on the predicted number of carcass encounters and varied from week to week depending on carcass densities. When selecting a carcass tagging rate the field lead attempted to select a rate that could be maintained throughout the entirety of the survey and would maximize the number of fish to be tagged while completing the survey within daylight hours of a single day. The tagging rate (ex: 1 in 5 or 1 in 10) also ensured even distribution of tags throughout the survey. In the rare case where a survey could not be completed within one day, surveyors hung a flag at the stopping point and returned to the designated stopping point in order to complete the survey the following day.

Table 4. Criteria for assigning carcass condition of Chum in the CMR index reaches.

Condition	Criteria
1[a]	Fresh, Clear eyes, Red gills
2[a]	Clear eyes, Firm flesh, White gills
3[a]	Cloudy eyes, Flesh starting to soften
4	Cloudy eyes, Flesh soft, Falling apart
5[b]	Partial carcass, Skeleton

[a] Indicates taggable criteria. Both operculum needed to be present in order to tag the carcass. If one or both were not present, then the carcass did not get tagged and operculum status was recorded on the field card.
[b] Only counted if the carcass could be identified as a Chum.

Trap Returns

Chum are encountered at two fish traps located within the Satsop sub-basin, one located on Bingham Creek and the other on the EF Satsop River. All Chum encountered at the Bingham Creek trap are enumerated and passed upstream to spawn, while Chum encountered at BCH are either lethally spawned or passed upstream. The Chum passed upstream are included in the total spawning population by adding the total number passed upstream to the final escapement estimate.

The Bingham Creek trap at RM 0.9 has been in operation since 1982 and is used primarily for sampling adult Coho in the fall and the barrier portion is equipped with a downstream smolt trap during the spring months. The trap is operational year-round targeting Coho and Steelhead, but also encounters

Cutthroat, Chinook, and Chum. Most wild fish (i.e., intact adipose fins) are placed upstream of the trap, except for some cases to retrieve coded-wire tags from wild Coho. The trap is monitored for adults moving upstream and is operated as the fish come into the system. The trap is checked daily during the fall. Each fish is netted individually, Chum are enumerated and the sex is determined for each individual before it is placed upstream. The only time the trap is not in operation is if there is a malfunction (usually occurs during high flow events). In this case, the trap is closed and not opened again until the trap is running properly. Chum passed upstream of the Bingham Creek trap were not monitored for fall back (Chum were not marked so fall back could not be determined). Fall back over the dam could be flow dependent with higher flows pushing more fish back over the dam. For Coho (operculum punched when put upstream) fall back is very low (3 fallbacks out of 641 put upstream in 2016). Chum could potentially have greater fall back than Coho as Coho are much stronger swimmers and could be in better condition this far upstream than Chum.

The BCH trap is located on the EF Satsop River just upstream from the confluence of the EF Satsop River and Bingham Creek. The dam built at BCH on the EF Satsop River is approximately two and half meters tall and constitutes a complete barrier to Chum migration. To continue upstream all Chum must enter the fish ladder to the holding ponds. During the peak of the season the holding pond is sorted weekly. The Chum not removed for brood stock are enumerated and passed through an outlet pipe approximately 10 meters upstream of the barrier. The close proximity of the release tube to the barrier results in a fallback rate of approximately 5.3%. This rate was determined from a live mark-recapture study done in 2016 where live Chum collected and tagged at BCH, then recovered as carcasses on the spawning grounds. (Ashcraft et al. 2017). The total number of Chum received from BCH and included in the escapement estimate is not adjusted to compensate for fallback.

Peak Counts

The purpose of the peak counts in index and supplemental reaches was to determine the proportion of Chum spawning that occurred inside versus outside index reaches (Appendix A-2 and A-3). Surveys were conducted simultaneously in supplemental and index reaches during peak spawn time, providing a continuous view of spawning activity.

During each survey, live and dead Chum were tallied by reach and live Chum were categorized as holders or spawners using the same protocol as the AUC and carcass mark-recapture reaches. No additional biological sampling was conducted in supplemental reaches. Supplemental and index reaches provided a continuous view of spawning activity during peak spawn time when the surveys were conducted simultaneously. Reaches within the 'foot strata' survey type were surveyed by foot and reaches within the 'boat strata' survey type were surveyed by pontoon or raft. The reach breaks between index and supplemental reaches along each tributary and along the main stem rivers were indicated with bright pink flagging with black dots at top and bottom of reach.

Each supplemental reach was surveyed once during peak spawn time. To ensure consistency in data collection while accommodating for limited staff resources, peak counts were completed within a week time period within each survey type and sub-basin combination (e.g., peak counts in the Wynoochee foot strata were completed within one week). However, the weekly time periods for peak counts differed among survey type and sub-basin combinations (e.g., peak counts in the Wynoochee foot strata occurred on a different week than the Satsop foot strata). Ideally these surveys would be conducted during peak spawning to maximize the number of fish used in the calculations but surveys just prior to or after peak spawn timing were considered adequate if surveys needed to be adjusted based on river conditions. The peak spawn week was selected in advance using previous knowledge of the sub-basin available from the study completed in 2016 and WDFW D17 FMS and QDNR staff. Peak counts of live Chum in historical indexes reaches from the 1ast 10 years were observed on November 4th (statistical week 45) for the Wynoochee River and on November 12th (statistical week 46-47) for the Satsop River. Advance preparation was also made to partition the supplemental areas into reaches that could be completed as daily surveys and to secure stream access permissions from landowners to enter these areas. Volunteers from the WDFW D17 FMS were recruited ahead of time to ensure enough surveyors were available to cover each sub-basin.

Streams within the survey frame were prioritized at the beginning of the 2017 field season in anticipation of time constraints due to stream flows and high survey mileages associated with the peak counts. During the 2017 planning stages, streams with known Chum presence in 2015 and 2016 were given high priority for survey in 2017. Additional streams with a potential Chum presence were identified based on the WRIA catalog and scouting. These streams were designated medium or low priority for survey during the peak count week. If time allowed during the supplemental survey time frame, surveys were conducted in these additional tributaries.

Upper Limit of Occurrence

Supplemental surveys also provided field-based information on the upper limit of occurrence (ULO) of Chum spawning within tributaries of each sub-basin during the survey season. This information is vital to refining the survey frame used in the Chum project as well as the Chehalis Basin Upper Extent Project. The Chehalis Basin Upper Extent project is a basin-wide project focusing on the ULO of Chum, coho and steelhead with the goal of developing an empirical predictive model of Chum, coho and steelhead distribution in the Chehalis basin (E. Walther, WDFW, personal communication). Prior to the Chum spawning season, biologists from each project established a protocol for supplemental surveys that would satisfy the data needs of both projects.

An ULO was determined for each supplemental reach that had Chum present and recorded using a hand-held GPS unit. When possible, streams were surveyed on foot starting at the mouth, or the lowest known Chum presence, and walking upstream. In the case where boats were necessary, surveys were started several RM upstream of suspected Chum presence. Surveys continued until one of the four criteria were met.

1) Walked 1 km without any Chum presence
2) Encountered a permanent barrier of 1.5m in height
3) Stream increases to a slope of 15%
4) Stream loses flow and goes sub-surface at the time of peak spawning

Permanent barriers were primarily falls or cascades, and did not include beaver dams, log jams, landslides or culverts. The later are considered transient barriers since these can vary from year-to-year or are caused by anthropogenic influence. The height of the barrier is measured from the top of the water in the pool at the base to the top of the falls or cascade. Limiting stream gradient and barrier height are based on assumed Chum swimming and jumping ability (Powers and Osborne 1985, Resier et al. 2006). Chum presence was determined by identification of live or dead Chum within the stream, not redd identification.

All live and dead Chum were enumerated during the survey. Redds and the presence of Chinook, coho and steelhead were recorded based on the surveyor’s confidence in identification. Georeferenced locations included the beginning and end of each survey, the first and last Chum spotted and at any possible permanent or transient barriers. A description of the approximate barrier height and length was included and pictures taken if possible.

Data Management

Field data cards were completed in the field, and collected and regularly reviewed in-season by the project biologist. Cards were examined for any errors or missing information that was not recorded. Missing information was immediately addressed with the field staff. Georeferenced locations for each reach start and stop were added to this database as well. Data were summarized and entered into the

WDFW SGS database. The SGS database held a subset of the information collected for this study. Therefore, the complete set of biological and carcass tagging data were entered into the District 17 Chum database in Microsoft Access 2010. Once all information was entered electronically the data cards were collected for the entire survey year were archived at the WDFW Region 6 office. Chum carcass survey data (biological sampling) were entered into the District 17 Biological Sampling database. Once entered, scale cards were copied, originals delivered to the WDFW Scale Ageing Lab to be aged, and final ages were entered into the District 17 Biological Sampling database.

Analysis

Biological Sampling

Biological characteristics of Chum were summarized for all collected information including number of carcasses, sex composition, fork length and age composition.

Chum Distribution

Chum spawning distribution was summarized in two formats – 1. ULOs were displayed by reach type (AUC, CMR, Supplemental) and by strata (foot, boat), and 2. Chum densities (fish per mile) displayed for all surveyed reaches (index, supplemental) during the peak spawning week.

In addition, the proportion of spawning that occurred within the index reaches was calculated based on data collected during the peak spawning week when both index and supplemental reaches were surveyed. The proportion of spawning in the index reaches was calculated from live counts (holders, spawners) in all index reaches divided by live counts summed across all reaches (index, supplemental). The estimated proportion assumed a binomial variance:

(1) $n_i \sim binomial(p_i, N)$

where n_i is the sum of live counts summed across all index reaches (i), p_i is the proportion of spawning in the index reaches, and N is the sum of live counts summed across all index and supplemental reaches. The value of p_i was calculated separately for each sub-basin and strata (foot, boat).

Area-Under-the-Curve Calculations

Counts of live Chum were used to estimate area-under-the curve in the AUC and CMR index reaches. Area-under-the-curve was estimated in ‘fish-day’ units based on live counts and the number of days over which the live counts occurred. Data were organized by statistical week ensuring that a zero count occurred at the beginning and end of the time series and fish-days were calculated as (English et al 1992; Bue et al. 1998):

(2) $AUC = 0.5 * \sum_1^n (t_d - t_{d-1}) * (p_d - p_{d-1})$

where $t_d - t_{d-1}$ is the number of days between surveys, p_d is the number of live Chum observed on a given survey date, and p_{d-1} is the number of live Chum observed in the previous survey. Under this method, no fish are observed on the first (d = 1) or last survey (d = n). For most datasets, the count on the first and last survey week was zero; however, in the few cases where non-zero counts occurred at the beginning or end of the dataset, a zero count was added the week prior to the first surveyed week or after the last recorded survey for the purpose of calculation. Area-under-the curve was estimated for total live counts (holders, spawners) and for live counts of spawners only.

Spawner Abundance in CMR Index Reaches

Carcass tagging data were used to estimate spawner abundance in CMR index reaches. The carcass tagging data were analyzed with a Jolly-Seber (JS) estimator. The JS estimator is an open population mark-recapture model used to estimate abundance in situations where individuals immigrate and emigrate from the population over the course of study (Seber 1982; Pollock et al. 1990). The JS model has been successfully applied to mark-recapture data of live fish and carcasses in other salmon populations (McIssac 1977; Sykes and Botsford 1986; Schwarz et al. 1993, Bentley et al. 2018). When the estimator assumptions are met, the JS model produces an unbiased estimate of abundance with known precision.

The JS estimator of spawner abundance estimate for each reach was based on the "super population" model (Schwarz et al. 1993) which was parameterized in a Bayesian framework. A conceptual schematic of the JS model is shown in Figure 1. A comprehensive description of this JS model, including summary statistics, fundamental parameters, derived parameters, and likelihoods can be found in Rawding et al. (2014) and Bentley et al. (2018). In this model, spawner escapement is the sum of gross births (i.e., arrival of new carcasses) that enter the system over the study period and includes the estimated number of carcasses present during each sampling period and the carcasses estimated to have entered the system after one sampling period and removed from the system prior to the next sampling period.

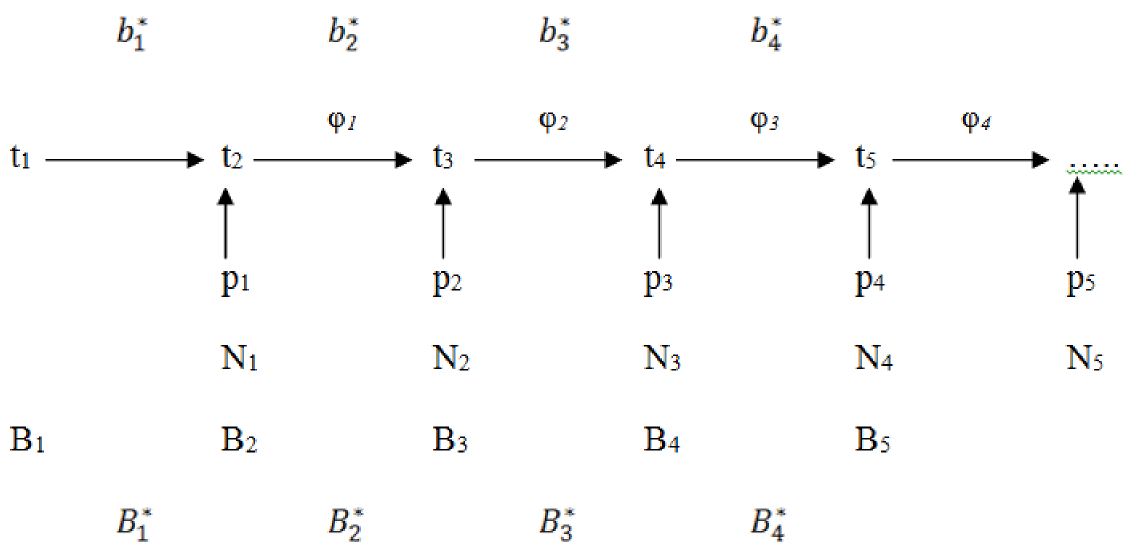

Figure 1. WinBUGS schematic for Jolly-Seber abundance estimation developed by D. Rawding (WDFW). Parameters include sample period (t_i), probability of capture at sample period *i* ($\boldsymbol{p_i}$), probability that a fish enters the population between sample period *i* and *i* +1 ($\boldsymbol{b_i^*}$), probability that a fish alive at sample period *i* will survive and remain in the population between sample time i and sample time i + 1 (φ_i), population size at sample period i (N_i), number of fish that enter after sample time *i* and survive to sample time *i* +1 (B_i), and the number of fish that enter between sampling occasion *i-1* and *i* ($\boldsymbol{B_i^*}$). Total abundance (*N*) is the sum of $\boldsymbol{B_i^*}$ over all sample periods.

Under the Bayesian framework, parameters were calculated from the posterior distribution which calculated from a prior distribution and the data collected (posterior = prior * data). Samples from the posterior distribution were obtained using Markov Chain Monte Carlo (MCMC) simulations (Gilks et al. 1996) in the WinBUGS software package. WinBUGS implements MCMC simulations using a Metropolis with a Gibbs sampling algorithm (Spiegelhalter et al. 2003). Two chains were run with the Gibbs sampler in WinBUGS saving a total of 8,000 iterations of the posterior distribution of each parameter after a 2,000 iteration burn-in. A vague prior was used for the calculations (Bayes-LaPlace uniform prior). The sensitivity of the prior was based on the overlap between a uniform prior and the posterior distribution

(Gimenez et al. 2009) and convergence was assumed for parameters with a Brook-Gelman-Rubin statistic value less than 1.1 (Su et al. 2001).

Four potential JS models were evaluated using the Deviance Information Criteria (DIC) (Spiegelhalter et al. 2002). DIC is similar to AIC criteria in that both criteria include a model error estimate (posterior mean deviance) penalized for the number of terms in the model. Each of the four models estimated capture probability (p_i - likelihood of detecting a carcass that was present during sample period i), survival probability (φ_i - likelihood that a carcass present in one sample period i would remain in the stream until the next sample period), and entry probability (b^*_i - likelihood that a carcass would arrive in at a given sample period). The four models (e.g., ttt, stt, tst, sst) included a combination of static (s) or time varying (t) capture and survival probabilities among survey periods; the entry probabilities among survey periods were considered to be time varying in each of the three models.

