

Evaluation of the Alignment of Lower Columbia River Salmon and Steelhead Monitoring Program with Management Decisions, Questions, and Objectives

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Executive Summary

The purpose of the Integrated Status and Trend Monitoring (ISTM) demonstration project is to develop a decision framework for integrating regional actions for monitoring the status and trends of aquatic habitat, watershed health, and anadromous salmonid populations. The Lower Columbia River subunit recovery domain¹ (hereafter LCR) has been chosen as the demonstration area for this project because it represents the challenge of integrating monitoring across multiple Evolutionary Significant Units (ESU) and Distinct Population Segments (DPS), and among multiple jurisdictions (e.g., the states of Oregon and Washington, the Federal Columbia River Power System (FCRPS), and federal and tribal management through U.S. v. Oregon and the Pacific Salmon Treaty). Five objectives were identified by the fish sub-workgroup of the ISTM project to meet demonstration project goals including: 1) Identify and prioritize management decisions, questions, and objectives; 2) Evaluate the extent to which existing programs align with these management decisions, questions, and objectives; 3) Identify the most appropriate monitoring design to inform priority management decisions, questions, and objectives; 4) Use trade-off analysis to develop specific recommendations for monitoring based on outcomes of objectives 1-3; and 5) Recommend implementation and reporting mechanisms.

The framework for making informed decisions on allocating limited monitoring resources was guided by monitoring needs identified in Oregon and Washington ESA recovery plans and by National Oceanic and Atmospheric Administration (NOAA) recovery plan monitoring guidance documents. Our first report addressed Objective 1² and resulted in a prioritization tool that considered fish population recovery priority, current natural origin fish abundance, the availability of infrastructure (e.g., dams, fish ladders, weirs) to monitor adult and juvenile migrations, and special cases identified in the recovery plans. The tool also considered the prioritization of Viable Salmonid Population (VSP) population monitoring indicators. The tool used spatially explicit information on *both* the relative priority of the VSP monitoring data and the feasibility/relative expense of obtaining it.

In this report we address Objective 2 by evaluating how existing monitoring programs align with the management decisions, questions, and objectives identified in Objective 1. Crawford and Rumsey (2009) identified ten indicators of viable salmonid populations (fry/parr, juvenile migrant, adult recruit, and spawner *abundance*, age structure, migration/spawn timing, sex ratio, and origin *diversity*, and fry/parr and spawner distribution *spatial structure*). We describe criteria to evaluate these 10 indicators against the priorities identified in the first report for all 103 populations of salmonids that are included in recovery plans for the LCR. In addition to identifying monitoring gaps, there are recommendations for improving population-specific indicators to better meet the inference goals for monitoring. Graphs succinctly display monitoring gaps and opportunities by species, adult and juvenile life stage, population, and indicator.

The scoring system developed here establishes an upper standard for specific monitoring approaches. Some current monitoring programs in the LCR scored below the standard, but that may not mean these efforts are providing low quality information. Useful information can be and is being obtained from monitoring programs that fail the standard. This report is focused on providing regional managers and policy makers with the information they need to understand the caveats that should be associated with information they receive from existing monitoring programs, as well as specifics on what is needed to improve the quality of this information, relative to ESA reporting.

¹ <http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/>. The LCR is a subunit of the Willamette/ Lower Columbia Recovery Domain

² http://www.pnamp.org/sites/default/files/pnamp2010-004_istm_fish_obj1.pdf

Background

Most anadromous salmonid ESU's and DPS's (hereafter ESU's) in the Pacific Northwest are currently listed as threatened or endangered under the Endangered Species Act (ESA). In support of determining the recovery of these ESU's, millions of dollars are spent annually to monitor the status and trend of the populations within these ESU's, and to evaluate the effectiveness of actions taken to improve their status. Given greater information need and decreasing financial resources, monitoring programs need to be cost-effective, efficient, and coordinated. By leveraging past monitoring experiences and developing well-coordinated monitoring approaches, technical and fiscal resources can be shared more effectively among monitoring entities, and the resulting information can be provided to decision makers in a more efficient and comprehensive manner. This in turn results in greater scientific credibility, greater cost-effectiveness in use of limited funds, and greater accountability to stakeholders (PNAMP 2005).

The primary purpose of the Integrated Status and Trend Monitoring (ISTM) demonstration project is to improve integration of existing and new efforts that are intended to address status and trend monitoring needs (PNAMP 2009). As a demonstration effort, it evaluates processes and tools to support development and management of integrated regional strategic action plans or roadmaps for monitoring the status and trends of aquatic habitat, watershed health, and salmon populations (including steelhead). The Lower Columbia River (LCR) area (Figure 1) has been chosen for this demonstration project because it is representative of the challenges faced when integrating monitoring efforts across multiple salmon Evolutionary Significant Units (ESU) and steelhead Distinct Populations Segments (DPS), between the states of Oregon and Washington, including the operation of the Federal Columbia River Power System (FCRPS) and Bonneville Dam, and federal and tribal management through U.S. v. Oregon and the Pacific Salmon Treaty. Although numerous entities are involved in monitoring in the LCR, the existing monitoring efforts are not well coordinated, and often lack the spatial coverage, certainty, or species coverage necessary to answer questions related to the status and trends of fish populations in the LCR.

The ISTM demonstration project is made up of the Fish, Habitat monitoring, and Master sample sub-workgroups. The specific goal of the fish sub-workgroup is to assist entities tasked with monitoring Pacific Northwest salmonid populations by developing tools and recommendations for a coordinated monitoring program that collects and reports data on Viable Salmonid Population (VSP) indicators and to assure that quantitative monitoring designs are of sufficient quality to determine the status and trends of LCR salmon and steelhead populations. To compliment this goal, the habitat monitoring component of ISTM is developing recommendations for integrating aquatic ecosystem monitoring to support this key information need in the LCR. The Master sample component of ISTM involves incorporating the "master sample" concept into the selection of monitoring sampling locations in the LCR. Entities tasked with monitoring salmon and steelhead populations in the Pacific Northwest can use these ISTM tools and recommendations to implement an integrated, scientifically sound monitoring program that meets the needs of regional decision-makers and managers. In this report we apply the ISTM Fish recommendations to develop a specific monitoring plan for salmonid populations in the LCR, with a focus on monitoring the four VSP parameters of abundance, spatial structure, diversity, and productivity (McElhany et al. 2000). The first three metrics are independent metrics that categorize the abundance of salmonids, their distribution, and genetic and life history diversity. The final metric, productivity, is a time series or density dependent cohort analysis based on the abundance and diversity metrics.

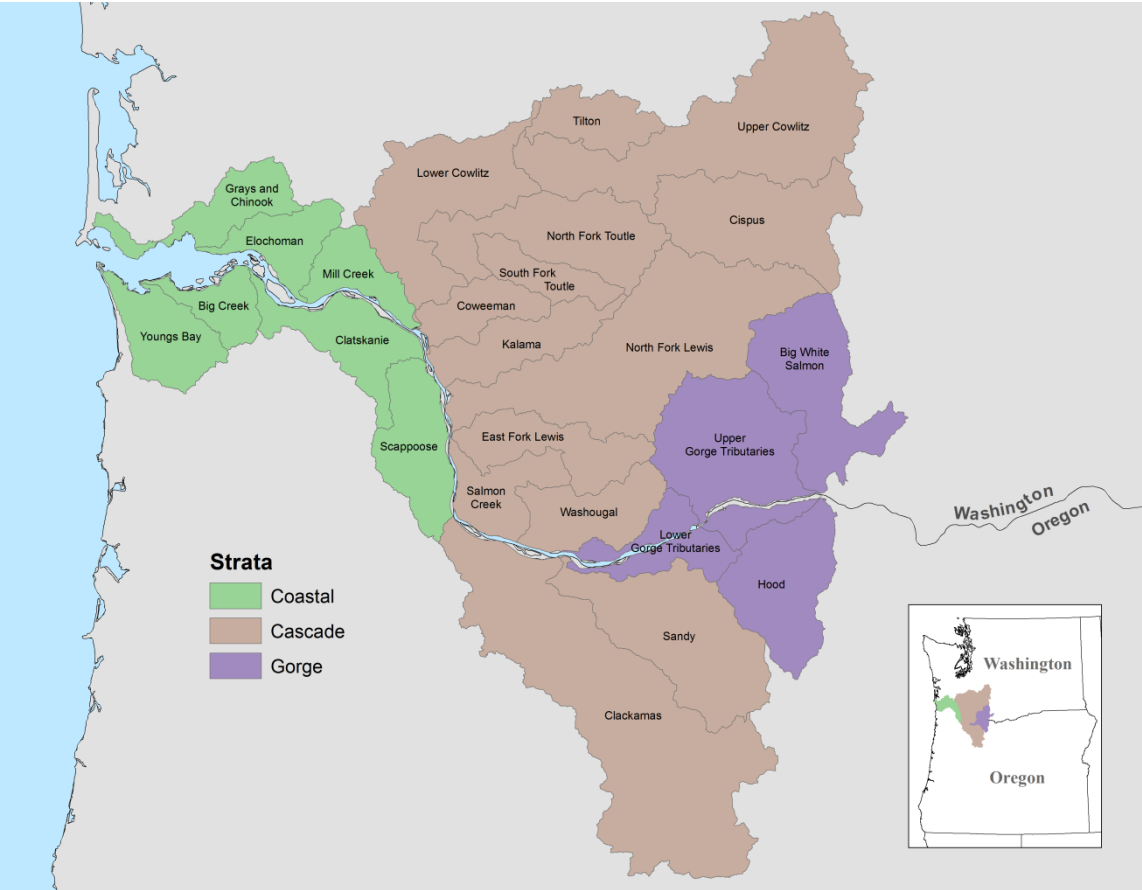


Figure 1. Lower Columbia River pilot project area showing generalized³ boundaries of salmon and steelhead populations and the regional groupings (i.e., strata) in which they occur within the LCR subunit recovery domain.

To develop these coordinated, cost-effective, transparent, and scientifically defensible monitoring programs, the ISTM developed the following five objectives:

1. Identify and prioritize management decisions, questions, and objectives.
2. Evaluate extent to which existing programs align with these management decisions, questions, and objectives.
3. Identify most appropriate monitoring design to inform priority management decisions, questions, and objectives.
4. Develop and use a trade-off analysis to develop specific recommendations for monitoring based on outcomes of objectives 1-3.
5. Recommend implementation and reporting mechanisms.

Rawding et al. (2010a) reported on Objective 1, identifying and prioritizing management decisions, questions, and objectives based on Oregon and Washington recovery plans (LCFRB 2010a, LCFRB 2010b, ODFW 2010), NOAA Monitoring Guidance (Crawford and Rumsey 2009), and overarching statewide strategies such as the

³ See <http://www.nwr.noaa.gov/ESA-Salmon-Listings/> for species specific maps.

Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery Monitoring Oversight Committee 2002) and other important regional guidance including the Columbia River Basin Monitoring, Evaluation, Research, and Reporting (MERR) Plan (NPCC 2010). The Rawding et al. (2010a) report identified and prioritized management decisions, questions, and objectives for integrated status and trend monitoring of salmonid populations in the LCR. To rank monitoring importance, a prioritization tool was developed that provides a scored assessment of each populations recovery priority, current natural origin abundance, the potential for monitoring migrating adult and juvenile fish, and special cases identified in the recovery plans, along with the prioritization of VSP population monitoring indicators by life stage. The prioritization tool incorporated spatially explicit information on *both* the priority of the monitoring data and the current feasibility/relative expense of obtaining it. A scoring algorithm was developed to prioritize monitoring within species across the LCR, and among watersheds which all have multiple species. The first objective also resulted in a recommended monitoring framework of VSP indicators based on high priority management decisions (Table 1).

This report describes the results of Objective 2, which evaluated the extent to which existing monitoring efforts align with monitoring priorities based on the management decisions and questions for integrated status and trend monitoring of salmon and steelhead populations in the LCR.

Considerations for Evaluation of VSP Indicator Monitoring

In general, monitoring of VSP indicators (i.e., abundance, productivity, diversity, and spatial structure) is conducted to determine either the trend of the indicators, the current status of the indicators, or both. Trend evaluation consists of a time series analysis of the metrics or indicators over time. Trend analysis is often used to assess if the slope of the indicator is stable over time (no trend), increasing, or declining. For example, the trend of natural origin adult spawner abundance could be defined as increasing. In contrast, a status evaluation might compare the indicator to a goal or reference condition. The output from status analyses is often expressed as a percentage of the goal. For example, the status of the natural origin spawners in a population might be 50% of the recovery goal.

Both types of monitoring are important and address different aspects of salmonid ESU recovery. We note here that the ESU is the “listing” unit and that in recovery plans the populations have variable recovery targets to meet ESU delisting criteria. The trend evaluations assess if the indicator of population status (e.g., natural origin spawner abundance) is on a trajectory toward the delisting goal for that population. Trends are useful as an early sign that population performance is improving or not, and may signal the need for additional actions. Status may be viewed as a comparison of the current state of an indicator and the recovery goal for the indicator. An ESU that has populations meeting their respective VSP targets is a good candidate for delisting under biological criteria, but the ESU may still be subject to listing factor criteria before it can be removed from ESA protection. When status and trend estimates of VSP indicators do not reflect true population performance, are biased, or have other sources of large uncertainty, their utility is limited for reducing the risk of incorrect management decisions, such as delisting, or failure to implement adequate recovery actions, etc.

Table 1. VSP Indicator sub-categories and their rationale from Objective 1 (Rawding et al. 2010a)

Indicator	Rationale
Abundance Fry/Parr	Monitoring an index of fry/parr abundance is a useful and relatively cost effective tool for evaluating juvenile abundance trends for coho and steelhead. It can help to identify potential bottlenecks that impact a population. However, because the ultimate currency on which population viability is measured is adult abundance, monitoring for fry/parr abundance does not rank as a high priority compared to monitoring adult abundance
Abundance Juvenile Migrants	Monitoring the abundance of juvenile outmigrants (JOM) is an important component of the productivity assessment of a population and freshwater habitat conditions. The importance of this type of monitoring is linked to recovery priorities because while important, information on JOM are not explicitly required for all populations. Juvenile migrant monitoring is most useful for populations where significant habitat actions are planned, to estimate marine survival of natural origin fish, and in designs to evaluate the effectiveness of specific restoration actions.
Abundance Adult Recruits	Information on adult recruits (i.e., escapement + harvest) is a key component of evaluating population productivity, which is a key component of evaluating population viability.
Abundance Spawners	Information on spawner abundance is a key component of evaluating population viability.
Diversity Age Structure	The Technical Recovery Team (TRT) gives information on diversity a lesser weight in viability calculations compared to information on abundance and productivity. However, information on age structure is required for productivity calculations, a key component of evaluating population viability.
Diversity Migration/Spawning Timing	Migration timing is an important component of diversity. However, because the TRT gives information on diversity a lesser weight in viability calculations compared to information on abundance and productivity, migration timing is given a moderate score.
Diversity Sex Ratio	Although the TRT gives information on diversity a lesser weight in viability calculations compared to information on abundance and productivity, information on sex ratio is an important component of productivity calculations, which is a key component of evaluating population viability.
Diversity Origin	Although the TRT gives information on diversity a lesser weight in viability calculations compared to information on abundance and productivity, information on age structure, sex, and origin are important components of productivity, which is a key component of evaluating population viability.
Spatial Structure Fry/Parr Distribution	The distribution of juvenile salmon and steelhead can provide an important snapshot of the spatial structure of a population as well as provide insights into habitat conditions. Surveys for juvenile fish are generally less costly than surveys for adult fish and therefore may be a cost effective alternative to distribution surveys for adults. However, as with abundance estimates, because the ultimate currency on which population viability is measured is adult abundance, monitoring for fry/parr abundance does not rank as a high priority compared to monitoring spawner distribution.
Spatial Structure Spawner Distribution	The spatial structure of spawners is an important component of status assessments. As with diversity, the TRT gives information on spatial structure a lesser weight in viability calculations compared to information on abundance and productivity. We give spatial structure for spawners a high priority because it is an important assessment of the overall impact of habitat actions on a population.

Bias and precision describe the difference between an estimate, its uncertainty, and the true value (Figure 2). Specifically, bias is the average difference between the estimate and the true value. There are many causes of bias. In this document we are concerned with bias that occurs either during the sampling process (observer error), or because of a non-representative sample site selection (i.e., spatial bias). An example of bias associated observer error is systematically under or over counting the number of adult spawners that are present at surveyed sites. Spatial bias may occur when spawning survey reaches are chosen opportunistically rather than randomly. Some bias may be corrected, such as when a double tagging experiment is used to estimate tag loss in a mark recapture experiment, but in many cases there is no correction available. Precision can be viewed as how consistent monitoring results would be if multiple measurements were taken. Precision is often expressed as the standard deviation of the estimate. Both the precision and bias of an estimator needs to be evaluated to assess uncertainty. The level of uncertainty determines whether an estimator can provide reliable information to status and trend monitoring.

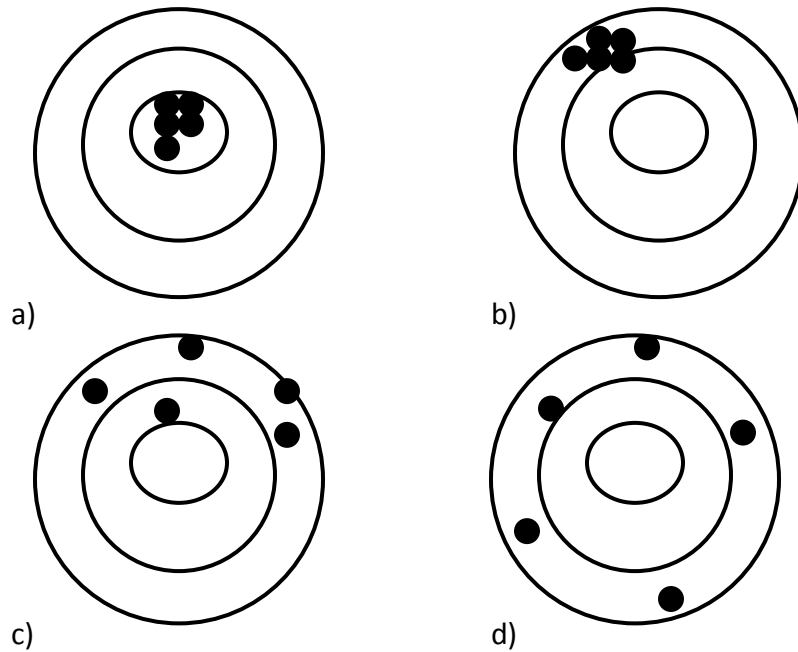


Figure 2. An illustration of bias and precision: a) precise and unbiased; b) precise and biased; c) biased and imprecise; d) unbiased and imprecise.

Approach

There is an enormous amount of information on the efficacy of various approaches for monitoring fish and wildlife populations (Seber 1982, Williams et al. 2002, Amstrup et al. 2005, Thompson et al. 2008, Link and Barker 2010, Royale and Dorazio 2008) with a number of reviews (Seber 1986, Seber 1992, Schwarz and Seber 1999). These texts and reviews concentrate on the statistical framework of estimating the abundance of open and closed populations using mark-recapture, change in ratio, distance sampling, occupancy sampling, and spatial sampling. Review of the application of these and other methods for estimating salmon and steelhead abundance have been compiled by Cousens et al. (1982), Newman (2009), Parsons and Skalski (2009a, 2009b), Rawding (2009a; 2009b), Reidinger (2009), and Parsons and Skalski (2010). The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP 2007) and many other VSP monitoring population reviews have been compiled⁴. In addition, Zhou (2002) and Murdoch et al. (2010) assessed indicators such as origin, sex ratio, and fish length. Broad scale reviews of diversity and spatial structure indicators are not available. The current report is not a repeat of previous reviews but summarizes the findings of these reviews with regards to bias and precision as related to current monitoring approaches for salmon and steelhead in the LCR.

As with all monitoring evaluations and critiques, there is some subjectivity in the evaluation (Parsons and Skalski 2010). We limit this subjectivity by developing rules of thumb for ranking the bias and precision of methods commonly used in the LCR. Monitoring programs that demonstrate that they meet all the assumptions required for an unbiased estimate and meet precision goals are ranked the highest while methods that do not meet key assumptions, are highly biased, or produce no estimate of precision are ranked the lowest (Table 2). Further, we apply these scoring guidelines to each indicator so that the evaluation of indicator scores is consistent across populations and species within the LCR.

⁴ <http://www.cbfwa.org/csmeep/web/content.cfm?ContextID=16>

Extirpated or functionally extinct populations have insufficient numbers of fish to monitor effectively. Many of these populations are given a current monitoring effort score of 0.00 because there is no monitoring effort ; monitoring on these populations may fail precision standards due to small sample sizes. An asterisk (*) is associated with the population name of extirpated or functionally extinct populations in the tables and graphs in this report.

Table 2. General scoring criteria for VSP indicators and rationale used to assess alignment of monitoring programs.

