STATE OF WASHINGTON June 2019

Grays Harbor Fall Chum Abundance and Distribution, 2018

by Lea Ronne,
Amy Edwards and
Mara Zimmerman

Washington Department of
FISH AND WILDLIFE
Fish Program
Fish Management Division

FPT 19-05

Grays Harbor Fall Chum Salmon (*Oncorhynchus keta)* Abundance and Distribution, 2018

Washington Department of Fish and Wildlife

Lea Ronne
Region 6 Fish Management
48 Devonshire Rd, Montesano WA 98563

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

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

June 2019

Acknowledgements

We would like to thank our WDFW survey staff for collecting data and samples: Giulio Del Piccolo, Brady Green, Stephanie Lewis, Caitlin McNamara, Callie Miller, Frank Staller, Patrick Landback, Garrett Moulton, Curt Holt, Mike Scharpf, Kim Figlar-Barnes, Oliver Crew, Ben Stillman, Nick VanBuskirk, Brian Barry, Craig Loften, Jesse Guidon, Danielle Williams, Kyle Vandegraaf, Sky Cropper, and Neala Kendall. We would like to thank our volunteer for helping conduct supplemental surveys, Joe Kalisch. Thanks to Eric Walther with help designing 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. Thank you to Jeremy Parker and the staff at the Humptulips Hatchery for providing data and gear storage. We would like to thank Quinault Division of Natural Resources (QDNR), Steve Franks from Satsop Springs Hatchery 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 from WDFW and Adam Rehfeld from QDNR, who reconciled and input data. Special thanks to Thomas Buehrens and Jeremy Wilson from Region 5 for assisting with data analysis. We would also like to thank Rayonier Inc., the Fruit Growers Supply 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.

Table of Contents

List of Tables

List of Figures

Executive Summary

Background

Escapement estimates for the Grays Harbor Chum Salmon (*Oncorhynchus keta*) population have been derived by the Washington Department of Fish and Wildlife (WDFW) each year for the past fifty years. Even at its inception in the 1970s, the current method for estimating Chum escapement was considered hastily put together out of necessity and required updating as soon as possible (Brix 1978). The current method appears to underestimate the number of Chum returning to Grays Harbor and lacks information on their distribution, but WDFW has been unable to dedicate the resources necessary for assessing the degree of underestimation. In 2014, the Aquatic Species Enhancement Plan (ASRP) Technical Committee of the Chehalis Basin Strategy began conducting studies on the habitat and aquatic species within the Chehalis Basin to understand the impacts of potential flood reduction and restoration actions. The accurate abundance and distribution of Chum returning to Grays Harbor were identified by WDFW and the ASRP as key information gaps for restoration, and work began in 2015 to fill in these gaps.

In 2015, a pilot study in Grays Harbor tributaries informed a survey frame in sub-basins to identify index reaches with high densities of Chum spawners. In 2016, a survey design was developed and implemented that utilized carcass tagging, live/dead counts, and peak spawning surveys to determine the abundance and distribution at a sub-basin level. The new survey design was first implemented in the Wynoochee and Satsop sub-basins in 2016 and 2017 (Edwards and Zimmerman 2017). In 2018, the new methodology was applied to the Humptulips sub-basin, and data from 2017 and 2018 were used to calculate abundance estimates for the Humptulips, Wynoochee, and Satsop sub-basins. The 2018 analysis resulted in a combined abundance estimate of 48,046 Chum within the tributaries of the Humptulips, Wynoochee, and Satsop. Grays Harbor tributaries with significant Chum spawning (Hoquiam, Wishkah, etc.) have yet to be assessed with the new methodology and were not included in the abundance estimate. Regardless, the escapement estimates calculated with the new methodology were consistently higher than escapement estimates for the entire Grays Harbor Chum population using the current methodology. The 2017 Wynoochee and Satsop abundance estimates alone were 50% greater than the total Grays Harbor estimate. In 2018, the Humptulips, Wynoochee, and Satsop abundance estimates were 69% greater than the total Grays Harbor estimate for the year. These findings justified the purpose of this study as well as further efforts to improve spawning escapement information on Grays Harbor Chum.

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 (AUC) 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 that were used to estimate survey life represented a range of stream size classes – side channel, small, medium, and large. Abundance in all index reaches was based on AUC 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 2018, the focus was the Humptulips sub-basin but abundance estimates were also calculated for the Wynoochee and Satsop using 2018 index live counts and 2017 distribution data.

Results

- **Distribution inside versus outside index reaches:** In the Humptulips tributaries, 44% and 46% of Chum spawning occurred within the index reaches with the highest densities observed in Stevens, O'Brien, and Donkey creeks. In the Humptulips mainstem, 32% and 40% of Chum spawning occurred within the index reaches with the highest densities of Chum observed between river miles 13.9-28.1 and 33.9-43.0. The two different proportions represent values provided by the different types of live counts (spawners only versus total live). Proportions in the Humptulips were calculated using counts from 2018 index reaches and one-time peak distribution surveys. In the Wynoochee 11% of spawning occurred within tributary index reaches and 11% occurred in mainstem index reaches. In the Satsop, 24% of spawning occurred within tributary index reaches and 40% occurred in mainstem indexes. The distribution proportions were derived from total live counts and did not distinguish spawner status. Proportions in the Wynoochee and Satsop were calculated using live/dead counts from 2017 surveys, but distribution inside and outside index reaches was based on 2018 surveys.
- **Area-under-the-curve in index reaches:** In the Humptulips sub-basin, fish-day calculations summed across 16 index reaches ranged between 70,173 (spawners only) and 87,619 (total live). In the Wynoochee sub-basin, fish-day calculations summed across six index reaches equaled 22,819 (total live). In the Satsop sub-basin, fish-day calculations summed across 14 index reaches equaled 18,938 (total live).
- **Abundance in carcass tagging index reaches:** Chum spawner abundance was estimated to be 164 in the small index (Elwood Creek) and 4,229 in the medium stream index (Stevens Creek).
- **Survey life:** In this study, survey life (days ± SD) represented BOTH the number of days a live Chum is present AND the observer efficiency within an index reach. For 2018, small channel index (Elwood Creek) survey life was 9.5 days (±0.9) using spawners only and 13.4 days (±1.3) using total live counts. For the 2018 medium channel index (Stevens Creek), survey life was 7.5 days (±0.2) using spawners only and 10.3 days (±0.22) using total live. For the 2017 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.
- **Abundance in all index reaches:** In the Humptulips sub-basin, abundance within the 16 index reaches was estimated between 9,011 (spawners only) and 8,204 (total live counts). In the Wynoochee sub-basin, abundance within the six index reaches was estimated to be 2,171 (total live counts). In the Satsop sub-basin, abundance within the 14 index reaches was estimated to be 1,903 (total live counts).
- **Spawner abundance:** The 2018 Chum spawner abundance (±SD) for the Humptulips sub-basin was estimated to be 22,328 (±345) using spawner counts only and 20,258 (±297) using total live counts. Chum spawner abundance for the Wynoochee sub-basin was estimated to be 19,964 (±956) using total live counts. Chum spawner abundance for the Satsop sub-basin was estimated to be 7,824 (±309) using total live counts.

Conclusions

The overall estimates of Chum spawner abundance differed slightly based on the type of counts (spawners only or total live counts including spawners and holders) used in the analysis. Both provided estimates that were consistently higher than those derived using the existing methodology for Grays

Harbor Chum. All together, we estimated a 2018 Chum spawner abundance of approximately 48,000 (total live counts) or 50,000 (spawner only counts) for the sub-basins included in the study. Our estimate in the Humptulips, Wynoochee, and Satsop sub-basins was 20,000 and 22,000 more than the number of Chum estimated for the entire Grays Harbor basin using the existing methodology (n = 28,413). Similar to our findings in 2016 and 2017, these results suggest that the existing methodology likely underestimates the abundance of Grays Harbor Chum salmon.

A Chum abundance estimate using the new methodology was derived for the first time in the Humptulips sub-basin. Abundance estimates were also derived for the Wynoochee and Satsop sub-basins using live counts collected by multiple survey crews in 2018 and distribution data from 2017, which was not previously calculated. The abundance estimates appear to be sensitive to how live counts are collected. Designating spawner status for live Chum to account for fish that are passing through, but not spawning within the reach eventually leads to two different survey life estimates separated by as much as 3.9 days. Survey crew also appears to affect Chum live counts, with different crew counts varying as much as 30%. In addition to the importance of consistent live counts, distribution and index selection potentially greatly affects the final abundance estimate. The Satsop sub-basin abundance estimate was less than half the estimate for either the Humptulips or Wynoochee. Two possibilities for this discrepancy were identified: low Chum spawner abundance and/or low flows reduced use of some index spawning habitats. Overall, this work demonstrates that the current method of estimating escapement, underestimates Chum abundance. Moreover, further work needs to be done to better understand basin wide distribution, account for inter-annual variation, and refine methodologies.

Introduction

In 2014, the Aquatic Species Enhancement Plan Technical Committee of the Chehalis Basin Strategy identified a knowledge gap in Chum Salmon (*Oncorhynchus keta*) abundance, distribution, and spawning habitats and recommended further studies within the sub-basins of Grays Harbor to address these issues. 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 Chum include two populations in the WDFW Salmon Stock Inventory (SaSI) database - Humptulips Chum and Chehalis Chum (WDFW 2002). The Humptulips population include Humptulips River and its tributaries and the Chehalis population include tributaries of the Chehalis River from the Hoquiam River to the Black River. The majority of Chum spawning occurs in the Humptulips, Hoquiam, Wishkah, Wynoochee, and Satsop rivers and their tributaries. Additional spawning is observed in Black River, Cloquallum Creek, and other smaller mainstem tributaries, as well as in the south harbor tributaries, such as Elk and Johns Rivers. 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, which uses a single escapement goal for the combined populations. In 2019, genetic work summarizing the Chum population structure indicated genetic separation between Humptulips and Chehalis Chum (Small et al. 2019). However, the difference between sub-basin spawning aggregates is too low to be detected in a mixed stock fishery, and suggests Grays Harbor Chum are a metapopulation with straying between nearby tributaries.

The existing methodology for estimating spawner abundance of Chum was developed by WDFW almost four decades ago. 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 total Chum 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, WDFW personal communication; 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. Spawner surveyors collect additional counts of live and dead Chum in areas surveyed for Chinook and Coho each year, but these Chum counts are not incorporated into the current escapement estimate. 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. 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%
Total					10.80%

The current method for estimating Chum spawner abundance relates the greatest counts of live and dead fish 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 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 several assumptions that require additional validation, which may 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 escapement goal of 21,000 Chum is accurate.** 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 met its escapement goal of 21,000 Chum in the year(s) when 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 period. 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 modified by natural processes such as beaver activity, and anthropogenic pressures also influence the landscape. All of these local disturbances 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 mainstem river has not changed over time.** Substantial habitat changes 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 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 silt abundance 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). In 2016, work continued to further update methods to estimate Chum spawner abundance and these new methods were implemented in the Wynoochee and Satsop sub-basins. The updated methodology incorporated data collected from established index reaches for Chum, Coho, and Chinook estimation. The updated methodology utilized carcass tagging, live/dead counts, and peak spawning surveys to determine the abundance and distribution of Chum in the Wynoochee and Satsop sub-basins (Ashcraft et al. 2017).

After completing the analysis and final report for Chum spawners returning in 2016, we decided to return to the Wynoochee and Satsop sub-basins in 2017 and re-implement the updated methodology to address specific uncertainties associated with the 2016 estimates (Edwards and Zimmerman 2017). Changes to the updated methodology were successfully implemented during the 2017 field season, resulting in an abundance estimate of 28,000 to 32,000 Chum returning to the Wynoochee and Satsop sub-basins (Edwards and Zimmerman 2017). The estimate for the Satsop and Wynoochee sub-basins was 9,000 to 13,000 fish higher than the number of spawners estimated for the entire Grays Harbor basin using the existing methodology (n = 18,627). Due to our confidence in the accuracy of the 2017 abundance estimate, we decided to shift our focus to implementing the updated methodology in the Humptulips sub-basin for the 2018 field season to continue assessing the entire Grays Harbor Chum population.

Objectives

The 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 to be implemented in future years.

The objectives for the **2018 field survey season** were to:

- Implement study design in Humptulips sub-basin of the Grays Harbor Chum salmon population,
- Update the survey frame for the Humptulips sub-basin, and document the upper limit of occurrence (ULO) of spawning and potential barriers to Chum,
- Conduct surveys throughout the entire Humptulips survey frame during peak spawn timing and collect counts 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 in the Humptulips, Wynoochee and Satsop sub-basins,
- Implement live counts and carcass mark-recapture (CMR) study concurrently on a weekly basis within additional CMR index reaches selected in the Humptulips 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 of 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. A velocity barrier exists for Chum at the Humptulips Hatchery trap, so no additional trap counts were added to the Humptulips sub-basin abundance estimate. Chum collected at three traps located on the EF Satsop were added to the total spawner abundance for the Satsop sub-basin.

Table 2. Surveys conducted for Chum salmon in the Humptulips, Wynoochee and Satsop rivers, 2018.

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

*No CMR surveys were conducted in the Wynoochee and Satsop sub-basins in 2018

Study Area

The study was conducted on the Humptulips, Wynoochee, and Satsop mainstem and tributaries. The Humptulips River enters the north side of Grays Harbor with headwaters in the Olympic Mountains. Both the Wynoochee and Satsop rivers are right bank tributaries to the Chehalis River with headwaters in the Olympic Mountains. The Wynoochee River enters the Chehalis mainstem at river mile (RM) 13.0, and the Satsop River enters the Chehalis mainstem at RM 20.2. Comprehensive surveys were conducted in the Wynoochee and Satsop sub-basins in 2017, and detailed descriptions of the study areas can be found in Edwards and Zimmerman (2017).

The Humptulips River has a drainage area of 276 square miles and is a rain-fed watershed. At RM 28.1 the mainstem splits into the East Fork (EF) Humptulips and West Fork (WF) Humptulips. The EF Humptulips River is 29.9 RM in length, while the WF Humptulips is 32.2 RM in length (Phinney and Bucknell, 1975). The mainstem Humptulips is tidally influenced up to RM 6.7. From the mouth up to the EF and WF confluence, the Humptulips River is surrounded by privately owned land, including the area around the Big Creek drainage. Two major tributary systems enter the mainstem Humptulips below RM 28.1. The Big Creek drainage enters the Humptulips at RM 8.3, while the Stevens Creek drainage enters upstream at RM 13.7. The lower portion of the two forks and the Stevens Creek drainage are predominately surrounded by private timber landowners. The U.S. National Forest boundary crosses the EF Humptulips at RM 13.5, while the WF Humptulips first enters at RM 40.6. A gorge section less than a mile long begins at RM 46.0 on the WF Humptulips River. Chinook, Coho, and Steelhead have been recorded above of the gorge, but no Chum have been documented upstream. The entire Humptulips sub-basin was heavily splash-dammed throughout the 19th century to transport logs to mills in Grays Harbor. The WDFW Humptulips Hatchery is located near the mouth of Stevens Creek, and is the only hatchery located within the Humptulips sub-basin. No Chum are released from the Humptulips Hatchery.

Two hatchery facilities release Chum 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). On years when Chum programs are in place, Bingham Creek Hatchery and SSH have released an approximate annual average of 180,000 and 215,000 fry, respectively (Table 3). Hatchery and trap operations on the EF Satsop at BCH and Bingham Creek give a census count of Chum entering the trap and record the number of Chum transported upstream of the trap. Details of the hatchery facilities and fish trap passage barriers can be found in Edwards and Zimmerman (2017).

Table 3. Number of hatchery Chum released from Bingham Creek Hatchery (BCH) and Satsop Springs Hatchery (SSH) in the Satsop sub-basin, 2007-2019. 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	--	198,300	198,300
2008	--	197,800	197,800
2009	130,100	--	130,100
2010	193,800	325,000	518,800
2011	188,700	338,400	527,100
2012	198,100	--	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	226,000	350,300
2019	109,900	187,020	296,920
Average	**176,082**	**216,156**	**325,502**

[a] Total = BCH + SSH

Survey Frame

The survey frame for the Humptulips River included the entire known distribution of Chum within the sub-basin. 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 District 17 Fish Management Staff (WDFW D17) 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 1970s (WDFW unpublished data). Based on this information, a survey frame for this study was established in 2018. The survey frame for the Wynoochee and Satsop sub-basins included the long-term indexes and supplemental reaches surveyed by the WDFW D17 and QDNR staff on an annual basis.

The 2018 survey frame was divided into foot and boat strata based on the way in which surveyors access the river. Foot strata were determined by the ability of a surveyor to survey most to all of the stream by foot. Reaches 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.

A total of 17 AUC index reaches were surveyed in 2018 in the Humptulips, 5 indexes in the Wynoochee, and 19 indexes in the Satsop. Indexes where no Chum were identified, or the entirety of the Chum spawning season was not encompassed, were removed or data analyzed as peak counts. For the past 30 years, spawning ground surveys have been conducted in the Humptulips, Wynoochee, and Satsop by WDFW D17 and QDNR as part of their annual stock monitoring program in the Chehalis River basin. Of the 41 indexes surveyed in 2018, 35 were historical indexes. These historical indexes not only provide necessary live/dead information for AUC calculations, but allow for information on Chum to be applied to historical data from these reaches. An additional six AUC reaches were added to the list of established reaches and surveyed by WDFW Chum Project staff in 2018 (Appendix B-1, B-2, B-8).