Survey Life

Survey life (*SL*) in each CMR index reach was the area-under-the-curve divided by the JS spawner abundance estimate, where both estimates were independently derived for that index reach. <u>This derivation of survey life represents BOTH the duration of time that live Chum were present AND the observer efficiency in the spawning index reaches.</u> Area-under-the-curve values were treated as true values because no information on observer consistency was available, but JS spawner abundance was included as a distribution of values that incorporated the mean (μ_N) and standard deviation (σ_N) of the JS model estimate of spawner abundance. A Monte Carlo simulation (10,000 model simulations) provided the distributions of values for this calculation:

$$(3)\quad N^{CMR} \sim norm(\mu_N, \sigma_N)$$

$$(4)\quad SL = {AUC^{CMR}}/{N^{CMR}}$$

For each CMR index reach, survey life was calculated separately for area-under-the-curve estimates based on total live counts (holder, spawners) and live counts for spawners only.

Spawner Abundance in AUC Index Reaches

Spawner abundance (N^{AUC}) in each AUC index reach was the area-under-the-curve divided by the survey life estimate, where the area-under-the-curve was calculated from live counts in the AUC index reach and survey life was selected from the CMR index reach of the corresponding stream size classification. Area-under-the-curve values were treated as true values because no information on observation consistency was available, but survey life was included as a distribution of values that incorporated the mean (μ_{SL}) and standard deviation (σ_{SL}) of the estimate (see equation 4). A Monte Carlo simulation (10,000 model simulations) provided the distribution of values for this calculation:

$$(5)\quad SL \sim norm(\mu_{SL}, \sigma_{SL})$$

$$(6)\quad N^{AUC} = {AUC^{AUC}}/{SL}$$

Spawner Abundance for Foot and Boat Strata

Total spawner abundance was calculated separately for each watershed and strata. Total spawner abundance was the summed abundances in all index reaches (CMR, AUC) divided by the proportion of spawning (p_i) that occurred within the index reaches. The proportion of spawning that occurred in the index reaches was calculated from peak count data in index and supplemental reaches (see equation 1). This approach has been demonstrated to be effective for estimating population abundance of salmonids, especially if spawning numbers within the index reaches are a high proportion of total spawning in the strata (Liermann et al. 2015). Index reach abundances (N_i) were included as a distribution of values that incorporated the mean (μ_N) and standard deviation (σ_N) of the summed estimates (JS model for CMR indexes, equation 6 for AUC indexes). The proportion of spawning in index reaches was also included as a distribution of values that incorporated the mean (μ_p) and standard deviation (σ_p) of the estimated proportion (equation 1). A Monte Carlo simulation (10,000 model simulations) provided the distribution of values for this calculation:

$$(7)\ N_{w,s,i} = \sum(N_{w,s,i}^{CMR},\ N_{w,s,i}^{AUC})$$

$$(8)\ N_{w,s} = {}^{N_{w,s,i}}/_{p_{w,s,i}}$$

The final estimate was reported as abundance (mean of the simulated distribution), standard deviation (also calculated from the simulated distribution), and coefficient of variation (standard deviation divided by the abundance). Coefficient of variation is a measure of precision that is scaled to the magnitude of the values included in the estimate.

Results

Habitat Characteristics of Index Reaches

Habitat measurements were successfully completed for 15 of the 24 index reaches in 2017 (Table 5). The remaining indexes were not surveyed due to time constraints at the beginning of the Chum spawning season. The size classifications designated to streams without measurements were based on knowledge from WDFW Chum Project staff of the relative BFW and characteristics of un-measured streams compared to similar streams with quantified habitat. Both Neil Creek (RM 1.0-0.0) and Schafer Creek (RM 6.5-4.3) were originally given a small size classification based on an average BFW, but carcass tagging was unsuccessful in these sections. With no ability to calculate survey life for small streams the small stream classification was combined with the medium size classification. This limited the categories to side-channel, medium and large.

Of all index reaches, there were a total of 4 side-channels, 2 small channels, 12 medium channels, and 5 large channels. The average BFW for large streams was determined to be 45 meters or greater, and primarily consisted of mainstem sections. The medium size classification encompassed a range in average BFW from 13.8 to 20.9. Although Schafer 6.5-4.3 has an average BFW similar to side-channels, it is given a small size classification due to connectivity with the rest of Schafer Creek and its further distance from the mainstem Wynoochee river than other side-channels. Max residual depth increased with average BFW across all reaches and size classifications, with the deepest measurement of 1.81 meters located in the lowermost EF Satsop River section. Due to lack of distinguishable pools in side-channels max RD was not able to be measured.

Table 5. Habitat measurements and size classification of index reaches used for estimation of Chum salmon abundance in the Wynoochee and Satsop sub-basins, 2017.

Sub-basin	Stream	Reach Length (m)	Average Bankfull Width (m)	Average Thalwag Depth (m)	Max Depth (m)	Max Residual Depth (m)	Size Class
Wynoochee	Wynoochee 15.4 – 13.7	1100	57.9	---	---	---	Large
	Wynoochee 20.4 – 15.4	900	48.5	---	----	---	Large
	Schafer Creek 3.1 – 0.0[d]	200	19.5	0.57	2.0	1.44	Medium
	Schafer Creek 3.6 – 3.1	375	19.1	0.56	1.05	0.93	Medium
	Schafer Creek 4.3 – 3.6	350	15.6	0.28	1.15	1.02	Medium
	Schafer Creek 6.5 – 4.3[e]	200	7.1	0.15	0.55	0.48	Small
	Neil Creek 1.0 – 0.0[e]	200	13.80	0.67	1.5	0.84	Small
Satsop	EF Satsop River 10.0 – 6.3	1300	63.4	0.73	1.81	1.66	Large
	EF Satsop River 11.0 – 10.0	1150	66.9	0.7	1.67	1.42	Large
	EF Satsop River 12.4 – 11.0	---	---	---	---	---	Large
	EF Satsop River 14.7 – 12.4	---	---	---	---	---	Medium
	MF Satsop River 1.7 – 0.3	---	---	---	---	---	Medium
	MF Satsop River 3.3 – 1.7	---	---	---	---	---	Medium
	Decker Creek 5.8 – 5.2	315	18.8	0.39	1.3	1.1	Medium
	Schafer Slough 0.4 – 0.0[c]	76	6.98	0.17	---	---	Side Channel
	Maple Glen 0.3 – 0.0[c]	140	7.6	0.25	---	---	Side Channel
	Creamer Slough 0.3 – 0.0[c]	---	---	---	---	---	Medium
	Dry Bed Creek 1.0 – 0.0[ab]	340	17.7	---	---	---	Medium
	Decker Creek 1.1 – 0.5	---	---	---	---	---	Medium
	Decker Creek 1.8 – 1.1	---	---	---	---	---	Medium
	Decker Creek 6.8 – 5.8	350	20.9	0.53	1.34	1.08	Medium
	Tributary 0462 0.2 – 0.0	125	8.0	0.54	---	---	Side Channel
	Tributary 0462A 0.1 – 0.0	---	---	---	---	---	Side Channel

[a] Creek partially, or completely dry when measurements were taken
[b] Tributary remained almost completely dry through entire season
[c] Long term chum index
[d] Section is normally split at RM 1.3, but habitat measurements were taken continuously through both sections
[e] Reaches were planned to be surveyed as CMR, but lack of carcass data resulted in these reaches being analyzed using AUC data. Survey life associated with medium size streams was used for analysis due to the lack of carcass tagging data from small streams in 2017.

Biological Sampling

For the purposes of this report, Chum biological data were summarized from the Satsop and Wynoochee sub-basins only, although data were collected more broadly from the Grays Harbor basin by the WDFW. For both the Wynoochee and Satsop sub-basins, Chum returned at three, four and five years of age (Table 6). In the Wynoochee, the majority of Chum returned at age four at 57% (n = 16), followed by age five at 29% (n = 8), with the smallest proportion returning at age three at 14% (n = 4) (Table 6). The age composition in Chum returning to the Satsop varied from the Wynoochee, with the majority returning at age three (41%, n = 66), followed by age four (33%, n=53) and the smallest proportion returning at age five (26%, n = 44) (Table 6). With only 28 Chum sampled in the Wynoochee, the small sample size could influence the ratios, resulting in a different age composition compared to the Satsop.

The average fork length was 76 cm (±6, one standard deviation) for males and 69 cm (±5) for females in the Wynoochee (Table 6). Males had an average fork length of 79 cm (±5 SD) and a female average fork length of 71 cm (±4 SD) in the Satsop sub-basin (Table 6). The percentage of males and females in the Wynoochee was almost equal with 79 (52%) males and 74 (48%) females. In the Satsop more males were sampled than females, with 255 (56%) and 202 (44%) respectively.

Table 6. Summary of scale age in years and fork length in cm for Chum from the Wynoochee and Satsop sub-basins, 2017.

		Scale Age (years)				Fork Length (cm)		
Basin	**Sex**	**Sample Size**	**3**	**4**	**5**	**Sample Size**	**Mean (±SD)**	**Total**
Wynoochee	M	17	2	11	4	62	76±6	**79 (52%)**
	F	11	2	5	4	63	69±5	**74 (48%)**
	Total	**28**	**4 (14%)**	**16 (57%)**	**8 (29%)**	**125**		**153**
Satsop	M	80	36	25	19	175	79±5	**255 (56%)**
	F	81	30	28	23	121	71±4	**202 (44%)**
	Total	**161**	**66 (41%)**	**53 (33%)**	**42 (26%)**	**296**		**457**

Distribution

The Wynoochee survey frame included 89.0 river miles (RM, Table 7); however, 19.0 RM were not surveyed due to no visibility or access constraints resulting in 70.0 RM surveyed in 2017 (Figure 4). The Satsop survey frame included 149.9 RM; however, 10.3 RM were not surveyed due to a combination of no visibility, access constraints, or time constraints resulting in 139.6 RM surveyed in 2017. Details of the non-surveyed areas are provided in Appendix A-4. More river miles were surveyed by boat than by foot in both sub-basins. In the Wynoochee, 43.9 RM were surveyed by boat compared to 26.1 RM by foot, and in the Satsop 80.0 RM were surveyed by boat and 51.9 RM were surveyed by foot.

Peak surveys were completed within a week time frame for each sub-basin and strata. A large rain event was predicted to raise river levels and decrease visibility starting November 12th, and surveys of boat strata (main stem) were prioritized in case survey conditions in these areas were lost for the remainder of the season (Figure 2 and Figure 3). The Wynoochee boat strata was surveyed between November 6th and 9th and the Satsop boat strata was surveyed between November 7th and 11th. Wynoochee foot strata was surveyed between November 15th and 22nd, but the Satsop foot strata was not surveyed until December 1st through 8th due to a heavy rains and flooding that prevented safe access to the river between November 22nd and 28th (Figure 3).

Table 7. Total river miles of known Chum distribution in each sub-basin that were surveyed and not surveyed in 2017. River miles are shown by strata and data collection method.

	Wynoochee			Satsop		
	Foot	Boat	Total	Foot	Boat	Total
AUC	3.2	6.7	9.9	4.0	7.7	11.7
CMR	4.3	0.0	4.3	0.2	4.7	4.9
Trap Counts[a]	---	---	---	---	---	7.7
Supplemental Counts	18.6	37.2	55.8	47.7	67.6	115.1
Total Surveyed	**26.1**	**43.9**	**70.0**	**51.9**	**80.0**	**139.6**
Not Surveyed[b]	**---**	**---**	**19.0**	**---**	**---**	**10.3**
Total Survey Frame	**---**	**---**	**89.0**	**---**	**---**	**149.9**

[a] 100% capture traps are located on Bingham Creek at RM 0.9 and Satsop Springs Hatschery (EF Satsop River at RM 17.5). The areas above the Bingham Creek trap and Bingham Creek Hatchery on the EF Satsop River were not surveyed for upper extent/limit of Chum. This mileage is estimated based on the SalmonScape Chum distribution and District 17 local knowledge for Bingham Creek. The EF Satsop River mileage is based on surveys conducted in 2016.

[b] Not Surveyed indicates river miles that were not surveyed in 2017 but were included in the survey frame.

Chum were observed in 51.1 RM out of 70.0 RM surveyed in the Wynoochee sub-basin (Appendix A-2, Figure 5). The proportion of Chum within index reaches was 10% (n = 693/6,906) in the boat strata and 93% (n = 370/400) in the foot strata (Table 8). Based on peak counts, Schafer and Neil creeks appeared to contain the highest densities of Chum spawning within Wynoochee tributaries. Schafer Creek is the largest tributary below the Wynoochee dam and Neil Creek is a tributary to Schafer. During the 2017 peak spawning surveys, ULOs were observed at RM 6.1 in Schafer Creek and RM 0.5 in Neil Creek. The ULO in the Wynoochee main stem was further upstream than expected. Based on peak counts, a total of 316 live Chum were observed above the gorge and the uppermost Chum was recorded within 0.5 RM of the barrier fish trap, indicating that the gorge was not a barrier to Chum migration in 2017.

Chum were observed in 81.0 RM of the 139.6 RM surveyed in the Satsop sub-basin (Appendix A-3, Figure 6). The proportion of Chum observed within index reaches was 70% (n = 1,124/1,604) in the Satsop boat strata (Table 8). Surveys within the foot strata were delayed by high flows from storm events and ultimately occurred two to three weeks after peak (Figure 3) when there were few observations of live fish 0% (n = 0/8) within index reaches. However, carcass counts during 'peak' surveys of the Satsop foot strata provided a more substantial sample size and 44% (n = 484/1,086) of Chum carcasses were observed within the index reaches in the Satsop foot strata. Based on peak counts, Decker Creek (EF Satsop River tributary) appeared to have the highest densities of Chum spawning within Satsop tributaries. Despite the high spawner densities, no Chum were observed in the upstream-most index in Decker Creek (RM 11.4-10.9) and the ULO in Dry Bed Creek (tributary to Decker) was at RM 3.2. The ULO in the Satsop main stems were recorded at RM 30.4 in the WF Satsop River, RM 5.2 in Canyon River and 13.0 in the MF Satsop River. The ULO was not determined for Bingham Creek or the EF Satsop River; survey of these reaches were considered low priority for survey since numbers provided at the respective traps were sufficient for creating the Chum escapement estimate.

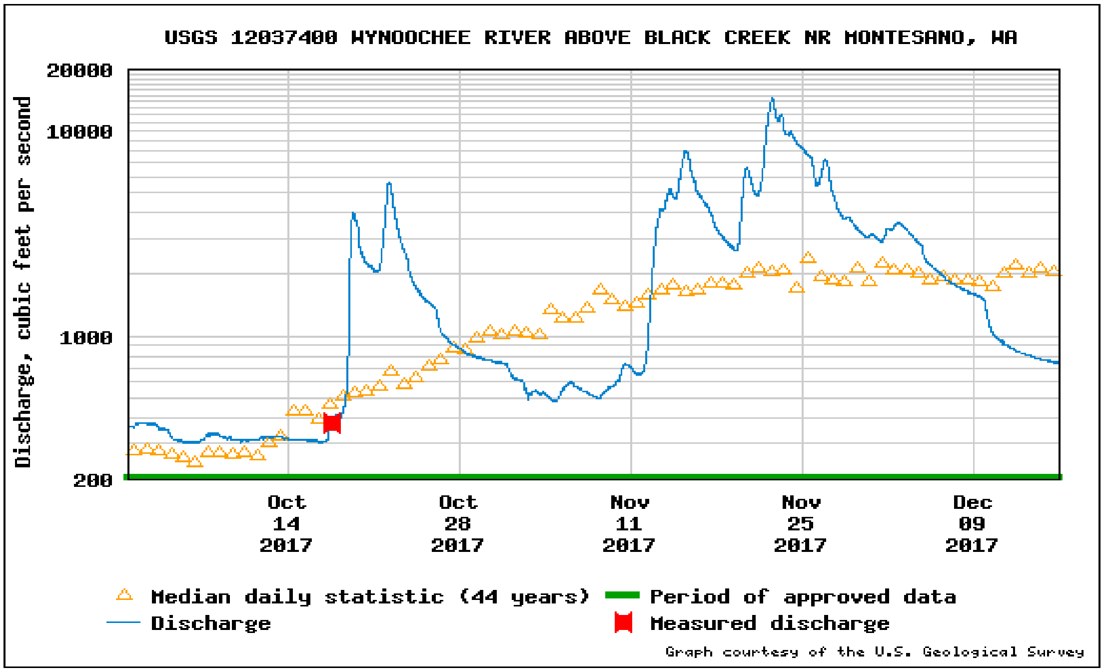

Figure 2. Daily discharge for the Wynoochee River during the 2017 Chum survey season.