Score	Rationale
1.00	Precision and bias requirements are met AND there are no untested critical assumptions
0.75	Precision and bias requirements appear to be met BUT there are some locally untested critical assumptions (assumption tests are available within the population domain or under similar environmental conditions)
0.50	Precision and bias requirements appear to be met BUT there are some completely untested critical assumptions (assumption tests not available)
0.25	Precision OR bias requirements are not met AND assumptions may or may not be tested
0.00	No monitoring OR Precision AND bias requirements are not met AND assumptions may or may not be tested.

Monitoring Method Scoring Criteria

There are three basic components of a monitoring program design that influence the precision and bias of gathered information⁵. The first, referred to as “spatial design”, identifies where in the domain of inference⁶ data are collected. The second component, “temporal design”, identifies when data will be collected. The third component is “response design”, and indicates how the data will be collected.

There are four general categories of spatial design: 1) Census⁷, 2) Model-based⁸, 3) Survey⁹, and 4) Opportunistic¹⁰. In general, given the same temporal and response design, data obtained using a census spatial design will be more precise and less spatially biased than an opportunistic design. This is because a census is a direct count of all individuals so there are no sources of bias or imprecision associated with the census spatial design. Conversely, opportunistic designs are not a random sample and therefore may be highly biased and imprecise because data may be only representative of the sites sampled. For the same response design, model and survey-based spatial designs will generally have precision that is lower than census-based designs and higher than opportunistic-based designs. The bias of model and survey-based spatial designs will generally be similar to census-based with the same response design, and lower than non-representative opportunistic-based designs.

The temporal design of a monitoring program can also have a significant impact on the bias and precision of results. For example, a negative bias in the spawner abundance estimate would occur if spawning surveys were not conducted over the entire spawning period. An imprecise estimate of abundance based on periodic live counts may occur if 1) the time between the survey frequency is too long to detect variation in fish abundance over the season (Bue et al. 1998) or 2) assuming the distribution of counts is normal distributed (Hill 1997) when they are not (Hilborn et al. 1999).

Finally, how data are collected (i.e., the response design) can significantly impact the bias and precision of results. For example, observer error, such as consistently under or over estimating the number of juvenile fish observed during snorkel surveys, can result in a significant negative or positive bias of juvenile fish abundance estimates. Variability between observer counts can result in reduced precision estimates.

We scrutinized the influence of spatial, temporal, and response design on the precision and bias of existing monitoring efforts in the LCR and developed scoring criteria of information quality for sampling methods for each Viable Salmonid Population (VSP) indicator. These scoring criteria were organized by VSP indicator sub-categories (Table 1). The scoring criteria and the scoring rationale for each VSP indicator sub-category are described below. In each table you will notice some rationale text in *italics*. *Italicized* text highlights key elements of the scoring criteria that make it unique from the next higher score.

⁵ see resources at <https://salmonmonitoringadvisor.org/>

⁶ e.g., a salmon or steelhead population area

⁷ A census consists of counts over the entire spatial area used by the population.

⁸ Model-based designs assume a super population in which the random component is responsible for creating the elements in the population. A sample is drawn from a subset of population elements to predict those population elements not sampled based on a model.

⁹ Survey-based designs use a specified method of randomization, such as a simple random sample, to select sampling units from the population. The probabilistic nature of the sample is the only source of randomness that plays a part when making inference to the population.

¹⁰ Opportunistic designs include observations made without a specific sampling design.

Indicator: Index of Fry/Parr Abundance

This indicator pertains to monitoring on the abundance of juvenile coho and steelhead during their fresh water residence period. It is targeted on coho and steelhead because all or most juvenile chum and LCR Chinook salmon migrate into the mainstem and estuary soon after emergence. The early migratory behavior of chum and LCR Chinook often results in low juvenile presence during the time when surveys are typically conducted (late summer when water visibility is best). Attempts to monitor the distribution of chum and Chinook shortly after they emerge can be difficult to interpret because many of them will be moving downstream, leading to a potential for double counting. Sampling the entire frame for juvenile Chinook would be difficult because they tend to spawn and rear in larger streams and rivers that are challenging to sample. Monitoring an averaged estimate or “index” of the abundance of juvenile coho and steelhead rather than a census of all individuals is a useful and relatively cost effective tool for evaluating trends in their abundance. An index can also be useful for identifying potential population bottlenecks.

An index can be used instead of an absolute estimate of juvenile fish population abundance to indicate population trends or relative seeding levels. For example, an annual estimate of the density of juvenile coho in pools is adequate to determine both population trend and relative seeding levels. While NOAA offers no guidance for bias and precision of these data, we believe that expectations for fry/parr abundance data should be similar to that proposed by NOAA for juvenile migrant abundance estimates, namely, that estimates be unbiased and the coefficient of variation¹¹ (CV) for salmon should be less than 15% and the CV for steelhead should be less than 30% (Crawford and Rumsey 2009).

Electrofishing (using pass/removal or mark/recapture techniques) or counts of fish observed by snorkelers are the two primary methods used to obtain information on the abundance of juvenile coho and steelhead in streams and rivers. At a given sample site, if electrofishing gear is working properly and all critical assumptions (described below) are met, electrofishing abundance estimates are generally less biased than snorkel counts (Rodgers et al. 1992). However, snorkel counts are generally less expensive than electrofishing estimates on a sample unit basis, and the two methods may be combined. In this case, snorkel counts are conducted at the majority of sites and electrofishing is used to “calibrate” the snorkel counts. Because electrofishing estimates are generally less biased than snorkel counts, an electrofishing-calibrated snorkel count is more accurate than snorkel counts alone (Hankin and Reeves 1988). Conversely, Dolloff et al. (1993) determined that the combination of snorkel surveys and electrofishing efforts increased the accuracy of electrofishing estimates 1.7–3.3 times because snorkel surveys covered a greater area of the sampling unit.

Method: Electrofishing

Electrofishing-based abundance estimates generally involve pass/removal or mark-recapture techniques (Temple and Pearsons 2007). One advantage of electrofishing is that it can be equally effective in fast water (e.g., riffle/rapid) and slow water (e.g., pool) habitat units. Open or closed population estimates can be made with this method. A closed population estimate requires placement of block nets at the start and end of each stream unit to prevent fish from entering or leaving the site during sampling.

¹¹ The coefficient of variation (CV) is defined as the ratio of the standard deviation σ to the mean μ expressed as a percentage:

$$CV\% = \frac{\sigma}{\mu} (100)$$

Precision and Bias: Because electrofishing can physically harm fish, tests of the repeatability of electrofishing estimates are usually not conducted. This results in uncertainty in the precision of estimates or systematic negative bias especially if the electroshocker is not functioning properly.

Critical Assumptions: Temple and Pearsons (2007) indicated that the assumptions used to estimate abundance based on electrofishing efforts were the same as those used to generate mark-recapture estimates of abundance on a closed population. The critical assumptions for the mark-recapture approach are: 1) the population is closed, 2) there are no tagging effects (no tag loss, no tag induced mortality, and the mark history of each fish is recorded correctly on each sampling occasion), and 3) all fish have an equal probability of capture during the first or second event, or marked and unmarked fish completely mix between sampling events. For removal estimates, the second assumption is changed to: the probability of capture for every fish is equal, it does not change between removal passes, and the number of fish captured during each removal survey is correctly reported. Many factors can influence capture efficiencies including fish size, species composition, habitat complexity, and sampling effort. These factors need to be assessed through multiple mark-recapture or removal passes.

Method: Snorkeling

Snorkel counts involve making one or more upstream or downstream passes through the sampling units and recording the number of fish observed. When multiple snorkel passes are conducted, individual passes may be averaged and the average used as an index of fish abundance in a sampling unit (O’Neal 2007).

Precision and Bias: Observer error (i.e., lack of repeatable results made by the same observer) and differences in observation probabilities between observers, sampling sites, and observation times can significantly impact the precision and bias of snorkel counts. Because snorkeling does not physically harm fish, tests of survey repeatability can be conducted for quality control.

Critical Assumptions: Snorkel surveys are rarely used to estimate juvenile abundance due to differences in observation probabilities between observers, sites, and observation times. However, snorkel surveys are often conducted concurrently with electrofishing surveys to determine observer efficiency (Hankin and Reeves 1988, Dolloff 1993). The critical assumption in making observer efficiency estimates is that the sampling sites selected are representative of the larger sampling area. The consistency of snorkeling observation efficiency estimates is improved when standard snorkeling procedures are used (Thurow 1994).

Table 3. Criteria for scoring programs that monitor an index of juvenile abundance.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	Representative sample site selection throughout inference domain with abundance estimates obtained by <i>pass-removal or mark-recapture</i> estimates that do not violate critical assumptions.
0.75	CV met, AND	Representative sample site selection throughout inference domain and the use of the Hankin and Reeves method of obtaining abundance estimates (i.e. <i>snorkel counts calibrated to electrofishing estimates</i>). Critical assumptions of removal and mark/recapture estimates not violated.
0.50	CV met, AND	Representative sample site selection throughout inference domain using <i>uncalibrated</i> snorkel counts with quality control re-surveys conducted to assess repeatability of counts. Critical assumptions of snorkel counts not violated.
0.25	CV met, OR	<i>Representativeness of sample sites is unknown</i> ; snorkel counts are uncalibrated; <i>no quality control re-surveys are conducted</i> . Critical assumptions of snorkel counts may potentially be violated.
0.00	CV not met AND	No monitoring OR <i>unrepresentative sample site selection</i> .

Scoring: Based on the methods and critical assumptions for this indicator, and our general scoring rules (Table 2), specific criteria is given in Table 3 to score existing monitoring efforts for indices of juvenile abundance in the LCR.

Indicator: Juvenile Migrant Abundance

NOAA guidance for juvenile outmigrant abundance is that estimates should be unbiased and the CV for salmon should be less than 15% and less than 30% for steelhead (Crawford and Rumsey 2009). While we have adopted their recommendations, we believe the target CV for steelhead should be similar to salmon (i.e., < 15%). Our rationale for this is that juvenile outmigrant monitoring is often tied to the evaluation of restoration actions, estimation of marine survival, and estimates of freshwater productivity and capacity through spawner to smolt recruitment analysis. As the CV of a sample increases, the uncertainty associated with these evaluations and estimates increase. At some point estimates become so imprecise that they no longer provide useful information to support fisheries management decisions (Walters and Ludwig 1981, Hilborn and Walters 1992). However, the selection of sampling sites for multi-species outmigration monitoring in large basins frequently involves trade-offs. For example, one cost effective strategy for monitoring juvenile outmigration abundance of multiple species is to site the juvenile trap at the lowest accessible site in the watershed with sufficient water velocity to direct fish into the trap. At these sites it may be a challenge to achieve a CV < 15% for steelhead because of their low abundance, large size, and swimming ability.

To maximize the usefulness of juvenile outmigrant estimates, the estimates should be representative of the population. For example, smolt trapping on a small tributary or in a headwater area of the mainstem represents a low percentage of the juvenile outmigrant population and is less representative of the population than sampling near the mouth of the river. A subpopulation from a small tributary or headwater may have different biological characteristics than the entire population. Rawding et al. (2010a) suggests that representative juvenile outmigrant monitoring should sample 30% or more of the rearing area of a population.

The two basic methods of juvenile outmigrant monitoring are mark-recapture and weirs. Mark-recapture designs are further divided into trap efficiency and “back-calculation” designs (Volkhardt et al. 2007). The trap efficiency method uses periodic releases of marked individuals above the trap to estimate the proportion of the migration that is captured. Expanding catch by the trap efficiency provides an estimate of juvenile abundance. The release of marked groups may be analyzed daily or daily releases may be pooled and analyzed under a weekly stratification. The “back-calculation” design uses juveniles tagged with coded wire tags (CWT) or passive integrated transponder (PIT) tags. Juvenile abundance is estimated with the Petersen model and based on the number of tagged fish released and a second sample of the number of tagged and untagged adults. Weirs offer an alternative method for estimating juvenile outmigrants (Zimmerman and Zubkar 2007). As long as the weirs remain effective in catching all the outmigrants, the sum of daily catches is the juvenile outmigrant estimate.

Method: Closed Population Mark-Recapture Abundance Estimates

The most common method for estimating juvenile outmigrant abundance in the LCR is through the use of a single or double trap mark-recapture design (Olsen et al. 1995, Rawding et al. 1999, Solazzi et al. 2001, Rawding and VanderPloeg 2001, Rawding and Groesbeck 2004, Seiler et al. 2003, Rawding and Cochran 2005, Sharpe and Glaser 2007) although weirs are sometimes used (Hillson 2002). Specifically, the trap operates throughout the migration period and all or a portion of the catch of juveniles are marked and released. Marks are typically rotated daily or weekly because trap efficiency may vary during the migration period. By varying marks on a daily or weekly basis, estimates of abundance are more closely associated with short term variability in trap efficiency during the migration period (Volkhardt et al. 2007). This approach is often referred to as the Darroch or stratified Petersen estimator (Darroch 1961, Seber 1982, Bjorkstedt 2000). When

discrete releases occur, Petersen estimates may be calculated for each period and summed over the season (Topping and Zimmerman 2011) or used to develop flow trap efficiency relationships (Volkhardt et al. 2007). These approaches are the preferred method for estimating juvenile abundance when trap efficiencies vary over the outmigration period (Dempson and Stansbury 1991, Schwarz and Dempson 1994, Thedinga et al. 1994). The pooled Petersen method is used to “back-calculate” smolt abundance by tagging juveniles and sampling returning adults in order to estimate tag proportion (Volkhardt et al. 2007).

Precision and Bias: Assuming no tagging effects or closure violations, the precision of the Petersen-based smolt abundance estimates are dependent on the number of fish recaptured (Seber 1982). One rule of thumb for mark–recapture studies is that at least five to ten recaptures should occur for each marked group to minimize bias (Seber 1982, Schwarz and Taylor 1998). When this does not occur estimates may be biased and imprecise. Efforts should be made to ensure sufficient recaptures. Thompson et al. (1998) suggest that the target population should contain at least 100 individuals with capture probabilities of at least 0.3 but preferably above 0.5. If a population size exceeds 100 individuals, lower capture probabilities will suffice. Alternatively, more sampling periods could be used. Studies with smaller populations (< 100) will need more sampling periods and/or high capture probabilities. Hierarchical and spline-based Bayesian approaches have offered some practical solutions when the numbers of recaptured fish are low (Mantyniemi and Romakkaniemi 2002, Rivot and Prevost 2002, Bonner and Schwarz 2011).

Critical Assumptions: Conditions for the appropriate use of the Petersen estimator are: 1) all fish have an equal probability of being marked in the first event (1a), or all fish have an equal probability of being inspected for marks in the second event (1b); or marked fish mix completely with unmarked fish between sampling events (1c); 2) there is no recruitment or emigration between sample events; 3) there is no tag-induced mortality; 4) fish do not lose their marks between events; and 5) all marked and unmarked fish are recognizable and reported. For smolt outmigration estimates an additional assumption is often made that all marked smolts emigrate past the trap (Carlson et al. 1998). In addition, assumption 1, often termed the equal catchability assumption, is satisfied if one of the above three conditions (1a, 1b, 1c) is met. This assumption is considered the “Achilles heel” of the Petersen Estimator (Arnason et al. 1996) because catchability can be influenced by many factors.

Diagnostic chi-square tests are used to test these critical assumptions (Darroch 1961, Arnason et al. 1996, Schwarz and Taylor 1998). Assumption 1b, recapture probabilities are constant across all recovery strata, is determined by the equal proportions test. Assumption 1c, capture probabilities are constant across all tagging strata, is determined by the complete mixing test. The pooled Petersen estimator is consistent if p-values from either test are greater than the type 1 error. If p-values are less than the type 1 error rate, then a Darroch or stratified Petersen estimator should be used (Schwarz and Taylor 1998). The Petersen estimator is only consistent for homogeneous groups. Because juvenile capture and recapture probabilities may be influenced by size (length) and/or life stage, diagnostic chi-square or Kolmogorov-Smirnov tests should be conducted to determine if stratification by either of these factors is required for unbiased estimates.

The second assumption is closure, that the population size remains constant during the sampling effort. For juvenile outmigration studies, the closure assumption is met if mark and recovery is conducted throughout the migration period and for each species enumerated (Arnason et al. 1996). Missed days are considered a closure violation. Catch may be interpolated between periods or extrapolated before trap installation or after trap removal (Volkhardt et al. 2007) or Bayesian based spline methods may be used to extrapolate catch (Bonner and Schwarz 2011).

Double tagging methods (Seber 1982) or tag retention experiments (Thedinga et al. 1994) can be used to assess assumption 3, that there is no tag loss. Assumption (4), that marks do not affect the survival or catchability of fish can be determined with holding experiments (Thedinga et al. 1994, Carlson et al. 1998). Assumption (5) is that all tagged and untagged fish are correctly identified and reported. This assumption is typically met when fish are carefully examined and their tag status recorded. If there is a need to better quantify this assumption, which may occur when fish numbers are high, Rajwani and Schwarz (1997) recommended re-sampling previously sampled fish for missed tags. Thedinga et al. (1994) proposed a similar method to assess the number of missed marked fish. If any of the above violations occur, the abundance estimator could be extended by including uncertainty closure, tag loss, tag survival, and missed tag rates through the use of bootstrapping (Thedinga et al. 1994, and Carlson et al. 1998), normal approximation with the delta method (Seber and Felton 1981), maximum likelihood, or Bayesian methods.

Scoring: As previously mentioned in Rawding et al. (2010a), we suggested that representative juvenile outmigrant monitoring should sample at least 30% of the rearing area in a population. The equal catchability and closure assumptions are viewed as the most critical assumptions since they may have varying and unpredicted effects on the abundance estimator. Tagging effect assumptions are less critical because when standardized tagging protocols are used, the tagging effect on abundance estimates is generally small. Alternatively, estimates can be made from similar tagging experiments and applied to the target population. We developed specific indicator scoring guidelines (Table 4) based on the methods and critical assumptions used to estimate juvenile outmigrant abundance and our general scoring rules (Table 2). The highest score meets the precision goal and assesses tag loss, tag survival, missed tags, missed days, and ensures equal catchability for homogeneous groups during a time period. A high score is a product of meeting the precision standard, the annual tests of critical assumptions including missed days and equal catchability, and use of standard protocols that reduce the probability of tag loss, handling mortality, and missed marks. Alternatively, studies can be implemented to provide appropriate correction factors. A moderate score for smolt trapping occurs when the precision target is met, there is an adjustment for missed days, and a representative sampling design including standard protocols is implemented but no equal catchability tests are calculated. A low score results when the CV is not met or only the moderate standards for bias are met. The lowest score reflects failure to meet the precision target, equal catchability and closure assessments, as well as a lack of standard protocols for operating the trap and analyzing the data.

Table 4. Criteria for scoring programs that monitor the abundance of juvenile migrants using mark-recapture methods.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	Sampling locations represent at least 30% of available rearing area. Standard sampling protocols are used that reduce the probability of tag loss, handling mortality, and missed marks. The trap operates over the migration period. <i>Adjustments are made for missed days, tag loss, tag survival, & missed tags.</i> Equal catchability tests are implemented for time periods, fish length, and life stage.
0.75	CV met, AND	Sampling locations represent at least 30% of available rearing area. Sampling protocols are used that reduce the probability of tag loss, handling mortality, and missed marks. The trap operates over the migration period. <i>Adjustments are made for missed days only.</i> Equal catchability tests are implemented for time periods, fish length, and life stage.
0.50	CV met, AND	Sampling locations represent at least 30% of available rearing area. Sampling protocols are used that reduce the probability of tag loss, handling mortality, and missed marks. The trap operates over the migration period. Adjustments are made for missed days only. <i>No equal catchability tests are conducted.</i>
0.25	CV met, OR	Sampling locations represent at least 30% of available rearing area. Sampling protocols are used that reduce the probability of tag loss, handling mortality, and missed marks. The trap operates over the migration period. Adjustments are made for missed days. No equal catchability tests are conducted.
0.00	CV not met AND	No monitoring OR <i>unrepresentative sample site selection OR sampling protocols to reduce the probability of tag loss, handling mortality, and missed marks are not implemented OR the trap is not operated over entire migration period.</i>

Method: Juvenile Abundance Estimates Using Weirs

A weir is a porous manmade barrier built across a stream used to capture migrating fish in flowing waters (Zimmerman and Zubkar 2007). Weir counts are considered the gold standard for monitoring because when the operation is 100% effective over the migration period the result is an abundance census with no uncertainty. For example, weirs are operated in the LCR for juvenile chum salmon in Duncan Creek (Hillson 2002). Some weir operations include a temporal subsampling design to expand counts when counts are not conducted 24/7 (Irvine et al. 2003). When juvenile abundance is high (many thousands) at weirs or in traps, abundance may be based on a calibrated electric counter (Seiler and Kishimoto 1999) or use volume and weight along with a subsample to determine number and composition of fish in the sample (Seiler et al. 2001).

Precision and Bias: Under ideal conditions a weir provides an unbiased census of juvenile abundance when all fish are carefully identified and enumerated. When a weir is not 100% efficient, other methods including interpolation, statistical distribution of migration patterns (Hilborn et al. 1999), or the use of smoothing functions and splines (Irvine et al. 2003, Bonner and Schwarz 2011) can be used to estimate missed days. The precision of the weir estimate will decrease as a result of missed sampling days and the amount of variability in daily fish passage.