A total of eight CMR index reaches were planned in 2018. Surveys in the CMR index reaches were conducted by WDFW Chum Project staff only in the Humptulips sub-basin. CMR reaches were selected based on past knowledge of Chum abundance within the study areas (long-term salmon reaches surveyed by QDNR and WDFW D17, the 2015 pilot study, WRIA catalog salmon use classification, SalmonScape distribution, and the WDFW 1980s Chum habitat assessment). CMR index reaches were of variable stream size known to have Chum spawner numbers that ensured 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 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 to provide information on environmental covariates possibly associated with survey life. The ‘survey life’ parameter (described in the section below) was a critical parameter in the final estimation of Chum abundance and is a key component in AUC calculations (English et al. 1992). Habitat data for the Humptulips was collected in 2018, while data for the Wynoochee and Satsop was collected in 2017. Stream size was identified as a feasible, quantifiable metric that may provide insight into survey life due to variables such as stream flow, predator access, and visibility likely differing between smaller and larger stream channels.

Habitat metrics for all CMR and AUC indexes included average bankfull width (BFW). Bankfull width is the width of the dominant channel formed by a recurring flow. 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 a mainstem river and thought to be breached during high water events in the fall. 'Small' index reaches had BFW between 5 and 15 meters and were generally secondary or tertiary tributaries. 'Medium' index reaches had BFW of 15 to 30 meters and were directly connected to the mainstem. 'Large' index reaches had BFW of 40 m or greater and generally mainstem river sections.

General Survey Methods

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. 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 scale from excellent visibility to poor visibility for the reach. Stream flow was recorded based on a scale of low flow/height to high flow/height for the reach. The direction being surveyed was either upstream or downstream. All boat strata were surveyed downstream. 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 either holding or spawning. Chum spawn from mid-October to mid-December based on QDNR and WDFW D17 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. Chum are typically smaller than Chinook and larger than Coho. Chum holding in pools with Chinook and Coho are identified by their darker coloration but can be difficult to enumerate depending on the number of individuals in the pool. The surveyor made an estimate of the total number of Chum holders based on their observation of the activity in the pool.

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 similar across all WDFW Chum Project, WDFW D17 and QDNR surveyors.

Biological sampling of Chum carcasses was conducted in the CMR and AUC index reaches to obtain information on sex, size, and age. The first ten carcasses in QDNR reaches or twenty carcasses in WDFW reaches of each one hundred carcasses encountered were sampled depending on the following: the species could be determined, the caudal/tail section was intact (not previously sampled), and scales were available for collection. If the carcass could not be identified by species, it was recorded as species not determined and not sampled. If the carcass was identified as a Chum and the caudal/tail region was missing, the carcass was not sampled. If the carcass was identified as Chum and it had a cut tail, it was recorded as a dead Chum previously mark sampled. Belly-slit or filleted (angler caught) Chum 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 or released whole back into the stream with opercula tags. 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 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.

CMR index reaches had the same protocols and timing as AUC indexes with the exception of how carcasses were handled. Surveys were continued until no live Chum or fresh (taggable) carcasses were observed for two consecutive weeks after the peak spawning period. Live and dead Chum were enumerated during each survey.

Data collection for carcasses in CMR indexes included carcass condition, 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 opercle to determine whether a plastic tag was stapled to the inside. Previous tag status for opercles were recorded as tag number, not present (if the opercle was present but no tag), or unknown (if the opercle area was missing) for both sides of the carcass. If a carcass was not able to be examined due to its location, then it was counted as an unknown species with unknown tail status and considered out of sample. Chum carcasses with a cut tails were not included in the dead count since they were previously counted.

Figure 1. Surveyor attaching carcass tag to Chum opercula, and carcass tag attached to underside of Chum opercle.

Untagged (maiden) carcasses were assigned as being in taggable or untaggable condition. ‘Untaggable’ condition meant that the maiden carcass scored a 4 or 5 on the qualitative condition scale or was missing one of the two opercula. Carcasses considered untaggable were counted and assigned as male, female or sex not determined (SND). Tails were cut prior to returning them to the stream to indicate that the fish had been investigated and counted. Carcasses considered to be taggable had a square plastic tag with a four-digit number stapled under the opercula (Figure 1). Tags with the same number were placed under each opercle. 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 (SND) for each tagged carcass, then returned the carcass to the stream from where they were collected with tails intact. If the tagged carcass was a part of the first ten fish encountered in QDNR indexes and the first twenty in WDFW indexes, scales were taken.

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 to be tagged while completing the survey within daylight hours of a single day. The tagging rate (e.g. 1:5 or 1:10) 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 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 opercula needed to be present to tag the carcass. If one or both were not present, then the carcass did not get tagged and opercle status was recorded on the field card.
[b] Only counted if the carcass could be identified as a Chum.

Trap Returns

Chum were 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 were enumerated and passed upstream to spawn, while Chum encountered at BCH were either lethally spawned or passed upstream. The total Chum returning to the traps were included in the final escapement estimate. A fallback rate was not applied to the final number of fish passed. For detailed protocols and handling of Chum at BCH, SSH and the Bingham Creek trap refer to Edwards and Zimmerman (2017).

Peak Counts

Once during the survey season supplemental surveys are conducted across the sub-basin to document the entirety of Chum spawning. Supplemental surveys are conducted during peak spawning to ensure the most accurate picture of Chum density and distribution. The proportion of what is seen inside indexes to what is seen in the rest of the basin, or supplemental surveys (Appendix A-1 through A-5), can be applied to the weekly index surveys for expansion to the whole sub-basin throughout the entire season. These peak surveys were conducted in the Humptulips over a two-week period. To accommodate for limited staff resources the basin was split into areas that could be covered in a single day to minimize inconsistencies in data collection (counting moving fish more than once). Additional staff and volunteers were recruited to ensure enough surveyors were available to cover each sub-basin. The entire Wynoochee and Satsop basins were surveyed during peak in 2017 (Edwards and Zimmerman 2017).

During each survey, live and dead Chum were enumerated by reach, and live Chum were categorized as holders or spawners using the same protocol as the AUC and CMR reaches. No additional biological sampling was conducted in supplemental reaches. The reach breaks between index and supplemental reaches were indicated by flagging the top and bottom of each reach. Advanced preparation was made to partition the supplemental areas into reaches and to secure stream access permissions from landowners to enter those areas.

Streams within the survey frame were prioritized at the beginning of the 2018 field season in anticipation of time constraints due to stream flows and high survey mileages associated with the peak counts. During the 2018 planning stages, streams with known Chum presence from 2015 and historical surveys were given high priority for survey in 2018. 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 the Humptulips sub-basin during the 2018 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.

The ULO was determined for each supplemental reach 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 latter are considered transient barriers since these can vary from year-to-year or are caused by anthropogenic influence. The height of the barrier was 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 was 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 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 regularly reviewed in-season by the project biologist. Cards were examined for any errors or missing information that was not recorded. Missing information was addressed with the field staff. Georeferenced locations for each reach start and stop were added to the database. Data were summarized and entered into the WDFW SGS database. The SGS database could hold only 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 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 collections including number of carcasses, sex composition, fork length, and age composition.

Chum Distribution

Chum spawning distribution was summarized in two formats: 1) The Humptulips survey area by reach type (AUC, CMR, Supplemental) and by strata (foot, boat); and 2) Chum densities with ULOs (fish per mile) 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 strata (foot, boat). The proportion of spawning inside and outside of indexes in the Satsop and Wynoochee were determined using information from the 2017 surveys. Indexes surveyed for Chum in 2017 and 2018 remained as indexes, but indexes surveyed in 2017 and not in 2018 were considered supplemental surveys for the proportions (Appendix A2, A4, and A5).

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 according to English et al. (1992) and Bue et al. (1998):

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

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. There are four critical assumptions that must be met to achieve an unbiased estimate (Bentley et al. 2018; Seber 1982):

- **Equal Catchability**: Each carcass present in the study system during a specific sample event, whether tagged or untagged, has the same probability of being captured.
- **Equal Persistence**: Each carcass present in the study system during a specific sampling event, whether tagged or untagged, has the same probability of survival.
- **Tag Loss and Recovery**: Tagged carcasses do not lose their marks and all marks are recognized and read properly on recover.
- **Instantaneous Sampling**: All samples are instantaneous, i.e., the sampling time is negligible, and each release is made immediately after the sample.

The JS estimator of spawner abundance estimate for each reach was based on the "super population" model (Schwarz et al. 1993) parameterized in a Bayesian framework (Figure 2). 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.

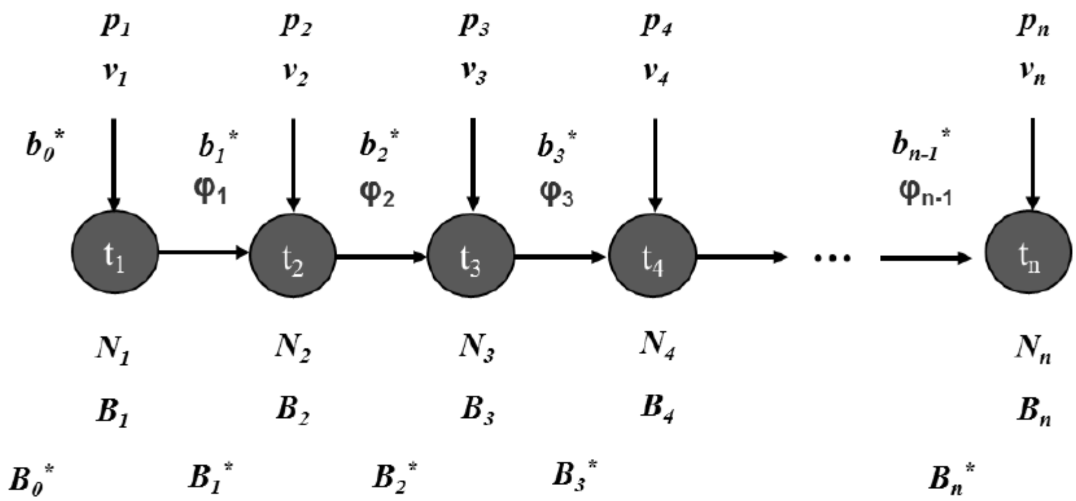


Figure 2 Conceptual diagram of "super population" Jolly-Seber abundance model developed by Schwarz et al. (1993) – diagram adapted by Kale Bentley from Schwarz and Arnason (2006) (Bentley et. al. 2018). Fundamental parameters of the model include: sample period *i* (t_i), probability of capture at sample period *i* (p_i), probability that a carcass captured at time *i* will be released, opposite of a loss-on-capture (v_i), probability that a carcass enters the population between sample periods *i* and *i*+1, which is referred to as probability of entry (b_i*), and the probability of a carcass persisting between sample periods *i* and *i*+1 (φ_i). Derived parameters of the model include: population size at sample period *i* (N_i), number of fish that enter after sample period *i* and survive to sample period *i* +1 (B_i), and number of fish that enter between sampling period *i*-1 and *i*, these are referred to as gross births (B_i*). Total abundance is calculated as the sum of *B** 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 40,000 iterations of the posterior distribution of each parameter after a 5,000 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 Crew Adjustments

An adjustment was needed to standardize counts made by different survey crews. Live counts of Chum within index reaches were collected by three crews: WDFW Chum Project, WDFW D17 and QDNR. Counts from the WDFW Chum crew were used as control counts since the majority of surveys were conducted by this crew for the purpose of documenting Chum. Correction factors were determined for counts from index reaches surveyed by WDFW D17 and QDNR to adjust for potential different observation rates due to differences in survey focus (see Recommendations section Edwards and Zimmerman 2017). Survey crew adjustment coefficients were derived from comparing counts from overlapping surveys where Chum were counted in the same sections of stream either same day or within one day of each other. A Monte Carlo simulation (200,000 model simulations using three chains with a thinning rate of ten) using JAGS software package provided the distributions of values for a proportion adjustment with error (code written by Thomas Buehrens, WDFW Science Division 2019). During weeks when crews did not designate spawner/holder status, counts were separated into spawners and total live based on the overall proportion of Chum spawners to total live Chum counted within each sub-basin, each statistical week.

Survey Life

Survey life ($\widehat{SL}$) 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. 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. 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 (200,000 model simulations) provided the distributions of values for this calculation:

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

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

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 ($\widehat{N}^{AUC}$) 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 (100,000 model simulations) provided the distribution of values for this calculation:

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

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

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 ($\hat{p}_i$) 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 ($\widehat{N}_i$) 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 (100,000 model simulations) provided the distribution of values for this calculation:

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

$$(8)\ \widehat{N}_{w,s} = \widehat{N}_{w,s,i} \big/ \hat{p}_{w,s,i}$$

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 Humptulips index reaches in 2018 (Table 5). The size classifications designated to streams without measurements were based on knowledge from WDFW Chum Project staff of the relative bankfull width (BFW) and characteristics of un-measured streams compared to similar streams with quantified habitat.

Of all index reaches, there were a total of 4 side-channels, 6 small channels, 13 medium channels, and 8 large channels. The average BFW for large streams ranged from 40.5 to 57.9 meters, and primarily consisted of mainstem sections. The medium size classification encompassed a range in average BFW from 13.1 to 19.1 meters, while the small streams ranged from 4.7 to 9.5 meter BFW.

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

Sub-basin	Stream	Reach Length (m)	Average Bankfull Width (m)	Size Class
Humptulips	Humptulips River 16.7-19.2	---	53.0[b]	Large
	Humptulips River 23.1-28.1	---	55.4[b]	Large
	WF Humptulips River 36.7-40.6	100	49.4	Large
	EF Humptulips River 0.0-1.6	82	40.3	Large
	EF Humptulips River 1.6-4.4	82	40.5	Large
	Big Creek 8.5-9.1	16	6.1	Small
	Big Creek 9.1-9.7	100	4.7	Small
	Stevens Creek 4.5-5.2[a]	---	17.1[b]	Medium
	Stevens Creek 5.2-6.2[a]	---	14.7[b]	Medium
	Stevens Creek 6.2-7.1	300	18.7	Medium
	Brittain Creek 0.0-0.2	---	9.5[b]	Small
	Elwood Creek 0.0-0.6	100	5.9	Small
	O'Brien Creek 0.0-0.5	19	7.4	Small
	Donkey Creek 0.0-0.5	39	17.0	Medium
	Donkey Creek 0.8-1.5	33	13.1	Medium
	Widow Creek 0.0-0.3	9	4.9	Small
Wynoochee	Wynoochee 15.4 – 13.7	1100	57.9	Large
	Wynoochee 20.4 – 15.4	900	48.5	Large
	Schafer Creek 3.6 – 3.1	375	19.1	Medium
	Schafer Creek 4.3 – 3.6	350	15.6	Medium
Satsop	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
	Schafer Slough 0.4 – 0.0[a]	76	7.0	Side Channel
	Maple Glen 0.3 – 0.0[a]	140	7.6	Side Channel
	Creamer Slough 0.3 – 0.0[a]	---	---	Side Channel
	Decker Creek 1.1 – 0.5	---	---	Medium
	Decker Creek 1.8 – 1.1	---	---	Medium
	Tributary 0462 0.2 – 0.0	125	8.0	Side Channel

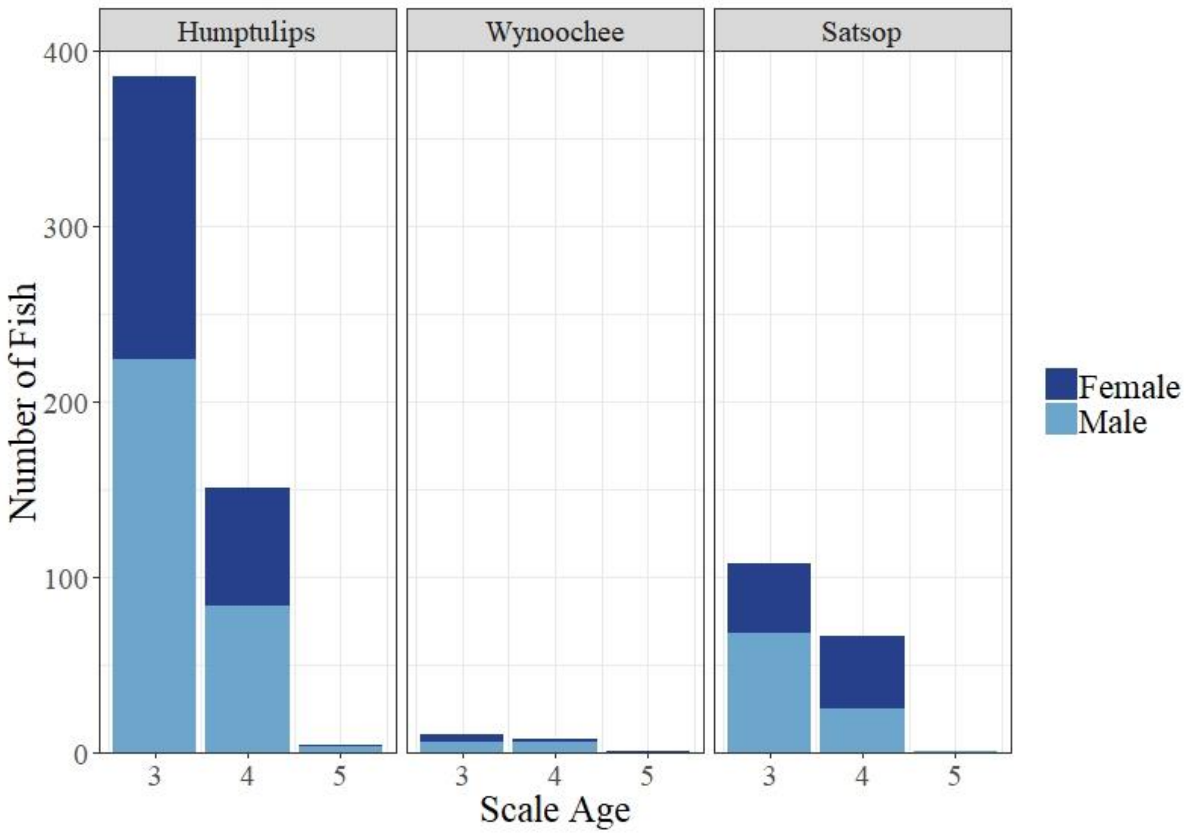
[a] Long-term Chum index
[b] From Tim Beechie at NOAA

Biological Sampling

Chum from the Wynoochee and Satsop sub-basins returned at three, four and five years of age (Figure 3). In Humptulips, the majority of Chum returned at age three 71% (*n* = 386), followed by age four at 28% (n = 151), with the smallest proportion returning at age five at 4% (n = 4). The Wynoochee Chum returned at 53% (n = 10) age three, closely followed by 42% (n = 8) age four and 5% (n = 1) age five. The age composition in Chum returning to the Satsop was similar to the Wynoochee and Humptulips, with the majority returning at age three (62%, n= 108), followed by age four (38%, n=66) and the smallest proportion returning at age five (<1%, n = 1). With only 19 Chum sampled in the Wynoochee, the small sample size could influence the ratios, resulting in a different age composition compared to the Humptulips and Satsop sub-basins.