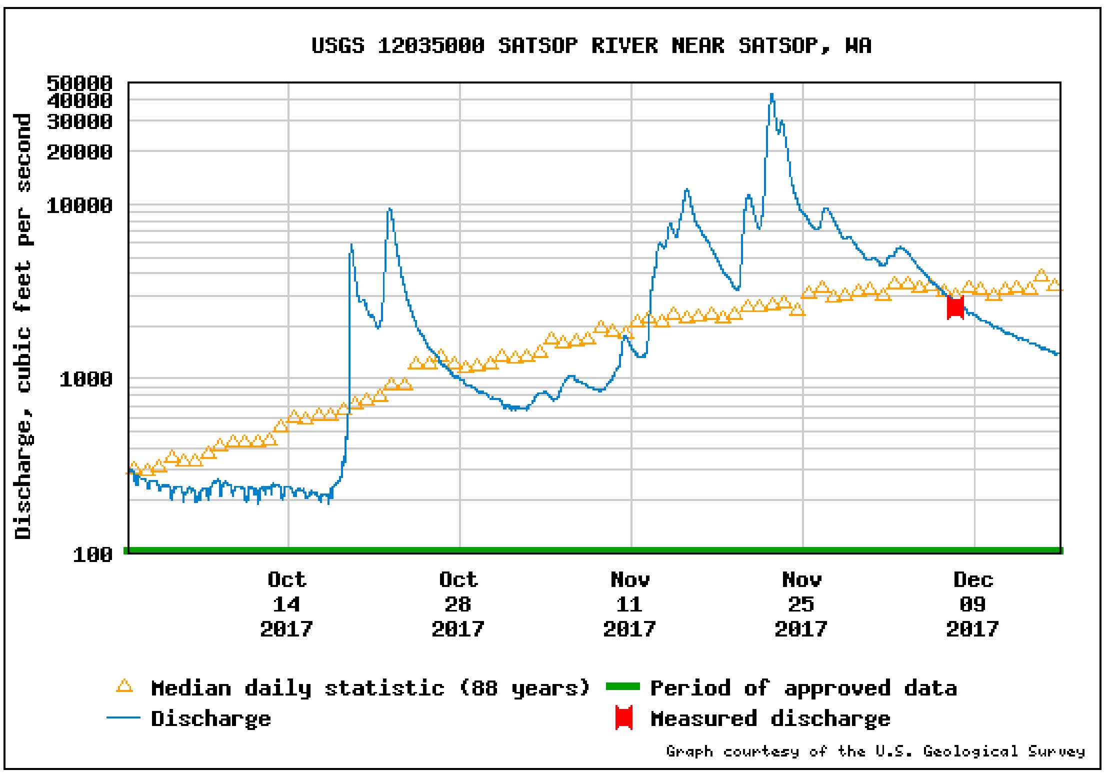

Figure 3. Daily discharge for the Satsop River during the 2017 Chum survey season.

2017 Chum Distribution with Upper Limits of Occurence

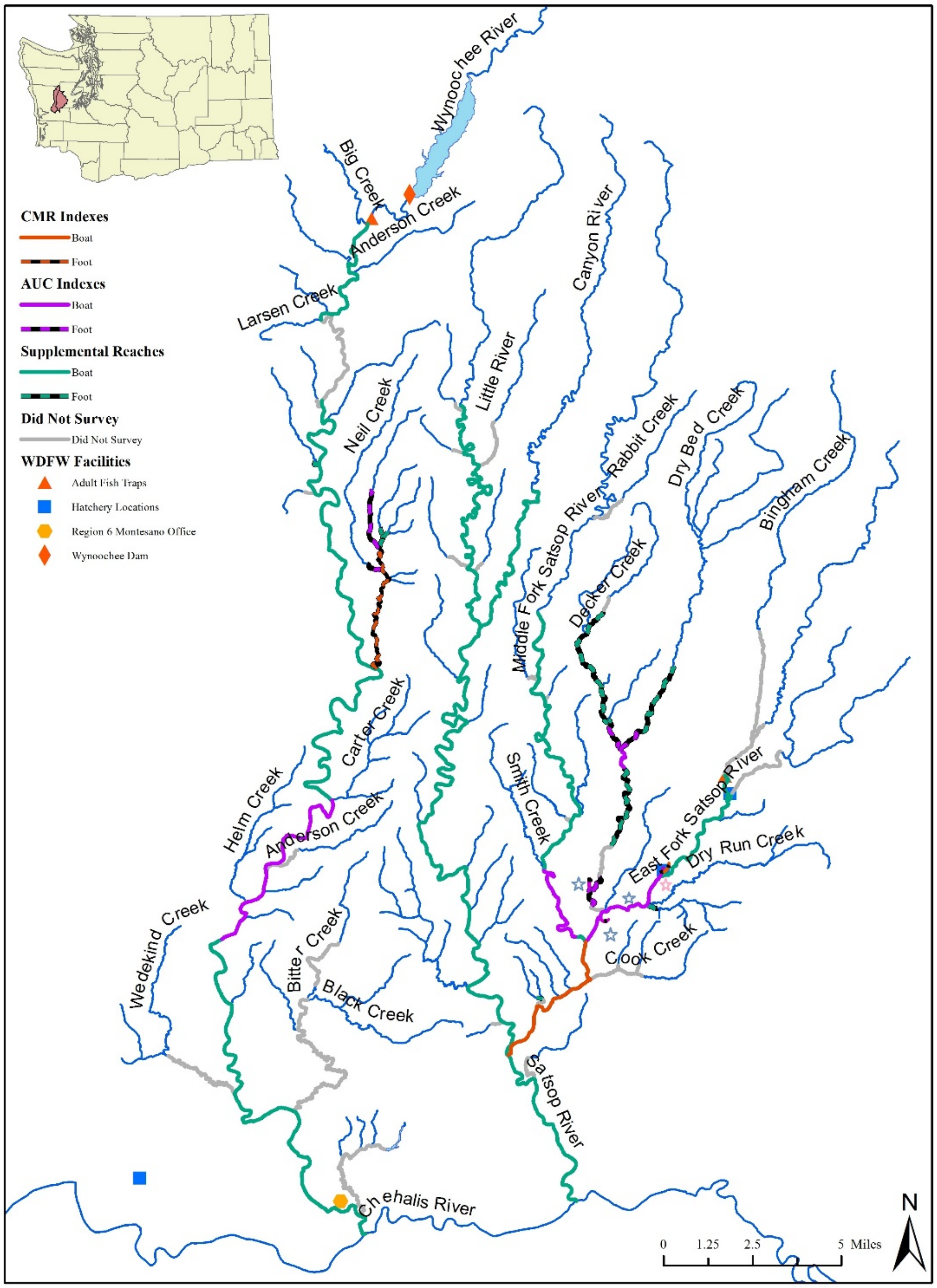

Figure 4. Methods used to survey Chum salmon distribution in the Wynoochee and Satsop sub-basins. Methods include by reach type (AUC, CMR, Supplemental) and survey strata (foot, boat). Upper limit of occurrence indicated as the top of the reach. Reaches not surveyed but assumed to include Chum are shown.

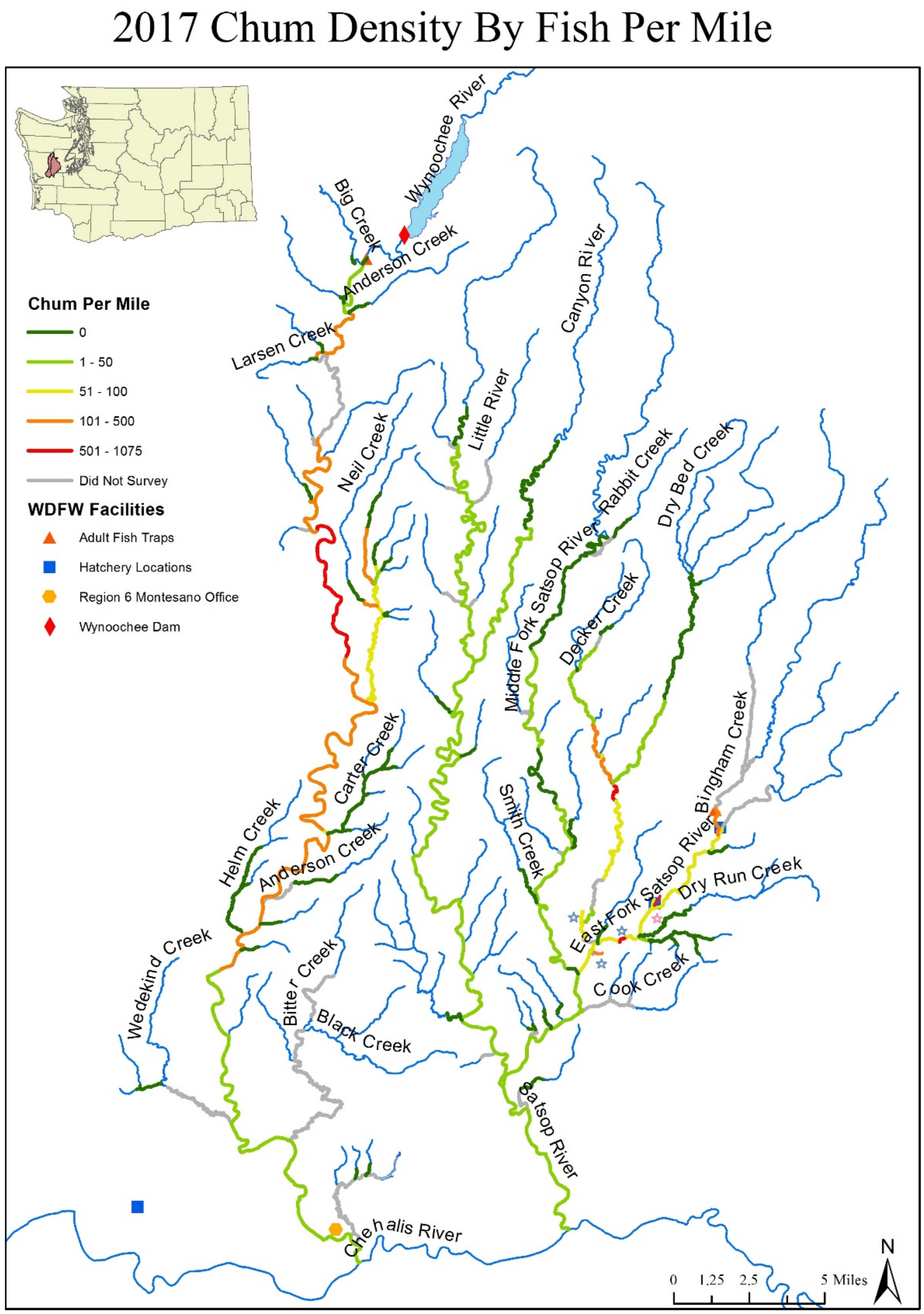

Figure 5. Chum density shown as fish counted per mile during a single week peak spawn survey in the Wynoochee and Satsop sub-basins. Reaches not surveyed but assumed to include Chum are shown. Blue stars indicate long-term Chum index reaches; Rose star indicates Tributary 0462 index reach.

Table 8. Counts (N) and proportion (p) of Chum salmon in each survey strata (boat, foot) within index (AUC, CMR) and supplemental survey reaches of the Wynoochee and Satsop rivers, fall 2017. Counts are during a single week survey close to peak spawning for each strata.

Basin	Strata	Type	Distance (RM)	Spawner N	Spawner p	Total Live N	Total Live p	Carcasses N	Carcasses p
Wynoochee	Boat	Index	6.7	693	0.10	853	0.11	34	0.03
		Supplemental	37.2	6213[a]	0.90	6798	0.89	1052	0.97
		Total	43.9	6906	1.00	7651	1.00	1086	1.00
Wynoochee	Foot	Index	7.5	370	0.93	405	0.92	285	0.96
		Supplemental	18.6	30	0.07	34	0.08	13	0.04
		Total	26.1	400	1.00	439	1.00	298	1.00
Satsop	Boat	Index	12.4	1124	0.70	1277	0.69	105	0.72
		Supplemental	67.6	480	0.30	580	0.31	40	0.28
		Total	80	1604	1.00	1857	1.00	145	1.00
Satsop	Foot	Index	4.2	0	0	8	0.44	484	0.45
		Supplemental	47.5	8	1.00	10	0.56	602	0.55
		Total	50.4	8	1.00	18	1.00	1086	1.00

[a] Upper mainstem Wynoochee survey conducted by foot instead of boat due to lack of boat access. Counts included in boat strata due to similar habitat

Area-Under-the-Curve

During the 2017 season, 29 index reaches were surveyed on a weekly basis enumerating live and dead Chum. Area-under-the-curve estimates were not calculated for 5 of the 29 index reaches due to absence of Chum, low numbers of Chum, or low survey frequency (Figure 6). In several surveys, surveyors did not partition live counts between spawners and holders (Appendix A). When spawner/holder designation was not available, the total live counts in these weeks were apportioned according to the overall ratio of spawner-to-holder across all index reaches in that week.

In the Wynoochee index reaches, the difference in fish-day calculations using spawner counts only versus total live counts was 24,656 for spawners only versus 32,211 for total live counts (Table 9). In the Satsop index reaches, this difference was 49,086 for spawners only versus 55,384 for total live counts. Within each sub-basin and strata, fish-day calculations based on total live counts were slightly larger than those for spawners only with differences of 11.6%, 15.4% and 9.3% for the Wynoochee boat, Wynoochee foot and Satsop boat strata respectively. The fish-day calculations between total live counts and spawner counts only were minimal (4.1%) in the Satsop foot strata. Tributary 0462, which is included in the Satsop foot strata, was the only reach where no holders were observed and fish-day calculations were therefore equivalent between the two calculations.

The peak timing of live counts in the Wynoochee sub-basin occurred the first week of November, slightly earlier than the peak timing of live counts in the Satsop River which occurred the second and third week of November (Figure 7 to 9). The timing of peak live counts was more consistent among index reaches in the Wynoochee sub-basin than in the Satsop sub-basin. In the Satsop sub-basin, peak timing of live counts in main stem index reaches occurred a week earlier than most of the smaller tributary and side channels (e.g., Maple Glen and Creamer Slough) index reaches. The arrival of Chum spawners in the side channels corresponded with stream flows. Flows remained low through the October and early November with the first major rain event beginning the second week of November. With the exception of Schafer Slough, which is connected to the main stem EF Satsop River, the first live Chum were not observed in the side channel index reaches until the first week or second week of November.

Both spawners and holders were observed through mid-November in the index reaches located in Schafer Creek and the EF Satsop River (RM 11.0-6.3). In comparison, no holders were observed throughout the season the Satsop Tributary 0462 index, a small side-channel near SSH. Live fish classified as holders were also infrequent in other side channels index reaches.

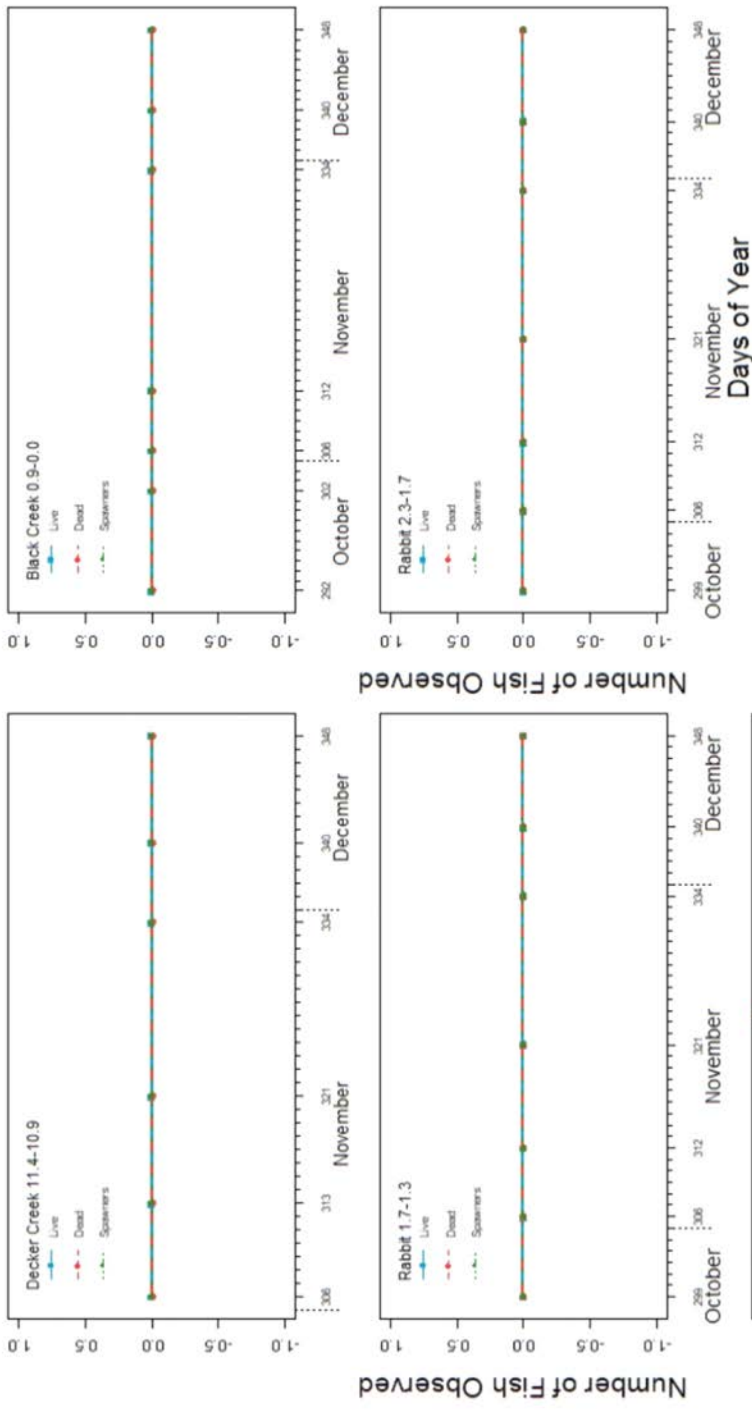

Figure 6. Number of live and dead Chum observed in index reaches (AUC, CMR) in the Satsop and Wynoochee sub-basins in 2017 where Chum presence was absent, small, did not encompass the entire season, or low survey frequency.