Critical Assumptions: Key assumptions for weir operations include: 1) the weir is 100% effective at capturing all immigrating and emigrating fish, and 2) all fish are identified and enumerated correctly. Sampling effectiveness depends on proper installation and regular visual inspection of the weir and its trap. Alternatively, the periodic release of marked groups of fish could be used to determine if the weir is 100% effective at trapping fish. Accurate identification and enumeration of all fish requires careful inspection. One approach to assure that fish are correctly identified and enumerated is to have a second person re-sample the catch.

Scoring: As previously mentioned in Rawding et al. (2010a), we suggested that representative juvenile outmigrant monitoring should sample at least 30% of the rearing area of a population. The key assumption for the weir abundance estimate is that it is 100% effective at capturing fish. Based on the methods and the critical assumption for weir-based juvenile abundance estimates and our general scoring rules (Table 2), specific scoring guidelines were developed for this VSP indicator (Table 5). The highest score meets the precision standard; the weir operates over the entire migration period and is regularly inspected or tested to assure 100% efficiency in trapping fish. A method for estimating fish abundance on missed sampling days is implemented. A high score is achieved if the precision standard is met, the weir is properly installed and maintained, and a method is used to estimate abundance on days when the weir is not effective. A moderate score for juvenile weir operations results when the precision target is met, there is an adjustment for missed days but the number of missed days is protracted or the missed days occur during the peak of migration. A low score for weir abundance estimates results when either the CV is met or the moderate standards for bias are met. The lowest score results when the CV is not met and weir operation is intermittent.

Table 5. Criteria for scoring programs that monitor juvenile migrant abundance using weirs.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	Sampling locations represent at least 30% of available rearing area. Weir operates over the entire migration period and is <i>regularly inspected</i> to ensure that no fish pass without being enumerated. Inspection may be visual or include a marked release. During flow periods when weir is not 100% efficient other methods which include interpolation, statistical distributions to describe migration patterns, or smoothing functions and splines, are used adjust juvenile migrant estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.75	CV met, AND	Sampling locations represent at least 30% of available rearing area. Weir operates over the entire migration period but is <i>only inspected at the start and end of the season</i> . During flow periods when the weir is not 100% efficient, other methods including interpolation, statistical distributions to describe migration patterns, or smoothing functions and splines, are used adjust juvenile migrant estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.50	CV met, AND	Sampling locations represent at least 30% of available rearing area. Weir operates over migration period but is <i>inspected only upon installation</i> . During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distributions to describe migration patterns, or smoothing functions and splines, are used adjust juvenile migrant estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.25	CV met, OR	Sampling locations represent at least 30% of available rearing area. Weir operates over entire migration period but is inspected only upon installation. During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distributions to describe migration patterns, or smoothing functions and splines are used adjust juvenile migrant estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.00	CV not met AND	No monitoring OR <i>unrepresentative sample site selection OR weir operations too intermittent to provide a reliable estimate</i> .

Indicator: Adult Recruitment

Adult recruitment is the number of pre-harvest adult recruits produced from a brood year. NOAA recommends spawner information derived from cohort analysis to estimate the geometric mean of recruits-per-spawner to assure robust productivity estimates. The major elements used to estimate adult recruitment include spawner abundance, origin, age, and harvest impacts in ocean and freshwater fisheries. Because we score spawner abundance, age, and origin in separate sections, this adult recruitment section focuses on identifying direct and indirect fisheries impacts. There are no specific NOAA precision guidelines for this VSP

indicator. Rather than developing arbitrary guidelines, we focused on reporting the precision of harvest or harvest rate estimates. Currently these metrics are rarely reported. Additional resources should be focused on development of precision standards for fisheries impacts.

Fisheries impact estimates for various fisheries can be found in US vs. Oregon reports, state catch record card reports, and various Fish Management and Evaluation Plans (FMEP), which are required in the LCR when tributary fisheries catch or “take” fish listed under the Endangered Species Act. However, the methods used to estimate fisheries impacts are often not described in sufficient detail to allow the re-creation of harvest or exploitation rates or calculate the uncertainty of an estimate. Harvest and exploitation rates for CWT groups is an exception to this situation (Johnson 1990, Johnson 2004, Bernard et al. 1996, 1998). In the LCR, the CWT program is currently limited to Chinook and coho salmon, primarily of hatchery origin. Alternative methods need to be developed for other species and for when the CWT program does not sample all major fisheries and spawning grounds for Chinook and coho salmon. There is also a need to sample naturally spawning hatchery strays.

Method: CWT Program

In the LCR, the CWT program is conducted by the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), the Pacific States Marine Fisheries Commission (PSMFC), and the United States Fish and Wildlife Service (USFWS). The program consists of tagging, recovery, and reporting components. The tagging component usually consists of CWT application at hatcheries (although some wild stocks are also tagged). A known number of CWTs are applied to a known number of juveniles in a release group. The recovery component consists of fisheries and escapement sampling, where a known number of fish are sampled and the number of CWT fish are determined. The snouts are removed from fish testing positive for a CWT and are sent to a CWT lab for decoding. Based on tag codes, each fish is assigned back to its release group. In the LCR, CWT sampling is conducted in commercial, sport, and treaty fisheries in the mainstem Columbia River from the mouth past McNary Dam (RM 292) in Washington tributary fisheries, and in spawning areas (both hatcheries and rivers) from the mouth to the White Salmon River. The total catch and escapement to various rivers and hatcheries are censused or estimated based on various sampling designs to provide information to estimate exploitation rates. This information is stored on the publicly accessible CWT and Catch/Effort databases at the Regional Mark Information System (RMIS). Figure 3 provides a schematic of the handling and management of CWT program data.

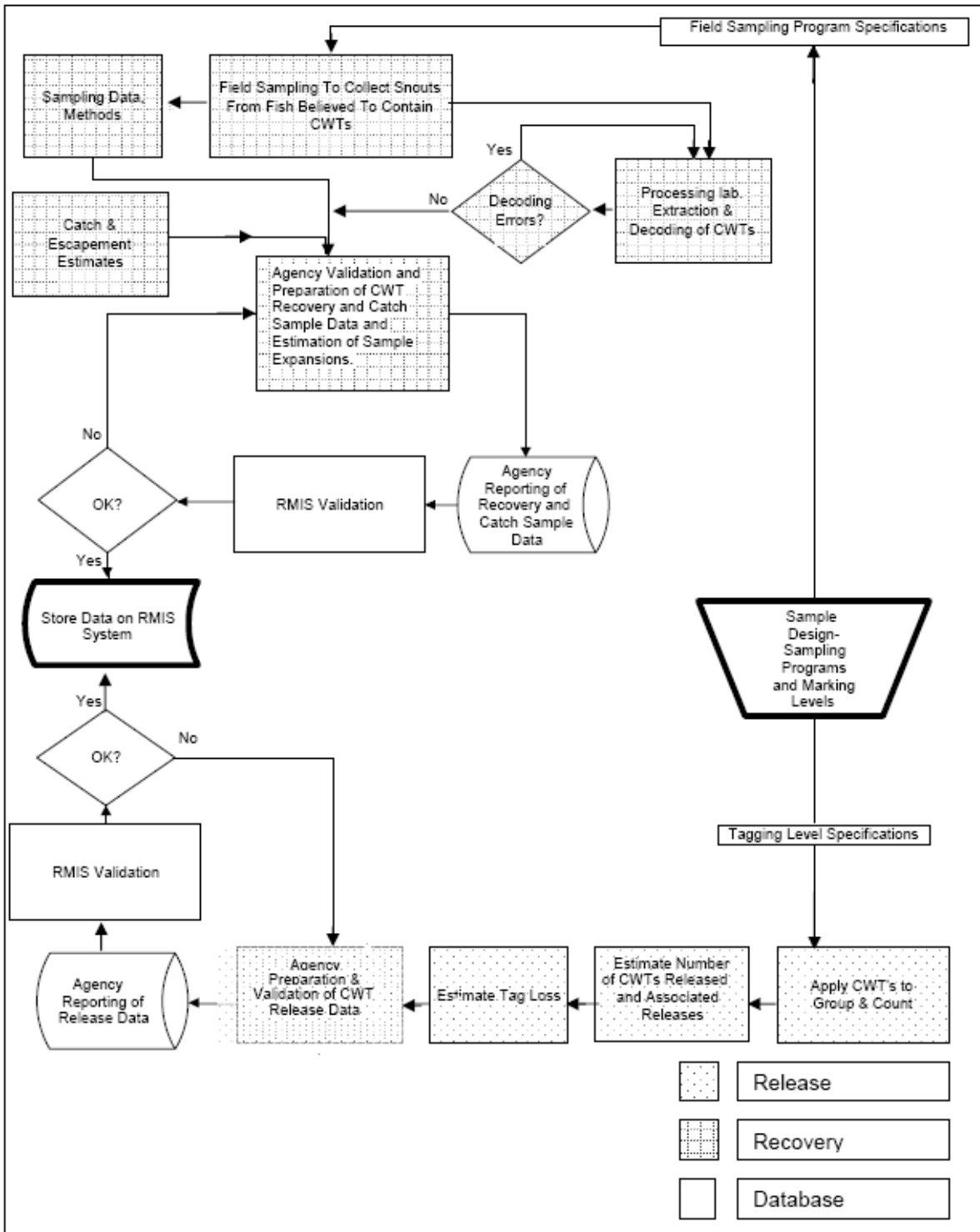


Figure 3. Data handling and management sequence for the Coded Wire Tag (CWT) program, with a focus on tag release, recovery, and reporting (from PSCCWTWG 2008 RMIS = Regional Mark Information System).

These data and analyses allow the CWT program to meet its primary goal which is the generation of exploitation rate estimates on tagged fish. Due to the difficulties associated with tagging wild stocks, CWTs are most often applied to hatchery groups. The Pacific Salmon Commission (PSC) CWT work group (PSCCWTWG) Action Plan in Response to the Coded Wire Tag Expert Panel Recommendations report (2008) indicates “the fundamental objective of the CWT system is the estimation of the tagged fish in harvest or escapement from tags observed in samples, expanded for the fraction of the total harvest or escapement that is sampled.”

Various reviews and recommendations have been made to improve the CWT program including comments by the Independent Scientific Review Panel (ISRP), the expert panel (Hankin et al. 2005), and the Pacific Salmon Commission (PSC) CWT work group (PSCCWTWG 2008). The specific recommendations are comprehensive and will take additional funding and time to implement.

The CWT program has identified double index tag (DIT) groups as a way to adapt the CWT program to selective fisheries. These groups are hatchery origin fish but they are not mass marked. Similar to natural origin fish, all caught DIT fish are required to be released. This design accounts for indirect mortality caused by the catch and release of fish by selective fisheries.

In the Columbia Basin, millions of juvenile salmon and steelhead are tagged with passive integrated transponder (PIT) tags. Almost all of these PIT-tagged fish originate above Bonneville Dam (BON). WDFW recently received funding from Bonneville Power Administration (BPA) to implement fisheries PIT tag sampling in the mainstem Columbia River. WDFW is developing methods to estimate harvest rates using PIT tag sampling and BON PIT tag detections. These methods will most likely be applied to populations that have negligible ocean fisheries and migrating juveniles that are large enough to be PIT tagged. For example, this approach might be useful for LCR steelhead populations that originate above Bonneville Dam.

Precision and Bias: Interactions among factors such as tagging levels, survival rates, fisheries distributions, and estimates of total catch/escapement affect the uncertainty of exploitation rate estimates for individual stocks. A matrix that incorporates these factors and their effects on exploitation rates is unavailable. The current CWT levels include tag group sizes of ~200,000 for subyearling fall Chinook, ~100,000 for yearling spring Chinook, and ~75,000 for coho salmon. The recommended target for fisheries sampling is 20% and this goal is typically met in the mainstem Columbia River fisheries. However, CWT recovery rates from LCR tributary fisheries and spawning ground surveys are much lower than 20%. In most years 100% of hatchery coho and Chinook salmon are sampled for CWT at hatcheries. Recently, under the PSC Chinook Agreement, the United States and Canada each committed \$1.5 million annually for five years to improve the CWT program. A CWT Implementation Team (CWTIT) has been established to develop and prioritize recommendations on how to use this funding. One issue the CWTIT is addressing is re-evaluation of the original hatchery juvenile tagging and adult sampling rates.

Critical Assumptions: Hatchery CWT groups are used as surrogates for natural origin populations. The application of hatchery CWT exploitation rates to wild populations assumes that the maturation rates, timing, and distribution in fisheries are the same for both groups. Based on this key assumption, exploitation rates for representative hatchery populations are used to estimate exploitation and harvest rates for wild stocks consistent with ESA recovery and viability analyses (LCTCWG 2008). DIT groups require the same assumptions as standard CWT groups and include the assumption of representative sampling in all major fisheries and spawning grounds, and that DIT groups have the same maturation, timing, and distribution in fisheries as the natural origin fish they represent. DIT groups may provide a more accurate estimate of impacts to natural origin fish as the magnitude of selective fisheries increases. In fact, standard CWT groups may over-estimate harvest rates as the number of selective fisheries increases.

Scoring: Based on the methods and critical assumptions for CWT-based adult escapement and our general scoring rules (Table 2), specific indicator guidelines for scoring were developed for the CWT method (Table 6). Precision targets for total catch and escapement have not been directly identified, so scoring criteria were developed based on the reported precision for direct and indirect fisheries impacts. The highest score reflects a CWT program using natural origin fish, and sampling in all major fisheries and spawning grounds. If natural origin fish are not available, the use of wild broodstock DIT groups is recommended to more accurately reflect

natural origin harvest and harvest rates at the population scale. A high score allows hatchery fish to be used instead of natural origin fish as long as they are representative of the wild fish. Precision must be reported for indirect and direct mortalities in the highest and high ratings. For a moderate score, monitoring relies on representative hatchery fish to represent wild fish and sampling of most major fisheries and spawning grounds. Precision must be reported for harvested fish with a point estimate for release mortality rates at the ESU/DPS scale. A low score reflects the same criteria for the moderate score for bias with point estimates for harvest and release mortality rates. The lowest score is given when a CWT effort does not meet sufficient tagging and sampling goals to report on harvest rates.

Table 6. Criteria for scoring the adult recruitment indicator based on the Coded Wire Tag (CWT) program.

Score	Precision Guideline	Bias Guideline
1.00	CV calculated for harvest rate and released mortality rate, AND	A natural origin CWT program for salmon and steelhead that meets tagging goals and CWT sampling goals for <i>all</i> ocean ports and Columbia River fisheries, and spawning grounds. A hatchery program that meets established tagging goals using <i>wild broodstock</i> may be an acceptable substitute as long as timing and maturity rates are similar to the wild population. Estimates are available at the population scale.
0.75	CV calculated for harvest rate and release mortality rate, AND	A natural origin CWT program for salmon and steelhead that meets CWT sampling goals of <i>all</i> ocean ports and Columbia River fisheries, and spawning grounds. A hatchery program using <i>local stock</i> that meets established tagging goals may be an acceptable substitute as long as timing and maturity rates are similar to wild population. Estimates are available at the population scale.
0.50	CV calculated for harvest rate with point estimate for release mortality rate, AND	A natural origin CWT program for salmon and steelhead that meets CWT sampling goals of <i>all</i> ocean ports and Columbia River fisheries, and spawning grounds. Hatchery program using <i>local stock in an adjacent river</i> that meets established tagging goals may be an acceptable substitute as long as timing and maturity rates are similar to wild population. Harvest estimates are available at the <i>MPG</i> scale.
0.25	<i>Point estimate for harvest and release mortality rate, AND</i>	A natural origin CWT program for salmon and steelhead that meets established tagging goals and CWT sampling of all ocean ports and Columbia River fisheries, and spawning grounds. Hatchery program using local stock in an adjacent river may be an acceptable substitute as long as timing and maturity rates are similar to wild population. Harvest estimates are available at the <i>DPS</i> or <i>ESU</i> scale
0.00	<i>CV not calculated AND</i>	No monitoring <i>OR the CWT tagging program does not meet tagging and fishery sampling goals.</i>

Method: Freshwater Fisheries Monitoring

This approach is usually applied to populations that have negligible ocean fisheries and include LCR chum salmon, steelhead, and possibly some populations of spring Chinook salmon. Selective recreational freshwater fisheries were implemented in the Columbia River basin in the 1980s. Currently many LCR commercial and sport fisheries are selective and require the release of salmon and steelhead with intact adipose fins. This approach can be very effective in reducing mortality of wild fish (Hooton 1987, Bendock and Alexandersdottir 1993, Vander Haegan et al. 2004, Nelson et al. 2005, Cowan et al. 2007, Ashbrook et al. 2008, Griffith et al. 2009).

For tributary sport fish, Lindsay et al. (2004) used a tributary creel survey to estimate harvest of hatchery salmon and the ratio of harvested hatchery fish to the number of released natural origin salmon. In addition, they developed an anatomical relationship between survival of released fish and hooking location, and estimated hooking location by gear type in the creel survey. The creel survey also recorded effort by gear type. The supplemental information on gear type, hooking location, survival, and ratio of hatchery to natural origin fish released allowed an estimate of the mortality of natural origin fish from released fish. A mortality rate could also be applied from studies on hooking mortality. These methods could be extended to analyze harvest

data from catch record cards (Pollock 1994) and random angler interviews in order to estimate the ratio of hatchery fish kept to released wild fish.

In the mainstem Columbia River many populations from different ESU/DPS migrate through fisheries together. Therefore, the catch is composed of many populations, which is termed a mixed stock fishery. Unless tag groups are available, other methods such as genetic analysis are needed to separate fish into management groups or ESU/DPS (Milner et al. 1985). Allozyme analysis has been used in the Columbia River basin to estimate spring Chinook stock composition in a commercial fishery and steelhead harvests by DPS from the fall treaty fishery (Shaklee 1986, Kassler et al. 2002). With advances in genetic techniques, it may be possible to estimate stock composition at a finer scale (Winans et al. 2004, Seeb et al. 2007, Narum et al. 2008). The genetic approaches were successful when both natural and hatchery origin fish were harvested. However, current fisheries management focuses on the protection of natural origin populations, and may require the release of wild fish. It can be difficult to obtain genetic samples on fish before they are released. Genetic samples could be obtained by placement of observers on board commercial fishing boats or contracting fishermen to specifically capture fish for genetic analyses (Rub et al. 2010). Similar approaches could be used for sport fisheries and could include genetic sample collection by volunteer anglers.

Precision and Bias: For a single population, the precision of the natural origin estimate is based on the estimated number of hatchery fish derived from creel surveys. The precision of creel surveys depends on factors such as the number of anglers interviewed, variability in the catch per unit effort, number of effort counts, trip duration, and the number of complete trips. Factors that affect the precision of catch record card estimates of harvest include the return rate of the cards, response rate on phone surveys, and recollection of catch. Precision is also affected by the ratio of hatchery fish kept to wild fish released, the sample size of anglers used to develop the ratio, as well as the precision of hooking mortality estimates. Additional factors influence the precision of mixed stock fisheries estimates; those factors include the number of populations in the baseline and differential population impacts.

Critical assumptions: Because the Columbia River is open to fishing during some or all of the time LCR salmon and steelhead are present, critical assumptions of the mixed stock fishery in the mainstem Columbia River must be met. Most populations are subject to a freshwater fishery so both mixed and single fishery assumptions apply. For some populations, freshwater fishing is closed and these assumptions do not apply.

The first assumption is that all major freshwater fisheries are sampled and a harvest estimate is available for each fishery. The second assumption is that mixed stock fisheries harvest estimates are available by population and/or ESU. This usually requires genetic sampling of the fisheries. The genetic baseline must cover all the populations and there must be genetic markers available to differentiate populations. Not all fish caught are retained and many fisheries require the release of unmarked fish, which are mostly natural origin fish. In these fisheries, a critical assumption is that the interception or handling rate of released fish can be estimated, and the survival of released fish can be estimated.

Scoring: Based on the methods and critical assumptions of freshwater fisheries monitoring for adult recruitment and our general scoring rules (Table 2), specific guidelines for scoring were developed (Table 7). Because precision goals have not been directly identified for adult recruitment, scores were developed based on the reported precision of direct and indirect fisheries impacts. The highest score reflects harvest rate for natural origin fish in all major freshwater fisheries through the use of statistical designs to estimate harvest and escapement with genetic stock identification (GSI) in mixed stock fisheries. A high score requires a genetic baseline for most major populations. Precision must be reported for indirect and direct mortality estimates to receive the highest or a high score. A moderate score uses the same information as the high score except the

reporting scale is at the ESU/DPS level rather than at the population level. A low score uses the same criteria as the moderate score for bias but provides point estimates for harvest and release mortality rates. The lowest score occurs when a monitoring program does not have a statistical design for reporting harvest rates.

Table 7. Criteria for scoring the adult recruitment indicator based on Columbia River fisheries monitoring without CWT groups.