The average fork length (cm ± SD) was 74±4 across the 627 males sampled, and 67±4 for the 603 females in the Humptulips. The fork length totals and averages are comprised of Chum sampled for carcass tags, and Chum sampled for scales, but not tagged. No lengths were taken on Chum in the Wynoochee and Satsop. In all three sub-basins, more males were sampled than females, with 311 (57%) males and 230 females (43%) in the Humptulips, 12 (63%) and 7 (37%) in the Wynoochee and 94 (54%) males and 81 (46%) females in the Satsop. The male to female ratio in the Humptulips was based only on fish sampled for scales.

Figure 3. Summary of scale age in years for Chum sampled on the spawning grounds from the Humptulips, Wynoochee and Satsop sub-basins, 2018.



Distribution

Peak surveys conducted in the Humptulips sub-basin November 8th to November 15th and covered the majority of Chum spawning. The Humptulips survey frame included 125.7 RM (Table 6); however, 16.9 RM were not surveyed due to no visibility or access constraints resulting in 108.8 RM surveyed in 2018. Details of the non-surveyed areas are provided in Appendix A-6 and A-7. In the Humptulips, Wynoochee and Satsop 15.8 RM, 3.8 RM and 16.8 RM, respectively, were surveyed by boat compared to foot surveys of 6.6 RM, 2.8 RM and 5.8 RM, respectively. For the peak supplemental surveys in the

Humptulips sub-basin more river miles were surveyed by foot than by boat, with 46.3 RM surveyed by foot and 40.1 RM surveyed by boat. Peak surveys were completed within a week for each strata, and only in the Humptulips sub-basin in 2018.

Table 6. Total river miles of known Chum distribution in the sub-basins that were surveyed and not surveyed in 2018. River miles are shown by strata and data collection method.

	Humptulips			Wynoochee			Satsop		
	Foot	**Boat**	**Total**	**Foot**	**Boat**	**Total**	**Foot**	**Boat**	**Total**
AUC	3.4	10.8	14.2	2.8	3.8	6.6	5.8	16.8	22.6
CMR	3.2	5.0	8.2	---	---	---	---	---	---
Trap Counts[a]	---	---	---	---	---	---	---	---	7.7
Supplemental Counts	46.3	40.1	86.6	---	---	---	---	---	---
Total Surveyed	**52.9**	**55.9**	**108.8**	**2.8**	**3.8**	**6.6**	**5.8**	**16.8**	**30.3**
Not Surveyed[b]	**13.2**	**3.7**	**16.9**	---	---	---	---	---	---
Total Survey Frame	**66.1**	**59.6**	**125.7**	**2.8**	**3.8**	**6.6**	**5.8**	**16.8**	**30.3**

[a] 100% capture traps are located on Bingham Creek at RM 0.9 and Satsop Springs Hatchery (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 2018 but were included in the survey frame.

2018 Humptulips Chum Survey Area and Method

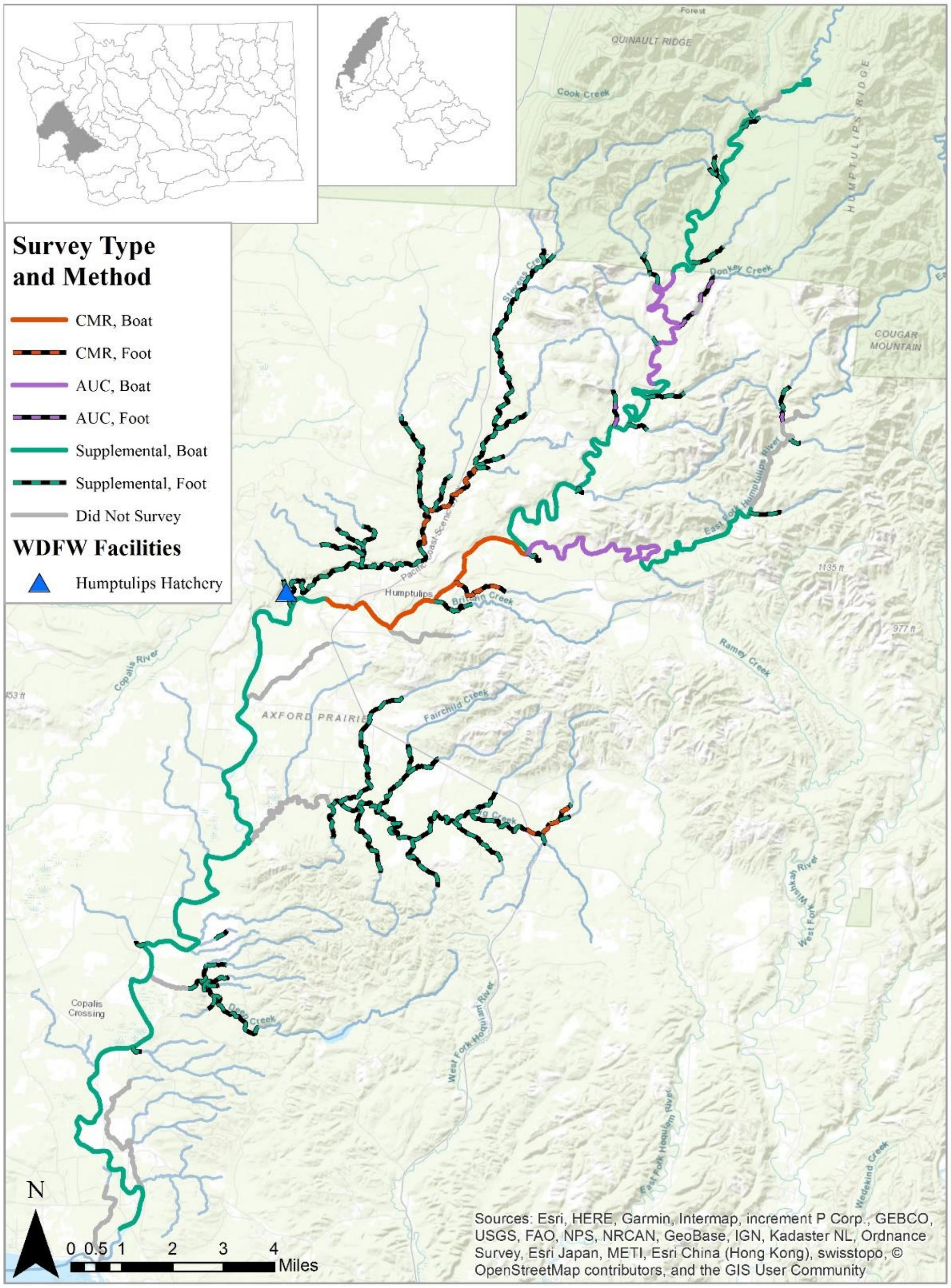


Figure 4. Methods used to survey Chum salmon distribution in the Humptulips sub-basin. Methods include by reach type (AUC, CMR, Supplemental) and survey strata (foot, boat). Reaches not surveyed but assumed to include Chum are shown.

2018 Humptulips Fall Chum Density

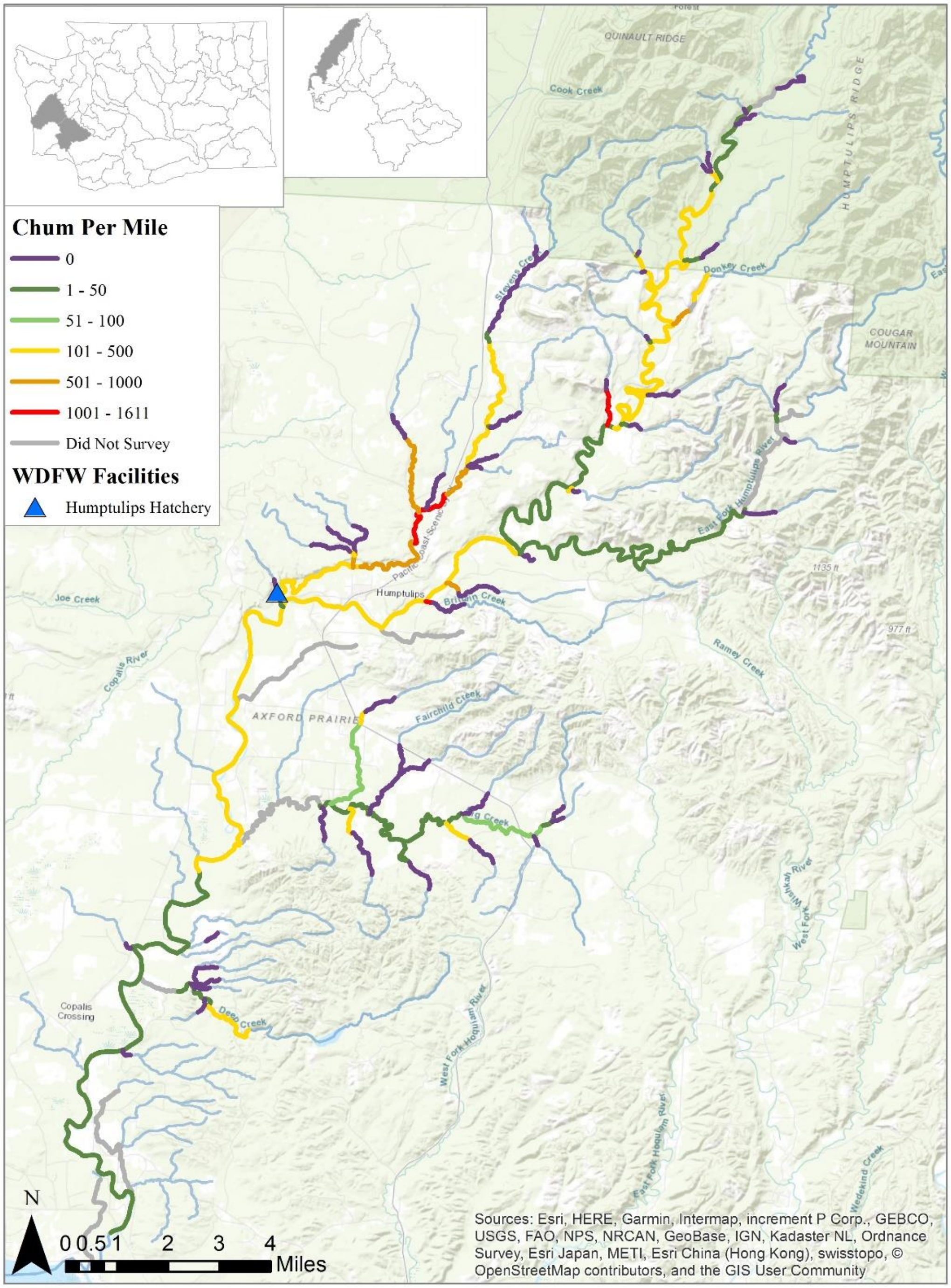


Figure 5. Chum density shown as fish counted per mile during a single week peak spawn survey in the Humptulips sub-basin. Reaches not surveyed but assumed to include Chum are shown.

Chum were observed in 88.6 RM out of 108.8 RM surveyed in the Humptulips sub-basin (Appendix A-3, Figure 5). The proportion of spawner Chum within index reaches was 40% (*n* = 989/2,489) in the boat strata and 46% (*n* = 4,212/9,119) in the foot strata (Table 7). For total counts (spawners and holders), 32% (*n* = 1,148/3,537) of Chum were in within index reaches for the boat strata and 44% (*n* = 4,727/10,766) were within indexes for the foot strata. Based on peak counts, Stevens Creek contained the highest density of Chum spawning within Humptulips tributaries. Big Creek, although similar in drainage size as Stevens Creek, did not receive the same spawning densities. O'Brien Creek and the lower 0.2 RM of Brittain Creek also received high densities of spawning.

Twenty or 35% of the streams surveyed as supplemental or index reaches terminated in permanent barriers. During the 2018 peak spawning surveys, ULOs were observed at RM 10.3 in Stevens Creek and RM 9.4 in Big Creek. The ULO of the WF Humptulips mainstem was at the base of the gorge, indicating the cascades and falls within the gorge may be a barrier to Chum. No ULO was determined for the EF Humptulips mainstem due to safety concerns. However, the furthest upstream Chum in the EF Humptulips were recorded in Widow Creek. Widow Creek enters the EF Humptulips at RM 9.7.

The 2018 survey frame was used to retrospectively estimate proportions of Chum in the Wynoochee and Satsop sub-basins based on 2017 data. The Chum within Wynoochee sub-basin foot and boat index reaches was 11% (n=820/7,651) and 11% (n=50/439). In the Satsop sub-basin, 35% (*n*=655/1,857) of Chum spawned in the index reaches within the boat strata and 24% (*n*=258/1,086) within the foot strata. The Satsop foot strata proportions were determined using carcass counts since the foot surveys were conducted in early December after the majority of live Chum had expired. Proportions were calculated using total live counts because the majority of counts were not separated into holders and spawners.

Table 7. Counts (N) and proportion (p) of Chum salmon in each survey strata (boat, foot) within index (AUC, CMR) and supplemental survey reaches of the Humptulips River (fall 2018), Wynoochee River (fall 2017) and the Satsop River (fall 2017). Counts are during a single week survey close to peak spawning for each strata.

				Spawner		**Total Live**		**Carcasses**	
Basin	**Strata**	**Type**	**Distance**	**N**	**p**	**N**	**p**	**N**	**p**
Humptulips	Boat	Index	15.8	989	0.40	1,148	0.32	---	---
		Supplemental	40.1	1,500	0.60	2,389	0.68	---	---
		Total	55.9	2,489	1.00	3,537	1.00	---	---
	Foot	Index	6.6	4,212	0.46	4,727	0.44	---	---
		Supplemental	46.3	4,907	0.54	6,039	0.56	---	---
		Total	52.9	9,119	1.00	10,766	1.00	---	---
Wynoochee	Boat	Index	3.8	---	---	820	0.11	68	0.06
		Supplemental	37.8	---	---	6,831	0.89	1,018	0.94
		Total	41.6	---	---	7,651	1.00	1,086	1.00
	Foot	Index	2.8	---	---	50	0.11	42	0.14
		Supplemental	18.6	---	---	389	0.89	255	0.86
		Total	21.4	---	---	439	1.00	397	1.00
Satsop	Boat	Index	16.8	---	---	655	0.35	58	0.40
		Supplemental	63.1	---	---	1,202	0.65	87	0.60
		Total	79.9	---	---	1,857	1.00	145	1.00
	Foot	Index	5.8	---	---	8	0.44	258	0.24
		Supplemental	46.4	---	---	10	0.56	828	0.76
		Total	52.2	---	---	18	1.00	1,086	1.00

Survey Crew Adjustment

A total of 60 independent but overlapping surveys, conducted no more than one day apart, were compared between three survey crews: WDFW Chum crew, WDFW D17 and QDNR. Of the 60 surveys, 20 were overlapping between the WDFW Chum crew and WDFW D17 in Stevens Creek during the 2018 spawning season. The remaining 40 surveys were overlapping between the WDFW Chum crew and QDNR survey crew from the Humptulips and Wynoochee sub-basins across the 2016-2018 spawning seasons. As the primary focus of the WDFW Chum crew was Chum counts, they were given an observer efficiency of one. In Stevens Creek where the two WDFW crews overlapped, the average counts from the WDFW D17 team were 3.3% lower than the WDFW Chum crew with an observer efficiency (±SD) of 0.968 (±0.035) (Figure 6). In areas where the WDFW Chum crew and QDNR crew overlapped, the QDNR Chum counts were on average 30.8% lower than the WDFW Chum crew with an observer efficiency of 0.733 (±0.020).