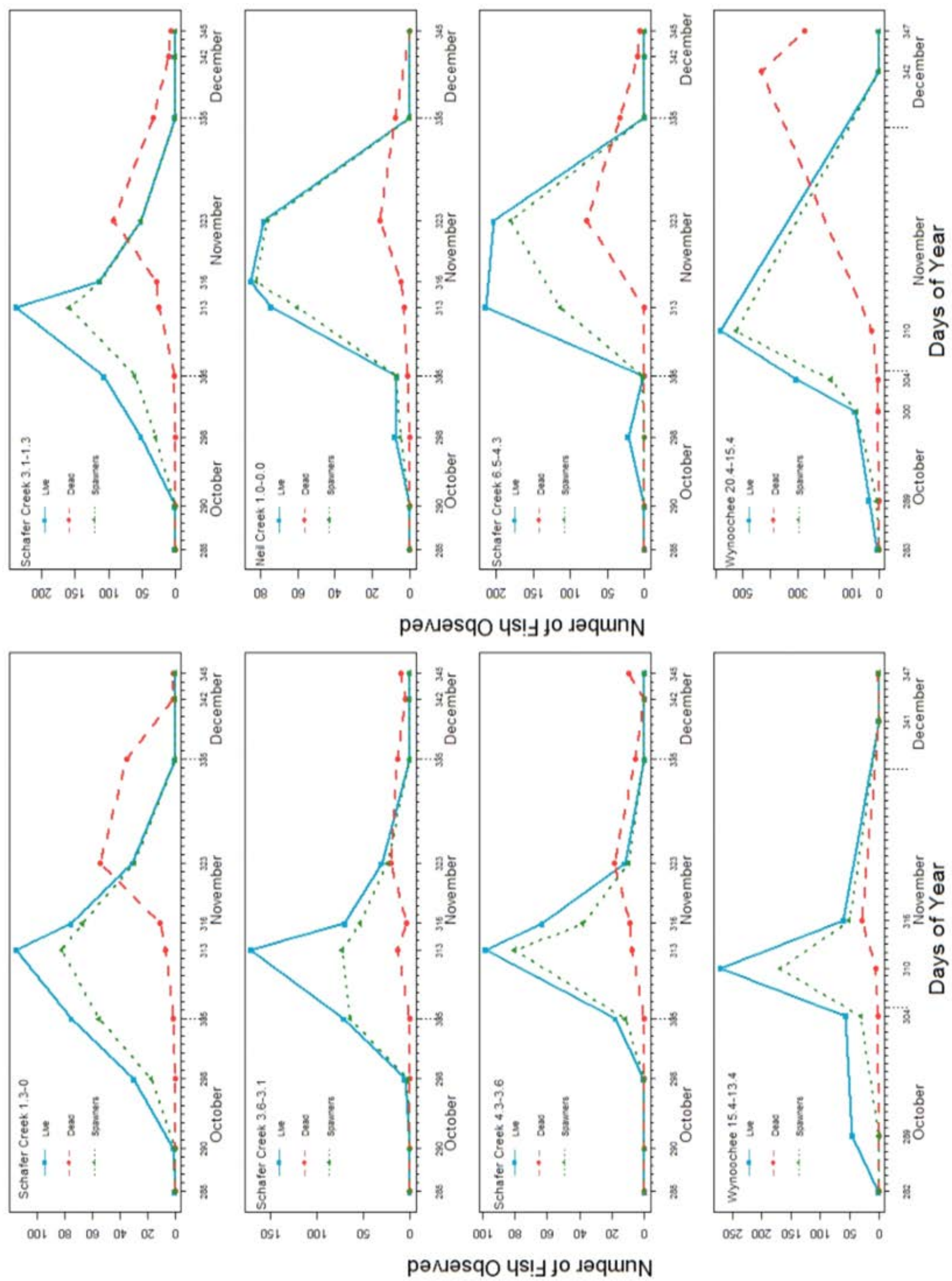

Figure 7. Number of live and dead Chum observed in index reaches (AUC, CMR) of the Wynoochee sub-basin, 2017. Live count data shown as 'spawners only' and 'total live' counts**.**

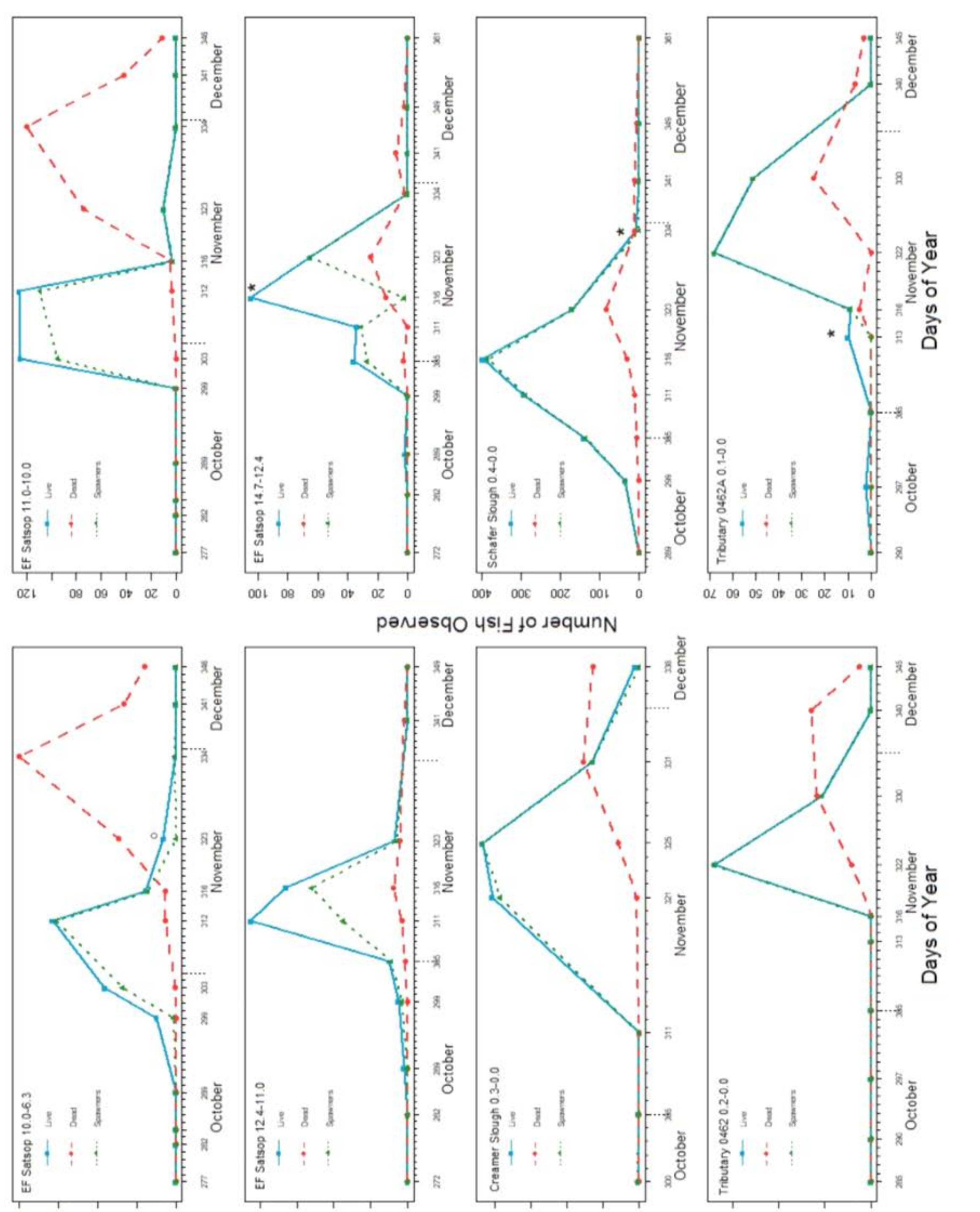

Figure 8. Number of live and dead Chum observed in index reaches (AUC, CMR) of the Satsop sub-basin, 2017. Live count data shown as 'spawners only' and 'total live' counts. Black star indicates where spawner status was not designated for live fish. Creamer Slough and Schafer Slough are long-term Chum reaches used in the current escapement estimation method.

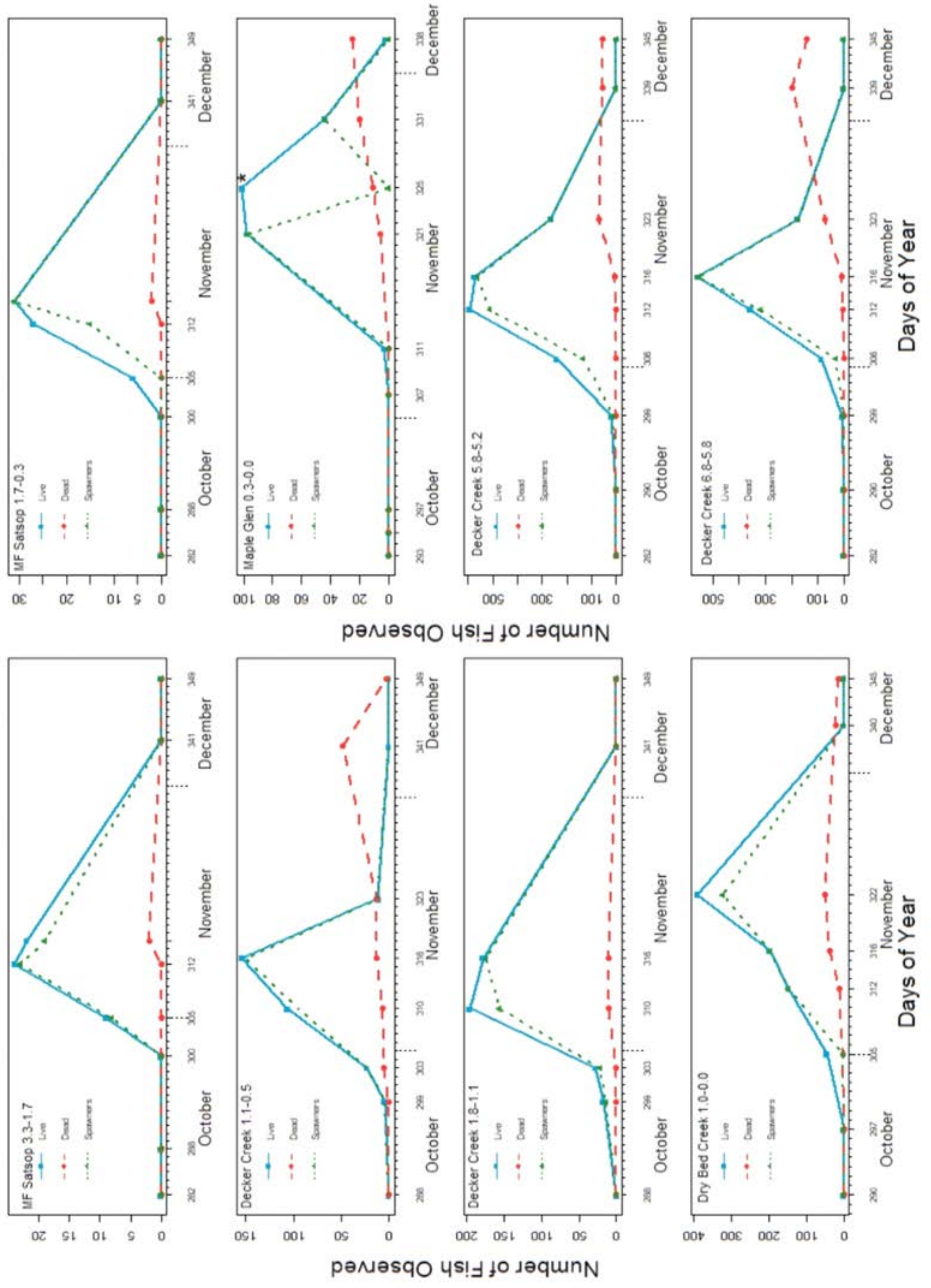

Figure 9. Number of live and dead Chum observed in index reaches (AUC, CMR) of the Satsop sub-basin in 2017. Live count data shown as 'spawners only' and 'total live' counts. Black star indicates where spawner status was not designated for live fish. Maple Glen long-term Chum reaches used in the current escapement estimation method. The section on the WF Satsop was surveyed as an index, but for analysis purposes this section was only used for peak surveys due to low survey frequency during the middle of peak Chum spawning**.**

Table 9. Area-under-the-curve in fish-day units for Chum in index reaches of the Wynoochee and Satsop sub-basins, fall 2017. Fish-days were calculated for 'spawners' only and total live count (holders, spawners). Index reaches were surveyed by either foot or boat (strata) and were surveyed using one of two survey types (AUC = live counts, CMR = live counts and carcass tagging).

				Fish Days	
Sub-Basin	**Index Reach Name**	**Strata**	**Type**	**Spawners Only**	**Total Live**
Wynoochee	Wynoochee 15.4 – 13.7	Boat	AUC	2,124	3,677
	Wynoochee 20.4 – 15.4	Boat	AUC	11,575	13,603
	Wynoochee Boat Subtotal			**13,699**	**17,280**
Wynoochee	Schafer Creek 1.3-0.0	Foot	CMR	1,602	2,096
	Schafer Creek 3.1-1.3	Foot	CMR	2,587	3,554
	Schafer Creek 3.6-3.1	Foot	CMR	1,390	2,146
	Schafer Creek 4.3-3.6	Foot	CMR	815	1,111
	Schafer Creek 6.5-4.3	Foot	AUC	3,012	4,339
	Neil Creek 1.0-0.0	Foot	AUC	1,552	1,686
	Wynoochee Foot Subtotal			**10,957**	**14,931**
Satsop	EF Satsop River 10.0-6.3	Boat	CMR	3,565	4,290
	EF Satsop River 11.0-10.0	Boat	CMR	1,427	1,738
	EF Satsop River 12.4-11.0	Boat	AUC	658	1,077
	EF Satsop River 14.7-12.4	Boat	AUC	930	1,635
	MF Satsop River 3.3-1.7	Boat	AUC	439	493
	MF Satsop River 1.7-0.3	Boat	AUC	525	621
	Decker Creek 5.8-5.2	Boat	AUC	9,671	10,910
	Satsop Boat Subtotal			**17,213**	**20,763**
Satsop	Schafer Slough 0.4-0.0	Foot	AUC	6,549	6,789
	Maple Glen 0.3-0.0	Foot	AUC	1,438	1,512
	Creamer Slough 0.3-0.0	Foot	AUC	2,869	2,988
	Dry Bed Creek 1.0-0.0	Foot	AUC	5,648	6,794
	Decker Creek 1.1-0.5	Boat	AUC	1,900	1,991
	Decker Creek 1.8-1.1	Boat	AUC	3,944	4,315
	Decker Creek 6.8-5.8	Foot	AUC	6,885	7,521
	Tributary 0462 0.2-0.0	Foot	CMR	1,667	1,667
	Tributary 0462A 0.1-0.0	Foot	AUC	976	1,046
	Satsop Foot Subtotal			**31,873**	**34,621**

Spawner Abundance in CMR Index Reaches

A total of 420 carcasses were tagged and released among 9 index reaches and 248 tagged carcasses were recovered over a span of ten weeks among all CMR index reaches in the Wynoochee and

Satsop sub-basins (Appendix B-1). Recovery rate of tagged carcasses was higher in the Wynoochee (64%, 190/295) then the Satsop (46%, 55/125). Carcass drift between index reaches occurred at a negligible rate, but after combining CMR index reaches for analysis eliminated the issue with carcass drift.