Score	Precision Guideline	Bias Guideline
1.00	CV calculated for harvest rate and release mortality rate, AND	<p><u>Single Population Fisheries</u>- Statistically designed program to estimate harvest and escapement are implemented for the population. Ratio of handled natural origin fish to harvested fish is available through annual surveys. Gear mortality studies for the species are available.</p> <p><u>Mixed Stock Fisheries</u>- Same as above for single population fisheries. In addition, baseline is available for all <i>populations classified as primary and contribution</i> in the Washington LCR recovery plan <i>or targeted for very low, low, or moderate risk of extinction</i> in the Oregon LCR recovery plan. Genetic markers have been identified to distinguish populations and fisheries are representatively sampled for released natural origin fish. Estimate is at the <i>population scale</i>.</p>
0.75	CV calculated for harvest rate and release mortality rate, AND	<p><u>Single Population Fisheries</u>- Statistically designed program to estimate harvest and escapement are implemented for the population. Ratio of handled natural origin fish to harvested fish is available through annual surveys. Gear mortality studies for the species are available.</p> <p><u>Mixed Stock Fisheries</u>- Same as above for single population fisheries. In addition, baseline is available for all <i>populations classified as primary</i> in the Washington LCR recovery plan <i>or targeted for very low or low risk of extinction</i> in the Oregon LCR recovery plan. Genetic markers have been identified to distinguish populations and fisheries are representatively sampled for released natural origin fish. Estimate is at the <i>population or MPG scale</i>.</p>
0.50	CV calculated for harvest rate with point estimate for release mortality rate, AND	<p><u>Single Population Fisheries</u> – Use of representative population to estimates fisheries impacts for an unmonitored population as described above.</p> <p><u>Mixed Stock Fisheries</u>- Statistically designed program to estimate harvest and escapement are implemented for the <i>ESU/DPS</i>. Ratio of handled natural origin fish to harvested fish is available through periodic annual surveys. Gear mortality studies for the species are available. In addition, baseline is available for all populations classified as primary in the Washington LCR recovery plan or targeted for very low or low risk of extinction in the Oregon LCR recovery plan. Genetic markers have been identified to distinguish populations, and fisheries are representatively sampled for released natural origin fish. <i>Estimate is at the ESU or DPS scale</i>.</p>
0.25	<i>Point estimate for harvest and release mortality rate, AND</i>	<p><u>Single Population Fisheries</u> – Use of representative population to estimates fisheries impacts for an unmonitored population as described above.</p> <p><u>Mixed Stock Fisheries</u>- Statistically designed program to estimate harvest and escapement are implemented for the <i>ESU/DPS</i>. Ratio of handled natural origin fish to harvested fish is available through annual surveys. Gear mortality studies for that species are available. In addition, baseline is available for all populations classified as primary in the Washington LCR recovery plan or targeted for very low or low risk of extinction in the Oregon LCR recovery plan. Genetic markers have been identified to distinguish populations and fisheries are representatively sampled for released natural origin fish. Estimate is at the <i>ESU or DPS scale</i>.</p>
0.00	<i>CV not calculated AND</i>	No monitoring OR <i>Sampling is insufficient to obtain estimates of harvest or exploitation rates</i> .

Indicator: Adult Spawner Abundance.

The proposed NOAA guidelines for adult spawner abundance estimates are that the estimates are unbiased and have a CV < 15% (Crawford and Rumsey 2009). We have adopted a precision standard of a CV < 15% for high recovery priority populations and a CV < 25% (Robson and Reiger 1964) for the lowest priority populations. Our rationale for this is that in the short-term, the lowest priority populations are likely to be small with few fish of natural origin. Precise monitoring of these populations will be challenging (Thompson

2004) and can be very expensive. Given current fiscal resources, precise monitoring of very small populations could consume most of the limited funding available for monitoring. Therefore, the balance we recommend for prioritizing spawner abundance effort is less intensive monitoring of small low priority populations and more effort on populations with high recovery priority. One advantage of targeting high recovery priority populations for spawner abundance estimates is that these populations are more likely to be the beneficiaries of and able to respond to habitat restoration actions.

It is more difficult to estimate the abundance of jacks than adults in most years due to the lower abundance and smaller size of jacks compared to adult fish. This fact decreases the probability of jack detection and recovery. NOAA precision guidelines for adult spawner abundance were adopted from the Chinook Technical Committee (CTC), and some CTC members have proposed jack abundance estimates have a CV < 25% . We believe this is an appropriate initial goal for this group of fish.

The most common methods for monitoring adult salmon and steelhead in the LCR include weir counts (Olsen et al. 1995, Hillson 2002), closed population mark-recapture (Rawding and Cochran 2005, Rawding 2009a, Kinsel 2009), open population mark-recapture for live fish and carcasses (Rawding and Hillson 2003, Rawding et al. 2006, Sharpe et al. 2011), area-under-the-curve AUC) (Suring et al. 2006, Rawding et al. 2006a), redd surveys (Rawding et al. 2006a), and peak count expansion (Harlan 1999). When the assumptions for unbiased estimates are met, multiple methods can produce similar abundance estimates (Gallagher and Gallagher 2005). Studies that compared two different methods and found similar abundance estimates include weir and mark-recapture estimate for adult coho salmon in Big Beef Creek and Chinook salmon in Bogus Creek (Eames and Hino 1981, Sykes and Botsford 1986), AUC and mark-recapture estimates of coho salmon in the Smith River and Chinook salmon in the Nicola rivers (Jacobs 2002, Parken et al. 2003), and mark-recapture and peak count expansion of Chinook salmon in the Nicola River (Parken et al. 2003).

This section will discuss open population mark-recapture, AUC, peak count expansion, and redd-based spawner abundance estimates. It should be noted that AUC, peak count expansion, and redd counts are calibrated estimates, which means that key assumptions such as observer efficiency, survey life, and reds-per-female or -adult are based on studies from other populations or years. The use of standard protocols (Johnson et al. 2007) and appropriate training of personnel are essential to assure observer accuracy and efficiency in order to generate reliable females- or adults-per-redd counts.

In the LCR, dams have been constructed upstream of the mouth of rivers such as the Cowlitz, Toutle, Lewis, and Clackamas rivers (LCFRB 2010b). Fish ladders have been constructed to facilitate fish passage up the Kalama, Washougal, and Wind rivers. In these and other cases, estimates of spawner abundance may be a combination of census and mark-recapture efforts above the adult fish collection site, with spawner abundance estimates such as AUC, peak count expansion, or redd counts used below the site. In cases where multiple methods were used to calculate spawner abundance, a weighted score was generated based on the monitoring effort score for each method and an estimate of the amount of spawning habitat associated with the method. In other cases, where habitat use was unknown, abundance was used as a surrogate. The weighted score is rounded down to the next category to standardize scoring and help identify actions to improve monitoring efforts.

For example, the spawner abundance estimates for Kalama River winter steelhead are based on a weir census count above the fish ladder (Rkm 16; Bradford et al. 1996) and redd surveys below the ladder. Over 80% of the winter steelhead spawn above Rkm 16 and less than 20% spawn below this barrier. The census would be scored as a 1.00, redd surveys are scored as 0.25. The weighted average score would be: $(1.00 * 0.8) + (0.25 * 0.2) = 0.85$. Our convention is to round the score down, in this case to 0.75.

Method: Adult abundance estimates using weir or Petersen mark-recapture

Weir and Petersen mark-recapture critical assumptions, precision, and scoring have been discussed in the juvenile abundance section. However, there are subtle differences in weir operations for adult fish. Unlike juveniles, adults at weirs or passage barriers may not be handled before being passed upstream. For example, adults may be counted using video or infrared (Hatch et al. 1994, Heibert et al. 2000, Shardlow and Hyatt 2004). In addition, weirs are often used in larger streams and rivers where it is very unlikely that the weir will remain effective during the entire fish passage period. In these cases, the weir and associated trap are used for marking and/or recapture events.

The adult mark-recapture and weir scoring is similar to that used for juveniles with the addition of length/age, origin, and sex selectivity for the highest and high scores. Traditional mark-recapture methods include tagging of salmon and steelhead via capture at traps, or by netting or angling, and recovery of adults at a tributary weir or through carcass surveys (McPherson et al. 1999, Miller et al. 2010, Begich, R.N. 1993, Rawding and Cochran 2005). For steelhead, this could also include the capture of kelts at a weir (Mayer et al. 2005) or spawned out carcasses. A mark-recapture approach could also survey anglers for the capture of tagged and untagged fish (Gray 2006). Other modifications of mark-recapture programs on adults have used mark-resight approaches where adults are observed by snorkeling (Rawding and Cochran 2005) or walking surveys (Jacobs 2002) rather than captured. A novel mark-resight approach by Korman et al. (2002) periodically estimated spawner abundance by radio tagging adult steelhead and simultaneously used snorkeling and radio tagging to estimate snorkel efficiency of live fish. Korman et al.'s (2002) study used the AUC method to estimate total number of fish days and radio tracking to provide an estimate of stream life. AUC abundance was estimated by dividing the fish days of the survey life by radio tagging. Although this approach combines two methods, it should be scored as a mark-recapture method because the critical assumptions of mark-recapture are more difficult to meet. Selectivity tests are used to determine if the estimates must be stratified. Tables 8 and 9 provide the criteria for scoring adult spawner abundance using the Petersen estimator and weirs, respectively.

Table 8. Criteria for scoring monitoring programs for adult spawner abundance using the Petersen Mark-Recapture method.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and jacks</i> , AND	Representative sampling throughout the inference domain. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. Fish are captured over the entire migration period. <i>Adjustments are made for missed days, tag loss, tag survival, & missed tags.</i> Equal catchability tests are implemented for time periods, fish length/age, sex, and origin.
0.75	CV met for <i>adults</i> , AND	Representative sampling throughout the inference domain. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. Fish are captured over entire migration period. <i>Adjustments are made for missed days only.</i> Equal catchability tests are implemented for time periods, fish length/age, sex, and origin.
0.50	CV met for adults, AND	Representative sampling throughout inference domain. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. Fish are captured over entire migration period. Adjustments are made for missed days only. <i>No equal catchability tests are implemented for time periods, fish length/age, sex, or origin.</i>
0.25	CV met for adults, <i>OR</i>	Representative sampling throughout inference domain. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. Fish are captured over entire migration period. Adjustments are made for missed days only. <i>Equal catchability tests are not implemented for time periods, fish length/age, sex, or origin.</i>
0.00	<i>CV not met for adults AND</i>	No monitoring <i>OR unrepresentative sample site selection OR no sampling protocols to ensure careful fish handling, marking, and inspection for marks OR fish are not captured over entire migration period. Equal catchability tests may or may not be implemented for time periods, fish length/age, sex, or origin.</i>

Table 9. Criteria for scoring monitoring programs for adult spawner abundance using weirs.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and jacks</i> , AND	Sampling locations represent 100% of available spawning area. Weir operates over entire migration period and is <i>routinely inspected</i> to ensure that no fish pass without being enumerated. Inspection may be visual or include a marked release. During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distribution describing migration patterns, or smoothing functions are used adjust adult passage estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.75	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. Weir operates over migration period but is <i>only inspected at the start and end of the season.</i> During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distribution describing migration patterns, or smoothing functions are used adjust adult passage estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.50	CV met for adults, AND	Sampling locations represent 100% of available spawning area. Weir operates over migration period but is <i>inspected only upon installation.</i> During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distribution describing migration patterns, or smoothing functions are used adjust adult passage estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.25	CV met for adults, <i>OR</i>	Sampling locations represent 100% of available spawning area. Weir operates over migration period but is inspected only upon installation. During flow periods when weir is not 100% efficient, other methods including interpolation, statistical distribution describing migration patterns, or smoothing functions are used adjust adult passage estimates. The use of such estimation techniques must be limited to less than 10% of the time the trap is operated.
0.00	<i>CV not met for adults AND</i>	No monitoring <i>OR unrepresentative sample site selection OR weir operations too intermittent to provide a reliable estimate.</i>

Method: Spawner abundance estimates using Open Population Mark-Recapture

Details on Jolly-Seber (JS) model study designs, assumptions, and analytical methods for mark-recapture experiments can be found in the publications of Jolly (1965), Seber (1965), Seber (1982) and Pollock et al. (1990). Open population mark-recapture abundance estimates require that fish are sampled and marked throughout the run or spawning period. The JS model has been used to estimate salmon escapement through carcass surveys (Sykes and Botsford 1986) and live tagging efforts (Schwarz et al. 1993).

Precision and Bias: As with Petersen mark-recapture, recommended tag recoveries are 5-10 fish per release group. Asymptotic large sample variances can be derived from net recruitment using the Delta method (Schwarz and Arnason 1996) when the number of tag recoveries is high. When tag recoveries are low, bootstrapping, maximum likelihood (Cormack 1992), and Bayesian methods may provide more accurate interval coverage.

Critical Assumptions: Five JS assumptions must be met to obtain unbiased population estimates from open population models (Seber 1982). The five assumptions are:

1. Equal Catchability: Every animal in the population whether tagged or untagged, has the same probability of being caught in the i^{th} sample given that it is alive and in the population when the sample is taken;
2. Survival: Every tagged animal has the same probability of surviving from the i^{th} to the $(i+1)^{\text{th}}$ sample and of being in the population at the time of the $(i+1)^{\text{th}}$ sample, given that it is alive and in the population immediately after the i^{th} release;
3. Handling Mortality: Every animal caught in the i^{th} sample has the same probability of being tagged and returned to the population;
4. Tag Loss: Tagged animals do not lose their marks and all marks are recognized on recovery; and
5. Instantaneous Sampling: All samples are instantaneous, i.e., sampling time is negligible and each release is made immediately after the sample.

Goodness of fit (GOF) methods are typically used to test assumptions 1 and 2 based on a series of contingency tables. These tests can be implemented in software used in JS analysis including JOLLY or MARK (Pollock et al. 1985, White and Burnham 1999). A Bayesian goodness of fit test could also be used (Brooks et al. 2000, Dupuis and Schwarz 2007). Handling mortality (assumption 3) is assessed through holding fish or from the results of gear mortality studies (Lindsay et al. 2004, Vander Haegen et al. 2004). Tag loss (assumption 4) is assessed through double tagging studies and can be directly incorporated into the estimator (Cowan and Schwarz 2006). Missed tags can be assessed by resampling efforts. Instantaneous sampling is impossible to achieve but as long as this assumption is not seriously violated (e.g., sampling delay following tagging is small compared to the sampling interval) it is acceptable (Schwarz et al. 1993).

With the JS model, additional assumptions must be met in order to estimate recruitment parameters for the beginning and end of the sampling period. The JS model is not able to directly estimate births at the start or end of a study because the probability of capture is not identifiable without further assumptions. Inclusion of additional assumptions makes it possible to estimate net births at the beginning and end of the study. A well-designed mark-recapture study should commence before a significant number of fish enter the stream or spawning area, and extend until recruitment is completed. Net births should approach zero during these periods and have little effect on the population estimate (Schwarz et al. 1993).

Assumptions concerning recruitment between sampling efforts are needed to estimate annual salmon escapement with the JS model. The typical assumption is that recruitment took place at the mid-point of sampling or was uniform across the period. Schwarz et al. (1993) conducted a sensitivity analysis on

adjustment factors used on estimates and found that the estimates do not vary much when survival is high because most fish survive to the next sampling occasion. However, when survival is low, adjustment factors and estimated births may vary considerably. Schwarz et al. (1993) noted the actual distribution of recruitment is unknown, and suggested care be taken when selecting a recruitment adjustment factor.

Scoring: Meeting equal catchability and survival assumptions are critical because these factors may have variable and unpredicted effects on the abundance estimator. Assumptions about tagging and handling effects are less of a concern when standardized protocols are used. When standard tagging and handling protocols are used, the effects of these procedures on fish abundance are generally small. Alternatively, tagging and handling experiments can be done under controlled conditions to establish mortality rates for the procedure and then applied to the target population. We developed specific scoring guidelines for open population mark-recapture spawner abundance estimates (Table 10) based on our general scoring rules and the methods and critical assumptions for estimating abundance with this approach (Table 1). The highest score meets the precision goal for both adults and jacks and assesses tag loss, tag survival, missed tags, and ensures equal catchability and survival for homogeneous groups. A high score is a product of meeting the precision standard for adults, annual tests of critical assumptions including equal catchability and survival, and standard protocols that reduce the probability of tag loss, handling mortality, and missed marks. Alternatively the results of outside studies may be used to estimate these effects. A moderate score occurs when the precision target for adults is met, there is an adjustment for missed days, and representative sampling is attempted but no equal catchability or survival tests are implemented. When the CV is not met, but the moderate standards for bias are achieved, a low score is recorded. The lowest score indicates that neither the precision target nor standard protocols were met, and sampling was intermittent.

Method: Spawner abundance estimates using Area-Under-the-Curve method

Area-under-the-curve (AUC) escapement or spawner abundance estimates are based on two components. The first component is a curve of escapement or the number of spawners as a function of time over the entire spawning period for a survey area. This curve is developed in-season as fish are periodically counted (Parken et al. 2003). The AUC is an integral of all the factors that influenced the sequential estimates of fish counts in a survey area. An estimate of fish-days is derived from the AUC, which starts at zero on fish-day zero and ends at zero fish the last day of the survey. The second component of the AUC methodology is an estimate of fish residence time in the survey area (English et al. 1992).

AUC and fish residence time estimates are influenced by factors that affect the length of time fish are alive in the stream and a surveyor’s ability to observe fish (termed observer efficiency) and should be based on annual stream-specific estimates (English et al. 1992). Spawner abundance estimates are expanded based on in-season observer efficiency and mean fish residence time estimates; the total number of fish-days is divided by an estimate of the mean number of days fish spend in the survey area (termed survey life). Survey area and an appropriate measure of fish residence time in the stream must be clearly defined (English et al. 1992).

The AUC approach is used to estimate spawner abundance for chum, coho, and Chinook salmon in the LCR (Keller 2005, Rawding et al. 2006, Suring et al. 2006). Data needs for this approach include sequential spawner counts and estimates of observer efficiency and survey life. In the LCR, spawner counts are typically conducted at seven to ten day intervals over the spawning period rather than daily to reduce costs. The uncertainty of spawner abundance estimates increases as the time interval between sequential counts increases (Hill 1997; Bue et al. 1998).

Table 10. Criteria for scoring monitoring programs for adult spawner abundance using the Jolly-Seber Method.

Score	Precision Guideline	Bias Guideline
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1.00	CV met for adults <i>and jacks</i> , AND	Sampling locations represent 100% of available spawning area. Sampling occurs over spawning and migration period. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. <i>An adjustment is made for missed days, tag loss, & tag survival.</i> Equal catchability and survival GOF and selectivity tests for length/age, sex, and origin are implemented.
0.75	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. Sampling occurs over spawning and migration period. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. <i>No adjustment is made for missed days, tag loss, & tag survival.</i> Equal catchability and survival GOF and selectivity tests for length/age, sex, and origin are implemented.
0.50	CV met for adults, AND	Sampling locations represent 100% of available spawning area. Sampling occurs over spawning and migration period. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. <i>No adjustment is made for missed days, tag loss, & tag survival. No equal catchability and survival GOF and selectivity tests for length/age, sex, and origin implemented.</i>
0.25	CV met for adults, OR	Sampling locations represent 100% of available spawning area. Sampling occurs over spawning and migration period. Sampling protocols are used that ensure careful fish handling, marking, and inspection for marks. <i>No adjustment is made for missed days, tag loss, & tag survival. No equal catchability and survival GOF and selectivity tests for length/age, sex, and origin implemented.</i>
0.00	CV not met for adults AND	No monitoring OR unrepresentative sample site selection OR sampling protocols are not used that ensure careful fish handling, marking, and inspection for marks OR fish are not captured over entire migration period.

Observer efficiency is estimated by releasing a known number of marked fish and conducting a fish count the next day (Hetrick and Nemeth 2003) or week (Szerlong and Rundio 2007). The probability of detecting all salmon present in a survey area is determined by comparing the spawner count to mark-recapture or -depletion estimates (Solazzi 1984; Irvine et al. 1992).

The life span of a mature salmon in a survey area is termed survey life or survey area residence time (English et al. 1992). A mark-recapture approach can be used to determine survey life (Lady and Skalski 1998; Manske and Schwarz 2000). Radio or PIT tags can be used to estimate the time from tagging until death (Shardlow et al 2007; Pierce et al. 2011) or tag recovery (Willis 1954; Szerlong and Rundio 2007), and to develop tag depletion curves (Irvine et al. 1992; Hetrick and Nemeth 2003).

Alternatively, apparent survey life can be estimated as the difference between total fish days and escapement (Parken et al. 2003). Spawn timing and death distributions may also be used to estimate fish arrival and death or presence (Hilborn et al. 1999, Rawding et al. 2006, Szerlong and Rundio 2007). These approaches enumerate only fish classified as spawners and all spawning areas are surveyed. If all of the uncertainty of a survey life estimate is incorporated into the AUC, the estimate is referred to as apparent survey life and is equal to the survey life divided by observer efficiency. Trapezoidal approximation may also be used to estimate AUC (English et al. 1992; Bue et al. 1998). Additional AUC approaches can be found in Parsons and Skalski (2010).