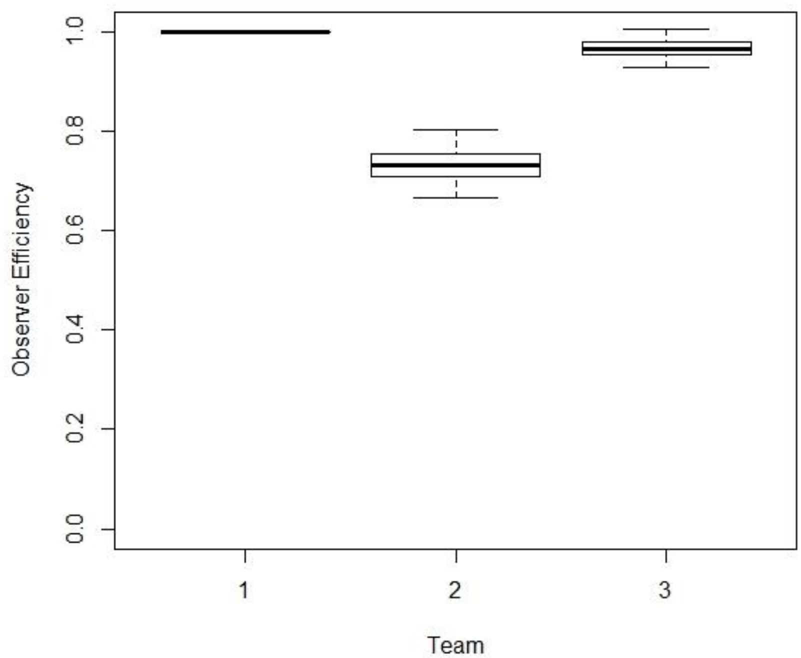


Figure 6. Observer efficiency for live Chum counts for three separate survey teams from overlapping index and supplemental surveys across the Humptulips and Wynoochee sub-basins from 2016 through 2018. Team 1 is WDFW Chum crew, Team 2 is QDNR and Team 3 is WDFW D17. Counts from the WDFW Chum crew (Team 1) are considered control counts and do not have an error associated with them.

Area-Under-the-Curve

Area-under-the-curve estimates were not calculated for 6 of the 41 index reaches due to absence of live Chum or low survey frequency (Appendix A-5). In several surveys in the Wynoochee and Satsop sub-basins, surveyors did not partition live counts between spawners and holders.

In the Humptulips index reaches, fish-day calculations using total live counts in the boat versus foot strata was 20,090 and 67,530, respectively, and 87,620 fish-days when combined for the entire Humptulips sub-basin (Table 8). The three index sections located in Stevens Creek contributed 65% of the fish-days for the foot strata. In the Wynoochee index reaches, the difference in fish-day calculations was 15,603 for boat strata and 7,216 for foot strata using total live counts. In the Satsop index reaches, this difference was 6,954 for boat strata and 11,983 for foot strata. Tributary 0462 was the only reach where no spawners were observed therefore fish-day calculations were zero for spawner only counts. In the uppermost Decker Creek section, no holders were observed therefore the fish-days for spawners only and total live are equivalent. Chum counts in the side-channel indexes remained low and delayed in 2018 compared to 2017. Creamer Slough had calculated fish-days of 2,988 in 2017, which dropped to 138 fish-days in 2018 with a peak count nine days delayed. Maple Glen had calculated fish-days of 1,512 in 2017, which dropped to 483 fish-days in 2018 with a peak count nine days delayed. Creamer Slough and Maple Glen are two of the four long-term Chum index reaches used with the current methodology of estimating escapement for Grays Harbor.

Table 8. Area-under-the-curve in **fish-day units** for Chum in index reaches of the Humptulips, Wynoochee and Satsop sub-basins, fall 2018. 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**	**Spawners Only SD**	**Total Live**	**Total Live SD**
Humptulips	Humptulips River 16.7-19.2*	Boat	AUC	2,766	98.2	3,164	106.2
	Humptulips River 23.1-28.1	Boat	CMR	5,781	0	7,698	0
	WF Humptulips River 36.7-40.6	Boat	AUC	6,786	0	7,541	0
	EF Humptulips River 0.0-1.6	Boat	AUC	914	0	1,044	0
	EF Humptulips River 1.6-4.4	Boat	AUC	627	0	643	0
	Humptulips Boat Total			**16,874**	**98**	**20,090**	**106**
Humptulips	Big Creek 8.5-9.1	Foot	AUC	527	0	755	0
	Big Creek 9.1-9.7	Foot	AUC	44	0	82	0
	Stevens Creek 4.5-5.2	Foot	CMR	9,740	0	15,777	0
	Stevens Creek 5.2-6.2	Foot	CMR	14,749	0	18,713	0
	Stevens Creek 6.2-7.1	Foot	CMR	7,344	0	9,181	0
	Brittain Creek 0.0-0.2*	Foot	AUC	1,121	32.4	1,559	37.4
	Elwood Creek 0.0-0.6	Foot	CMR	1,550	0	2,178	0
	O'Brien Creek 0.0-0.5	Foot	AUC	8,265	97.7	8,317	98
	Donkey Creek 0.0-0.5	Foot	AUC	6,771	78.4	7,395	85
	Donkey Creek 0.8-1.5	Foot	AUC	3,161	41.4	3,545	46.3
	Widow Creek 0.0-0.3	Foot	AUC	27	0.4	28	0.4
	Humptulips Foot Total			**53,299**	**136**	**67,530**	**143**
Wynoochee	Wynoochee 13.7-15.4	Boat	AUC	---	---	5,338	82.5
	Wynoochee 29.1-31.2*	Boat	AUC	---	---	10,265	270.6
	Wynoochee Boat Total			**---**	**---**	**15,603**	**283**
Wynoochee	Schafer Creek 3.1-4.3*	Foot	AUC	---	---	5,437	136.7
	Tributary 0298 0.0-0.3*	Foot	AUC	---	---	1,450	42.9
	Tributary 0299 0.0-0.1*	Foot	AUC	---	---	315	10.4
	Bitter Creek 1.3-2.5*	Foot	AUC	---	---	14	0.7
	Wynoochee Foot Total			**---**	**---**	**7,216**	**144**
Satsop	EF Satsop River 11.0-12.4	Boat	AUC	---	---	3,437	51.8
	EF Satsop River 12.4-14.7	Boat	AUC	---	---	1,918	22.9
	MF Satsop River 1.7-3.3	Boat	AUC	---	---	495	5.8
	MF Satsop River 0.3-1.7	Boat	AUC	---	---	560	7.3
	WF Satsop River 7.3-17.0	Boat	AUC	---	---	544	7.2
	Satsop Boat Total					**6,954**	**58**
Satsop	Schafer Slough 0.0-0.4	Foot	AUC	---	---	4,291	51.1
	Maple Glen 0.0-0.3	Foot	AUC	---	---	483	6.9
	Creamer Slough 0.0-0.3	Foot	AUC	---	---	138	2.7
	Tributary 0462 0.0-0.2	Foot	AUC	---	---	30	0.4
	Black Creek 0.0-0.9	Foot	AUC	---	---	90	1.2
	Decker Creek 0.5-1.1	Foot	AUC	---	---	3,390	40.4
	Decker Creek 1.1-1.8	Foot	AUC	---	---	3,434	40.5
	Decker Creek 10.9-11.4	Foot	AUC	---	---	17	0.3
	Dry Run Creek 0.0-2.3*	Foot	AUC	---	---	110	1.4
	Satsop Foot Total					**11,983**	**77**

*QDNR index reach

Spawner Abundance in CMR Index Reaches

A total of 951 carcasses were tagged and released among all CMR index reaches in the Humptulips sub-basins (Appendix C-2). Recovery rate of tagged carcasses was highest in the medium stream (Stevens, 57% n = 398/692), followed by small streams (Elwood, 54% n = 48/89) with the lowest recovery rate in the large mainstem section (32% n = 55/170). Of the original eight planned carcass tagging index reaches, three adjacent reaches in Stevens creek were combined for JS analysis due to carcass drift (27%) from one reach to the next. Four others did not receive enough carcasses to produce an abundance estimate.

Equal catchability and survival assumptions were tested using a logistic regression and Bayesian goodness-of-fit tests. The logistic regression results indicated the recovery of Chum carcasses was not associated with either sex or length with one exception; Stevens Creek regression indicated length may be causing a deviation from the assumption of equal catchability. However, tagged Chum not recovered had an average length of 69.7cm (±4.5) compared to recovered tagged Chum with an average length of 71.2cm (±5.0). The mean difference between length of carcasses not recovered and recovered was 0.5 (±0.4). The effects of size selectivity while statistically significant were not biologically significant so the null model was used. The Bayesian GOF test indicated the JS model that included variable catchability and survival provided the best fit for Elwood and Stevens Creek (Bayesian p-value = 0.53 and 0.32, respectively). For the Humptulips mainstem none of the models had a GOF Bayesian p-value above 0.05 indicating none of the models fit the data. Therefore, a JS estimate for the mainstem was not produced.

Tag loss was evaluated by tagging each carcass twice. Of the 501 recoveries of tagged carcasses, five were recovered with a single missing tag, all others were recovered with two tags. Loss of both opercle tags was < 0.01% and considered negligible. To address the assumption that all tags were detected, standardized data collection, recording methods and thorough training of the field crews were implemented. The assumption of instantaneous sampling was met by completing the survey of each CMR index reach within a single day, surveying continuously from top to the bottom of the reach. One exception was Stevens Creek RM 6.2-7.1 during the highest carcass abundance. The crew was able to mark their ending location and return the following day to complete the survey.

Estimates of spawner abundance for CMR index reaches Elwood and Stevens Creek were determined to be 164 and 4,229 (Table 9), respectively. Inputs used for the JS model provided in Table 10 and 11, and the m-array can be found in Appendix C-1.

Table 9. Chum abundance estimated using a Jolly-Seber open population abundance estimator and carcass tagging data, Fall 2018.

Index Reach Name	N	SD	95% Low	95% High
Elwood Creek 0.0-0.6	164	15.6	142	202
Stevens Creek 4.5-7.1[a]	4,229	91.0	4,061	4,417

[a] Combined estimate for three index reaches: Stevens Creek 4.5-5.2, Stevens Creek 5.2-6.2, Stevens Creek 6.2-7.1.

Table 10. Summarized carcass tagging data used as inputs in the Jolly-Seber open population abundance estimate for Elwood Creek, Fall 2018. Periods 4 and 5 were combined for analysis purposes.

Survey Periods	Dates	n	m	R	r	z	u
1	11/15/2018	26	0	18	17	0	26
2	11/21/2018	99	17	63	23	0	82
3	11/29/2018	24	15	2	2	8	9
4,5	12/6/2018	22	10	0	0	0	12

n = number captured at sample time, previously tagged and untagged.
m = number captured at sample time that were previously tagged
R = number of tagged releases at sample time
r = number of R releases, recaptured in a future period.
z = number of R releases recovered not at the next period but a later period
u = number captured at sample time, unmarked

Table 11. Summarized carcass tagging data used as inputs in the Jolly-Seber open population abundance estimate for Stevens Creek, Fall 2018. Periods 5, 6 and 7 were combined for analysis purposes.

Survey Periods	dates	n	m	R	r	z	u
1	11/8/2018	31	0	22	17	0	31
2	11/14/2018	283	16	217	180	1	267
3	11/20/2018	1987	174	351	116	7	1813
4	12/2/2018	798	81	94	78	42	717
5,6,7	12/8/2018	496	120	0	0	0	376

n = number captured at sample time, previously tagged and untagged.
m = number captured at sample time that were previously tagged
R = number of tagged releases at sample time
r = number of R releases, recaptured in a future period.
z = number of R releases recovered not at the next period but a later period
u = number captured at sample time, unmarked

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. When comparing survey life between index reaches of three stream size classifications from 2017 and 2018 data (side-channel, small stream, medium stream) the smaller streams have longer survey life. No survey life was estimated for the large classification due to lack of carcass tagging results from these reaches.

Survey life estimates were derived for both spawner only counts and total live (holders, spawners) counts. The survey life estimates for Elwood Creek increased from 9.5 (±0.9) days using spawner counts to 13.4 (±1.3) days using total live counts; a difference of 3.9 days (Table 12). This trend was mirrored in Stevens Creek where the survey life estimate increased from 7.5 (±0.2) days using spawner counts to 10.3 (±0.22) days using total live counts; a difference of 2.8 days. The variation in survey life estimates within index reaches emphasizes the importance of accurate live-counts and subsequent fish-day calculations within index reaches.

A total of four survey life estimates were successfully calculated between 2017 and 2018 across three sub-basins. The medium stream size classification was replicated between the two years. However, the survey life estimate from the 2018 small stream and the 2017 medium stream were the most similar, instead of the two medium stream survey life estimates. The Stevens Creek survey life estimate was 1.5 to 2.2 days less than Schafer Creek survey life estimate, while the Elwood Creek survey life was 0.5 to 0.9 days greater than Schafer Creek. The average survey life estimate across the four reaches is 8.75 (±1.38) days using spawner counts only and 11.30 (±1.90) days using total live counts, with a median of 10.02 days.

Table 12. Survey life (SL) estimates for Chum salmon, fall 2017 and 2018. 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**	**Year**	$\hat{N}$ **(SD)**	**AUC**	$\widehat{SL}\ (SD)$	**AUC**	$\widehat{SL}\ (SD)$
Tributary 0462 0.2-0.0	Side Channel	2017	186(9)	1,667	8.98(0.43)	1,667	8.98 (0.43)
Schafer Creek 4.3-0.0[a]	Medium	2017	721(72)	6,393	9.00(0.93)	8,906	12.50 (1.30)
Elwood Creek 0.6-0.0	Small	2018	164(15.6)	1,550	9.50(0.9)	2,178	13.40(1.3)
Stevens Creek 7.1-4.5[b]	Medium	2018	4,229(91)	31,832	7.50(0.2)	43,671	10.30(0.22)

[a] Multiple index reaches combined due to low Chum numbers
[b] Multiple index reaches combined due to heavy carcass drift between reaches

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 (2017) was applied to side-channel index reaches, survey life from Elwood Creek was applied to index reaches with a small size classification, and survey life from Stevens Creek was applied to index reaches with a medium or large size classification. No unique survey life estimate was calculated for large stream sections; therefore, medium survey life was applied to large streams as the next closest in size. Although two medium survey life estimates were available, the medium survey life derived in 2018 was used to coincide with index data collected in 2018.

In the Humptulips boat strata, all five indexes were classified as large. Chum abundance was estimated to be 2,241 (±27) when estimated with spawner counts only and 1,944 (±24) when estimated with total live counts (Table 13). Including both spawners and holders decreased the strata abundance estimate by 13.3% over an estimate based on spawner counts only.

The Humptulips foot strata had five indexes classified as medium and six indexes classified as small. Chum abundance was estimated to be 6,770 (±104) derived with spawner counts only and 6,260 (±85) derived with total live counts. Including both spawners and holders decreased the strata abundance by 7.5% over an estimate based on spawner counts only.

In the Wynoochee, abundance estimates were calculated using total live counts only. The Wynoochee boat strata included two index reaches, both classified as large. The foot strata in the Wynoochee encompassed four index reaches, one classified as medium and three classified as small. Chum abundance was estimated to be 1,511 (±24) in the boat strata and 660 (±15) in the foot strata.

In the Satsop, abundance estimates were calculated using total live counts only. The Satsop boat strata included five index reaches, two classified as large and three classified as medium. The foot strata in the Satsop encompassed nine index reaches with three classified as medium, two classified as small and four classified as side-channel. Chum abundance was estimated to be 674 (±8) in the boat strata and 1,229 (±25) in the foot strata.

Table 13. Chum spawner abundance ($\hat{N}$) and standard deviation (*SD*) in index reaches surveyed in the Humptulips, Wynoochee and Satsop rivers, Fall 2018. 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 organized by sub-basin and survey strata (boat, foot).