Of carcasses that were not tagged, the most numerous category was Condition 4 & 5 (carcasses in a condition too poor for tagging, Appendix B-2). A total of 973 carcasses in condition 4 & 5 were inspected for tags and enumerated throughout the Wynoochee and Satsop sub-basins. All carcasses in condition 4 & 5 had their tails cut prior to returning to the stream, which signified a 'loss on capture' in the JS mark-recapture model. An additional 245 carcasses in taggable condition (condition 1-3) were inspected, enumerated, tail cut, and released back into the stream without a tag when subsample rates were applied during the peak spawning weeks.

Assumptions of the JS model were tested prior to generating the abundance estimates for each CMR index reach. Assumptions regarding equal catchability and survival of carcasses were tested using a logistic regression and Bayesian goodness-of-fit tests. The logistic regression results indicated that recovery of carcasses was associated with either sex ($p = 0.7$) or length ($p = 0.3$) of the Chum. The Bayesian GOF test indicated that the JS model that included variable catchability and survival provided the best fit to the datasets from all three reaches (Bayesian *p-value* = 0.4 to 0.7, a value of 0.5 indicates perfect fit and a value of 0 or 1 indicates poor fit). The assumption of no tag loss was evaluated by double tagging the carcasses and evaluating the recovery of double versus single tagged carcasses. Of the 248 recoveries of tagged carcasses, 7 individuals were recovered with a single tag and all others were recovered with two tags. Tag loss was therefore considered to be negligible and was not incorporated into the analysis. The assumption that all tags were detected was addressed with standardized data collection and recording methods and with thorough training of the field crew prior to the field season. The assumption of instantaneous sampling was met by completing the survey of each CMR index reach within a single day, surveying continuously from the top to the bottom of the reach. One violation of the instantaneous sampling assumption occurred in the EF Satsop River (RM 10.0 to 6.3) and is described below.

Carcass tagging in the EF Satsop River (RM 10.0 to 6.3) was incomplete during statistical week 47 (week of November 19th). Given the large number of carcasses in this reach, the field crew applied a subsample rate to the tagging effort but was still unable to inspect and sample each Chum within the one-day survey. In order to safely exit the river during daylight hours, the crew truncated the sampling at a determined stop point and shifted to recording carcass counts and condition only for the remainder of the reach. Efforts to return and complete this survey the following day were not possible after the river rose almost three feet overnight. The crew did note the location that the survey was truncated so that the data could be properly apportioned within the reach. As a result, carcasses in the lower portion of this CMR reach were not inspected for tags (recaptures) during week 47 and did not have available tags for recapture during week 48 (week of November 26th). Therefore, we identified tags released below the truncation location on week 46 (not available for recapture the following week) and removed them from the data set used for analysis. This solution assumed that the instantaneous recapture rates in the upper portion of this index reach were representative of the entire index reach during week 47 and 48.

Due to the low number of tags released in Neil Creek (RM 1.0-0.0) and Schafer Creek (RM 6.5-4.3), mark-recapture estimates of abundance could not be derived for these two index reaches. Therefore, these two index reaches were treated as AUC indexes for the purpose of analysis. To further accommodate for low numbers of tags and use carcass tagging data in a mark-recapture estimate of spawner abundance, the four index reaches in Schafer Creek were combined into a single index reach (RM 4.3-0.0) and two index reaches in the EF Satsop River were combined into a single index reach (RM 11.0-6.3).

Estimates of spawner abundance were derived for three CMR index reaches – Satsop Tributary 0462, Schafer Creek and the EF Satsop River (Table 13) using inputs to the JS model provided in Tables 10 to 12. Chum spawner abundance was estimated to be 186 (173 – 208 95% C.I.) in Satsop Tributary 0462, 721 (605 - 885 95% C.I.) in Schafer Creek and 3,408 (2,402 – 4,755 95% C.I.) in the EF Satsop River.

Table 10. Summarized carcass tagging data used as inputs in the Jolly-Seber open population abundance estimate for Satsop Tributary 0462, fall 2017.

		Survey Period			
Measure	**Definition**	**1**	**2**	**3**	**4**
Captured	Number of total fish handled in this survey period	21	61	102	53
Released	Number of fish tagged and released in each survey period	21	52	48	2
Unmarked	Maiden fish observed in each survey period	21	58	75	13
Delays	Number of fish captured before time i, not captured at time i, and captured after time i	0	8	4	0
Recaptures	Number of fish recaptured from fish tagged and released each survey period	17	50	47	0
Marked	Number of fish captured in each survey period that were previously marked	0	9	54	51

Table 11. Summarized carcass tagging data used as inputs in the Jolly-Seber open population abundance estimate for Schafer Creek (river mile 0.0 to 4.3), fall 2017. Data are summed across four index reaches: Schafer Creek 1.3-0.0, Schafer Creek 3.1-1.3, Schafer Creek 3.6-3.1, and Schafer Creek 4.3-3.6.

		Survey Period						
Measure	**Definition**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Captured	Number of total fish handled in this survey period	2	38	22	32	33	18	6
Released	Number of fish tagged and released in each survey period	2	37	8	26	26	1	0
Unmarked	Maiden fish observed in each survey period	2	54	50	184	87	11	27
Delays	Number of fish captured before time i, not captured at time i, and captured after time i	0	0	8	5	5	5	0
Recaptures	Number of fish recaptured from fish tagged and released each survey period	1	22	3	7	17	1	0
Marked	Number of fish captured in each survey period that were previously marked	0	1	14	6	7	17	6

Table 12. Summarized carcass tagging data used as inputs in the Jolly-Seber open population abundance estimate for EF Satsop River (river mile 11.0 to 6.3), fall 2017. Data are summed across two index reaches: EF Satsop River 10.0-6.3 and EF Satsop River 11.0-10.0.

		Survey Period					
Measure	**Definition**	**1**	**2**	**3**	**4**	**5**	**6**
Captured	Number of total fish handled in this survey period	18	29	25	87	56	23
Released	Number of fish tagged and released in each survey period	18	21	24	84	15	0
Unmarked	Maiden fish observed in each survey period	32	31	221	620	179	89
Delays	Number of fish captured before time i, not captured at time i, and captured after time i	0	0	2	1	15	0
Recaptures	Number of fish recaptured from fish tagged and released each survey period	8	3	2	55	8	0
Marked	Number of fish captured in each survey period that were previously marked	0	8	1	3	41	23

Table 13. Chum abundance in three index reaches estimated using a Jolly-Seber open population abundance estimator and carcass tagging data, fall 2017.

Index Reach Name	N	SD	95% Low	95% High
Tributary 0462 0.2-0.0	186	9	173	208
Schafer Creek 4.3-0.0[a]	721	72	605	885
EF Satsop River 10.0-6.3[b]	3,408	615	2,402	4,755

[a] Combined estimate for four index reaches: Schafer Creek 1.3-0.0, Schafer Creek 3.1-1.3, Schafer Creek 3.6-3.1, and Schafer Creek 4.3-3.6.

[b] Combined estimate for two index reaches: Satsop River 10.0-6.3 and Satsop River 11.0-10.0.

Live Trap Counts

The Bingham Creek trap handled 158 Chum over a five-week period with the first individual trapped on October 25th and the final individual trapped November 24th (Table 14). Of the Chum captured in the Bingham trap, 154 were passed upstream and 4 were mortalities. The BCH collected 161 Chum over the season of which 39 were lethal spawned, 102 passed upstream, and 20 were pond mortalities.

The SSH collected 534 Chum over the season. A small amount of spawning occurs in the main channel/ladder leading up to the first holding pond at SSH. This channel, also known as Tributary 0462A, was surveyed as an AUC index reach in 2017. However, upon further investigation we learned that SSH staff remove most of the live Chum from Tributary 0462A prior to spawning, a process which certainly overlapped and confounded the live counts collected by survey crews. As a result, Tributary 0462A was not included in the abundance estimate for stream spawners under the assumption that most of these Chum were included in the SSH counts.

Table 14. Counts of live Chum returning to three trap locations in the Satsop River sub-basin, 2017.

Location	N
Bingham Creek Trap	158
Bingham Creek Hatchery	161
Satsop Springs Hatchery	534
Total	**853**

Survey Life

The estimate of survey life in this study includes BOTH the duration of time that live fish were present AND the observer efficiency in the spawning reach. Survey life estimates were consistently longer when derived from total live counts (holders, spawners) than from spawner counts only, except for Tributary 0462, which did not differ between the two calculations because all fish recorded in this reach were spawners (Table 15). When comparing survey life between index reaches of the three stream size classifications (side-channel, medium stream, large stream), the large stream had a shorter estimate of survey life (1.52 – 1.83 days) than the medium size stream and side-channel (8.98 – 12.5 days). No survey life was estimated for the small stream classification due to lack of carcass tagging results from these reaches. Survey life differences between the side-channel and medium stream depended on which live counts were included in the estimates. When all live counts (holders, spawners) were included in the calculation, survey life in the side channel Tributary 0462 (8.98 days) was shorter than the medium channel Schafer Creek (12.5 days). However, when live spawner counts only were used in the calculation, survey life in the side channel Tributary 0462 (8.98 days) was comparable to the medium stream Schafer Creek (9.00 days). Estimates of survey life for the Schafer Creek index had a difference of 3.5 days between the estimate derived using total live counts and the estimate using spawners only. The survey life estimated for the EF Satsop River was significantly lower than the two other survey life estimates; differing from Tributary 0462 by 7.15 days for total live counts and 7.46 days for spawner counts only, and differing from Schafer Creek by 10.67 days for total live counts and 7.48 for spawner counts only.

Table 15. Survey life (SL) estimates for Chum salmon in three CMR index reaches, fall 2017. Survey life estimates were derived from carcass tagging estimates of spawner abundance (N) and live fish-days (AUC). Fish-days were calculated from counts of 'spawners only' and 'total live' (spawners and holders). Data are mean and one standard deviation (SD) of the posterior distribution.

			Spawners Only		Total Live	
Index Reach Name	**Size Class**	**N(SD)**	**AUC**	SL (SD)	**AUC**	SL (SD)
Tributary 0462 0.2-0.0	Side Channel	186 (9)	1,667	8.98 (0.43)	1,667	8.98 (0.43)
Schafer Creek 4.3-0.0[a]	Medium	721(72)	6,393	9.00 (0.93)	8,906	12.50 (1.30)
EF Satsop River 11.0-6.3[b]	Large	3,408 (615)	4,992	1.52 (0.31)	6,028	1.83 (0.37)

[a] Combined estimate for four index reaches: Schafer Creek 1.3-0.0, Schafer Creek 3.1-1.3, Schafer Creek 3.6-3.1, and Schafer Creek 4.3-3.6.

[b] Combined estimate for two index reaches: Satsop River 10.0-6.3 and Satsop River 11.0-10.0.

Spawner Abundance in AUC Index Reaches

Spawner abundance in AUC index reaches was estimated from the area-under-the curve calculations and one of the three available estimates of survey life. Survey life from Tributary 0462 was applied to side-channel index reaches, survey life from Schafer Creek was applied to index reaches with a small or medium size classification, and survey life from the EF Satsop River survey life was applied to index reaches in the Satsop sub-basin with a large size classification. Although we intended to apply the EF Satsop River survey life to index reaches with a large size classification in the Wynoochee sub-basin as well, initial analyses indicated that this application yielded an unlikely high abundance in the Wynoochee boat strata of 87,000 – 93,000 fish (9,300 – 9,800 fish within the index reaches). The survey life estimate in the EF Satsop River index was surprising low, and although there were reasonable explanations for this value for the Satsop sub-basin (see Discussion). However, this estimate did not appear to transfer to main stem conditions in the Wynoochee sub-basin. As a result, our final analysis of the Wynoochee boat strata and associated index reaches in the large stream classification was based on the Schafer Creek index survey life.

In the Wynoochee boat strata, two index reaches were both classified as large. Chum abundance was estimated to be 1,545 (±130) when estimated with spawner counts only and 1,398 (±130) when estimated with total live counts. Including both spawners and holders decreased the strata abundance estimate by 9.5% over an estimate based on spawner counts only.

In the Wynoochee foot strata, four index reaches were classified as medium and two were classified as small (although analyzed using the survey life of the medium channel, see above). Chum abundance was estimated to be 1,235 (±54) with spawner counts only and 1,208 (±54) when derived with total live counts. Including both spawners and holders decreased the strata abundance estimate by 2.2% over an estimate based on spawner counts only.

In the Satsop boat strata, three index reaches were classified as large and the remaining four index reaches were classified as medium. Chum abundance was estimated to be 5,164 (±488) when estimated with spawner counts only and 5,125 (±489) when estimated with total live counts. Including both spawners and holders decreased the strata abundance estimate by 0.7% over an estimate based on spawner counts only.

In the Satsop foot strata, four index reaches were classified as medium and five index reaches were classified as side channels. Chum abundance was estimated to be 3,467 (±118) when estimated with spawner counts only and 3,114 (±99) when estimated with total live counts. Including both spawners and holders decreased the strata abundance estimate 10.2% over an estimate based on spawner counts only.

Table 16. Chum spawner abundance (*N*) and standard deviation (*SD*) in index reaches surveyed in the Wynoochee and Satsop rivers, fall 2017. Abundances of the index reaches were fish-day calculations (see Table 9) divided by survey life for a given stream size (see Table 15). Data are organized by sub-basin and survey strata (boat, foot).

				Spawners Only		Total Live	
Sub-Basin	**Index Reach Name**	**Strata**	**Size Class**	***N***	***SD***	***N***	***SD***
Wynoochee	Wynoochee 15.4 – 13.7	Boat	Large	240	24	298	29
	Wynoochee 20.4 – 15.4	Boat	Large	1,305	128	1,100	108
	Subtotal	**Boat**	**---**	**1,545**	**130**	**1,398**	**130**
Wynoochee	Schafer Creek 1.3-0.0	Foot	Medium	181	18	170	17
	Schafer Creek 3.1-1.3	Foot	Medium	291	29	287	29
	Schafer Creek 3.6-3.1	Foot	Medium	157	16	174	17
	Schafer Creek 4.3-3.6	Foot	Medium	92	9	90	9
	Schafer Creek 6.5-4.3	Foot	Small	339	34	351	35
	Neil Creek 1.0-0.0	Foot	Small	175	17	136	14
	Subtotal	**Foot**	**---**	**1,235**	**54**	**1,208**	**54**
Satsop	EF Satsop River 10.0-6.3	Boat	Large	2,435	435	2,426	433
	EF Satsop River 11.0-10.0	Boat	Large	975	176	984	178
	EF Satsop River 12.4-11.0	Boat	Large	450	79	610	108
	EF Satsop River 14.7-12.4	Boat	Medium	105	10	133	13
	MF Satsop River 1.7-0.3	Boat	Medium	59	6	50	5
	MF Satsop River 3.3-1.7	Boat	Medium	50	5	40	4
	Decker Creek 5.8-5.2	Boat	Medium	1,090	109	882	89
	Subtotal	**Boat**	**---**	**5,164**	**488**	**5,125**	**489**
Satsop	Schafer Slough 0.4-0.0	Foot	Side-channel	731	35	758	36
	Maple Glen 0.3-0.0	Foot	Side-channel	160	8	169	8
	Creamer Slough 0.3-0.0	Foot	Side-channel	320	16	334	16
	Dry Bed Creek 1.0-0.0	Foot	Medium	637	64	550	55
	Decker Creek 1.1-0.5	Foot	Medium	215	22	161	16
	Decker Creek 1.8-1.1	Foot	Medium	445	45	349	35
	Decker Creek 6.8-5.8	Foot	Medium	776	78	609	61
	Tributary 0462 0.2-0.0	Foot	Side-channel	186	9	186	9
	Tributary 0462A 0.1-0.0[a]	Foot	Side-channel	---	---	---	---
	Subtotal	**Foot**	**---**	**3,467**	**118**	**3,114**	**99**

[a]Satsop Tributary 0462A is the inlet to Satsop Springs hatchery. Nearly 100% of the Chum arriving in this channel were actively removed throughout the season by hatchery staff. Therefore, Chum returning to this channel are included in the Satsop Springs live counts.