A survey of representative reaches is frequently conducted for an AUC approach rather than sampling of the entire spawning area. Spatial sampling designs may include: simple random, systematic, stratified random, adaptive cluster, or a spatially balanced (GRTS) design (Courbois et al. 2008). Spatially and temporally balanced sampling designs (Steven 2002; Firman and Jacobs 2002), stratified random designs (Irvine et al. 1992), and simple random designs (Courbois et al. 2008) seem to be used most frequently. In practice random temporal sampling is difficult to implement due to ineffective sampling when water turbidity is high. When

sampling occurs under highly turbid conditions, an adaptive systematic temporal sampling design may be used for a one or two week period to approximate random temporal sampling with one of the spatial sampling designs.

Precision and Bias: The precision of AUC estimates is related to the number or proportion of spawning reaches surveyed, variability in the AUC reach estimates, and the standard deviation of observer efficiency and survey life estimates (Hilborn et al. 1999).

The ability of individual surveyors to detect the true number of spawners is variable and dependent on a variety of factors including fish abundance, flow, turbidity, habitat, and surveyor experience (Shardlow et al. 1987; Jones et al. 1998; Hetrick and Nemeth 2003; Korman et al. 2002). Coho salmon observer efficiencies ranged from 25% to 100% in a small Alaska stream and were dependent on wind, lighting, and turbidity. The sample size was nine and the mean observer efficiency was 65% in this study. Estimates of observer efficiency for Oregon coastal coho salmon were 75.5% with 95% CI from 68.7% to 82.3% based on 51 samples. In contrast, Holt (2006) estimated observer efficiency from small Vancouver Island streams at 86.5% based on over 30 surveys. Szerlong and Rundio (2007) estimated observer efficiency at 22% with 95% CI from 18.1 to 25.9% based on three samples; by accounting for tag loss Szerlong and Rundio (2007) increased mean observer efficiency to ~ 34%. Work on the Oregon coast with AUC coho salmon spawner abundance estimates suggests the following rule of thumb: to meet a CV of 15%, thirty 1-mile reaches or 30% of the spawning areas must be surveyed (Jeff Rodgers, ODFW personal communication).

Variation in survey life estimates can also affect the precision of estimates. The mean stream life of salmon sampled in Oregon coastal streams is 11.3 days (Jacobs and Cooney 1997). However, estimates of coho salmon survey life ranged from 7 to 20 days in four Vancouver Island streams during a four-year period (Holt 2006). The greatest uncertainty in AUC generated spawner abundance estimates is the selection of appropriate observer efficiency and survey life estimates.

Critical Assumptions: AUC critical assumptions are the same as those for closed mark-recapture and the weir monitoring methods. The open population model requires an additional assumption regarding recruitment between sampling occasions and at the start and end of the study, but in most cases these assumptions are defensible and have a small effect on abundance estimates. Conversely, calibrated estimates generated by AUC, peak count expansion, or redd surveys can provide considerably biased spawner abundance estimates when observer efficiency, survey life, expansion factors, and the use of surrogate data from adjacent populations or different years are ignored or inaccurate.

The first critical assumption for AUC is that representative spatial and temporal sampling occurs throughout the spawning period. If concurrent observer efficiency and survey life estimates are made, the second critical assumption for AUC is that these estimates are spatially and temporally representative of the survey area and occur throughout the spawning period. Concurrent observer efficiency and survey life studies are costly, so AUC spawner abundance estimates often rely on observation efficiency and survey life from adjacent populations or from the same populations in other years. The use of these kinds of surrogate estimates in calculations of spawner abundance should be carefully considered.

In the LCR, WDFW uses the apparent residence time estimates of Chinook and chum from LCR streams to calculate AUC spawner abundance estimates. These resident time estimates are made annually for Chinook and chum salmon on a range of small to medium streams. ODFW has used observer efficiency and survey life estimates from coastal surveys in AUC calculations of spawner abundance estimates for LCR streams (Suring et

al. 2006). WDFW is currently implementing large scale coho salmon monitoring and is exploring the possibility of using Oregon coastal coho salmon observer efficiency and survey life estimates in their calculations.

Scoring: We developed specific guidelines for AUC-based spawner abundance estimates (Table 11). Guidelines were based on AUC methodology, critical assumptions for estimating spawner abundance, and our general scoring rules (Table 1). The highest score requires meeting the CV for adults and jacks and includes representative sampling over the spawning period, and the use of MPG-specific observer efficiency and survey life by adult/jack or origin. A high score requires representative sampling over the migration or spawning period and the use of DPS/ESU-specific observer efficiency and survey life estimates by adult/jack or origin, and meeting the CV for adults. A moderate score requires meeting the CV for adults using a spatially balanced design. Observer efficiency and survey life estimates must be made under habitat and environmental conditions similar to those experienced by the surveyed population. Observer efficiency and survey life estimates may need to be estimated separately for adults/jacks and by origin. A low score for a spawner abundance estimate occurs when the CV for adults is achieved or a spatially balanced design is used with observer efficiency and survey life estimates from habitat and environmental conditions similar to those experienced by the population. The lowest score is given when the CV is not achieved and sampling is not representative.

Table 11. Criteria for scoring monitoring programs for adult spawner abundance using periodic live counts and area-under-the-curve (AUC) method.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and</i> jacks, AND	Sampling locations represent 100% of available spawning area. The probability of observing a spawning fish, the average number of days that spawners are alive on the spawning grounds, and observer variability in counting live spawners are obtained from <i>studies conducted within the MPG/stratum</i> where the AUC estimates are conducted. <i>Studies conducted in the MPG/stratum</i> where the AUC estimates are conducted show 95% CI overlap with spawner abundance estimates obtained from an alternate estimation method (e.g., weir counts, Peterson Mark-Recapture, Jolly-Seber).
0.75	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. The probability of observing a spawning fish, the average number of days that spawners are alive on the spawning grounds, and observer variability in counting live spawners are obtained from studies conducted within the MPG/stratum where AUC estimates are conducted. Studies conducted in the MPG/stratum where the AUC estimates are conducted show 95% CI overlap with spawner abundance estimates obtained from an alternate estimation method (e.g., weir counts, Peterson Mark-Recapture, Jolly-Seber).
0.50	CV met for adults, AND	Sampling locations represent 100% of available spawning area. The probability of observing a spawning fish, the average number of days that spawners are alive on the spawning grounds, and observer variability in counting live spawners are obtained from <i>studies conducted within the ESU/DPS or at places with similar environmental conditions</i> . <i>Studies conducted at places with similar environmental conditions</i> where the AUC estimates are conducted show 95% CI overlap with spawner abundance estimates obtained from an alternate estimation method (e.g., weir counts, Peterson Mark-Recapture, Jolly-Seber).
0.25	CV met for adults, OR	Sampling locations represent 100% of available spawning area. The probability of observing a spawning fish, the average number of days that spawners are alive on the spawning grounds, and observer variability in counting live spawners are obtained from studies conducted at places with similar environmental conditions. Studies conducted within the ESU/DPS or at places with similar environmental conditions where the AUC estimates are conducted show 95% CI overlap with spawner abundance estimates obtained from an alternate estimation method (e.g., weir counts, Peterson Mark-Recapture, Jolly-Seber).
0.00	CV not met for adults AND	No monitoring OR <i>unrepresentative sample site selection OR sampling was not conducted over the entire spawning period</i> .

Method: Spawner Abundance Estimates Using Peak Count Expansion (PCE)

A peak count provides an index of escapement. Because the relationship between the peak count and escapement is unknown, a peak count cannot be used to estimate escapement. There are a number of ways to estimate the escapement to peak ratio or a peak count expansion factor. These include the mean of the ratios (Parken et al. 2003), the ratio of the means, calibrated regression, and inverse prediction (Parsons and Skalski 2010). A peak count may be of live fish, carcasses, or both live fish and carcasses. In addition, peak counts may include single index, multiple indices, or the entire spawning distribution. The peak count method as commonly applied is unlikely to provide the representative sampling required for VSP indicator estimates on diversity because the annual bias of this method is higher than for AUC (Parken et al. 2003). The peak count expansion method requires additional sampling effort to collect complementary VSP indicator data. Alternative spawner abundance methods such as AUC or redd surveys accompanied by carcass recovery are likely to be more cost effective in meeting spawner abundance monitoring standards than peak counts with additional sampling efforts.

Precision and Bias: The precision of the peak count estimate is based on the correlation between the annual peak count and annual escapement. The standard deviation of the escapement estimate should capture the uncertainty in the expansion factor.

Critical Assumptions: The critical assumptions for the peak count expansion method are: 1) the peak day of abundance is known, 2) if the entire spawning distribution is not surveyed, the proportion of fish used in the index or indices is similar to that of the years used to develop the peak count expansion factor, 3) observer efficiency is similar to that of the years used to develop the peak count expansion factor, and 4) the number of fish observed on the peak day is similar to that of the years used to develop the peak count expansion factor.

Scoring: Specific indicator guidelines for scoring peak count expansion were developed (Table 12) following our general scoring rules (Table 2). The highest score requires meeting the CV for adults and jacks and also requires the use of updated expansion factors for both adults and jacks with a minimum of three surveys conducted to determine the peak. A high score meets the CV for adults and includes using updated expansion factors for adults and jacks with a minimum of three surveys conducted to determine the peak. A moderate score requires meeting the CV for adults and a single survey conducted at peak spawning. A low score for spawner abundance estimates with the peak count expansion method occurs when either the CV for adults is achieved or a single survey at peak spawning is conducted. The lowest score occurs when the CV is not achieved, the single peak count is not expanded, or the expansion rate is based on professional opinion.

Method: Spawner Abundance Estimates based on Redd Counts

Female salmon and trout excavate a depression in gravel substrate to deposit their eggs. The eggs are simultaneously fertilized by one or more males. The female quickly covers the eggs with gravel and the covered gravel egg nest is referred to as a redd. The spawning process continues until a female has deposited most of her eggs in a contiguous series of nests. Steelhead redd surveys in the LCR follow protocols similar to those developed by the American Fisheries Society (Gallagher et al. 2007). Spawning areas are surveyed every two weeks and all identifiable redds are flagged. The location of each flag is recorded on a map or captured with a Global Positioning Satellite (GPS) unit. In subsequent surveys, previously flagged redds are inspected to determine if they should be classified as “still visible” or “not visible”. A redd is classified as “still visible” if it would have been identified without the flagging present. A redd is classified as “not visible” if it does not meet this criteria. Reach scale redd counts are assumed to be a complete census of all redds in the reach.

Table 12. Criteria for scoring monitoring programs for adult spawner abundance using the peak count expansion method.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and</i> jacks, AND	Sampling locations represent 100% of available spawning area. At least 3 surveys are conducted to define the peak. An updated expansion factor (every 10 years) is used to convert peak spawner counts to a total spawner population estimate. Peak count expansion is based on three recent years of peak counts and independent estimates obtained from weir counts, mark-recapture, etc.
0.75	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. At least 3 surveys are conducted to define the peak. An updated expansion factor (every 10 years) is used to convert peak spawner counts to a total spawner population estimate. Peak count expansion is based on three recent years of peak counts and independent estimates obtained from weir counts, mark-recapture, etc.
0.50	CV met for adults, AND	Sampling locations represent 100% of available spawning area. A <i>single survey</i> is conducted at what is believed to be peak spawning. An updated expansion factor (every 10 years) is used to convert peak spawner counts to a total spawner population estimate. Peak count expansion is based on three recent years of peak counts and independent estimates obtained from weir counts, mark-recapture, etc.
0.25	CV met for adults, <i>OR</i>	Sampling locations represent 100% of available spawning area. A single survey is conducted at what is believed to be peak spawning. An updated expansion factor (every 10 years) is used to convert peak spawner counts to a total spawner population estimate. Peak count expansion is based on three recent years of peak counts and independent estimates obtained from weir counts, mark-recapture, etc.
0.00	<i>CV not met for adults AND</i>	No monitoring <i>OR No sampling OR unrepresentative sample site selection OR peak counts are not expanded or the expansion factor is based on professional opinion.</i>

Redd counts are often used to estimate salmonid escapement when mark-recapture, AUC, or peak count expansion methods fail due to low recoveries or observation of live fish is difficult. Redd counts are commonly used for winter steelhead spawner abundance estimates in the LCR (WDFW 2011). Redd counts provide an index of escapement rather than a count because the relationship between the number of redds and escapement is unknown. Typically the redd count is expanded using a females-per-redd estimate and total spawner estimate. Total escapement is estimated by expanding the estimated number of females to total spawners using the proportion of females in the population (Rawding 2006). The number of females-per-redd is estimated from the number of females surveyed during a weir census or a mark-recapture estimate divided by the observed number of redds. Technically, this is the apparent females-per-redd because it includes the uncertainty in redd identification and enumeration in the estimate. WDFW uses the females-per-redd data from Snow Creek, a small stream near Port Townsend, WA to expand redd counts to estimate the number of females-per-redd for LCR steelhead. Sex ratios from trapping data on the Cowlitz, NF Toutle, Kalama, or Wind rivers are used to expand the female estimate to total escapement.

One WDFW study design for steelhead entails a redd census on a single population (Rawding et al. 2006). A second approach used is an index/supplemental design. In this approach index spawning sites are surveyed throughout the spawning season. Once the peak of redd abundance has been established, the remainder of the spawning distribution is supplementally surveyed. Redd counts in the supplemental section are expanded based on the proportion of total redds still visible in the index sites on the date of the supplemental surveys. This approach may require separate estimates for different streams used by a population if spawning times differ at the index sites. A third survey type is the index/supplemental/unsurveyed design. Redd estimates are conducted as described above and redd densities in unsurveyed reaches are based on adjacent streams and

professional opinion. An alternate approach may be to randomly sample these unsurveyed reaches. The spatial designs used to conduct steelhead redd counts are the same as those described in the AUC method.

Two approaches are used to estimate natural origin spawner abundance with redd surveys. The timing approach (Scott and Gill 2008) delineates natural from hatchery origin spawners using an agreed upon date after which redd survey spawner abundance estimates are considered to represent natural origin spawners. Earlier spawners are assumed to be hatchery fish. This approach assumes that only a negligible portion of hatchery fish spawn after natural origin fish begin spawning. If redd counts are conducted over the entire hatchery and wild spawning period, mixture models may be used to apportion the escapement by origin (MacDonald and Pitcher 1979). An alternative approach involves carcass recoveries or observations of hatchery and natural origin fish based on a mass marking approach such as the removal of adipose fins from hatchery fish. This method is discussed in more detail in the origin section.

Precision and Bias: The precision of redd count-based spawner abundance estimates is related to the number or proportion of spawning reaches surveyed, variability in redd counts by reach, the standard deviation of females-per-redd, and the proportion of female spawners in the population.

Critical Assumptions: The critical assumption for redd count surveys is that representative spatial and temporal sampling is conducted throughout the spawning period. Because concurrent redd surveys and weir/mark-recapture surveys are expensive, redd-based abundance estimates often rely on apparent females-per-redd from adjacent populations or from the same population in previous years. This assumes the methods used to identify and enumerate females-per-redd follow standard redd survey protocols. The third critical assumption is that the apparent females-per-redd and sex ratio from other streams or years accurately represent the females-per-redd and sex ratio for the population in the current year.

The applicability of females-per-redd estimates for winter steelhead and salmon populations is the greatest uncertainty in redd-based spawner abundance estimates. Redd-based estimates are subject to several sampling difficulties. Individual redds may be difficult to identify due to superimposition, or spawning may overlap in timing with that of another species confounding redd counts on the species of interest (Gallagher and Gallagher 2005). There is also potential for more than one redd-per-female (Kuligowski et al. 2005), the presence of test digs, variation in redd characteristics (Crisp and Carling 1989), and counting errors due to observer experience and training (Dunham et al. 2001; Muhlfeld et al. 2006).

Scoring: Based on the methods and critical assumptions for redd-based spawner abundance estimates and our general scoring rules (Table 2), specific guidelines were developed for scoring these estimates in Table 13. The highest score requires meeting the CV for adults and jacks and includes representative sampling over the entire spawning period and the use of MPG-specific apparent females-per-redd by adult/jack or origin. A high score requires a CV for adults that is less than the population goal, representative sampling over the migration or spawning period, and the use of DPS/ESU specific apparent females-per-redd by adult/jack or origin. A moderate score requires meeting the CV for adults using a spatially balanced design. Apparent females-per-redd must be estimated at sites where habitat and environmental conditions are similar to that of the population of interest and separate estimates may be needed for adults/jacks and by origin. A low score for spawner abundance occurs when the CV for adults is achieved or a spatially balanced design is used with apparent females-per-redd estimates from habitat and environmental conditions similar to the population. The lowest score occurs when the CV is not achieved and sampling is not representative.

Indicator: Diversity – Age Structure

No formal targets for age structure precision were proposed by Crawford and Rumsey (2009). Crawford and Rumsey (2009) adopted the precision guidelines for abundance from the CTC. Some CTC members have proposed that adult age estimates fall within $\pm 5\%$ of the true value 95% of the time. This proposal for adult age composition may be appropriate for the highest recovery priority populations. For lower recovery priority populations, a more relaxed standard, that adult age estimates fall within 10% of the true value 95% of the time, might be more appropriate (Crawford et al. 2007).

Method: Scales

Representative scale samples are collected on the spawning grounds or at trap sites by selecting scales from an area ~15 scale rows wide and ~ 1-6 rows above the lateral line in a diagonal between the posterior insertion of the dorsal fin and anterior insertion of the anal fin (Crawford et al. 2007). Scale samples are removed with forceps using special care to select samples of good quality (round shape, non-regenerated) and that are not adjacent to one another (to minimize the effects of regeneration; Cooper et al. 2011). Scales are placed on the gummed portion of scale cards with their exterior surfaces facing up. Acetate impressions are made of the scale samples by a scale card press. Samples are covered with clear acetate (0.5mm thickness) and pressed under 1200-1300 PSI @ 100 degrees C for 30 seconds to 1 minute. Acetate impressions are allowed to cool and are then removed from the press. Acetate impressions of scales are aged using Gilbert/Rich or European aging notation (Groot and Margolis 1991). The age of a fish is determined from scale pattern analysis which involves identifying and counting annual growth annuli to produce a total age in years.

Because most salmonids in the LCR are not tagged, scale pattern analysis is the primary method available to estimate the age structure of a population. Murdoch et al. (2010) collected scales from 2,367 hatchery origin Chinook salmon with coded-wire tags (CWT) from 1999 to 2007. The age of these fish is known without error because CWT application and recovery dates are known for each fish. In a blind test, Murdoch et al. (2010) found that 98.9% of the CWT fish were correctly aged. Scale pattern analysis can be supplemented with CWT or PIT tag ages. The age of salmonids can be accurately estimated from scale pattern analysis.

Table 13. Criteria for scoring monitoring programs for adult spawner abundance using redd counts.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and jacks</i> , AND	Sampling locations represent 100% of available spawning area. Surveys are conducted over the entire spawning period. Females per redd and sex ratio are developed from the population within <i>MPG/stratum</i> .
0.75	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. Surveys are conducted over the entire spawning period. Females per redd and sex ratio are developed from the population within <i>MPG/Stratum</i> .
0.50	CV met for <i>adults</i> , AND	Sampling locations represent 100% of available spawning area. Surveys are conducted over the entire spawning period. Females per redd and sex ratio are from <i>studies conducted within the ESU/DPS or from areas with similar environmental conditions</i> .
0.25	CV met for <i>adults</i> , OR	Sampling locations represent 100% of available spawning area. Surveys are conducted over the entire spawning period. Females per redd and sex ratio are from <i>studies conducted within the ESU/DPS or from areas with similar environmental conditions</i> .
0.00	CV <i>not met for adults</i> AND	No monitoring OR <i>No sampling OR unrepresentative sample site selection OR sampling is not conducted over the entire spawning period</i> .

Precision and Bias: Precision estimates for age are not usually calculated but the number of readable scales is often known. Sample size guidelines have been developed for scale analysis to estimate the expected precision of age structure estimates (Crawford et al. 2007). These guidelines estimate that 128 and 510

readable scales need to be analyzed to achieve the 5% and 10% targets for age structure precision, respectively. These estimates are based on multinomial sampling guidelines published by Thompson (1987).

Mixture models provide an alternative approach to determine the age structure of a population (MacDonald and Pitcher 1979). In this approach, lengths are taken from many fish and scales are subsampled from the group with known lengths. Using length-only data and the subset of length at age data, the proportion of fish in each age group is estimated with maximum likelihood or Bayesian methods. The value of this approach is it eliminates the field and laboratory time required to collect, prepare, and age scale samples. However, the mixture model approach requires assumptions about the age distribution and may require different mixture models by sex. Given this uncertainty it is not possible to provide sample size guidelines to meet precision targets.

Critical Assumptions: To obtain an unbiased estimate, it is essential that the collection of age data be representative of the population. Fish of different ages may not be equally catchable due to a variety of circumstances. For example, adult salmonids may return and/or spawn at different ages and times. Spatial and temporal probabilistic designs for sampling on the spawning grounds or at a trap could be used to address this critical assumption. Because sampling in highly turbid water is ineffective, an adaptive systematic temporal sampling strategy is often implemented as necessary for one or two week periods to approximate random temporal sampling. This approach is accompanied by a spatially balanced or random sampling design. If the population is intensively monitored or small, scales may be sampled from all spawner carcasses encountered. A subsample of scales from spawners is adequate for age structure determination on larger populations. Random sampling of carcasses is preferred but practical field sampling considerations usually dictate a systematic sampling approach. Although there is no variance calculation for systematic sampling, the variance is often approximated assuming random sampling (Courbois et al. 2008).