				Spawners Only		Total Live	
Sub-Basin	**Index Reach Name**	**Strata**	**Size Class**	$\hat{N}$	***SD***	$\hat{N}$	***SD***
Humptulips	Humptulips 16.7-19.2	Boat	Large	367	8	306	7
	Humptulips 23.1-28.1	Boat	Large	768	17	745	16
	WF Humptulips 36.7-40.6	Boat	Large	902	19	730	16
	EF Humptulips 0.0-1.6	Boat	Large	121	3	101	2
	EF Humptulips 1.6-4.4	Boat	Large	83	2	62	1
	Subtotal	**Boat**	---	**2,241**	**27**	**1,944**	**24**
	Stevens Creek 4.5-5.2	Foot	Medium	1,294	28	1,528	33
	Stevens Creek 5.2-6.2	Foot	Medium	1,959	42	1,812	39
	Stevens Creek 6.2-7.1	Foot	Medium	976	21	889	19
	Donkey Creek 0.0-0.5	Foot	Medium	900	19	716	15
	Donkey Creek 0.8-1.5	Foot	Medium	420	9	343	7
	Big Creek 8.5-9.1	Foot	Small	56	5	57	5
	Big Creek 9.1-9.7	Foot	Small	5	1	6	1
	Brittain Creek 0.0-0.2	Foot	Small	119	11	117	11
	Elwood Creek 0.0-0.6	Foot	Small	164	16	164	16
	O'Brien Creek 0.0-0.5	Foot	Small	874	83	626	60
	Widow Creek 0.0-0.3	Foot	Small	3	0	2	0
	Subtotal	**Foot**	---	**6,770**	**104**	**6,260**	**85**
Wynoochee	Wynoochee 13.7-15.4	Boat	Large	---	---	517	11
	Wynoochee 29.1-30.2	Boat	Large	---	---	994	21
	Subtotal	**Boat**	**---**	**---**	**---**	**1,511**	**24**
Wynoochee	Schafer Creek 3.1-4.3	Foot	Medium	---	---	526	11
	Tributary 0298 0.0-0.3	Foot	Small	---	---	109	10
	Tributary 0299	Foot	Small	---	---	24	2
	Bitter Creek	Foot	Small	---	---	1	0
	Subtotal	**Foot**	**---**	---	---	**660**	**15**
Satsop	EF Satsop River 11.0-12.4	Boat	Large	---	---	333	7
	EF Satsop River 12.4-14.7	Boat	Medium	---	---	186	4
	WF Satsop 7.3-17.0	Boat	Large	---	---	53	1
	MF Satsop River 0.3-1.7	Boat	Medium	---	---	54	1
	MF Satsop River 1.7-3.3	Boat	Medium	---	---	48	1
	Subtotal	**Boat**	**---**	---	---	**674**	**8**
Satsop	Decker Creek 0.5-1.1	Foot	Medium	---	---	328	7
	Decker Creek 1.1-1.8	Foot	Medium	---	---	333	7
	Decker Creek 10.9-11.4	Foot	Medium	---	---	2	0
	Schafer Slough 0.0-0.4	Foot	Side-channel	---	---	479	23
	Maple Glen 0.0-0.3	Foot	Side-channel	---	---	54	3
	Creamer Slough 0.0-0.3	Foot	Side-channel	---	---	15	1
	Tributary 0462 0.0-0.2	Foot	Side-channel	---	---	3	0
	Dry Run Creek 0.0-2.3	Foot	Small	---	---	8	1
	Black Creek 0.0-0.9	Foot	Small	---	---	7	1
	Subtotal	**Foot**	**---**	---	---	**1,229**	**25**

Spawner Abundance for Foot and Boat Strata

Using spawner counts only for the Humptulips and total live counts for the Wynoochee and Satsop, the combined Chum spawner abundance for the three sub-basins was 50,116 (±1,063). This estimate has a coefficient of variation of 2.1%. The total Chum abundance in the Humptulips sub-basin was estimated to be 22,328 (±345), including 6,910 (±187) in the boat strata and 15,418 (±290) in the foot strata (Table 14).

Using total live counts, the combined abundance estimated for the Humptulips, Wynoochee and Satsop sub-basins was 48,046 (±1,048). This estimate has a coefficient of variation of 2.2%. The total Chum abundance in the Humptulips sub-basin was estimated to be 20,258 (±297), including 5,996 (±163) in the boat strata and 14,262 (±248) in the foot strata (Table 15). The total Chum abundance in the Wynoochee sub-basin was estimated to be 19,964 (±956), including 14,107 (±518) in the boat strata and 5,857 (±804) Chum in the foot strata. The total Chum abundance in Satsop sub-basin was estimated to be 7,824 (±309), including 1,910 (±65) in the boat strata, 5,183 (±302) in the foot strata, and 731 Chum enumerated at trap locations.

Abundance estimates based on spawner counts only were slightly higher than those using total live counts in the Humptulips sub-basin, difference of 4.2%. Even this slight difference indicates that in some circumstances the estimate is sensitive to the type of live counts used in the analysis. The abundance estimate for the Satsop sub-basin is 61% or 65% lower than the Humptulips estimate and 61% lower than the Wynoochee estimate, while the Wynoochee estimate is 1.5% or 11% lower than the Humptulips. It is unclear if the lower abundance in the Satsop sub-basin is a result of sampling and analysis methods, or if this area received fewer spawners compared to the other Grays Harbor sub-basins.

Table 14. Chum spawner abundance estimated using spawner counts only for Humptulips sub-basin, fall 2018. Estimates are the expansion of abundance ($\hat{N}$) in the index reaches based on the proportion ($\hat{p}$) of spawning observed in the index reaches.

		Abundance in Index Reaches		Proportion in Indexes		Abundance in Strata	
Watershed	**Strata**	$\hat{N}$	**SD**	$\hat{p}$	**SD**	$\hat{N}$	**SD**
Humptulips	Boat	2,241	27	0.40	0.010	6,910	187
	Foot	6,770	104	0.46	0.005	15,418	290
	Total	**9,011**	**107**	**---**	**---**	**22,328**	**345**

Table 15. Chum spawner abundance estimated using total live counts for Humptulips, Wynoochee and Satsop sub-basins, fall 2018. Estimates are the expansion of abundance ($\hat{N}$) in the index reaches based on the proportion ($\hat{p}$) of spawning observed in the index reaches.

			Abundance in Index Reaches		Proportion in Indexes		Abundance in Strata	
Watershed	**Strata**		$\hat{N}$	**SD**	$\hat{p}$	**SD**	$\hat{N}$	**SD**
Humptulips	Boat		1,944	24	0.32	0.008	5996	163
	Foot		6,260	85	0.44	0.005	14,262	248
		Total	**8,204**	**88**	**---**	**---**	**20,258**	**297**
Wynoochee	Boat		1,511	24	0.11	0.004	14,107	518
	Foot		660	15	0.11	0.015	5,857	804
		Total	**2,171**	**28**	**---**	**---**	**19,964**	**956**
Satsop	Boat		674	8	0.35	0.011	1,910	65
	Foot		1,229	25	0.24	0.013	5,183	302
	Trap		---	---	---	---	731	---
		Total	**1,903**	**26**	---	---	**7,824**	**309**

Live Trap Counts

The Bingham Creek trap handled 196 Chum over a five-week period with the first individual trapped on November 2nd and the final individual trapped November 28th (Table 16). The BCH collected 245 Chum over the season of which 109 were lethally spawned, 77 passed upstream, 38 were pond mortalities, and 21 were surplus. The SSH collected 290 Chum over the season of which 198 were lethally spawned, 36 were pond mortalities, and 56 were surplus.

Table 16. Counts of live Chum returning to three trap locations in the Satsop River sub-basin, 2018.

Location	N
Bingham Creek Trap	196
Bingham Creek Hatchery	245
Satsop Springs Hatchery	290
Total	**731**

Discussion

In 2018, the updated methodology for estimating the number of Chum in Grays Harbor was successfully implemented in a new sub-basin, the Humptulips. Additionally, we were able to utilize live counts from 2018 index reaches in the Wynoochee and Satsop sub-basins in combination with distribution data from peak surveys conducted in 2017 to calculate abundance estimates. From this we were able to calculate a combined escapement estimate of 50,116 (±1063) for the Humptulips, Wynoochee, and Satsop sub-basins with a coefficient of variation (CV) of 2.1% when spawner only counts were used for the Humptulips. When total counts were used on the Humptulips it was reduced to 48,046 (±1,048, CV 2.2%). Estimates in this report did not include Chum returning to the Hoquiam, Wishkah, Black rivers, Cloquallum Creek and other minor spawning areas in tributaries to Grays Harbor. Additional work is needed to apply the updated methodology to these tributaries.

In 2018, we successfully addressed several of the areas of improvement identified at the end of the 2017 field season. These improvements included calculating a survey life estimate for the small stream classification, continued use of designating spawner status while conducting live counts, ensuring that live count data were collected in a consistent manner among survey crews, and quantifying consistency in live counts across survey crews to assess variation in survey focus. Sections of EF Humptulips and Big Creek were unable to be surveyed so final estimates may be lower than the actual number of Chum in each sub-basin.

Estimates derived from the updated methodology were consistently higher than those derived using the existing methodology for Grays Harbor Chum. The 2018 estimate of 48,046 (total counts) or 50,116 (spawner counts for Humptulips) Chum for the Humptulips, Wynoochee and Satsop sub-basins alone was 69% or 76% higher than the current methods estimate for the entire Grays Harbor Chum population (n = 28,413). Two reasons for the difference in results may be the assumptions under the existing methodology that the peak live and carcass count in the four long-term Chum 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 each year. Results from the updated methodology indicate that neither of these assumptions are correct. Instead, using a total peak live and carcass count underestimates the number of spawners within each index, and the four long-term index reaches contribute less than 10.8% to the overall Grays Harbor population. Using the new AUC-based method, we estimated 3,800 Chum spawned in the four long-term index reaches compared to 3,088 Chum using the current peak live/dead method, an increase of 23%. Further, using the updated method, we estimate the four long-term Chum reaches contribute 7.6-7.9% to the Humptulips, Wynoochee, and Satsop Chum population. This estimate of contribution is missing counts from additional key spawning areas such as the Hoquiam and the Wishkah drainages. If added, these counts would likely further reduce the percentage the long-term Chum indexes contribute to the overall Grays Harbor Chum population under the new methodology.

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. The results indicated that the final estimate was sensitive to the way live counts were collected, the estimated survey life, and inter-annual changes in distribution. Discussed below are each of the study components in more detail and a number of recommendations to improve the effectiveness of the new updated methodology.

Distribution

The distribution of Chum within the Humptulips sub-basin by survey strata was documented during peak spawning which occurred between the first and third week of November. Supplemental surveys conducted throughout the basin highlighted upper limits of occurrence (ULO) and 'hotspots' of Chum spawning in the basin. Although the only distribution data available for the Wynoochee and Satsop is from 2017, Stevens Creek seems to receive some of the highest densities Chum spawning compared to the rest of the sub-basin tributaries. The index in Stevens Creek is the most unaltered of the four long-term Chum indexes, and it is likely to continue producing Chum in the near future. Several areas were unable to be accessed during peak spawning and the ULO of Chum on the EF Humptulips and a few lower sloughs remained undetermined due to safety concerns or lack of personnel. This increases the probability that total Chum in the Humptulips basin was underestimated. However, the areas not surveyed appear to primarily consist of habitat that is not preferred by Chum, so those areas are expected to contribute minimal adjustments to the population estimate.

When generating an estimate for both Wynoochee and Satsop sub-basins, the distribution from 2017 was utilized to expand for the areas that did not get surveyed in 2018. A potential error in this method stems from the apparent change in distribution in the 2018 long-term indexes for Satsop from what was found in 2017. It is likely this change in distribution is due to low water limiting access to several of the long-term indexes. Tributary 0462, which received consistent spawning in 2016 and 2017, only saw two Chum this season. Similar trends were observed in Maple Glen and Creamer Slough. Without repeat peak surveys in the Satsop to document the distribution, it is unclear if the number of fish returning drastically decreased in 2018 or if Chum redistributed elsewhere in the basin. The current method of estimation is dependent on only four indexes and is not robust against changes in distribution, which could lead to a lower percentage of Chum from the side-channels contributing to the basin abundance. One way to reduce uncertainty in the current estimate would be to have additional years of information on distribution in the basins instead of using proportions from a single year of data. Multiple years of data would allow us to see potential variation in distribution from year to year due to abundance, flows, and temperatures. This could generate better information on whether the stock is actually down or just redistributed. If low-flow years continue, consistent counts from side-channel indexes may become more unreliable and the current method of estimation might deviate even further from actual abundance.

Area-Under-the-Curve

Live counts were successfully obtained for AUC in indexes within Humptulips, Wynoochee, and Satsop sub-basins that covered the entire spawn timing with zero counts at the beginning and ending of the spawn time series. If AUC estimates were not calculated in an index, it was due to an absence of Chum or surveys that did not cover the entire spawn timing. Live Chum were separated into spawners and holders in the Humptulips and in some sections of the Satsop, allowing for the comparison on how spawner status (holders vs. spawners) influences abundance estimates. The live counts using 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 mainstem 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 and Satsop, spawners status (spawner, holder) were not regularly separated out so only total live counts were used. Going forward, working with other surveyor groups to get a consistent separation of spawner status on all surveys would be an easy, but impactful, step to refining the estimate protocols.

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. Overlapping surveys were conducted with the Chum focused surveys and other salmonid surveys so an adjustment rate was calculated for each crew not focused on Chum as the priority. The correction rate for similarly trained crews was small (3%) but for crews not trained similarly, a 30% adjustment rate was applied. This allowed for a larger range of surveys to be utilized for the final estimate.

Another potential source of variability in abundance estimates could be differences in detection rates among reaches. Accurate counts of live Chum can be especially challenging in large mainstem index reaches where visibility is often an issue and angler activity prevents surveyors from covering the entire reach. These conditions likely result in lower detection rates of live Chum in large river than small tributaries and side channels. For this reason, data collection and analysis were 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. In 2018, neither visibility nor angler presence appeared to affect detection of live Chum, although both have been a factor in previous years and could affect counts in future years.

The peak timing of live counts in the three sub-basins occurred the second week of November, with the exception of side channels in the Satsop, which peaked in the third week of November. The side channel sections are dependent upon adequate flow to attract fish. A small rain event occurred during the first couple days of November raising the Satsop river a small amount, but the first large rain event did not occur until the last week of November raising the river a significant amount after the peak Chum spawn period. Comparing index counts from 2017 to 2018 in the Wynoochee and Satsop, all five index reaches in the Wynoochee saw counts equal or higher in 2018. For the Satsop, nine out of the sixteen index reaches recorded a decrease in counts. Trap counts in the Satsop also decreased by 122 Chum. The lower index counts could indicate the decrease in Satsop abundance was due to fewer Chum, but without 2018 distribution data there is no way to confirm.

Carcass Tagging

Eight new carcass-tagging reaches in the Humptulips were originally established, however, carcasses were only successfully tagged in five of the reaches. Three Stevens index reaches were combined due to carcass drift and abundance estimates were not calculated in four reaches due to little or no fish presence. One survey was not completed in a single day but was able to be finished the following day. No other surveys remained incomplete.

A Jolly-Seber analysis to calculate an abundance estimate was unable to be conducted for the mainstem Humptulips. The reason for this is attributed to a violation of one assumption for a JS analysis. All carcasses must have an equal probability of detection (tagged and untagged). After tagging carcasses, they were put back where they were found instead of placing them in the water to mix with the rest of the population. Although this practice of returning carcasses to their location was implemented in all CMR reaches, this made a greater impact on the large mainstem section due to stream morphology and the lack of large woody debris. Abundance estimates were still successfully calculated for medium and small streams with statistical confidence. Even so, placing tagged carcasses in flowing water to mix with the population should be implemented in all CMR reaches in the future.

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 (SL) estimate was able to be calculated for medium and small streams. The SL estimate for Elwood Creek, the small stream, varied by 3.9 days depending on if spawner only or total live counts were used. This variation translates into a difference in abundance of 2,000 Chum and demonstrates the influence live counts have on the overall estimate.

Including the 2017 SL estimates, there are now four survey life estimates across three sub-basins. Two medium SL estimates, one small SL estimate and one side-channel estimate. The small stream survey life estimate in 2018 was similar to the medium from 2017, and the medium from 2018 was smaller than the medium from 2017. However, all four SL estimates remained close to the average 10 day survey life with median of days of 8.98, 11.45, 10.75 and 8.90 for the side-channel, small and medium SL, respectively. Many factors may contribute to the 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). This may indicate stream size is not as important to survey life as other factors or it may be that the difference only is evident in larger stream sizes. Until we are able to get a carcass tag estimate on a large stream with confidence, stream size being a factor cannot rule out. It also could indicate that each reach is unique and varies each year and if unique survey life estimates are to be calculated, they should be done annually for each index reach to capture the spatial and inter-annual variation (Irvine et al. 1992). Another explanation may be that although there is some variation in SL estimates from the ten-day average, the variation is minimal enough that perhaps SL estimates can be combined into a hierarchical mean that can be applied to all indexes across the sub-basins.

A second year of survey life (SL) estimates from Tributary 0462 side-channel were not obtained. No carcasses were found in this index in 2018, most likely due to low flows preventing access and predation of the two live fish seen. Obtaining a second side-channel SL estimate in the future would be useful for spatial and temporal comparison. High density spawning side-channels like in the Satsop were not located in the Humptulips, so if may prove difficult to obtain a SL side-channel estimate outside the Satsop. A survey life of 10 days is currently applied to live counts (holders and spawners) in WDFW Chum stock assessment in Puget Sound and appears to be supported by our data (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.

Recommendations

Habitat Characteristics of Index Reaches

- **Complete habitat surveys in all AUC and CMR index reaches.** Ensure habitat measurements are complete for all index reaches currently surveyed and continue to collect habitat measurements for any new index reaches. Examine potential strata split of large vs. medium and small and side-channels combined. It may be that we can apply the average 10-day survey life to smaller streams but need a separate survey life for large mainstem sections.

Distribution

- **Additional Distribution Coverage.** Expand coverage of the Humptulips to include sections that were not evaluated in 2018.
- **Explore additional or different Chum index reaches.** Based on the live Chum counts from 2018, some of the indexes could be adjusted or moved entirely to cover areas that have a higher concentration of Chum, potentially finding a section of large stream size that has a higher concentration for carcass tagging.
- **Repeat distribution surveys.** Repeat distribution surveys on Humptulips, Wynoochee, and Satsop to help determine changes due to environmental conditions.