Spawner Abundance for Foot and Boat Strata

Using spawner counts only, the combined abundance for the Wynoochee and Satsop sub-basins was 31,889 (±1,635) spawners (Table 17). This estimate had a coefficient of variation of 5.1%. The total Chum abundance in the Wynoochee sub-basin was estimated to be 16,728 (±1422), including 15,391 (±1421) in the boat strata and 1,337 (±62) in the foot strata. The total Chum abundance in the Satsop sub-basin was estimated to be 15,161 (±806), including 7,372 (±712) in the boat strata and 7,789 (±378) in the foot strata.

Using total live counts, the combined abundance estimated abundance for the Wynoochee and Satsop sub-basins was 28,312 (±1,342) spawners (Table 18). This estimate had a coefficient of variation of 4.7%. The total Chum abundance in the Wynoochee sub-basin was estimated to be 13,852 (±794), including 12,542 (±1082) in the boat strata and 1,310 (±62) Chum. The total Chum abundance in Satsop sub-basin was estimated to be 14,460 (±791), including 7,459 (±720) in the boat strata, 7,001 (±328) in the foot strata, and 853 Chum enumerated at trap locations.

Abundance estimates based on spawner counts only were slightly higher than those using total live counts in both sub-basins. However, the estimates using the two methods did not differ statistically in the Satsop sub-basin (point estimates from each method were within the 95% confidence intervals of the corresponding method). In the Wynoochee sub-basin, abundance estimates based on spawner counts only were 17.2% higher than those based on total live counts, indicating that in some circumstances the final estimate is sensitive to the type of live counts used in the analysis.

Table 17. Chum spawner abundance estimated using spawner counts only for Wynoochee and Satsop sub-basins, fall 2017. Estimates are the expansion of abundance (*N*) in the index reaches based on the proportion (*p*) of spawning observed in the index reaches.

			Abundance in Index Reaches		**Proportion in Indexes**		**Abundance in Strata**	
Watershed	**Strata**		***N***	**SD**	***p***	**SD**	***N***	**SD**
Wynoochee	Boat		1,545	130	0.10	0.004	15,391	1,421
	Foot		1,235	54	0.92	0.013	1,337	62
		Total	**2,780**	**141**	**---**	**---**	**16,728**	**1,422**
Satsop	Boat		5,164	488	0.70	0.011	7,372	712
	Foot		3,467	118	0.45	0.015	7,789	378
	Trap		---	---	---	---	853	---
		Total	**8,631**	**502**			**15,161**	**806**

Table 18. Chum spawner abundance estimated using total live counts for Wynoochee and Satsop sub-basins, fall 2017. Estimates are the expansion of abundance (*N*) in the index reaches based on the proportion (*p*) of spawning observed in the index reaches.

			Abundance in Index Reaches		Proportion in Indexes		Abundance in Strata	
Watershed	**Strata**		***N***	**SD**	***p***	**SD**	***N***	**SD**
Wynoochee	Boat		1,398	130	0.11	0.004	12,542	1,082
	Foot		1,208	54	0.92	0.013	1,310	62
		Total	**2,606**	**141**	**---**	**---**	**13,852**	**1,084**
Satsop	Boat		5,125	489	0.69	0.011	7,459	720
	Foot		3,114	99	0.45	0.015	7,001	328
	Trap		---	---	---	---	853	---
		Total	**8,239**	**499**			**14,460**	**791**

Discussion

The updated methodology for estimating the number of Grays Harbor Fall Chum spawners was implemented for the second consecutive year in 2017. The estimated number of Chum in the Wynoochee and Satsop sub-basins ranged between 28,312 and 31,889 spawners with a coefficient of variation between 4.7% and 5.1%. Estimates in this report did not include Chum returning to the Humptulips, Hoquiam, Wishkah, Black rivers and other minor spawning areas in tributaries to Grays Harbor and additional work is needed to apply the updated methodology to these spawning areas.

In 2017, we successfully addressed each of the areas of improvement identified at the beginning of the field season. These improvements included implementing a consistent sub-sampling strategy for carcass tagging, increasing coverage of main stem surveys, and ensuring that live count data were collected in a consistent manner among survey crews. A minimal section of planned survey area in each sub-basin was not surveyed due to constraints arising from weather and survey conditions. Although Chum are not thought to use these missed sections heavily, the lack of information from these areas means that the final estimates may be lower than the actual number of Chum spawners in each sub-basin.

Estimates derived from the updated methodology were consistently higher than those derived using the existing methodology for Grays Harbor Chum. Our 2017 estimate of 28,000 to 32,000 spawners for the Wynoochee and Satsop sub-basins alone was 50% to 68% higher than the spawner estimate for the entire Grays Harbor Chum population (n = 18,627, rounded to 19,000) derived using the existing methodology. Two reasons for the difference in results may be the assumption under the existing methodology that the peak live and carcass count in the long-term indexes represent total spawner abundance in these reaches and that the spawner abundance in the long-term index reaches represents 10.8% of the total population of Chum spawners. Results from the updated methodology indicate that neither of these assumptions is correct. We estimated that Chum spawner abundance in the long-term indexes was approximately 1,200 spawners, higher than the peak live and carcass count of 783 Chum obtained using the existing methodology. Further, our estimate of Chum spawner abundance in the three long-term index reaches was 3.8 – 4.4% of the spawner abundance for the Wynoochee and Satsop sub-basins combined. This comparison is missing counts from the fourth long-term Chum index (Humptulips) and spawner abundance from the remainder of the population; however, these additional values are unlikely to cause an increase in this calculated percentage of spawning within the long-term Chum index reaches.

The final spawner estimate was derived from multiple study components including peak counts from the entire spawning distribution, fish-days from index reaches, and mark-recapture abundance and survey life estimates in selected index reaches. The success of each component was necessary to achieve the final abundance estimate. Our results indicated that the final estimate was slightly sensitive the way live counts are collected and highly sensitive to the estimated survey life. Below we discuss each of the study components in more detail and provide a number of recommendations to improve the effectiveness of the new updated methodology.

Distribution

In the Wynoochee sub-basin, the majority of spawning was estimated from the main stem (i.e., boat strata) compared to the tributary (i.e., foot strata) habitat. Spawning activity was observed throughout the Wynoochee main stem, including areas above the gorge that had been previously thought to impede Chum migration. Several tributaries of the Wynoochee sub-basin where Chum were observed in 2016 had no Chum presence detected in 2017. These differences may have occurred due to lower spawner abundance overall in 2017 or may have been affected by the river flows during peak spawning. Peak spawning in the Wynoochee occurs in early November, after the first rise in fall flows in 2016 but prior to this event in 2017. Lower flows in 2017 may affect the proportion of Chum entering smaller tributaries for spawning. However, an estimate of main stem spawner abundance for the Wynoochee sub-basin was not derived in 2016 so the ratio of tributary to main stem spawning can not be compared between the two years.

In the Satsop sub-basin, spawner abundance was evenly split between main stem (i.e., boat strata) and tributary (i.e., foot strata) habitat. A similar distribution of spawning activity was observed in 2016. Unlike the Wynoochee sub-basin where spawner densities were high throughout the main stem, spawning activity in the Satsop sub-basin was more concentrated in specific areas, with the highest densities observed in the East Fork Satsop and its side channels and tributaries.

The distribution of Chum within each strata and sub-basin was documented during peak spawning which occurs between the first week of November and the first week of December. The Pacific Northwest region annually experiences large storm events during November that coincide with peak Chum spawning activity, making coordination of spawning ground surveys during this period challenging. Peak surveys within each strata (foot, boat) and sub-basin were planned to be completed within a seven-day time frame in order to provide counts useful for determining the proportion of spawning that occurred inside versus outside the index reaches. In order to successfully implement this component of the study, field crews needed to cover the entire spatial distribution of Chum spawning and complete this comprehensive survey within the seven-day period near the peak of spawning. Data collection near the peak of spawning ensure that counts are more likely to represent final spawning distribution and maximize the count data used to estimate the proportion of spawning within the index reaches. Larger counts increase the precision of the estimated proportions.

In 2017, survey conditions during the month of November presented a significant challenge in completing surveys of the Satsop tributaries (i.e., foot strata), including Decker Creek. River flows rose with the first significant rain event in the middle of November and remained high for the remainder of November with major flood events in the Wynoochee and Satsop. The rise in river flows overlapped in time with the planned index and supplemental surveys. Data collection from main stem sections had been prioritized prior to the field season and both index and supplemental reaches in the main stem of the Wynoochee and Satsop sub-basins were successfully surveyed close to the peak spawning period. Data collection from the foot strata of the Wynoochee sub-basin were conducted a week after peak spawning when good numbers of live fish and carcasses were still present. However, data collection from the foot strata of the Satsop sub-basin was not conducted early December, with the survey of Decker Creek offset from the remainder of this strata by more than one week. Surveys were delayed in Decker until flows receded to a level that field crews could safely navigate the stream. As a result, live count data in the Satsop foot strata were few and distribution of spawning in the Satsop foot strata relied on carcass rather than live count data. Further, the counts in Decker Creek were offset in time from the rest of the strata and may therefore be an underestimate of the proportional spawning occurring in this tributary.

Several streams were not surveyed in 2017 due to a combination of low visibility and access. In the Wynoochee sub-basin, Sylvia and Black creeks are channelized tributaries which become deep and increasingly turbid with high flows. Sylvia Creek does not appear to have many Chum present, but a large portion remained un-surveyed in both years. Chum presence was historically observed in Black Creek and Wedekind Creek, but these areas were difficult to survey under present conditions due to deep water, brushy habitat and silty substrate. The lowest extents of Wedekind, Helm, and Anderson (lower) creeks (i.e., tributary mouth to the first upstream road crossing) were not surveyed due to both visibility and access. In the Satsop sub-basin, surveys in the lower half mile of Decker Creek and Cook Creek were missed due to staffing constraints and oversight. Based on available habitat, these areas have a high probability of Chum use and should have been surveyed. The lack of count data from these areas mean that our estimate of Chum spawner abundance is likely to be slightly underestimated.

Area-Under-the-Curve

Live counts from the AUC and CMR index reaches had defined peaks bracketed by zero counts at the beginning and end of the time series. These data were adequate to calculate area-under-the-curve for the majority of the index reaches. The absence of Chum and low survey frequency were the most common reasons that area-under-the-curve could not be calculated for an index reach. Survey crews designated a spawner status for live counts, which provided information to explore whether and how spawner status influences the final abundance estimates. Live count data from four individual surveys were missing spawner status designation because the surveyor was unsure or forgot to make the classification. Although an analytical solution was applied to address this issue in the data, future efforts will be made to ensure that each surveyor properly assigns spawner status. Understanding the sensitivity of the final estimate to spawner status is important because all historical count data from these index reaches were collected as total live counts (spawners and holders). The live counts including spawners only may best reflect fish that spawn within the index reach whereas live counts including spawners and holders may incorporate fish that are migrating through a reach on the way to their terminal spawning area. This issue may differ by stream size and is likely to be more acute in main stem index reaches than small stream channels or side channel habitat.

Area-under-the-curve estimates were sensitive to the inclusion of all live counts versus those for spawners only, with fish-days derived from total live counts (spawners and holders) consistently greater than fish-days derived from spawner only counts. In the Wynoochee sub-basin, fish-days calculated from total live counts were 27% higher in the foot strata and 21% higher in the boat strata than counts of spawners only. In the Satsop sub-basin, fish-days calculated from total live counts were 8% higher in the foot strata and 17% higher in the boat strata than counts of spawners only. The difference between the two types of live counts was least prominent in the Satsop foot strata, which is the only strata containing index reaches with side-channel habitat. Side channels are terminal areas requiring adequate flow for fish to enter, which means Chum may be delayed in entering these areas until they are ripe and ready to spawn. Once Chum do enter the side channels, they are forced to spawn in these locations due to an absence of upstream habitat.

The methodology applied in this study relied on consistent detection rates of live fish among surveyors. The methodology is insensitive to different detection rates among surveys as long as this variability in detection rate is shared among all surveyors. In 2017, we implemented pre-season training and in-season cross checks among crew leads to increase the consistency in detection rates among the field crew; however, we did not empirically evaluate observer consistency. One source of inconsistency among surveyors may be survey focus (e.g., live/dead counts of Chum only vs. live/dead/redd counts of multiple species). Many of the AUC index reaches had a multiple species focus involving data collection of live, dead, and redd counts whereas the CMR index reaches had a single species focus on Chum involving data collection of live counts and carcass sampling only. When conducting redd surveys for coho and Chinook in the AUC index reaches, the surveyor must focus on the substrate to determine redd absence/presence. In comparison, when counting live fish, the surveyor must focus on the water column and movements within the water column and when counting and sampling carcasses, the surveyor must focus on stream banks, gravel bars, and logjams (i.e., places where carcasses might build up). The influence of survey focus on the consistency among observer counts needs to be evaluated in future years of study.

Another potential source of variability was differences in detection rates among reaches. Accurate counts of live Chum were especially challenging in large main stem index reaches where visibility is often an issue and angler activity prevents surveyors from covering the entire reach. These conditions likely results in lower detection rates of live Chum in large river than small tributaries and side channels. For this reason, the data collection and analysis was stratified between small streams surveyed on foot and large streams surveyed by boat. This stratification accounted for differences in detection rates as long as the detection rates within the boat strata (or foot strata) were similar among reaches.

Carcass Tagging

Carcass tagging was successfully accomplished in seven CMR index reaches, which were subsequently collapsed into three reaches to achieve adequate sample size for the JS estimate of abundance. The number of carcasses encountered in 2017 were low enough that we were able to sample all carcasses and survey each CMR index reach to completion each week, with the exception of two individual surveys where tagging of carcasses represented a subsample of all carcasses encountered. This result contrasted with 2016 when several CMR index reaches were incompletely surveyed due to larger numbers of carcasses and inadequate staff allocation among reaches. To ensure complete data sets were collected in 2017, the number of CMR index reaches was reduced from 2016 and subsample rates for tagging were planned in advance of the peak spawning week. Every effort was made to complete carcass tagging in all CMR index reaches on a given week. However, in tributaries where CMR index reaches were continuous, we strategically prioritized weekly surveys in the lower over upper reaches in anticipation of potential time shortages under peak work loads. This prioritization was only applied in the situations where survey conditions (i.e., carcass numbers, visibility, safety) might preclude survey of all CMR index reaches in a week time frame, which occurred twice during the 2017 season. The first incomplete CMR index survey in 2017 was the uppermost section of Schafer Creek, which was skipped one week during peak spawning. This index reach was ultimately dropped from the carcass tagging part of the analysis due to low carcass marks and recaptures in addition to the missing data. The second incomplete survey in 2017 occurred within the EF Satsop River (RM 10.0 – 6.3) CMR index reach. Given the large number of carcasses on a single week, the crew was unable to inspect each Chum within the available daylight hours and the reach was only partially surveyed on this day. An analytical solution to this issue is described in the results section but the issue adds some uncertainty to the final abundance estimate for this reach.

Survey Life

Live counts compiled into an area-under-the-curve estimate are reported in ‘fish-day’ units because the same fish may be counted on more than one weekly survey. Fish-days are then converted to a number of spawners by dividing by survey life. Survey life is reported in ‘day’ units and typically represents the number of days a live fish is present within the survey reach. However, the methodology used to estimate survey life in this study incorporated BOTH the length of time a live fish was present in the survey reach AND the observer efficiency.

A survey life of 10 days is currently applied to live counts (holders and spawners) in WDFW Chum stock assessment in Puget Sound (Ames et al. 1984). While the existing methodology for Grays Harbor Chum does not require an estimate of survey life, any estimates that rely on area-under-the-curve approaches will require this parameter. Therefore, an accurate estimate of survey life and an understanding of the variability of this parameter is vital to deriving accurate estimates of Chum spawner abundance in Grays Harbor as well as elsewhere in western Washington.

Many factors may contribute to our estimate of survey life and may result in variable estimates of survey life among reaches. Stream size may influence available holding habitat and predator abilities to remove fish, both of which may influence the length of time a live Chum will remain in a given index reach prior to spawning. Furthermore, surveyor detection rates of live Chum may vary greatly across stream sizes due to varying visibility associated with survey method (e.g., foot, boat) and survey condition (e.g., pool depth, water clarity). For this reason, our study was designed to evaluate the association between stream size and survey life estimates. This evaluation will determine whether and how stream size influences the survey life parameter and will be used to provide future recommendations on the application of survey life to area-under-the-curve calculations within the index reaches of varying channel sizes.