Another consideration in determination of age structure is that of length selectivity. Length selectivity has been documented in Chinook salmon carcasses recovered from rivers on the Oregon Coast and in eastern Washington (Zhou et al. 2002; Murdoch et al. 2010). Because length and age are correlated, this finding implies that there is age selectivity in carcass recoveries for some Chinook salmon populations. Length selectivity between jacks and adults has been reported for some LCR Chinook populations (Rawding et al. 2006). These findings imply that corrections for length may need to be developed to obtain unbiased age estimates on fish.

Sex and origin selectivity has been also been observed in Chinook salmon carcasses recovered from eastern Washington (Murdoch et al. 2010). This suggests that unbiased estimates of population age structure may require the development of stratified age estimates based on sex and origin as well as corrections for length selectivity.

Because steelhead are iteroparous, the collection of scale samples from carcasses on the spawning grounds is not possible. Traps or seines are typically used to collect steelhead scale samples for aging, although other methods such as angling may also be effective. The need to implement traps and seining efforts to collect steelhead scale samples limits the number of populations that can be monitored for age structure in the LCR. However, the fresh and saltwater age structure of sampled populations appears to be similar (WDFW, unpublished data). Therefore, we propose the use of representative age structure analyses from sampled populations be used as surrogates for unsampled populations. Bias in age structure, especially from carcass sampling, is a critical uncertainty that should be addressed in LCR monitoring designs.

Scoring: We developed specific indicator guidelines for scoring age diversity estimates (Table 14) based on the methods and critical assumptions of age structure diversity and our general scoring rules (Table 2). The highest score requires meeting the CV and representative sampling over the migration or spawning period accompanied by age or length selectivity tests that demonstrate no bias in age structure and include an unbiased estimate of jacks. A high score must meet the CV and include representative sampling over the migration or spawning period, which is likely to lead to unbiased estimates of *adult* age structure. Populations in the LCR that have been representatively sampled and meet the CV can provide age structure information for populations that are difficult to sample. Temporal and/or spatial sampling of a population over the majority of the migration period is likely to lead to relatively unbiased estimates. Implementation of either of these sampling designs leads to a moderate score for age structure estimates. A low score for age structure occurs when the CV is achieved or when there is representative spatial and temporal sampling from a similar population within the ESU/DPS. The lowest score occurs when the CV is not met and spatial/temporal sampling is non-representative.

Table 14. Guidelines for scoring monitoring of the age structure indicator.

Score	Precision Guideline	Bias Guideline
1.00	CV met for adults <i>and jacks</i> , AND	Representative spatial and temporal sampling for the <i>population</i> . Selectivity testing for this indicator is implemented.
0.75	CV met for <i>adults</i> , AND	Representative spatial and temporal sampling for the population. Selectivity testing for this indicator is implemented.
0.50	CV met for adults, AND	Representative spatial and temporal sampling from a similar population within the <i>MPG/Stratum</i> . <i>Selectivity testing for this indicator may or may not be implemented.</i>
0.25	CV met for adults, OR	Representative spatial and temporal sampling from a similar population within the ESU/DPS. <i>Selectivity testing for this indicator may or may not be implemented.</i>
0.00	CV not met for adults AND	No monitoring OR <i>unrepresentative sample site selection OR sampling does not occur over the entire spawning period.</i>

Indicator: Diversity – Migration/Spawn Timing

NOAA monitoring guidance is vague and uninformative for this indicator perhaps because inter-annual variation in migration and spawn timing may be influenced by fish abundance, hatchery programs, environmental conditions such as flow, turbidity, and temperature, as well as other factors. The migration and spawn timing of salmonids varies annually (WDFW, unpublished data). Monitoring programs could be established to detect statistical changes in migration and spawn timing but it is unclear if these changes are biologically relevant. Additional effort is needed to develop biologically relevant guidelines for the migration and spawn timing indicator.

Methods

The migration timing of a population is estimated with a closed mark-recapture or weir approach. Spawn timing is generally estimated with carcass mark-recapture, redd-based, or an AUC approach. Spawner origin is often determined with a spatial survey because either visual observation of live spawners or the examination of spawner carcasses are used to estimate natural origin spawn timing. Because spatial surveys are used to estimate spawner origin, we propose an interim guideline for assessing migration/spawn timing. That is when the spawner abundance of a population is based on a spatial sampling design, the same scoring approach be used to assess the migration/spawn timing indicator. It should be recognized that this approach, while convenient, may be more rigorous than needed to assess this indicator, and as mentioned above the additional development of scoring for this indicator is advised.

Precision and Bias: The precision of a spawn timing estimate is dependent on the number of reaches surveyed and the frequency of surveys. For AUC and redd surveys, precision also depends on the standard deviation of observer efficiency, survey life, females-per-redd, and the data used to estimate the proportion of female spawners. For mark-recapture estimates of migration or spawn timing, the precision of the indicator is dependent on the number of recaptures-per-period. The number of recaptures-per-period generally needs to be greater than ten to achieve precision goals.

Critical Assumptions: The critical assumptions for migration and spawn timing are the same as those previously reported in this report for spawner abundance (by method).

Scoring: Based on the methods and critical assumptions reviewed above and our general scoring rules (Table 2), we developed scoring criteria for the migration/spawn timing indicator (Table 15). Spawn timing estimates for LCR populations need to be developed from AUC, redd surveys, and open population abundance estimates based on carcass tagging. Closed population models will be used to provide migration timing estimates. As with estimates of spawning distribution, we recommend that the scoring for migration/spawn timing use the same guidelines as the spawner abundance indicator. The highest score for a migration/spawn timing indicator occurs when the precision standard (CV < 15%) is met and a mark-recapture, AUC, or redd survey methodology is used with an unbiased sampling strategy. Mark-recapture estimates must include assumption and selectivity testing. A high score is obtained if only the critical assumptions are tested or if the agency's spawning distribution layer is used as the sampling frame. A moderate score is achieved if the AUC or redd surveys are spatially balanced but the mark recapture estimate does not include selectivity tests. A low score occurs when either the CV is met or the score for bias is moderate. The lowest score is the result of non-representative sampling.

Table 15. Criteria for scoring the migration/spawning timing indicator.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	See Tables 8-13 for scoring pertinent to methodology employed.
0.75	CV met, AND	See Tables 8-13 for scoring pertinent to methodology employed.
0.50	CV met, AND	See Tables 8-13 for scoring pertinent to methodology employed.
0.25	CV met, OR	See Tables 8-13 for scoring pertinent to methodology employed.
0.00	CV not met AND	No monitoring OR See Tables 8-13 for scoring pertinent to methodology employed.

Indicator: Diversity – Sex Ratio

As with the age structure and origin indicators, specific precision targets have not been developed for the Diversity-sex ratio indicator. We propose to adopt the dual standards used in age structure and origin for sex ratio. Those standards are that estimates of sex ratio are within $\pm 5\%$ or $\pm 10\%$ of the true value 95% of the time for high and lower recovery priority populations, respectively.

Methods

Adult and jack salmon are identified to species based on unique physical characteristics. The sexual dimorphism of adult salmonids as they approach spawning allows fish to be accurately sexed based on visual characteristics. In addition, when salmon carcasses are examined for spawning success, the gonads can be used to positively identify sex. Ultrasound, endoscopy, or models may also be used to distinguish male and female adult salmonids (Bonar et al. 1989, Swenson et al. 2007, Alexander et al. 2010).

Precision and Bias: As with origin, the sex ratio of fish in a population can be described by a binomial distribution. Therefore the same sample size guidelines we provided for origin are recommended for sex.

Critical Assumptions: For an unbiased estimate of the sex ratio, it is essential that the data collected are representative of the population. Because the sex, age, and origin of a fish are determined from the same carcass sample, critical sampling assumptions from the age structure section apply to sex ratio, and include the use of temporal and spatial sampling designs and selectivity testing. The remaining critical assumption for the Diversity-sex ratio indicator is that fish sex is accurately identified.

Scoring: We developed specific guidelines for the Diversity-sex ratio indicator (Table 16) based on the methods and critical assumptions discussed above and our general scoring rules (Table 2). The highest score includes meeting the precision standard, representative sampling, and accurate sex identification based on the morphometric features of sexually mature fish or examination of the gonads. For sexually immature fish, a modeling approach or ultrasound inspection of the gonads is needed to identify sex. Selectivity tests for sex bias must be implemented. A high score requires the same information as the highest score except the selectivity test for sex bias is not required. A moderate score requires meeting the precision standard, representative sampling from a spatially balanced design over the majority of the migration or spawning period, and the use of morphometric differences to identify males from females. The low score occurs if the precision standard OR the moderate standard for bias is met. The lowest score occurs when the CV is not met and non-representative sampling occurs and only intermittent sampling occurs to estimate the sex ratio of a population.

Indicator: Diversity – Origin

Adult salmonids on the spawning grounds are classified as either of hatchery or natural origin. Hatchery origin spawners are the offspring of adults that were spawned in a hatchery. Natural origin spawners are the offspring of fish that spawned in a natural riverine environment. Specific precision targets have not been developed for the Diversity-origin indicator. We propose to adopt the dual standards used for the age structure indicator: that estimates of origin are within $\pm 5\%$ or $\pm 10\%$ of the true value 95% of the time for the highest and lower recovery priority populations, respectively.

Methods

Several methods are used to estimate the proportion of hatchery to natural origin spawners. The first method is to estimate origin based on a mass mark methodology. In this approach, hatchery salmonids are mass marked prior to release from the hatchery in order to distinguish them from wild fish. A mass marked fish has a clipped adipose fin. All fish with missing adipose fins are assumed to be hatchery fish. In the LCR, juvenile hatchery coho and Chinook salmon and steelhead are mass marked before release. A small percentage of hatchery-reared juvenile salmonids are not marked due to clipping errors. The error rate of mass mark fin clipping must be accounted for otherwise fin clipping errors will result in an over-estimation of natural origin spawners. In a similar mass mark approach, the otoliths of juvenile hatchery fish are marked with a temperature technique. The otoliths are removed from returning adult fish and compared to voucher samples to estimate the proportion of hatchery fish by age in a population. Scales are also sometimes used to confirm origin.

Table 16. Criteria for scoring monitoring efforts to estimate the sex ratio indicator.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	Representative spatial and temporal sampling <i>for the population</i> . A <i>selectivity test is implemented</i> for this metric. Carcasses are used to determine sex, or for sexually immature adults, ultrasound or models are used to identify the sex ratio.
0.75	CV met, AND	Representative spatial and temporal sampling for the population. A <i>selectivity test is not implemented</i> for this metric. Carcasses are used to determine sex, or for sexually immature adults, ultrasound or models are used to identify the sex ratio.
0.50	CV met, AND	As a surrogate for a population where sex ratio estimates are unavailable, representative spatial and temporal sampling from a <i>similar population within the MPG/Stratum is conducted</i> . A selectivity test is not implemented for this metric. <i>Morphometric features are used to identify the sex of sexually immature adults</i> .
0.25	CV met, OR	Representative spatial and temporal sampling is conducted on a similar population within the MPG/Stratum. A selectivity test is not implemented for this metric. Morphometric features are used to identify the sex of sexually immature adults.
0.00	CV not met AND	No monitoring <i>OR non-representative sampling OR sampling is not conducted over the entire spawning period</i> .

Chum salmon are mass marked with CWTs (ODFW) or by inducing a thermal check on the otoliths of juveniles fish (WDFW). A thermal check mass marking is created by manipulating the water temperature larvae are exposed to during the eyed and yolk absorption developmental stages. Each time the water temperature is dropped by 2-4 degrees C, a distinctive black band is deposited in the microstructure of developing otoliths. Exposure to chilled water for periods of 8 to 48 hours will essentially create bar codes on the otoliths that can be read. Voucher samples are taken from juvenile fish to determine mark quality and form. When the fish return as adults, their otoliths are collected and compared to the voucher samples to determine if a fish is of hatchery origin.

A second method that is used to estimate the proportion of hatchery and natural origin fish is the expanded mass mark method. With this method, all sampled fish are aged and classified as marked or unmarked. A weighted average mark rate is estimated from the specific recovery of different CWT hatchery release groups. The proportion of marked hatchery fish by age is estimated by expanding the number of mass marked fish and dividing by the weighted average hatchery mark rate.

A third method used to estimate the origin indicator is CWT expansion. In this method, a subsample of fish is aged and the number of spawners by age is calculated for the entire population. The number of hatchery fish by age is estimated by expanding the number of recovered CWT by the proportion of fish in the release that were CWTed and the proportion of the escapement that was checked for CWTs.

Precision and Bias: The normal approximation of the binomial distribution can be used to explore the fish sample sizes needed to meet 5% and 10% precision targets under the assumption that all hatchery fish are marked. The 95% CI half-widths are not uniform, so estimates are less precise when the proportion of marked fish is near 50%. Precision increases as the number of marked fish approaches the limits of the binomial distribution (Figure 4a). For example, a fish sample size of 100 meets the 95% CI half-width of 10% but if there are many (>85%) or few (<15%) hatchery fish, a sample size of 50 fish may meet the 10% precision target. To meet the 5% precision target for CV, the number of fish sampled must increase from 100 to 400. However, if the sampling distribution heavily favors either hatchery or natural origin fish, a sample size of 200 may be sufficient to meet the target. When the proportion of hatchery to natural origin fish is near 50%, estimates are most vulnerable to imprecision. The sample sizes required to meet given levels of precision are plotted in

Figure 4b. The precision of expanded mass mark and CWT methods are dependent on the juvenile tag rate and the number of adults sampled.

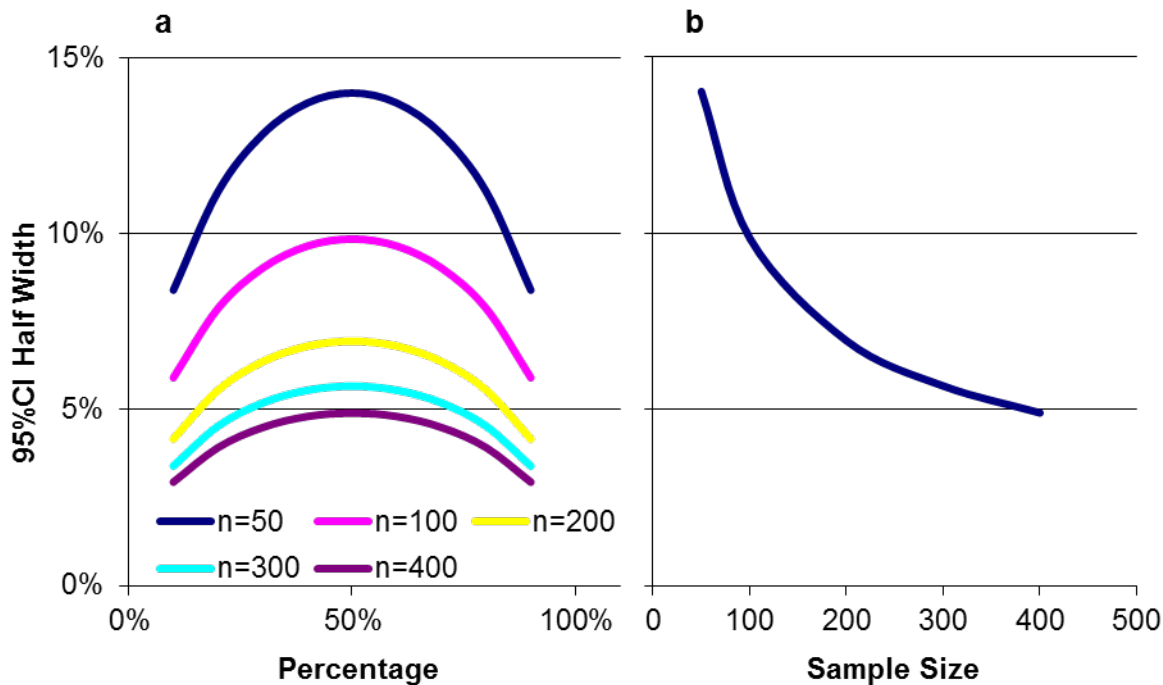


Figure 4. The 95% confidence interval (CI) half-widths for origin based on a range of hatchery to natural spawner proportions and sample sizes (a), and the 95% CI half-widths when 50% of the fish are of hatchery origin (b).

Critical Assumptions: To generate an unbiased estimate of origin, sampling must be representative of the population. Because data on fish age and origin are determined from the same samples, the same critical sampling assumptions from the age structure section apply to origin. Those critical assumptions are not repeated here. For the expanded mass mark method the critical assumption is that the juvenile QA/QC sample used to determine the brood year mass mark rate is representative of the population, and that marked and unmarked hatchery fish survive at the same rate. For the adipose-clip and otolith mass mark methods, the critical assumption is that 100% of hatchery fish are marked. For the expanded CWT method, the critical assumption is that the number of released hatchery juveniles and their CWT tagging rate is known.

Scoring: Based on the methods and critical assumptions for the Diversity-origin indicator and our general scoring rules (Table 2), guidelines for scoring origin are presented in Table 17. The highest score requires meeting the CV and includes representative sampling over the migration or spawning period accompanied by origin selectivity tests that demonstrate no bias in origin and the use of the expanded mass mark method, which should have negligible bias. A high score requires representative sampling over the migration or spawning period, which is likely to lead to unbiased estimates of origin with a CV less than the population goal. A moderate score is achieved when the CV is met with representative sampling over the majority of the spawning or migration period. Hatchery origin estimates assume a 100% mass mark rate on all juvenile fish. A low score for origin occurs when the CV is achieved OR representative sampling occurs over the majority of the spawning or migration period. The lowest score occurs when the CV is not achieved AND there is non-representative spatial/temporal sampling.

Table 17. Criteria for scoring monitoring efforts for the origin indicator.

Score	Precision Guideline	Bias Guideline
1.00	CV met, AND	Representative sampling of fish over the migration period or spawning ground surveys over the spawning period. <i>Selectivity test for this indicator is implemented.</i> Origin estimates are by age and corrected with the hatchery mass mark rates.
0.75	CV met, AND	Representative sampling of fish over the migration period or spawning ground surveys over the spawning period. <i>Selectivity test for this indicator is not implemented.</i> Origin estimates are by age and corrected with the hatchery mass mark rates.
0.50	CV met, AND	Representative sampling of fish over the migration period or spawning ground surveys over the spawning period. Selectivity test for this indicator is not implemented. Hatchery origin estimates <i>assume 100% mass mark rate.</i>
0.25	CV met, OR	Representative sampling of fish over the migration period or spawning ground surveys over the spawning period. Selectivity test for this indicator is not implemented. Hatchery origin estimates <i>assume 100% mass mark rate.</i>
0.00	CV not met AND	No monitoring <i>OR non-representative sampling OR sampling not over the spawning period</i>

Indicators: Spatial Structure –Juvenile and Spawner Distributions

NOAA recommends that census or probabilistic survey based methods be used to detect changes of $\pm 15\%$ in spawner and juvenile distributions with 80% certainty (Crawford and Rumsey 2009). This guidance on detection of changes in spawner and juvenile distribution is vague and somewhat difficult to interpret. Annual changes in juvenile or spawner distribution may be influenced by abundance, hatchery programs, flow, habitat restoration actions, and natural processes that form and remove intermittent barriers such as logjams. For example, the upper extent of the LCR fall Chinook spawning distribution changes annually (Rawding et al. 2010). Monitoring programs could be established to detect statistically significant changes in spatial distribution but it is unclear if these changes are biologically relevant or simply natural variation in distribution due to fluctuating environmental conditions. Additional effort is needed to develop biologically relevant guidelines for spatial structure. As an interim guideline, we propose that if juvenile and spawner abundance is based on a spatial survey design, then the scoring is the same for juvenile and spawner distribution. We believe that the juvenile spatial structure indicator is only useful for coho and steelhead in the LCR because chum typically move downstream immediately after emergence and juvenile LCR spring Chinook tend to migrate to mainstem and freshwater estuary habitat earlier than upriver spring Chinook. These early life history traits of chum and LCR spring Chinook provide narrow time windows for sampling juvenile distributions.

Methods

Due to the lack of specific guidelines, analytical approaches for juvenile and spawner distribution data have not been standardized. One approach is to determine the occupancy rate of juveniles or spawners (i.e., the percentage of sites in which at least one fish was observed in sampled reaches within the spawner distribution). ODFW defines adult occupancy as a peak count of at least 4 spawners-per-mile of stream surveyed. A time series analysis of the annual occupancy rate could be used to detect changes in occupancy over time. Another approach is to revisit randomly chosen sites annually. With this approach, year-to-year changes in the abundance of juveniles or spawners could be examined using contingency tables. By comparing and contrasting abundance by site, changes in the distribution of abundance could be compared to changes in distribution of occupancy.

It is difficult to determine the spatial structure of a population when mark-recapture methods are used unless recovery reaches were chosen based on probabilistic sampling. In addition, redd or live fish observations must be recorded concurrently with the recovery of carcasses. We propose an alternative method to estimate

spatial structure if a complete census of a closed population method is used to estimate abundance: a complete survey of the sampling frame coincident with the timing of peak spawner abundance.