Area-Under-the-Curve

- **Quantify water clarity**. Implementing a standardized measurement to quantify water clarity by measuring for clarity in the same location each survey may make it possible to develop a coefficient to compensate for poor visibility.
- **Solidify use of spawner status**. WDFW staff and QDNR staff were able to separate spawners and holders for Chum counts in the Humptulips in 2018. Steps should be taken to expand that to all sub-basins for all surveys. 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.

Carcass Tagging

- **Mixing**. Effort should be made to ensure all CMR indexes are appropriately mixing tagged carcasses with untagged to improve on the assumption that all carcasses have an equal probability of being detected. A survey life for large streams was not calculated in 2018 and represents a gap in our understanding of survey life. In order to successfully address this recommendation, adding a CMR index reach in the West Fork Humptulips is advisable.

Survey Life

- **Validate over a range of stream sizes**. 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. FPT 18-03.

Brix, R. 1978. Grays Harbor Chum Salmon Escapement Estimation. 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.

Edwards, A. and M. Zimmerman. 2018. Grays Harbor Fall Chum Abundance and Distribution, 2017. Washington Department of Fish and Wildlife, Olympia, Washington

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.

Irvine, J.R., R.C. Bocking, K.K. English and M. Labelle. 1992. Estimating Coho Salmon (*Oncorhynchus kisutch*) Spawning Escapements by Conducting Visual Surveys in Areas Selected Using Stratified Random and Stratified Index Sampling Designs. Canadian Journal of Fisheries and Aquatic Sciences 49: 1972-1981.

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. and A.N. Arnason. 2006. Jolly-Seber models in MARK. *In* Program MARK: A gentle introduction, fifth edition. *Edited* by E. Cooch and G White. pp. 401-452. Available from http://www.phidot.org/software/mark/docs/book.

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.

Small, M.P., A. Edwards, A. Terepocki, T. Seamons, L. Ronne, and M. Scharpf. 2019. Chum Salmon Population Structure in the Chehalis River. Washington Department of Fish and Wildlife, Olympia, Washington.

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 Humptulips, Wynoochee and Satsop Sub-basins, 2018

Appendix A-1. Live counts of Chum salmon in index reaches of the Humptulips sub-basin, fall 2018. Counts are during the single week used for calculating the proportion of spawners within index (AUC, CMR) versus supplemental survey reaches. 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 and QDNR staff. Tributary numbers are the WRIA stream catalog codes.

							Live Counts				
Sub-Basin	**Stream Name**	**Lower RM**	**Upper RM**	**Reach Length**	**Strata**	**Type**	**Spawner**	**Adjusted Count**	**Holder**	**Adjusted Count**	**Unknown**
Humptulips	Humptulips River	16.7	19.2	2.5	Boat	AUC	118	150	4	5	0
	Humptulips River	23.1	28.1	5.0	Boat	CMR	311	311	112	112	0
	WF Humptulips River	36.7	40.6	3.9	Boat	AUC	389	389	38	38	0
	EF Humptulips River	0.0	1.6	1.6	Boat	AUC	86	86	3	3	0
	EF Humptulips River	1.6	4.4	2.8	Boat	AUC	53	53	1	1	0
Humptulips	Big Creek	8.5	9.1	0.6	Foot	AUC	18	18	25	25	0
	Big Creek	9.1	9.7	0.6	Foot	AUC	8	8	3	3	0
	Stevens Creek	4.5	5.2	0.7	Foot	CMR	867	867	192	192	0
	Stevens Creek	5.2	6.2	1.0	Foot	CMR	1303	1303	110	110	0
	Stevens Creek	6.2	7.1	0.9	Foot	CMR	595	595	112	112	0
	Brittain Creek	0.0	0.2	0.2	Foot	AUC	38	48	7	9	0
	Elwood Creek	0.0	0.6	0.6	Foot	CMR	151	151	6	6	0
	O’Brien Creek	0.0	0.5	0.5	Foot	AUC	577	595	0	0	0
	Donkey Creek	0.0	0.5	0.5	Foot	AUC	416	429	32	33	0
	Donkey Creek[a]	0.8	1.5	0.7	Foot	AUC	189	195	24	25	0
	Widow Creek[a]	0.0	0.3	0.3	Foot	AUC	3	3	0	0	0
	Humptulips			**15.8**	**Boat**		**957**	**989**	**158**	**159**	**0**
	Humptulips			**6.6**	**Foot**		**4165**	**4212**	**511**	**515**	**0**

[a] Survey begins at falls impassable to Chum

Appendix A-2. Live and dead counts of Chum salmon in index reaches of the Wynoochee and Satsop sub-basins, fall 2017. The same index reaches listed were also surveyed in 2018. 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	Live Counts: Holder	Live Counts: Unknown	Dead Counts
Wynoochee	Wynoochee River	15.4	13.7	1.7	Boat	AUC	168	102	0	5
	Wynoochee River	31.2	29.1	2.1	Boat	AUC	0	0	550	35
	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
	Tributary 0298	0.3	0.0	0.3	Foot	AUC	2	4	0	3
	Tributary 0299	0.1	0.0	0.1	Foot	AUC	2	0	0	1
	Bitter Creek	2.5	1.3	1.2	Foot	AUC	0	0	0	0
Satsop	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
	West Fork Satsop	17.0	7.3	9.7	Boat	AUC	29	3	0	0
	Schafer Slough[a]	0.4	0.0	0.4	Boat	AUC	385	14	0	31
	Black Creek	0.9	0.0	0.9	Foot	AUC	0	0	0	0
	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
	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	11.4	10.9	0.5	Foot	AUC	0	0	0	0
	Dry Run Creek	1.2	0.0	1.2	Foot	AUC	0	0	0	0
	Dry Run Creek	2.3	1.2	1.1	Foot	AUC	0	0	0	0
	Tributary 0462	0.2	0.0	0.2	Foot	CMR	0	0	0	119
	Wynoochee			**3.8**	**Boat**		**168**	**102**	**550**	**40**
	Wynoochee			**2.8**	**Foot**		**38**	**12**	**0**	**43**
	Satsop			**16.8**	**Boat**		**518**	**34**	**103**	**58**
	Satsop			**5.8**	**Foot**		**0**	**0**	**8**	**258**

Appendix A-3. Live counts of Chum salmon in supplemental reaches in the Humptulips basin, fall 2018. Counts are during the single week used for calculating the proportion of spawners within index (AUC, CMR) versus supplemental survey reaches.

						Live Counts		
Sub-Basin	**Stream Name**	**Upper RM**	**Lower RM**	**Reach Length**	**Method**	**Spawner**	**Holder**	**Unknown**
Humptulips	Humptulips River	13.9	0.8	13.1	Boat	0	100	0
	Humptulips River	23.1	13.9	9.2	Boat	856	582	0
	West Fork Humptulips	35.2	28.1	7.1	Boat	137	88	0
	West Fork Humptulips	36.7	35.2	1.5	Boat	150	23	0
	West Fork Humptulips	43.6	40.6	3.0	Boat	313	64	0
	West Fork Humptulips	46.0	43.6	2.4	Boat	28	11	0
	West Fork Humptulips	47.2	46.7	0.5	Foot	0	0	0
	East Fork Humptulips	7.7	4.4	3.3	Boat	16	21	0
		Subtotal		**40.1**	**Boat**	**1,500**	**889**	**0**
Humptulips	Tributary 0004B	0.6	0.3	0.3	Foot	0	0	0
	Tributary 0004C	0.5	0.0	0.5	Foot	0	0	0
	Tributary 0004D[a]	0.1	0.0	0.1	Foot	0	0	0
	Tributary 0004E	0.1	0.0	0.1	Foot	10	0	0
	Tributary 0017	0.2	0.0	0.2	Foot	0	0	0
	Deep Creek	1.8	0.8	1.0	Foot	0	7	0
	Deep Creek[a]	3.0	1.8	1.2	Foot	283	102	0
	Tributary 0022	0.3	0.0	0.3	Foot	0	0	0
	Tributary 0022A	0.3	0.0	0.3	Foot	0	0	0
	Tributary 0024	0.6	0.0	0.6	Foot	0	0	0
	Tributary 0024A	0.3	0.0	0.3	Foot	0	0	0
	Tributary 0025	0.3	0.0	0.3	Foot	0	0	0
	Damon Creek	0.2	0.0	0.2	Foot	0	1	0
	Big Creek	3.3	2.6	0.7	Foot	3	11	0
	Big Creek	5.3	3.3	2.0	Foot	65	24	0
	Big Creek	7.1	5.3	1.8	Foot	25	18	0
	Big Creek	8.5	7.1	1.4	Foot	85	10	0
	Big Creek	9.8	9.7	0.1	Foot	0	0	0
	Tributary 0042A	0.1	0.0	0.1	Foot	0	0	0
	Tributary 0046	0.7	0.0	0.7	Foot	0	0	0
	Hansen Creek	2.2	0.0	2.2	Foot	140	21	0
	Hansen Creek	3.2	2.2	1.0	Foot	29	0	0
	Cedar Creek	1.6	0.0	1.6	Foot	28	43	0
	Fairchild Creek	1.7	0.0	1.7	Foot	0	0	0
	Tributary 0052	0.7	0.0	0.7	Foot	0	0	0

Tributary 0054	1.3	0.0	1.3	Foot	7	4	0
Tributary 0056	1.2	0.0	1.2	Foot	71	4	0
Tributary 0057	0.7	0.0	0.7	Foot	0	0	0
South Branch Big Creek[a]	0.2	0.0	0.2	Foot	0	0	0
Stevens Creek	2.5	0.0	2.5	Foot	862	319	0
Stevens Creek	4.5	2.5	2.0	Foot	1228	92	0
Stevens Creek	8.9	7.1	1.8	Foot	583	87	0
Stevens Creek	11.1	8.9	2.2	Foot	0	6	0
Stevens Tributary B	0.3	0.0	0.3	Foot	0	0	0
Hatchery Creek	0.3	0.0	0.3	Foot	0	1	0
Shotgun Creek	1.1	0.0	1.1	Foot	128	10	0
Tributary 0067	0.9	0.0	0.9	Foot	23	1	0
Tributary 0068	0.6	0.0	0.6	Foot	0	0	0
Tributary 0069	2.3	0.0	2.3	Foot	836	262	0
Tributary 0070[a]	0.0	0.0	0.0	Foot	0	0	0
West Fork Stevens Creek	0.8	0.0	0.8	Foot	0	0	0
Tributary 0072	0.6	0.0	0.6	Foot	0	0	0
Tributary 0072A[a]	0.2	0.0	0.2	Foot	0	0	0
Hematite Creek	0.8	0.0	0.8	Foot	3	0	0
Elwood Creek	1.2	0.6	0.6	Foot	0	0	0
Tributary 0083	0.8	0.0	0.8	Foot	0	0	0
Webfoot Creek[a]	0.0	0.0	0.0	Foot	0	0	0
Rock Creek[a]	0.2	0.0	0.2	Foot	0	0	0
Tributary 0088[a]	0.6	0.0	0.6	Foot	0	0	0
Furlough Creek[a]	0.2	0.0	0.2	Foot	28	0	0
O'Brien Creek	1.0	0.5	0.5	Foot	250	70	0
Jones Creek[a]	0.5	0.0	0.5	Foot	5	0	0
Tributary 0106	0.7	0.0	0.7	Foot	16	0	0
Tributary 0107[a]	0.3	0.0	0.3	Foot	0	3	0
Newburry Creek[a]	0.7	0.0	0.7	Foot	179	29	0
Newburry Trib A[a]	0.0	0.0	0.0	Foot	0	0	0
Newburry Trib B[a]	0.1	0.0	0.1	Foot	0	1	0
Rainbow Creek	0.7	0.0	0.7	Foot	1	6	0
Grouse Creek[a]	0.6	0.0	0.6	Foot	19	0	0
Grouse Tributary A[a]	0.2	0.0	0.2	Foot	0	0	0
Elk Creek[a]	0.4	0.0	0.4	Foot	0	0	0
	Subtotal		**46.3**	**Foot**	**4,907**	**1132**	**0**

[a] Survey truncated at falls determined to be impassable barrier for Chum

Appendix A-4. 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.

					Live Counts			
Stream	**Upper RM**	**Lower RM**	**Reach Length**	**Method**	**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	20.4	15.4	5.0	Boat	525	58	0	29
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[ae]	34.6	29.1	5.5	Boat	0	0	2,051	446
Wynoochee River	39.5	34.6	4.9	Boat	1,895	28	0	192
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
		Subtotal	**40.1**	**Boat**	**4,262**	**518**	**2,051**	**1,018**
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	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
Schafer Creek	1.3	0.0	1.3	Foot	29	2	0	55
Schafer Creek	3.1	1.3	1.8	Foot	51	0	0	97
Schafer Creek	6.5	4.3	2.2	Foot	180	23	0	78

Schafer Creek[c]	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	1.0	0.0	1.0	Foot	76	2	0	16
Neil Creek	1.1	1.0	0.1	Foot	0	0	0	0
Neil Creek[c]	1.6	1.1	0.5	Foot	0	0	0	0
Tributary 0298	1.2	0.3	0.9	Foot	19	0	0	0
Tributary 0298	1.7	1.2	0.5	Foot	0	0	0	0
Tributary 0300	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[d]	0.0	0.0	0.0	Foot	0	0	0	0
Larsen Creek[d]	0.2	0.0	0.2	Foot	0	0	0	0
Falls Creek[d]	0.3	0.0	0.3	Foot	0	0	0	0
Harris Creek[d]	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	**24.3**	**Foot**	**362**	**27**	**0**	**255**

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

[d] Survey truncated at falls determined to be impassable barrier for Chum

[e] Supplemental survey by WDFW Chum crew overlapped with QDNR index, so QDNR index live count subtracted from supplemental live counts to prevent double counting. 2,601-550=2051; 481-35=446

Appendix A-5. 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	Holder	Unknown	Dead Counts
Satsop River	6.3	0.0	6.3	Boat	2	12	0	23
Satsop River	10.0	6.3	3.7	Boat	72	5	0	32
Satsop River	11.0	10.0	1.0	Boat	2	1	0	7
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	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
Decker Creek	5.8	5.2	0.5	Boat	561	13	0	8
Bingham Creek	0.9	0.0	0.9	Boat	124	5	0	2
		Subtotal	**63.1**	**Boat**	**1086**	**115**	**1**	**87**
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
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
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	6.8	5.8	1.0	Foot	0	0	0	198
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[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	1.0	0.0	1.0	Foot	0	0	0	21
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
Tributary 0459C	1.2	0.0	1.2	Foot	0	0	0	0
Dry Run Creek[a]	5.1	2.5	2.6	Foot	0	0	0	0
Tributary 0462A	0.1	0.0	0.1	Foot	0	0	0	7
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	**46.4**	**Foot**	**8**	**0**	**2**	**828**

[a] Survey truncated due to lack of Chum, assumed no Chum presence
[b] 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-6. Supplemental reaches that were not surveyed in the Humptulips sub-basin, 2018. These streams were not surveyed due to inability to access, inadequate visibility, or unsafe survey conditions.