In 2017, survey life was calculated for three different stream size classifications: side channel, medium channel, and large channel. Survey life estimates in the side channel and survey life estimates based on spawners only in the medium stream channel were consistently nine days, varying just one day (10%) from the ten-day standard currently used by WDFW. In comparison, survey life estimates based on total live counts (holders, spawners) in the medium stream channel was 12.5 days, a 30% increase from the survey life based on spawners only and a 25% increase over the ten-day standard currently used by WDFW. One explanation for this result is that the location and habitat of the medium stream channel results in live Chum residing longer in this type of reach than in side channel reaches prior to spawning. Survey life values that vary by 30% are likely to cause a significant bias in the final abundance estimate for these reaches if they are not properly applied in the analysis and this level of variability should be confirmed with additional estimates of survey life in side channel, small channel and medium channel streams.

Survey life estimated for the large stream channel was drastically lower than the ten-day standard currently used by WDFW. While this calculation represented the combined effect of observer efficiency and longevity of live Chum within the index reach, the most likely explanation for the unexpectedly low value was low observer efficiency under the type of survey conditions encountered in large stream channel index reaches. Over the course of the season, the conditions encountered in the EF Satsop River index reaches differed from conditions in the side channel and medium stream index reaches in a manner that was likely to affect observer efficiency. For example, visibility in the EF Satsop River index reach was recorded as ‘poor’ for three weeks of surveys due to rain and suspended sediment. The three surveys with poor visibility occurred during the month of November, during peak spawning activity. In addition, two of the surveys during peak spawn weeks were conducted on Sundays, which coincided with higher angler activity throughout the index reach. Surveyors attempted to reduce their impact on the public by avoiding water being directly targeted for angling, which consequently reduced the numbers of live Chum that would have been detected in the absence of angling activity. Therefore, the live count data used to calculate area-under-the-curve in the large stream channel index likely had a much lower observer efficiency than live count data from the size channel and medium channel index where visibility was better and there was no angler activity. This explanation could account for the drastically low survey life estimated for the large stream channel index. However, 2017 is the first year we have derived a survey life estimate for a large stream channel and interpretation of this result would benefit from replicate estimates in subsequent years of study.

A survey life estimate was not calculated for small stream channels, leaving a gap in the size continuum included in our study methodology. The two CMR index reaches within the small size classification that were included in 2017 did not receive enough carcasses to produce a mark-recapture estimate of abundance. Although these two index reaches were also surveyed in 2016, mark-recapture estimates in this previous year was not completed due to incomplete surveys during peak spawning. Based on forecast models, fewer Chum were predicted to return to Grays Harbor in 2017. In order to improve understanding of the variability in survey life estimates, future efforts should prioritize carcass tagging efforts in index reaches of small size classification.

Recommendations

Habitat Characteristics of Index Reaches

- **Complete habitat surveys in all AUC and CMR index reaches**. Habitat measurements based on updated 2017 protocols were not completed for eight of the index reaches in 2017. Measurements from these reaches should be obtained prior to the next field season in addition to any additional index reaches from other sub-basins (i.e., Humptulips) that will be included in the planned survey coverage for 2018.
- **Explore site selection for Chum spawning**. Site selection within a reach for Chum spawning in the Wynoochee and Satsop rivers is not well understood. From the distribution data, we now have strong knowledge of where Chum spawning occurs at a reach level, but lack understanding for why localized habitat selection for spawning. Given the current interest in salmon restoration within the Chehalis River, further efforts to understand Chum site selection and associated habitat requirements may be useful to inform habitat protection and restoration efforts.

Distribution

- **Explore additional Chum index reaches.** Based on the live Chum counts, only ten percent of spawning in the main stem Wynoochee occurred within the index reaches. It is important to ensure index areas encompass the majority of spawning, which occurred further upstream of the current main stem indexes. Efforts should be made to explore the upstream area to determine if a new index reach can be established in an areas with high densities of Chum spawners.
- **Assess and possibly truncate the survey frame**. Distribution surveys were conducted during 2016 and 2017. Many of the indexes were surveyed both years, with no Chum observed. We recommend a review of the 2016 and 2017 distribution data to determine if the survey frame can be truncated and reduce survey frequency of specific supplemental reaches due to lack of Chum.

Area-Under-the-Curve

- **Quantify water clarity and angler avoidance**. Poor survey visibility due to rain events was experienced in all main stem indexes during the season and resulted in three weeks of missed surveys in the Wynoochee. Angler avoidance in the EF Satsop River led to incomplete survey cover for sections of river, likely reducing detection rates of live Chum. Metrics should be developed to quantify water clarity and missed habitat to possibly develop a coefficient to compensate for these factors. For water quality, small secchi-like disks can be made for each surveyor to carry and measure visibility in feet or meters for each survey. For angler avoidance, an estimated percentage of habitat-missed could be recorded for each survey. Alternately, the timing of main stem index surveys should take into consideration angler activity.

- **Continued use of spawner status**. All Region 6 surveyors adopted designation of spawner status in 2017. Several conversations took place among survey staff and supervisors at the beginning of the season to ensure a uniform understanding of the terms. Even so, occasional confusion surrounding the classification of what constituted a spawner and what constituted a holder occurred. Steps should be taken to ensure the definition for each classification is clear and easy for surveyors to apply. Supervisors should periodically check-in throughout the season to ensure the spawner/holder designation is being properly applied.
- **Emphasize consistency in live counts -** During training of CMR index crew, surveyors were calibrated to each other by counting live Chum over multiple passes and comparing counts at the end to ensure Chum were counted in the same manner. This practice should continue, and potentially incorporate other survey crews.
- **Quantify consistency in live counts among survey crews -** Live counts should be compared among field crews, specifically the Chum Project crew and WDFW D17 FMS to better assess consistency in observer counts. This evaluation will require field crews to survey the same sections independently within a few days of each other and should be coordinated between field supervisors so that field crews are not aware of the replicate surveys.

Carcass Tagging

- **Include small stream index**. Effort should be made to ensure indexes meeting the small stream classification are surveyed to completion in order to derive a mark-recapture estimate of abundance from the carcass tagging data. A survey life for small streams was not calculated in 2017 and represents a gap in our understanding of survey life. In order to successfully address this recommendation, a CMR index reach should be established in the appropriate stream size with high enough spawner densities to support a carcass tagging effort.

Survey Life

- **Validate over a range of stream sizes**. Chum spawning occurred in a range of stream sizes that were classified side-channel, small, medium and large. Results to date indicate that survey life of live Chum may differ based on stream size and type of live counts, but replicate estimates are needed validate and understand annual variability in these values. Future selection of CMR index reaches should continue to include a variety of stream size classifications. Based on current data gaps, emphasis should be placed on obtaining survey life estimates in the large size channels (most difficult to survey) and in the small stream channels (carcass tagging is challenging in this size classification due to low densities of Chum). In addition, the average BFW for CMR indexes was more than double between medium and large streams. Sampling stream reaches that fall in the gap between medium and large may provide new information.

References

Aquatic Species Enhancement Plan Technical Committee, 2014, Aquatic Species Enhancement Plan Data Gaps Report: Prepared for the Chehalis Basin Work Group, 154 p. http://chehalisbasinstrategy.com/publications/.

Ames, J. 1984. Puget Sound chum salmon escapement estimates using spawner curve methodology. *In* P. E. K. Symons and M. Waldichuk, editors. Proceedings of the workshop on stream indexing for salmon escapement estimation. Canadian Technical Report Fisheries and Aquatic Sciences No. 1326, Vancouver, British Columbia.

Anderson, K.E., A.J. Paul, E. McCauley, L.J. Jackson, J.R. Post, R.M. Nisbet. 2006 Instream flow needs in streams and rivers: the importance of understanding ecological dynamics. Frontiers in Ecology and Environment 4:309-318.

Ashcraft, S., A. Edwards, M. Zimmerman, and M. Scharpf. 2017. Final Report Grays Harbor Fall Chum Abundance and Distribution 2015 - 2016. Washington Department of Fish and Wildlife. Final report to Recreation Conservation Office.

Bentley, K., D. Rawding, S. Hawkins, J. Holowatz, S. Nelsen, and J. Grobelny. 2018. Estimates of Escapement and an Evaluation of Abundance Methods for North Fork Lewis River Fall-run Chinook Salmon, 2013 – 2017. Washington Department of Fish and Wildlife, Olympia, Washington

Bue, B.G., S.M. Fired, S. Sharr, D.G. Sharp, J.A. Wilcock, and H.J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream life estimates: the Prince William Sound pink salmon example. North Pacific Anadromous Fish Commission Bulletin 1:240-250.

English, K.K., R.C. Blocking, and J.R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area under the curve method. Canadian Journal of Fisheries and Aquatic Sciences 49: 1982.

Gilks, W., S. Richardson, and D. Spiegelhalter. 1996. Markov Chain Monte Carlo in Practice. Interdisciplinary Statistics, Chapman & Hall, Suffolk, UK.

Gimenez, O., B.J.T. Morgan, and S.P. Brooks. 2009. Weak identifiability in models for mark-recapture recovery data. Pages 1055-1067 in D.L. Thomson, E.G. Cooch, and M.J. Conroy, editors. Modeling processes in marked populations. Springer Series: Environmental and Ecological Statistics, Volume 3.

Liermann, M.C., D. Rawding, G.R.Pess, and B.Glaser. 2015. The spatial distribution of salmon and steelhead redds and optimal sampling design. Canadian Journal of Fisheries and Aquatic Sciences 72: 434-446.

McIssac, D. 1977. Total spawner population estimate for the North Fork Lewis River based on carcass tagging, 1976. Washington Department of Fisheries, Columbia River Laboratory Progress Report No. 77-01, Olympia, Washington.

Naiman RJ, Bilby RE, Schindler DE, Helfield JM. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5:399–417.

Phinney, L.A. and P. Bucknell, 1975. A catalog of Washington Streams and salmon utilization volume 2 Coastal Region. Washington Department of Fisheries.

Pollock, J.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:1-97.

Powers, P. D., and J. F. Orsborn. 1985. New Concepts in Fish Ladder Design: Analysis of Barriers to Upstream Fish Migration, Volume IV of IV, Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls, 1982-1984 Final Report. Washington State University, Albrook Hydraulics Laboratory.

Rawding, D.B. Glaser, and T. Buehrens. 2014. Lower Columbia River fisheries and escapement evaluation in southwest Washington, 2010, FPT 14-10. Washington Department of Fish and Wildlife, Olympia, Washington, http://wdfw.wa.gov/publications/01702/.

Regional Mark Information System. Accessed 03/13/2017. Pacific States Marine Fisheries Commission Regional Mark Processing Center.

Reiser, D. W., C.-M. Huang, S. Beck, M. Gagner, and E. Jeanes. 2006. Defining Flow Windows for Upstream Passage of Adult Anadromous Salmonids at Cascades and Falls. Transactions of the American Fisheries Society 135(3):668-679.

Schlosser, Issac J. 1991. Stream Fish Ecology: A Landscape Perspective. Bioscience 41: 704-712.

Schwarz, C.J., R.E. Bailey, J.R. Irvine, and F.C. Dalziel. 1993. Estimating salmon escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50:1181-1197.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company Limited, London.

Spiegelhalter, D.J., N.G. Best, B.P. Carlin, and A. VanferLinde. 2002. Bayesian measures of model complexity and fit (with discussion). Journal of the Royal Statistical Society B64:582-639.

Spiegelhalter, D., A. Thomas, N. Best, and D. Lunn. 2003. WinBUGS User Manual, Version 1.2.MCR Biostatistics Unit, Institute of Public Health and Epidemioliogy and Public Health. Imperial College School of Medicine, UK.

Su, Z., M.D. Adkinson, and B.W. VanAlen. 2001. A hierarchical Bayesian model for estimating historical salmon escapement and timing. Canadian Journal of Fisheries and Aquatic Sciences 58:16481662.

Sykes, S.D., and L.W. Botsford. 1986. Chinook salmon, *Oncorhynchus tshawytscha*, spawning escapement based on multiple mark-recaptures of carcasses. Fisheries Bulletin 84:261-270.

WDFW. 2002. Washington Department of Fish and Wildlife SalmonScape. Accessed August 2016. http://apps.wdfw.wa.gov/salmonscape/

Appendix A – Index and Supplemental Reaches Used in Chum Salmon Surveys in the Wynoochee and Satsop Sub-basins, 2017

Appendix A-1. Live and dead counts of Chum salmon in index reaches of the Wynoochee and Satsop sub-basins, fall 2017. Counts are during the single week used for calculating the proportion of spawners within index (AUC, CMR) versus supplemental survey reaches. Dead counts for CMR reaches include tagged recoveries. Some of the reaches included in this table are a part of the long-term monitoring conducted for Coho, Chinook, and Chum in the Chehalis River basin conducted by WDFW District 17 Fish Management. Tributary numbers are the WRIA stream catalog codes.

Sub-Basin	Stream Name	Upper RM	Lower RM	Reach Length	Strata	Type	Live Counts Spawner	Holder	Unknown	Dead Counts
Wynoochee	Wynoochee River	15.4	13.7	1.7	Boat	AUC	168	102	0	5
	Wynoochee River	20.4	15.4	5.0	Boat	AUC	525	58	0	29
	Schafer Creek	1.3	0.0	1.3	Foot	CMR	29	2	0	55
	Schafer Creek	3.1	1.3	1.8	Foot	CMR	51	0	0	97
	Schafer Creek	3.6	3.1	0.5	Foot	CMR	24	6	0	20
	Schafer Creek	4.3	3.6	0.7	Foot	CMR	10	2	0	19
	Schafer Creek	6.5	4.3	2.2	Foot	AUC	180	23	0	78
	Neil Creek	1.0	0.0	1.0	Foot	AUC	76	2	0	16
Satsop	Satsop River	10	6.3	3.7	Boat	CMR	72	5	0	32
	Satsop River	11.0	10.0	1.0	Boat	CMR	2	1	0	7
	Satsop River	12.4	11.0	1.4	Boat	AUC	52	14	0	8
	Satsop River	14.7	12.4	2.3	Boat	AUC	2	0	103	15
	Middle Fork Satsop	3.3	1.7	1.6	Boat	AUC	19	3	0	2
	Middle Fork Satsop	1.7	0.3	1.4	Boat	AUC	31	0	0	2
	Decker Creek	5.8	5.2	0.6	Boat	AUC	561	13	0	8
	Schafer Slough[a]	0.4	0.0	0.4	Boat	AUC	385	14	0	31
	Maple Glen[a]	0.3	0.0	0.3	Foot	AUC	0	0	2	25
	Creamer Slough[a]	0.3	0.0	0.3	Foot	AUC	0	0	6	64
	Dry Bed Creek	1.0	0.0	1.0	Foot	AUC	0	0	0	21
	Decker Creek	1.1	0.5	0.6	Foot	AUC	0	0	0	49
	Decker Creek	1.8	1.1	0.7	Foot	AUC	0	0	0	1
	Decker Creek	6.8	5.8	0.6	Foot	AUC	0	0	0	198
	Tributary 0462	0.2	0.0	0.2	Foot	CMR	0	0	0	119
	Tributary 0462A	0.1	0.0	0.1	Foot	AUC	0	0	0	7
	Wynoochee			**6.7**	**Boat**		**693**	**160**	**0**	**34**
	Wynoochee			**7.5**	**Foot**		**370**	**35**	**0**	**285**
	Satsop			**12.4**	**Boat**		**1124**	**50**	**103**	**105**
	Satsop			**4.2**	**Foot**		**0**	**0**	**8**	**484**

[a] Long-term chum index used by WDFW District 17 Fish Management

Appendix A-2. Live and dead counts of Chum salmon in supplemental reaches in the Wynoochee basin, fall 2017. Counts are during the single week used for calculating the proportion of spawners within index (AUC, CMR) versus supplemental survey reaches.