Spawner surveys are not possible for some populations due to high elevation snow, remote sites with limited access, or high gradient river canyons. In cases such as these, it is not possible to safely conduct spawning ground surveys or even observe spawners. We believe there should be alternative approaches for these situations. We suggest the following alternatives be considered: first, adult snorkel surveys could be conducted during a period of low water. This may allow representative sampling of the pre-spawning distribution (Rawding and Cochran 2005). Alternately, the spawning distribution may be estimated from fry surveys conducted shortly after emergence and before juveniles disperse downstream. One drawback of this approach is that some species, such as cutthroat trout and steelhead, can be difficult to distinguish at this life stage. Another issue with this approach is that the origin of the spawners is unknown and anadromy may be difficult to assess without otolith microchemistry (Zimmerman and Reeves 2000) or genetic methods. Another alternative is to use juvenile outmigrant trapping at multiple sites within a watershed to estimate juvenile and spawner distribution (Rawding and Cochran 2005). However, the number of smolt trap sites in a watershed is usually limited by resource constraints so changes in spatial structure could only be assessed over large scales. Because these alternative approaches do not actually measure spawner distribution, we suggest a maximum score of 0.5 be applied to these assessments.

Precision and Bias: The precision of the estimate is directly related to the number of reaches sampled, the number of spawners observed, and observer efficiency.

Critical Assumptions: For the occupancy methods described above it is assumed the detection probabilities are 100%. Lower detection probabilities will tend to underestimate fish occupancy rates. This problem is of more concern for small as compared to large populations, and when sample reaches are near the limits of fish distribution. These reaches typically have a lower density of spawners. Surveys conducted in highly turbid waters also result in detection probabilities less than 100%. For the sampling frame surveys, the critical assumptions are that observation efficiency is consistent throughout the survey and there is no difference in spawn timing by location. Critical assumptions for fry surveys are that fry distribution at the time of the survey reflects spawner distribution and the spatial structure of hatchery and natural origin spawners is similar. Another issue is that fry must be identified to species and resident fish must be distinguishable from anadromous fish. For the juvenile trapping method, the key assumptions are that the scale of the spatial structure is representative of the population and that the life stage trapped accurately reflects spawner distribution.

Scoring: Based on the methods and critical assumptions for Spatial structure—juvenile and spawner distributions and our general scoring rules (Table 1), specific guidelines for scoring were developed and are presented in Table 18. These guidelines are a modification of the sampling guidelines for age structure, origin, and sex ratio, and use spatial sampling designs to estimate spawner abundance. The highest score is achieved when the precision CV target is met for spawner abundance from a probabilistic spatial sampling design based on empirical distribution data, or a species distribution model is used. A complete survey of the spawning distribution near peak spawning is also required to achieve the highest score. For a high score, the sampling frame may be based on the agency's spawning distribution layer. The score is downgraded to moderate (0.5) if a spatially balanced design is used over the majority of the spawning period or a near peak survey covers 50% or more of the sampling frame. A low score occurs if the CV is met or the moderate bias guideline is met. The lowest score occurs when the precision CV standard is not met and non-representative sampling occurs in an uninformed sampling frame.

Determining Monitoring Gaps and Needs

For each VSP indicator and each salmon and steelhead population in the LCR, the existing monitoring efforts were scored according to the criteria described in the previous section. For any of the VSP indicators, a score of 1.0 indicates that there are currently no additional monitoring needs for that indicator. Scores less than 1.0 indicate the relative gap between the monitoring that is currently being conducted for an indicator and what is needed.

Table 18. Criteria for scoring monitoring effort for the juvenile and spawner distribution indicator.

Score	Precision Guideline	Bias Guideline
1.00	CV met for juvenile or spawner abundance met, AND	For juvenile distribution see Table 3. For spawner distribution see Tables 8-13 for scoring pertinent to methodology employed.
0.75	CV met for spawner abundance met, AND	For juvenile distribution see Table 3. For spawner distribution see Tables 8-13 for scoring pertinent to methodology employed.
0.50	CV met for spawner abundance met, AND	For juvenile distribution see Table 3. For spawner distribution see Tables 8-13 for scoring pertinent to methodology employed.
0.00	CV met for spawner abundance met, OR	No monitoring OR For juvenile distribution see Table 3. For spawner distribution see Tables 8-13 for scoring pertinent to methodology employed.

We scored the VSP monitoring activities for each LCR salmon and steelhead population following the guidelines developed for each indicator. Each VSP indicator score was multiplied by the indicator priority score developed in Objective 1 (Rawding et al. 2010). As described in the Objective 1 report, the prioritization score was derived from four component scores that assessed the fish population recovery priority, current natural origin fish abundance, infrastructure available to monitor the population, and special cases identified in the recovery plans. The difference between indicator priority score and current VSP monitoring efforts score is the monitoring gap. Total VSP indicator scores were calculated for each species as the sum of all the VSP indicator scores for a species and population multiplied by the indicator priority score. Similarly, total scores were determined for adults by population, and adults and juveniles by sub-basin. These metrics are described further in the Objective 1 report (Rawding et al. 2010). The prioritization scores and the VSP indicator scores were charted as bar graphs to show the gaps between priority monitoring needs and current monitoring efforts by species, sub-basin, and life stage. In addition, short summaries were compiled for each VSP indicator by population to highlight the recovery priority of each populations and current monitoring efforts. The monitoring gap provides managers and policy makers with information on the extent of recovery plan implementation.

Results

Documentation of the current LCR salmonid recovery monitoring program and its gaps are available as an Excel worksheet. These results are too detailed to present in the results section, but may be obtained from the authors or the PNAMP web site. The monitoring gaps in the current LCR salmonid recovery monitoring program are graphically displayed. The displays include combined gaps for adults and juveniles, adults only, and juveniles only, and are presented for each VSP indicator.

Chum Salmon

The comparison of the monitoring priorities for chum salmon populations with current monitoring efforts on this species in the LCR is available for review in Figure 5. Populations that have been extirpated or that are functionally extinct were scored 0.00 and denoted with an asterisk (*) next to the population name on the X axis to indicate that there are too few fish in the population to effectively monitor at this time.

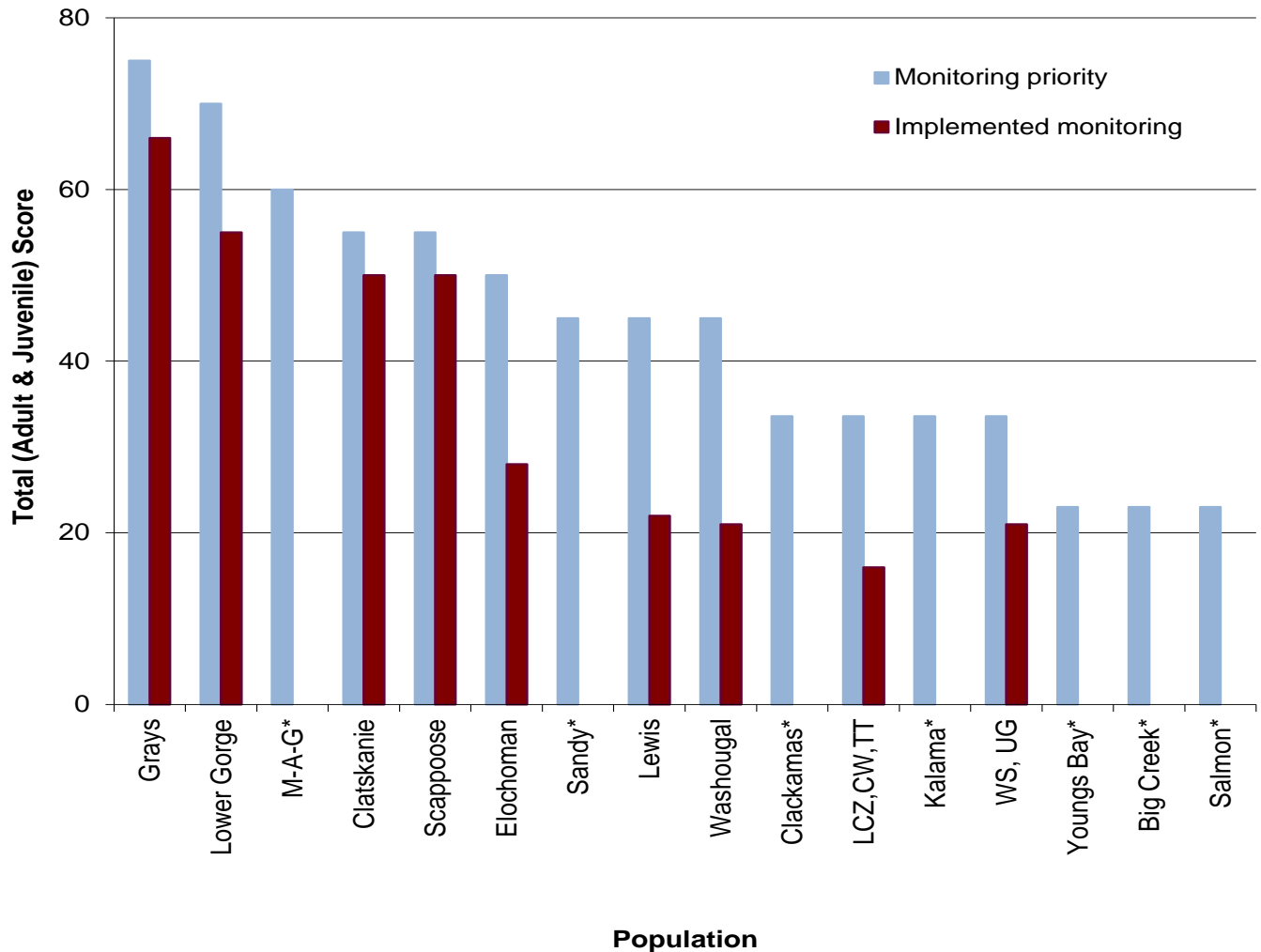


Figure 5. Comparison of chum salmon monitoring priorities and implemented monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show an “Implemented monitoring” bar on the graph because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (M-A-G = Mill-Abernathy-Germany Creek, LCZ, CW, TT = Lower Cowlitz, Coweeman, and Toutle rivers, WS,UG = White Salmon River and Upper Gorge tributaries).

The Salmon, Kalama, and Mill-Abernathy-Germany (M-A-G) creeks in Washington and Big Creek, Youngs Bay, and the Clackamas and Sandy rivers in Oregon are examples of watersheds with functionally extinct chum populations. The most abundant chum populations are found in the Grays River and Lower Columbia River Gorge streams. Chum reintroduction efforts are planned for the Clatskanie and Scappoose rivers. High monitoring effort scores indicate that personnel and fiscal resources are being allocated to maintain and enhance existing monitoring programs and develop and implement new monitoring efforts on these high

priority populations. The continuation of existing monitoring programs on abundant chum populations and implementation of new monitoring efforts to complement chum reintroduction efforts are high priorities.

Populations with low spawner abundance tend to have low VSP monitoring scores, indicating monitoring efforts need to be improved. Because the number of adult fish that return to spawn is low for these populations, it is difficult to meet the VSP precision standards for these populations; the result is lower scores. The Elochoman, Lewis, Washougal, and Cowlitz rivers and streams in the upper Columbia River Gorge are examples of watersheds where monitoring efforts are hampered by low fish abundance.

To provide better resolution of the monitoring gaps for chum salmon, we assessed monitoring efforts for the adult and juvenile life stages separately (Figures 6 and 7). For the juvenile life stage, chum fry distribution and abundance indicators are not required and smolt trapping meets the minimum standard of one site per stratum in the Coastal and Gorge strata. No juvenile monitoring is currently proposed for chum salmon in the Cascade stratum because there are no viable populations.

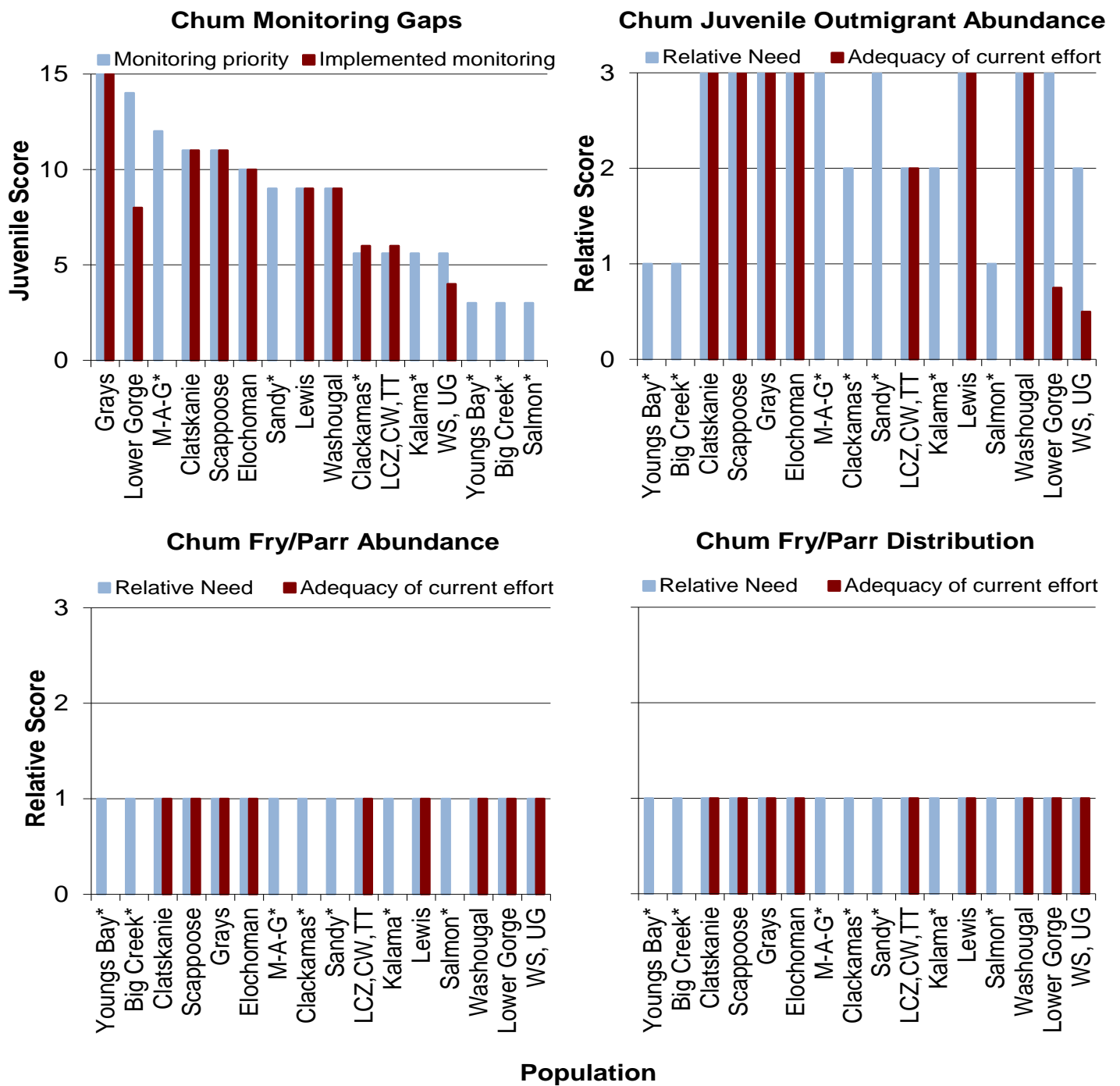


Figure 6. Comparison of juvenile chum salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of monitoring effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (M-A-G = Mill-Abernathy-Germany Creek; LCZ, CW, TT = Lower Cowlitz, Coweeman, and Toutle rivers; WS,UG = White Salmon River and Upper Gorge tributaries).

Deficiencies in the current chum salmon monitoring program occur at the adult stage (Figure 7). The migration and spawn timing and adult distribution indicators for monitoring priorities and current monitoring effort are aligned. For spawner abundance, improvements are needed for populations where chum salmon are present in low numbers because precision is poor and untested assumptions exist for AUC estimates. These same

populations also have low scores for age and sex monitoring for the same reasons. As these chum salmon populations rebuild, the adult abundance, sex, and age scores will improve. The origin scores are low for the Grays and Lower Gorge populations even though the otoliths of hatchery fish are thermally marked. Although this technology is reliable, the QA/QC criteria for implementing and verifying the thermal mark are not reliably met. The adult recruitment scores for chum salmon are low and this indicates that estimates of fisheries impacts for this species need improvement. The direct harvest of chum salmon is prohibited below BON, but indirect take as the result of incidental catch of chum salmon in commercial and recreational fisheries is a concern. Currently, there is no statistical monitoring program set up to estimate number of fish handled, stock composition, and release survival rate in these fisheries.

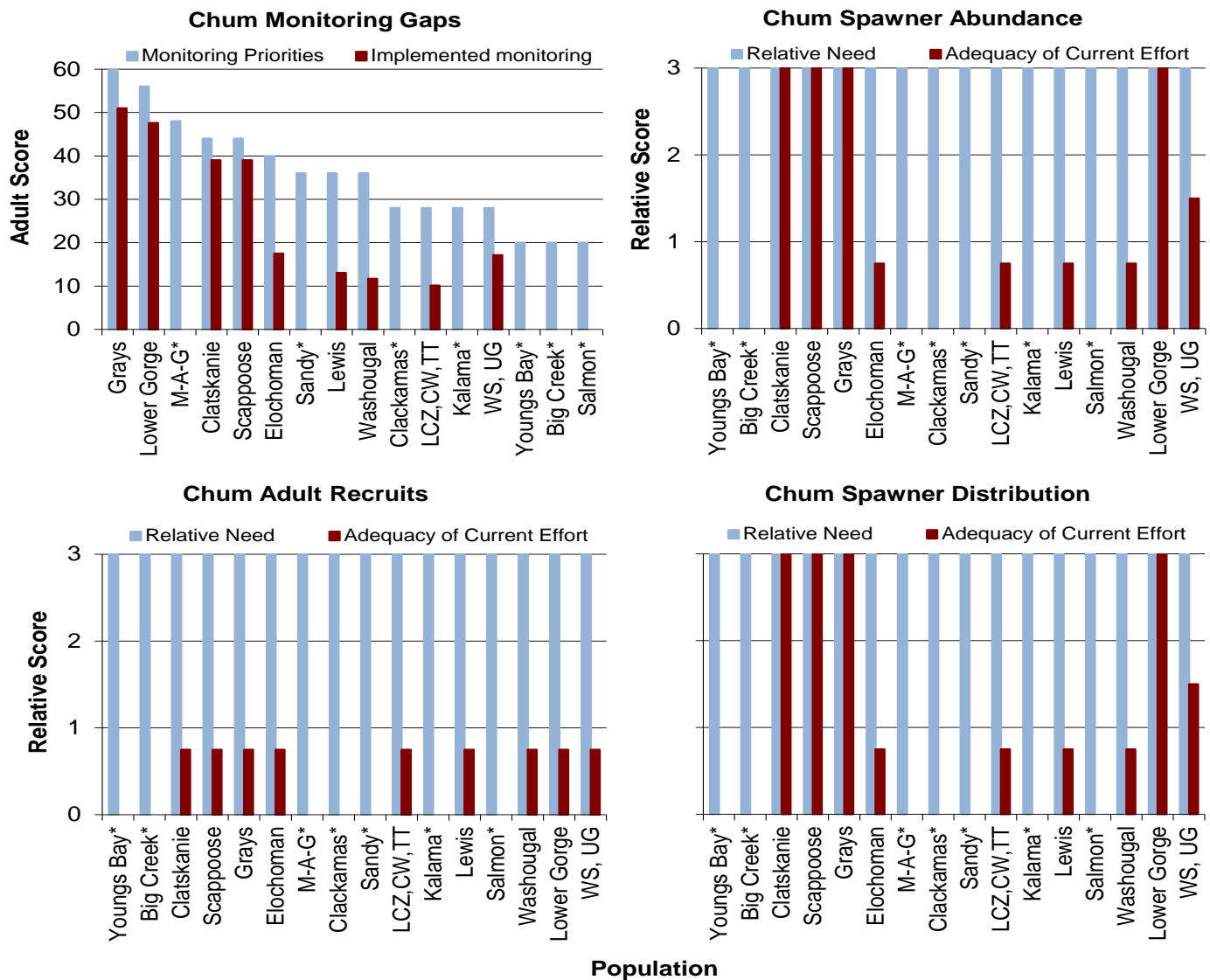


Figure 7. Comparison of adult chum salmon monitoring priorities and current monitoring effort in the LCR by population. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of monitoring effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (M-A-G = Mill-Abernathy-Germany Creek; LCZ, CW, TT = Lower Cowlitz, Coweeman, and Toutle rivers; WS, UG = White Salmon River and Upper Gorge tributaries).