Sub-Basin	Stream	Lower RM	Upper RM	Reach Length
Humptulips	Deep Creek[c]	0.0	0.8	0.8
	Big Creek[c]	0.0	2.6	2.6
	EF Humptulips[a]	7.7	10.7	3.0
	WF Humptulips[a]	46.0	46.7	0.7
	Tributary 0075[c]	0.0	1.5	1.5
	Tributary 0063[c]	0.0	3.0	3.0
	Burg Slough[b]	0.0	3.0	3.0
	Jessie Slough[b]	0.0	2.0	2.0
	Donkey Creek[a]	0.5	0.8	0.3
	Subtotal			**16.9**

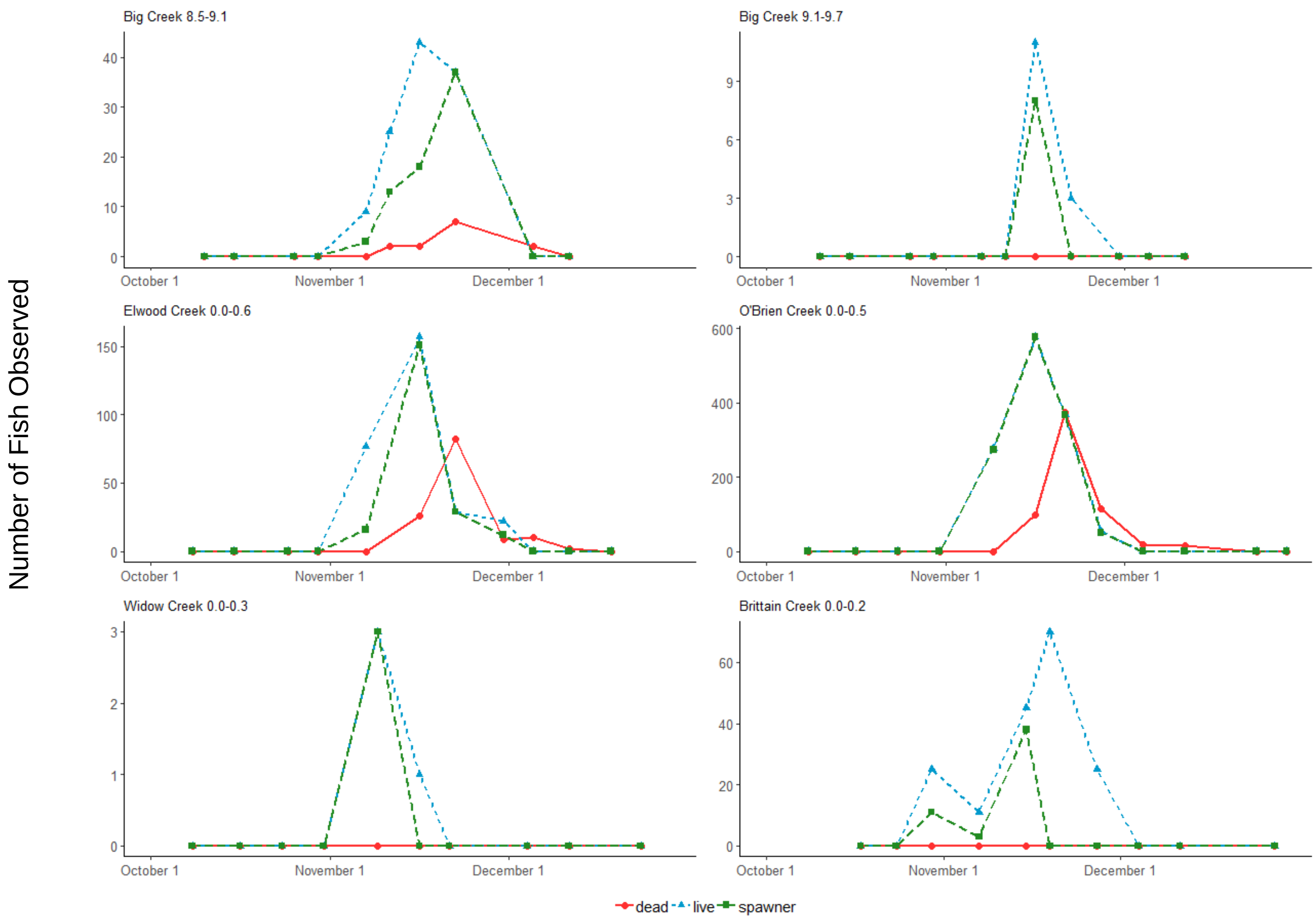
[a] Gorge section, deemed unsafe to survey during winter flows
[b] Not surveyed due to access issues or remote locations
[c] Not surveyed due to poor visibility or dangerous flow conditions

Appendix A-7. Supplemental reaches that were not surveyed in 2017 in the Wynoochee and Satsop. These streams were not surveyed due to inability to access, inadequate visibility, or unsafe survey conditions.

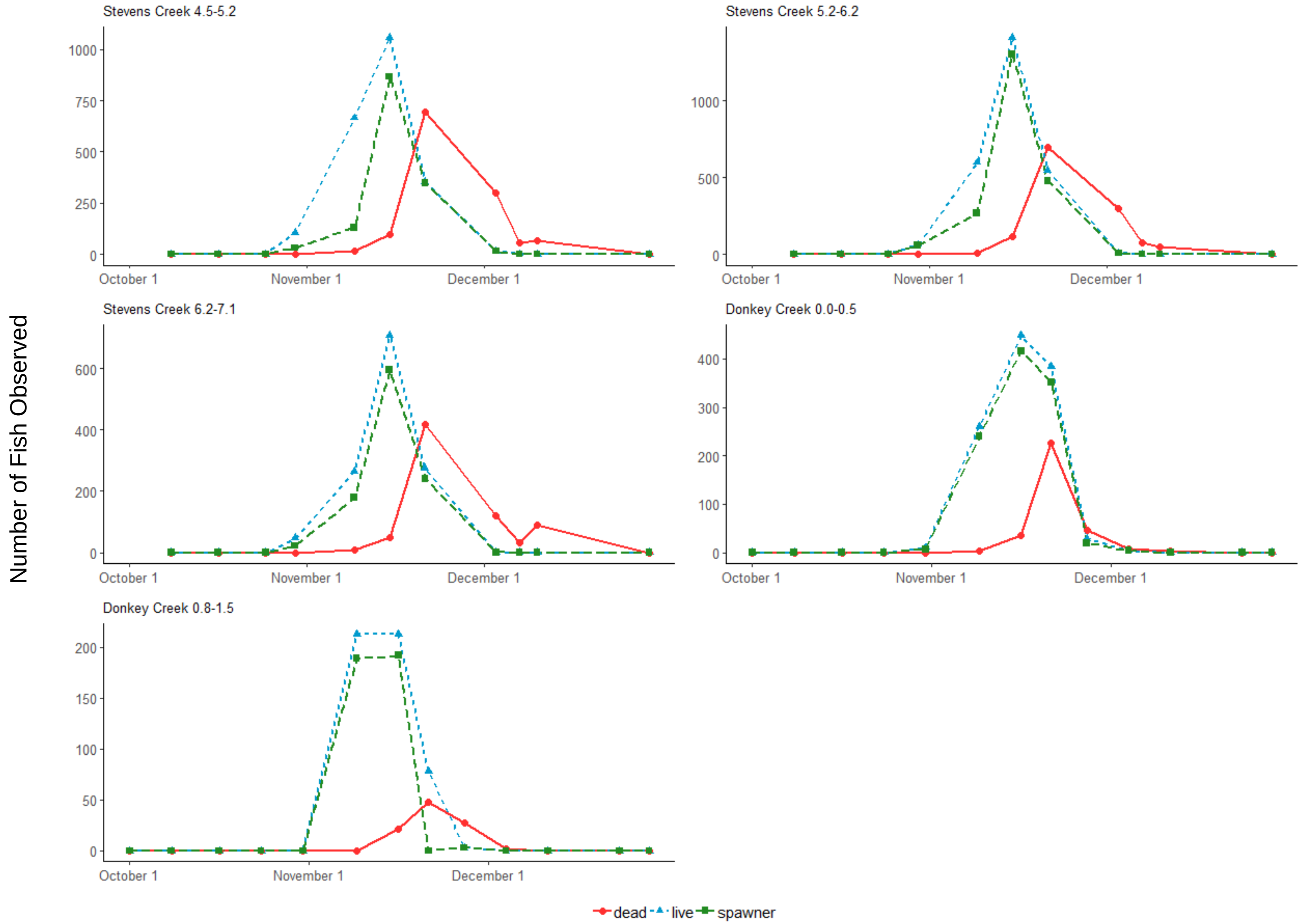
Sub-Basin	Stream	Upper RM	Lower RM	Reach Length
Wynoochee	Wynoochee[a]	43.5	39.5	4.0
	Tributary 0304[b]	0.3	0.0	0.3
	Tributary 0301[b]	0.3	0.0	0.3
	Helm Creek[c]	0.6	0.0	0.6
	Anderson Creek (Lower)[bc]	0.8	0.0	0.8
	Wedekind Creek[c]	2.3	0.0	2.3
	Bitter Creek[c]	2.5	0.5	2.0
	Black Creek[c]	5.4	0.0	5.4
	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

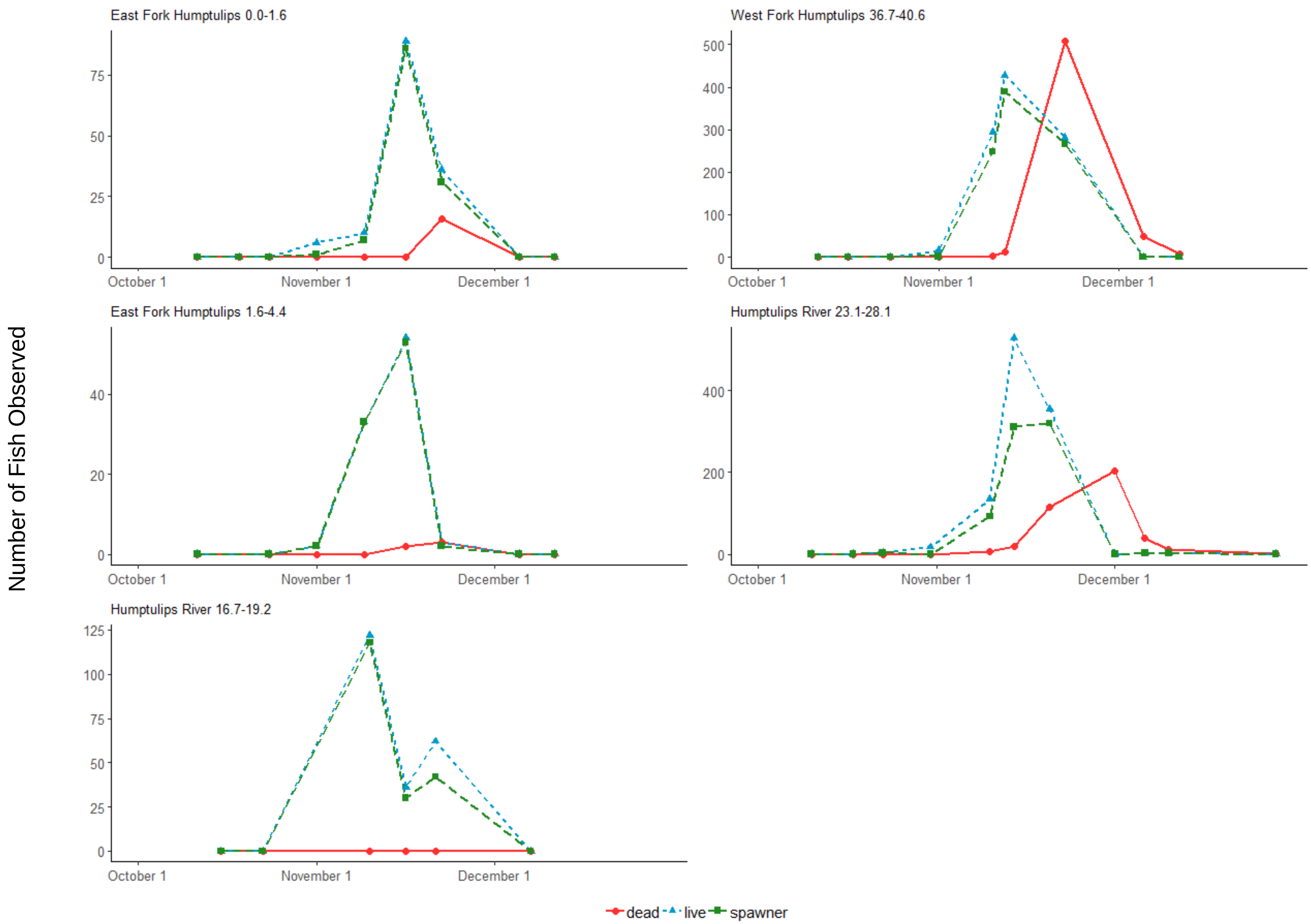
Appendix B: Live, Dead, Spawner counts from index reaches across the Humptulips, Wynoochee and Satsop sub-basins, 2018.



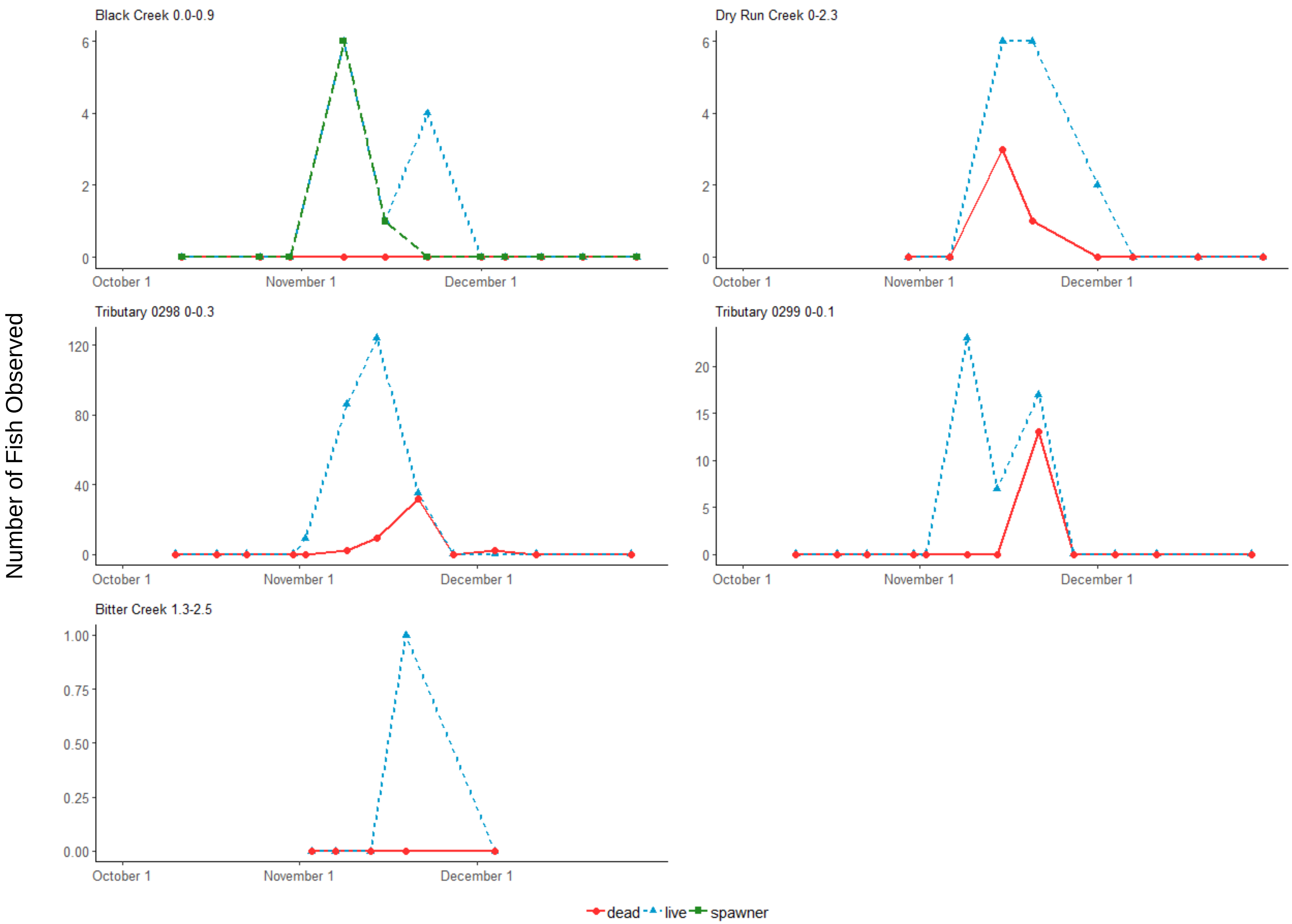
Appendix B-1. Number of live and dead Chum observed in small index reaches (AUC, CMR) of the Humptulips sub-basin, 2018. Live count data shown as 'spawners only' and 'total live' counts.



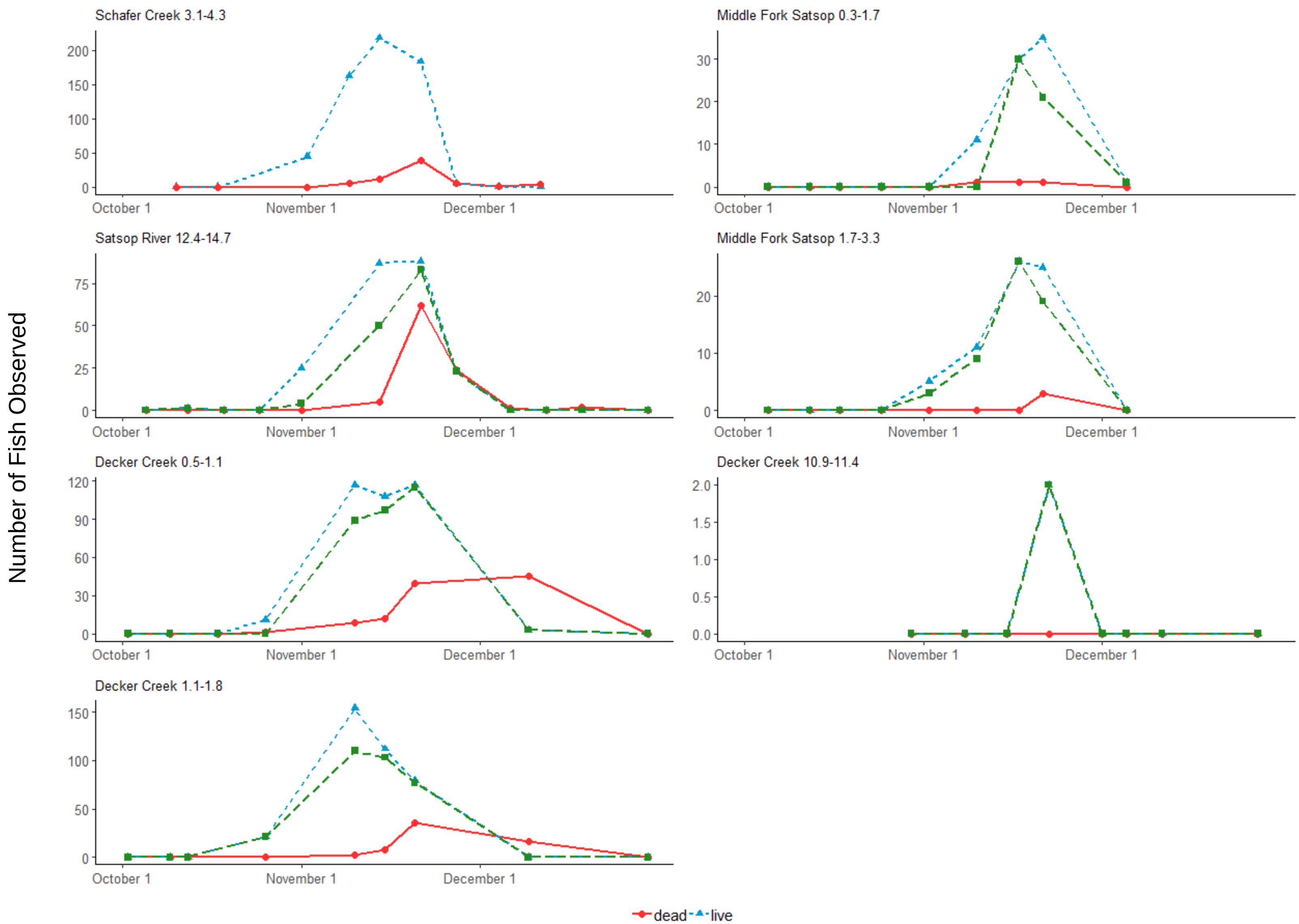
Appendix B-2. Number of live and dead Chum observed in medium index reaches (AUC, CMR) of the Humptulips sub-basin, 2018. Live count data shown as 'spawners only' and 'total live' counts.