Stream	Upper RM	Lower RM	Reach Length	Method	Live Counts Spawner	Holder	Unknown	Dead Counts
Wynoochee River	5.6	0.0	5.6	Boat	4	64	0	0
Wynoochee River	13.7	5.6	8.1	Boat	184	126	0	9
Wynoochee River	20.5	20.4	0.1	Boat	9	0	0	0
Wynoochee River	29.1	20.5	8.6	Boat	1,340	231	0	355
Wynoochee River[a]	34.6	29.1	5.5	Boat	2,476	125	0	481
Wynoochee River	39.5	34.6	4.9	Boat	1,895	28	0	192
		Subtotal	**37.2**	**Boat**	**6,213**	**585**	**0**	**1,052**
Wynoochee River[b]	47.9	46.0	1.9	Foot	49	1	0	1
Wynoochee River[b]	46.0	43.5	2.5	Foot	256	10	0	14
Tributary 0261A	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0261A	0.3	0.1	0.2	Foot	0	0	0	0
Tributary 0263	0.4	0.0	0.4	Foot	0	0	0	0
Tributary 0284	0.7	0.0	0.7	Foot	0	0	0	0
Tributary 0284A	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0287	0.3	0.0	0.3	Foot	0	0	0	0
Tributary 0287	0.5	0.3	0.2	Foot	0	0	0	0
Helm Creek	1.3	0.6	0.7	Foot	0	0	0	0
Helm Creek	2.7	1.3	1.4	Foot	0	0	0	0
Helm Creek	3.5	2.7	0.8	Foot	0	0	0	0
Helm Creek[d]	3.9	3.5	0.4	Foot	0	0	0	0
Helm Tributary C	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0289	0.6	0.0	0.6	Foot	0	0	0	0
Anderson Creek (Lower)	2.2	0.8	1.4	Foot	0	0	0	0
Carter Creek	1.8	0.0	1.8	Foot	0	0	0	0
Carter Creek	2.8	1.8	1.0	Foot	0	0	0	0
Carter Creek	3.2	2.8	0.4	Foot	0	0	0	0
Carter Creek Tributary B	0.1	0.0	0.1	Foot	0	0	0	0
Carter Creek Tributary C	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0292	0.3	0.0	0.3	Foot	0	0	0	0
Tributary 0293	0.7	0.0	0.7	Foot	0	0	0	0
Tributary 0294B	0.1	0.0	0.1	Foot	0	0	0	0

Continued on next page

Appendix A-2 continued.

Stream	Upper RM	Lower RM	Reach Length	Method	Live Counts Spawner	Holder	Unknown	Dead Counts
Schafer Creek	7.1	6.5	0.6	Foot	0	0	0	0
Tributary 0296	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0296A	0.1	0.0	0.1	Foot	0	0	0	0
Neil Creek	1.1	1.0	0.1	Foot	0	0	0	0
Neil Creek[d]	1.6	1.1	0.5	Foot	0	0	0	0
Tributary 0298	0.3	0.0	0.3	Foot	2	4	0	3
Tributary 0298	1.2	0.3	0.9	Foot	19	0	0	0
Tributary 0298[d]	1.7	1.2	0.5	Foot	0	0	0	0
Tributary 0299	0.6	0.0	0.6	Foot	2	0	0	1
Tributary 0300[d]	0.6	0.0	0.6	Foot	0	0	0	0
Tributary 0302	0.6	0.0	0.6	Foot	7	0	0	9
Save Creek[c]	0.0	0.0	0.0	Foot	0	0	0	0
Larsen Creek[c]	0.2	0.0	0.2	Foot	0	0	0	0
Falls Creek[c]	0.3	0.0	0.3	Foot	0	0	0	0
Harris Creek[c]	0.4	0.0	0.4	Foot	0	0	0	0
Anderson Creek (Upper)	0.6	0.0	0.6	Foot	0	0	0	0
Big Creek	0.6	0.3	0.3	Foot	0	0	0	0
	Subtotal		**18.6**	**Foot**	**30**	**4**	**0**	**13**

[a] Counts include QDNR index. Counts taken over two days, day one included mainstem counts and day two included exploring side-channels and braids

[b] Mainstem survey conducted by foot instead of by boat due to access issues and inability to take out boats. Counts will be included in mainstem boat strata due to similar habitat

[c] Mainstem survey conducted by foot instead of by boat due to access issues and inability to take out boats. Counts will be included in mainstem boat strata due to similar habitat

[c] Survey truncated at falls determined to be impassable barrier for chum

[d] Survey truncated due to lack of chum, assumed no chum presence

Appendix A-3. Live and dead counts of Chum salmon in supplemental reaches in the Satsop basin, fall 2017. Reaches in this table were surveyed once during the chum spawning season to determine chum distribution. Counts are during the single week used for calculating the proportion of spawners within index (AUC, CMR) versus supplemental survey reaches.

Stream	Upper RM	Lower RM	Reach Length	Method	Live Counts: Spawner	Live Counts: Holder	Live Counts: Unknown	Dead Counts
Satsop River	6.3	0.0	6.3	Boat	2	12	0	23
Satsop River	17.4	14.7	2.7	Boat	200	50	0	7
Satsop River	17.5	17.4	0.1	Boat	7	3	0	0
West Fork Satsop	7.3	0.0	7.3	Boat	15	0	1	1
West Fork Satsop	17.0	7.3	9.7	Boat	29	3	0	0
West Fork Satsop	20.0	17.0	3.0	Boat	1	9	0	1
West Fork Satsop	27.5	20.0	7.5	Boat	26	4	0	4
West Fork Satsop	31.9	27.5	4.4	Boat	10	2	0	2
Canyon River	9.3	0.0	9.3	Boat	6	2	0	0
Canyon River[a]	10.7	9.3	1.4	Boat	0	0	0	0
Middle Fork Satsop	0.3	0.0	0.3	Boat	0	0	0	0
Middle Fork Satsop	6.6	3.3	3.3	Boat	60	8	0	0
Middle Fork Satsop	9.6	6.6	3.0	Boat	0	0	0	0
Middle Fork Satsop	13.6	9.6	4.0	Boat	0	1	0	0
Middle Fork Satsop	16.8	13.6	3.2	Boat	0	0	0	0
Middle Fork Satsop	18.0	16.8	1.2	Boat	0	0	0	0
Bingham Creek	0.9	0.0	0.9	Boat	124	5	0	2
		Subtotal	**67.6**	**Boat**	**480**	**99**	**1**	**40**
Mitchell Creek	0.8	0.7	0.1	Foot	0	0	0	0
Mitchell Creek	1.4	0.8	0.6	Foot	0	0	0	0
Mitchell Creek[a]	1.8	1.4	0.4	Foot	0	0	0	0
Still Creek	0.1	0.0	0.1	Foot	0	0	0	0
Still Creek	0.7	0.1	0.6	Foot	0	0	0	0
Still Creek[a]	3.5	0.7	2.8	Foot	0	0	0	0
Tributary 0367[a]	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0368[a]	0.7	0.0	0.7	Foot	0	0	0	0
Singer Creek	0.5	0.0	0.5	Foot	0	0	0	0
Singer Creek[a]	0.8	0.5	0.3	Foot	0	0	0	0
Black Creek	0.9	0.0	0.9	Foot	0	0	0	0
King Creek	0.4	0.2	0.2	Foot	2	0	0	0
King Tributary A	0.2	0.0	0.2	Foot	0	0	0	0

Continued on next page

Appendix A-3 continued.

Stream	Upper RM	Lower RM	Reach Length	Method	Live Counts Spawner	Holder	Unknown	Dead Counts
Tributary 0408	0.1	0.0	0.1	Foot	0	0	0	0
Tributary 0408	0.6	0.1	0.5	Foot	0	0	0	0
Tributary 0409	0.5	0.3	0.2	Foot	0	0	0	0
Smith Creek	0.7	0.0	0.7	Foot	0	0	0	0
Smith Creek	1.2	0.7	0.5	Foot	0	0	0	0
Smith Creek[a]	2.4	1.2	1.2	Foot	0	0	0	0
Tributary 0420	0.8	0.0	0.8	Foot	0	0	0	0
Tributary 0420[a]	1.6	0.8	0.8	Foot	0	0	0	0
Rabbit Creek	1.7	1.3	0.4	Foot	0	0	0	0
Rabbit Creek	2.3	1.7	0.6	Foot	0	0	0	0
Rabbit Creek[a]	2.7	2.3	0.4	Foot	0	0	0	0
Decker Creek[b]	5.2	2.9	2.3	Boat	0	0	0	177
Decker Creek	8.0	6.8	1.2	Foot	1	0	0	366
Decker Creek	9.4	8.0	1.4	Foot	0	0	0	34
Decker Creek	10.5	9.4	1.1	Foot	0	0	0	16
Decker Creek	11.4	10.9	0.5	Foot	0	0	0	0
Decker Creek[a]	14.8	10.9	3.9	Foot	0	0	0	0
Decker Tributary H	0.1	0.0	0.1	Foot	5	0	0	1
Decker Tributary I	0.1	0.0	0.1	Foot	0	0	0	5
Decker Tributary J	0.1	0.0	0.1	Foot	0	0	0	0
Dry Creek[a]	1.3	0.0	1.3	Foot	0	0	0	0
Peterson Creek[a]	2.5	0.0	2.5	Foot	0	0	0	0
Dry Bed Creek	3.2	1.0	2.2	Foot	0	0	0	2
Dry Bed Creek	5.4	3.2	2.2	Foot	0	0	0	0
Dry Bed Creek	7.2	5.4	1.8	Foot	0	0	0	0
Dry Bed Creek[a]	8.4	7.2	1.2	Foot	0	0	0	0
Dry Bed Tributary A	0.6	0.0	0.6	Foot	0	0	0	0
Tributary 0457	0.3	0.0	0.3	Foot	0	0	0	0
Tributary 0457	0.5	0.3	0.2	Foot	0	0	0	0
Tributary 0457[a]	1.0	0.5	0.5	Foot	0	0	0	0
Tributary 459	1.0	0.0	1.0	Foot	0	0	2	1
Tributary 459	2.3	1.0	1.3	Foot	0	0	0	0
Tributary 0459B	0.4	0.0	0.4	Foot	0	0	0	0

Continued on next page

Appendix A-3 continued.

Stream	Upper RM	Lower RM	Reach Length	Method	Live Counts Spawner	Holder	Unknown	Dead Counts
Tributary 0459C	1.2	0.0	1.2	Foot	0	0	0	0
Dry Run Creek	1.2	0.0	1.2	Foot	0	0	0	0
Dry Run Creek	2.5	1.2	1.3	Foot	0	0	0	0
Dry Run Creek[a]	5.1	2.5	2.6	Foot	0	0	0	0
Tributary 0464	0.6	0.0	0.6	Foot	0	0	0	0
Tributary 0464[a]	1.5	0.6	0.9	Foot	0	0	0	0
		Subtotal	**47.7**	**Foot**	**8**	**0**	**2**	**602**

[a] Survey truncated due to lack of chum, assumed no chum presence

[b] Depending on flows this reach can be surveyed by either foot or boat. Reach was surveyed simultaneous with other Decker reaches, but boats were necessary due to high flows. Survey will be included in foot strata

Appendix A-4. Supplemental reaches that were not surveyed in 2017 in the Wynoochee and Satsop sub-basins. These streams were not surveyed in 2017 for a variety of reasons including: inability to access, inadequate visibility, or unsafe survey conditions.

Sub-Basin	Stream	Upper RM	Lower RM	Reach Length
Wynoochee	Wynoochee[a]	43.5	39.5	4.0
	Tributary 0304[b]	0.3	0.0	0.3
	Tributary 0301[b]	0.3	0.0	0.3
	Helm Creek[c]	0.6	0.0	0.6
	Anderson Creek (Lower)[bc]	0.8	0.0	0.8
	Wedekind Creek[c]	2.3	0.0	2.3
	Bitter Creek[c]	2.5	0.5	2.0
	Black Creek[c]	5.4	0.0	5.4
	Sylvia Creek[c]	3.3	0.0	3.3
	Subtotal			**19.0**
Satsop	Tributary 0463	0.3	0.0	0.3
	Decker Creek	10.9	10.5	0.4
	Decker Creek	2.9	1.8	1.1
	Decker Creek	0.5	0.0	0.5
	Rabbit Creek	1.3	0.0	1.3
	Halsea Creek	0.5	0.0	0.5
	Tributary 0421	0.1	0.0	0.1
	Tributary 0419[b]	0.1	0.0	0.1
	Tributary 0412[b]	0.3	0.0	0.3
	Tributary 0411[b]	0.0	0.0	0.0
	Cook Creek	1.5	0.0	1.5
	King Creek[b]	0.2	0.0	0.2
	Tributary 0400[b]	0.3	0.0	0.3
	Tributary 0399[b]	0.3	0.0	0.3
	Little River[b]	1.5	0.0	1.5
	Tributary 0397[b]	0.6	0.0	0.6
	Tributary 0396[b]	0.3	0.0	0.3
	Tributary 0365	0.3	0.0	0.3
	Mitchell Creek[b]	0.7	0.0	0.7
	Subtotal			**10.3**

[a] Gorge section, deemed unsafe to survey during winter flows
[b] Not surveyed due to access issues from land owners or remote locations
[c] Not surveyed due to poor visibility or dangerous flow conditions

Appendix B – Summary of Chum Biological and Tagging Information Collected in the Carcass-Mark-Recapture Index Reaches of the Wynoochee and Satsop Sub-basins, 2017

Appendix B-1. Number of carcass tags released and recovered by index reach during Chum carcass tagging surveys in the Wynoochee and Satsop sub-basins, fall 2017.

Sub-Basin	Index Reach	Tagged Fish	Tags Recovered	Tags Recovered in Non-Origin Reaches	Recovery Rate (%)
Wynoochee	Schafer 4.3-0.0	102	49	0	48
	Schafer 6.5-4.3	14	4	0	36
	Neil Creek 1.0-0.0	9	2	0	22
	Subtotal	**125**	**55**	**0**	**46**
Satsop	Tributary 0462	123	114	0	93
	Satsop 10.0-6.3	172	76	0	44
	Subtotal	**295**	**190**	**0**	**64**

Appendix B-2. Summary of all Chum carcasses handled by index reach, 2017. Condition includes: Tagged Condition 1-3 (tagged carcasses), Untagged Condition 1-3 (carcasses in taggable condition but not tagged), Untagged Condition 4-5 (carcasses inspected for tags but not in taggable condition), and Unknown Condition (carcasses not inspected for tags). The unknown condition category included carcasses that were seen but not handled due to unsafe location, unable to be retrieved, or did not have one or both operculum. Tagging condition is summarized by male (M), female (F), and sex not determined (SND).

Sub-Basin	Stream Reach	Stat Week	Tagged Condition 1-3			Untagged Condition 1-3			Untagged Condition 4-5			Unknown Condition	Tagging Rate
			M	F	SND	M	F	SND	M	F	SND	SND	
Wynoochee	Schafer 4.3 – 0.0	41	0	0	0	0	0	0	0	0	0		No fish tagged
		42	0	0	0	0	0	0	0	0	0		No fish tagged
		43	0	0	0	0	0	0	0	0	0		No fish tagged
		44	1	1	0	0	0	0	0	0	0		1:1
		45	19	18	0	0	0	0	3	6	8		1:1
		46	5	3	0	13	7	10	7	2	2		1:5
		47	12	14	0	35	48	18	20	20	18		1:5
		48	9	17	0	0	0	5	10	17	29		1:1
		49	0	1	0	0	0	0	0	0	10		1:1
		50	0	2	0	0	0	0	2	2	21		1:1
Satsop	Tributary 0462	41	0	0	0	0	0	0	0	0	0		No fish tagged
		42	0	0	0	0	0	0	0	0	0		No fish tagged
		43	0	0	0	0	0	0	0	0	0		No fish tagged
		44	0	0	0	0	0	0	0	0	0		No fish tagged
		45	0	0	0	0	0	0	0	0	0		No fish tagged
		46	0	0	0	0	0	0	0	0	0		No fish tagged
		46B	16	5	0	0	0	0	0	0	0		1:1
		48	30	23	0	0	1[b]	0	0	0	5		1:1
		49	20	28	0	1[b]	0	0	3	13	0		1:1
		50	1	1	0	0	0	0	2	2	7		1:1
Satsop	Satsop 11 – 6.3	40	0	0	0	0	0	0	0	0	0		No fish tagged
		41	0	0	0	0	0	0	0	0	0		No fish tagged
		41A	0	0	0	0	0	0	0	0	0		No fish tagged
		42	0	0	0	0	0	0	0	0	0		No fish tagged
		43	0	0	0	0	0	0	0	0	0		No fish tagged
		44	0	0	0	0	0	0	3	0	0		1:1
		45	8	9	1	0	0	5	3	0	3		1:1
		46	18	10	0	0	0	0	3	0	0		1:1
		47	15	9	0	61	26	17	33	30	6	24[a]	1:5
		48	57	27	0	0	0	0	87	71	277		1:1
		49	6	9	0	0	0	0	5	6	148		1:1
		50	3	0	0	0	0	0	0	0	89		1:1

[a] Due to time constraints, stopped sampling and tagging carcasses and switched to live/dead counts only 1.8 miles from end of survey

[b] Fish tagged, but tail accidently cut during course of survey