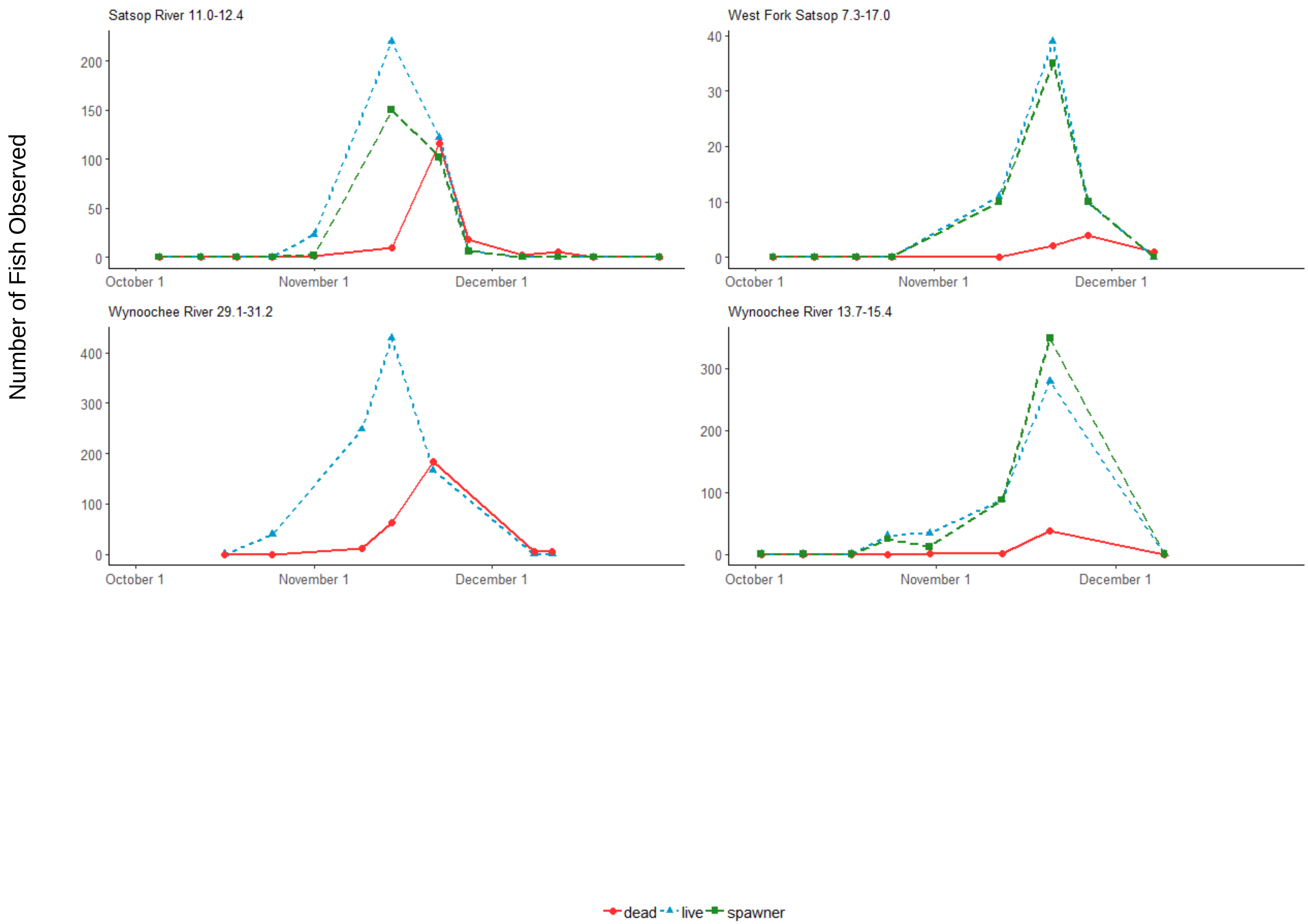
Appendix B-3. Number of live and dead Chum observed in large index reaches (AUC, CMR) of the Humptulips sub-basin, 2018. Live count data shown as 'spawners only' and 'total live' counts.



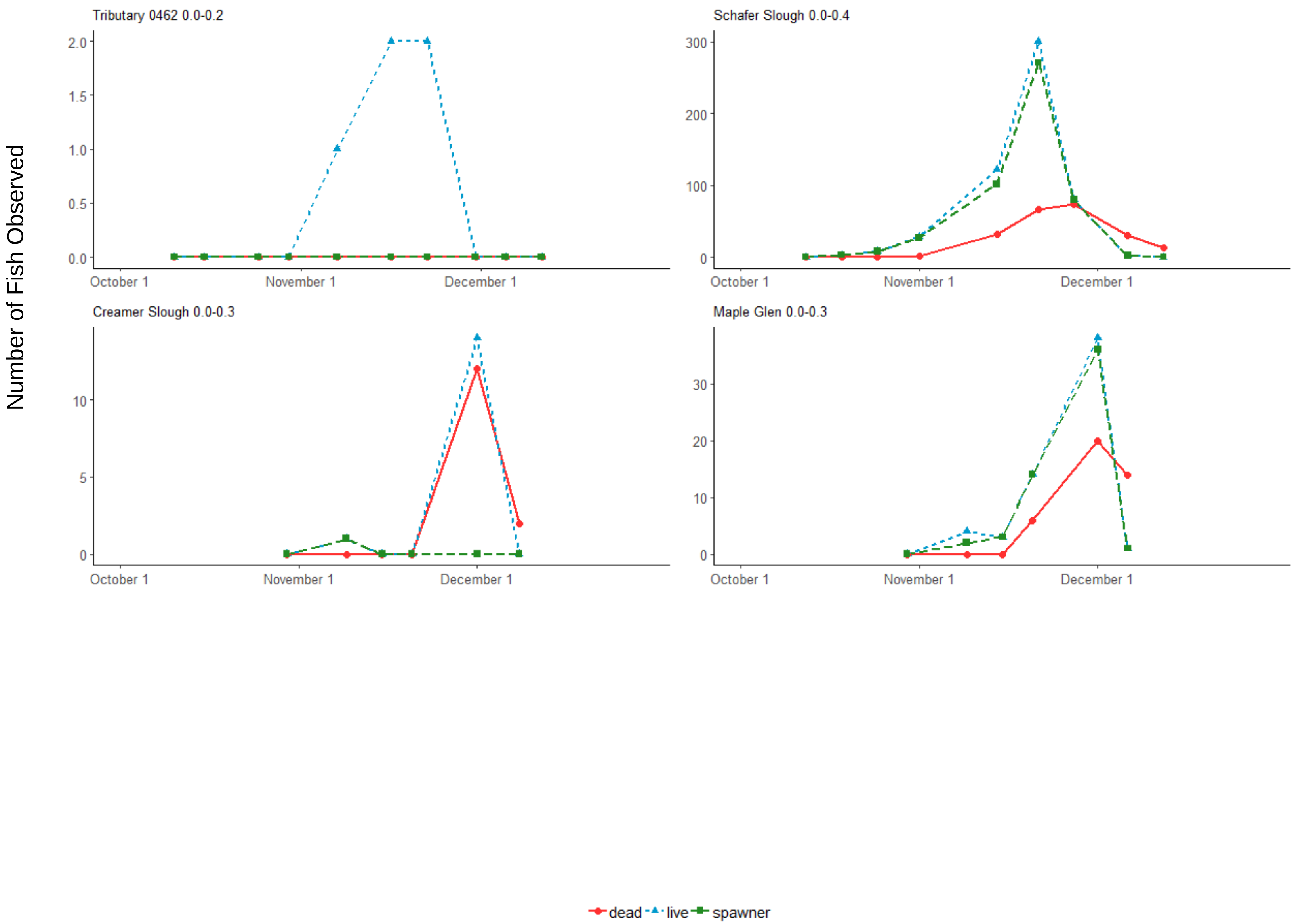
Appendix B-4. Number of live and dead Chum observed in small index reaches (AUC, CMR) of the Wynoochee and Satsop sub-basins, 2018. Live count data shown as 'spawner only' and 'total live' counts.



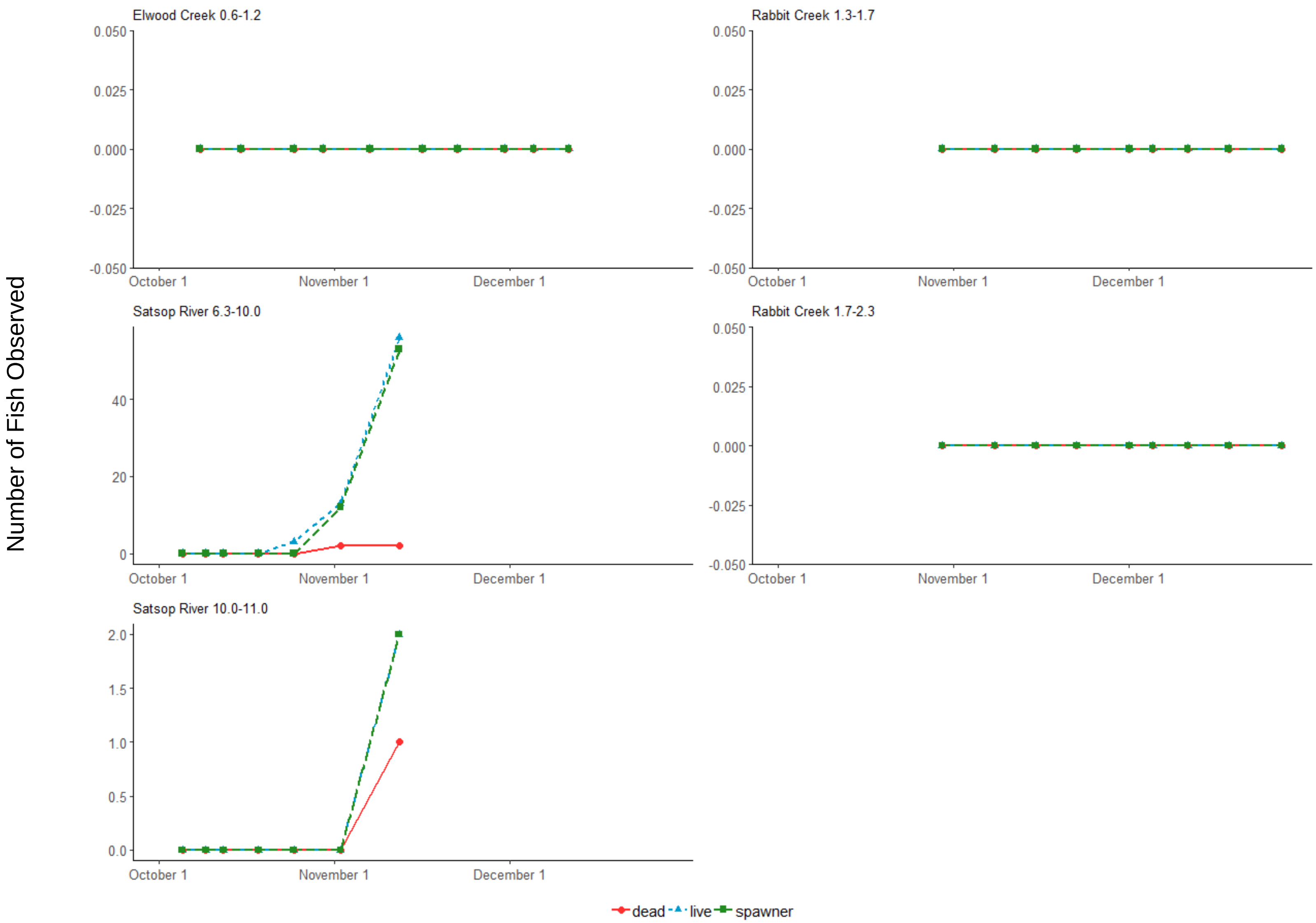
Appendix B-5. Number of live and dead Chum observed in medium index reaches (AUC, CMR) of the Wynoochee and Satsop sub-basins, 2018. Live count data shown as 'spawner only' and 'total live' counts.



Appendix B-6. Number of live and dead Chum observed in large index reaches (AUC, CMR) of the Wynoochee and Satsop sub-basins, 2018. Live count data shown as 'spawner only' and 'total live' counts.



Appendix B-7. Number of live and dead Chum observed in side channel index reaches (AUC, CMR) of the Satsop sub-basin, 2018. Live count data shown as ‘spawner only’ and ‘total live’ counts.



Appendix B-8. Number of live and dead Chum observed in index reaches (AUC, CMR) of the Humptulips, Wynoochee and Satsop sub-basins, 2018. Live count data shown as ‘spawner only’ and ‘total live’ counts. Index reaches unsuitable for AUC analysis due to no Chum presence or incomplete surveys.

Appendix C – Summary of Chum Biological and Tagging Information Collected in the Carcass-Mark-Recapture Index Reaches of the Humptulips Basin, 2018

Appendix C-1a. Carcass releases and recapture by periods presented as marray and marray.r from Jolly-Seber open population abundance estimate of **Stevens Creek**, Fall 2018. Periods 5, 6 and 7 were combined for analysis purposes.

marray

		Recovered by Day				
Day	#Released	7	13	25	30	Total
1	22	16	1	0	0	17
7	217	0	173	3	4	180
13	351	0	0	78	38	116
25	94	0	0	0	78	78

marray.r

	Recovered by Period				
Period	V1	V2	V3	V4	V5
1	16	1	0	0	5
2	0	173	3	4	37
3	0	0	78	38	235
4	0	0	0	78	16

Appendix C-1b. Carcass releases and recapture by periods presented as marray and marray.r from Jolly-Seber open population abundance estimate of **Elwood**, Fall 2018. Periods 4 and 5 were combined for analysis purposes.

marray

		Recovered by Day			
Day	#Released	7	15	22	Total
1	18	17	0	0	17
7	62	0	15	8	23
15	2	0	0	2	2

marray.r

	Recovered by Period			
Period	V1	V2	V3	V4
1	17	0	0	1
2	0	15	8	39
3	0	0	2	0

Appendix C-2. Summary of all Chum carcasses handled by index reach, 2018. 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	
Humptulips	Elwood Creek 0.0-1.6	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	4	14	0	0	0	0	2	5	1		1:1
		47	25	38	0	0	1[b]	0	0	4	15		1:1
		49	1	1	0	0	0	0	2	0	5		1:1
		49A	3	4	0	0	0	0	1	2	0		1:1
		50	0	0	0	0	0	0	0	2	0		No fish tagged
		51	0	0	0	0	0	0	0	0	0		No fish tagged
	Stevens Creek 4.5-7.1	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	10	12	0	0	0	0	5	5	0		1:1
		46	143	74	0	0	0	0	24	23	4		1:1
		47[a]	167	180	4	73	71	1123	62	79	53	1	1:5
		49	36	58	0	0	0	0	54	57	512		1:1
		49A	2	5	0	0	0	0	31	45	78		1:1
		50	0	1	0	0	0	0	0	0	206		No fish tagged
		52	0	0	0	0	0	0	0	0	7		No fish tagged
	Humptulips River 23.1-28.1	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
		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	2	1	0	0	0	0	3	0	0		1:1
		46	6	3	0	0	1[b]	0	2	0	6		1:1
		47	45	47	0	0	0	0	8	14	1		1:1
		48	34	25	0	0	0	0	56	50	38		1:1
		49	4	1	0	0	0	0	14	15	5		1:1
		50	2	0	0	0	0	0	4	2	3		1:1
		52	0	0	0	0	0	0	1	0	1		No fish tagged

[a] Stevens Creek section RM 6.2-7.1 not completed on 11/20/2018, crew returned following day to complete survey, counts summarized from both days

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