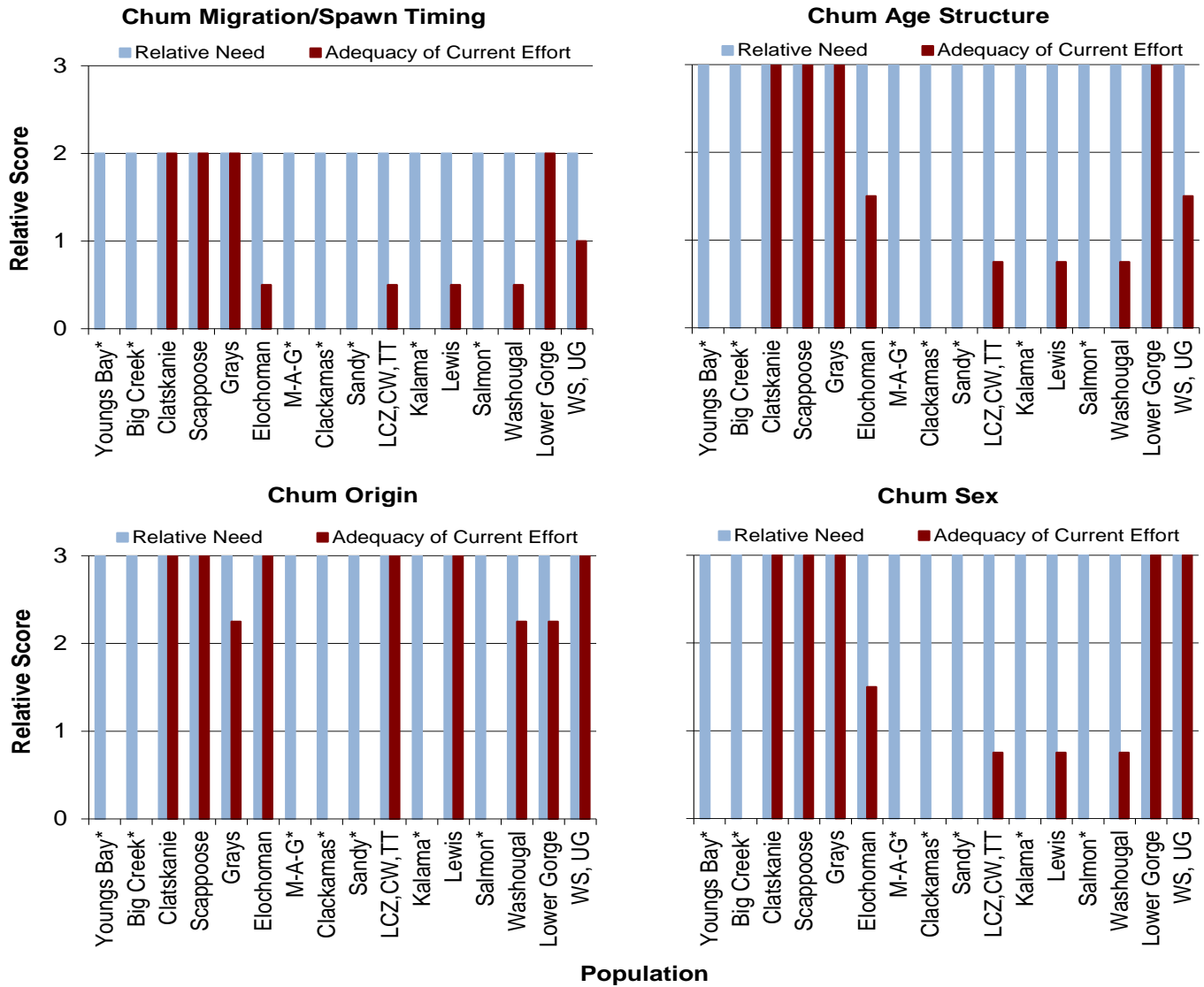


Figure 7 continued. Comparison of adult chum salmon monitoring priorities and current monitoring efforts in the LCR by population. Populations asterisked on the X axis do not show “Adequacy of monitoring effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (M-A-G = Mill-Abernathy-Germany Creek; LCZ, CW, TT = Lower Cowlitz, Coweeman, and Toutle rivers; WS,UG = White Salmon River and Upper Gorge tributaries).

Coho Salmon

The graphical assessment of the monitoring priorities and the current monitoring effort for coho salmon is given in Figure 8. The current monitoring effort is below desired levels for all coho populations in the LCR. Although some monitoring is currently conducted on the functionally extinct Youngs Bay and Big Creek populations, these populations have low monitoring priority because there are insufficient numbers of fish collected to meet monitoring precision standards. Monitoring efforts on the Upper Gorge/White Salmon and Upper Gorge/Hood have a low ranking. The remaining populations are in the middle and all scores indicate current monitoring efforts are inadequate to support recovery goals for this species.

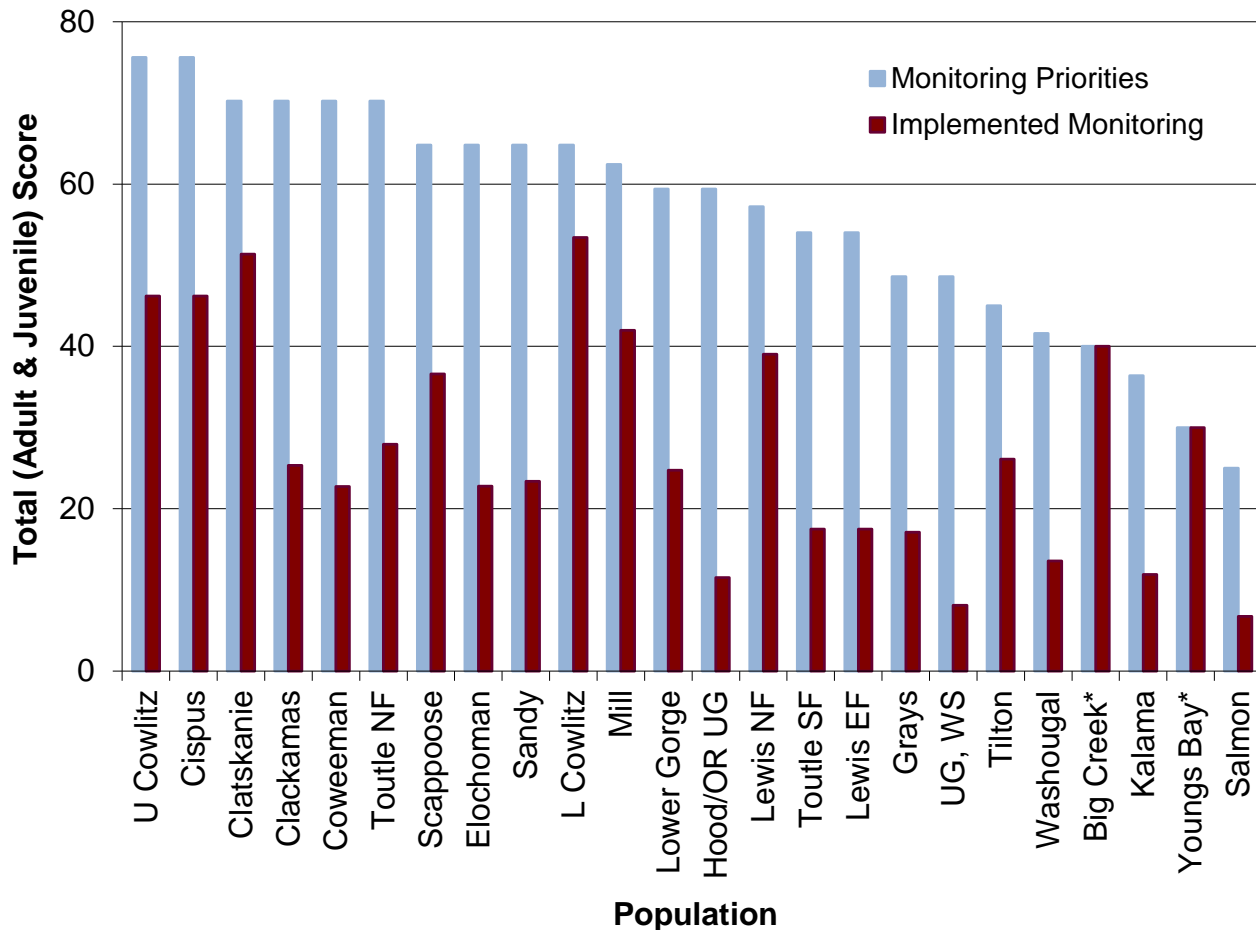


Figure 8. Comparison of coho salmon monitoring priorities and current monitoring effort in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. (U = Upper; NF = North Fork; L = Lower; Hood/OR UG = Hood River and Oregon Upper Gorge; SF = South Fork; EF = East Fork; UG, WS = White Salmon River and Upper Gorge tributaries).

Current juvenile monitoring priorities compared to monitoring efforts for coho indicate a need for improvement as well (Figure 9). The juvenile outmigrant program is meeting monitoring needs because there is at least one strong juvenile coho salmon monitoring program in each strata. Parr monitoring is meeting monitoring needs in some Oregon populations but is below desired levels in other Oregon populations. Washington has not developed a parr monitoring program, so Washington scores for the index of parr

abundance and spatial structure are zero and is reflected in the low juvenile scores for all Washington LCR coho populations.

Comparison of adult monitoring priorities and current monitoring efforts for coho are presented in Figure 10. Monitoring efforts on the Big Creek and Youngs Bays populations come closest to meeting their monitoring priority score. The low scores in the Upper Gorge and Hood River reflect a lack of adult monitoring in these areas by Washington and the removal of fish counting facilities on the Hood River in Oregon. Monitoring effort on most LCR coho populations is sufficient to achieve a moderate VSP monitoring score. The spawner abundance graph indicates that populations monitored with weirs tend to have higher monitoring effort scores than other populations. However, survival from weirs to spawning sites is a critical uncertainty for these populations.

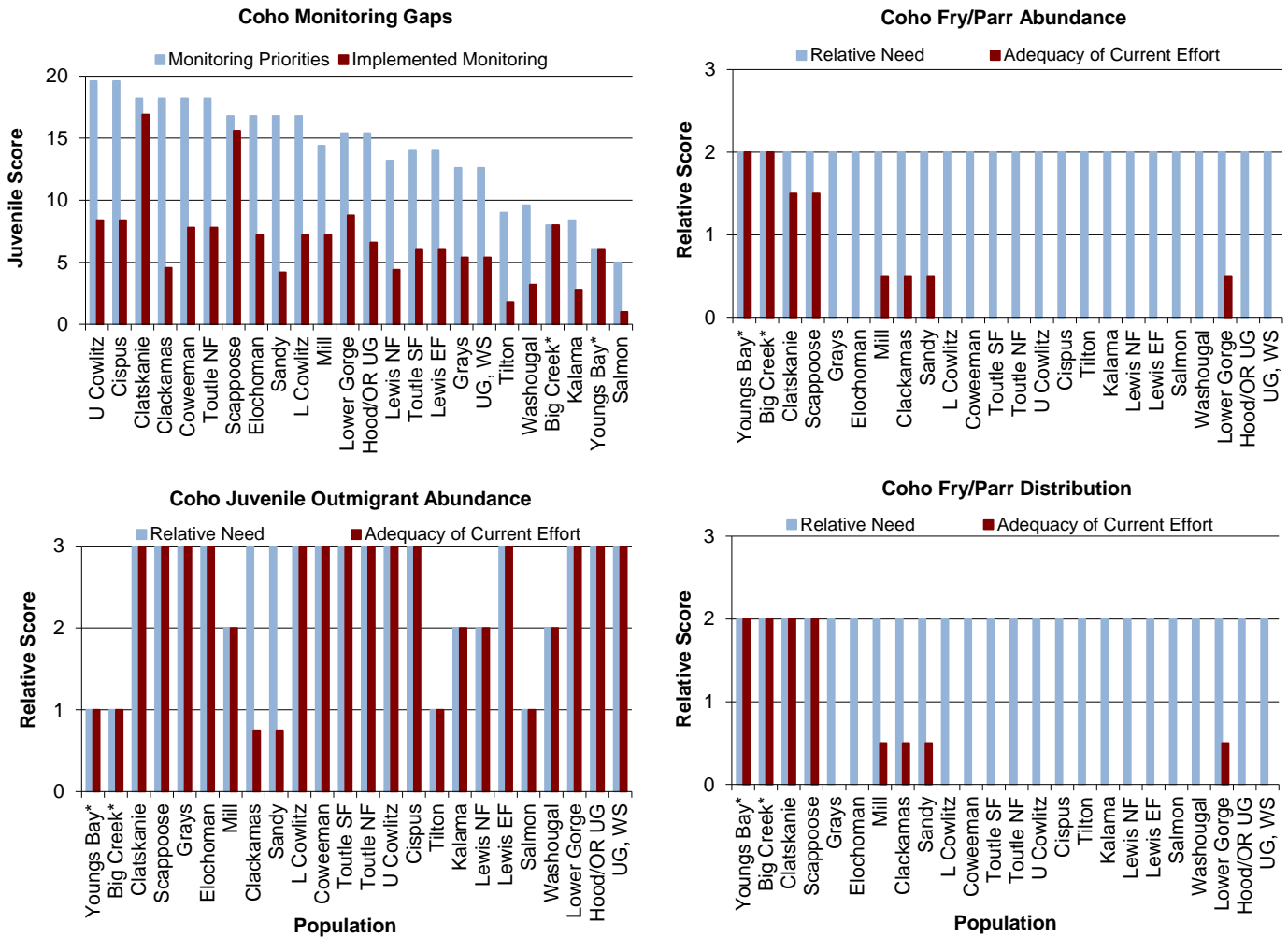


Figure 9. Comparison of juvenile coho salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. (U = Upper; NF = North Fork; L = Lower; Hood/OR UG = Hood River and Upper Gorge tributaries, OR; SF = South Fork; EF = East Fork; UG, WS = White Salmon River and Upper Gorge tributaries, WA).

Assessments of the adult recruitment indicator for coho populations in the LCR generated moderate to high scores. These moderate to high scoring assessments are the result of the extensive CWT mass marking program on juvenile hatchery coho salmon in the LCR. These hatchery fish are used as surrogates to estimate

harvest rates on wild populations. Double index tagging programs at hatcheries on the Lewis and Toutle rivers allow more accurate estimates of fisheries impacts on these wild populations which are subject to wild salmon release regulations. Coho migration/spawn timing is rated high in all monitored populations, while sex and origin are rated high except for some primary populations with low abundance and carcass recovery rates. Because of limited carcass recoveries, coho age structure scores were low for most LCR populations except where fish are trapped at dams, fish ladders, or weirs. While weirs and traps generally produce high assessment scores for many adult indicators, these approaches yield low scores for spawner distribution unless radio tracking or spawning ground surveys are implemented as well; this explains the low spawner distribution scores for the Cowlitz populations above the Barrier dam and Sediment Retention Structure (SRS) on the NF Toutle River.

The greatest area of concern for adult coho monitoring in the LCR is spawner abundance. With the exception of the populations monitored with weirs, ODFW uses AUC methods to estimate the adult abundance indicator and relies on untested critical assumptions of observer efficiency and residence times developed three decades ago on Oregon Coast populations. In 2010, WDFW initiated surveys on coho spawner abundance and relied mpg level estimates of redds-per-female that were imprecise . For some populations, the number of reaches-per-population may not be sufficient to achieve precision targets for the spawner abundance indicator.

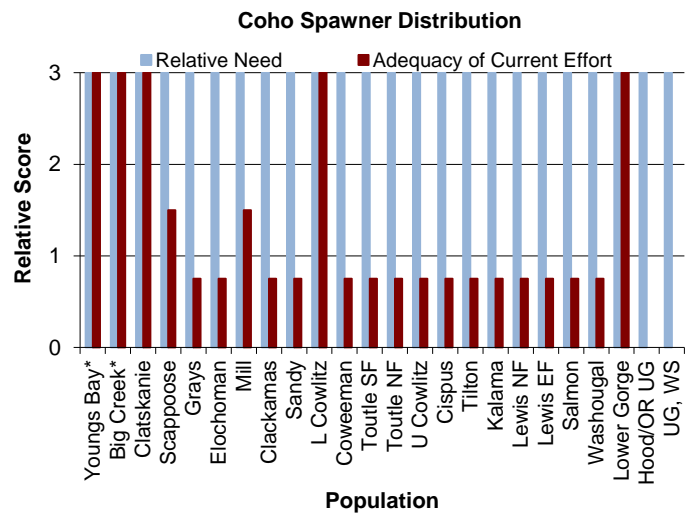
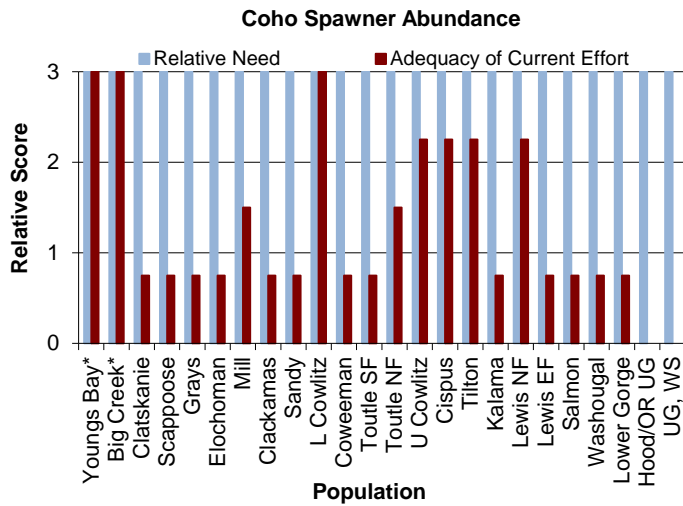
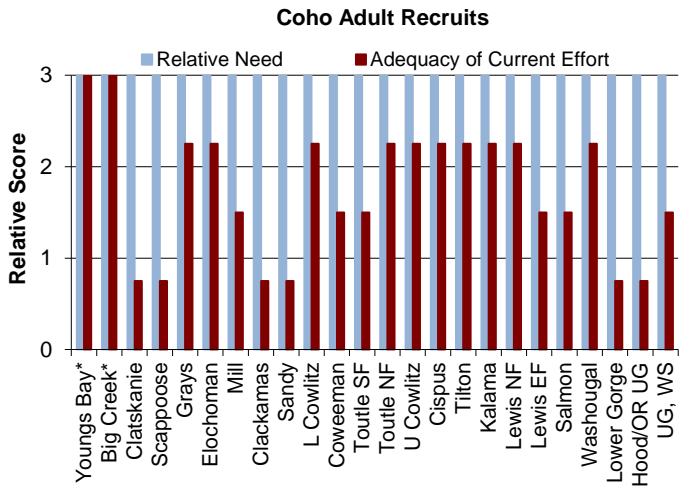
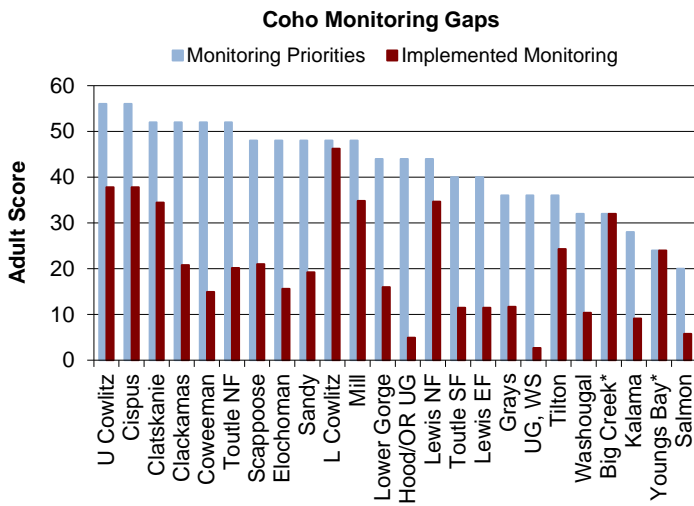


Figure 10. Comparison of adult coho salmon monitoring priorities and current monitoring effort in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. (U = Upper; NF = North Fork; L = Lower; Hood/OR UG = Hood River and Oregon Upper Gorge tributaries; SF = South Fork; EF = East Fork; UG, WS = White Salmon River and Washington Upper Gorge tributaries).

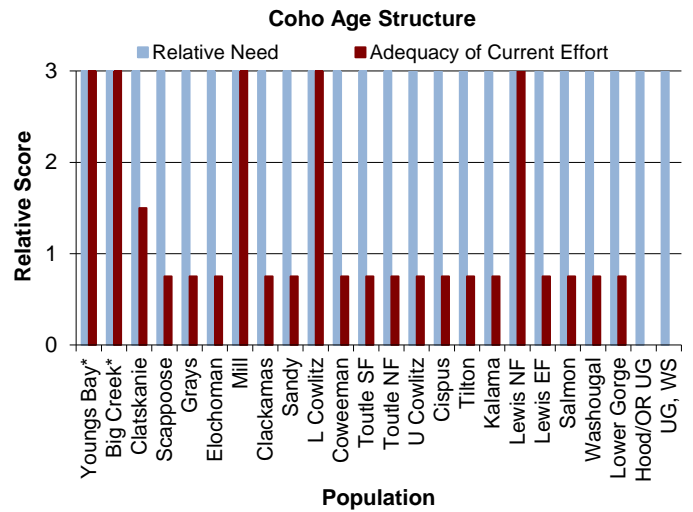
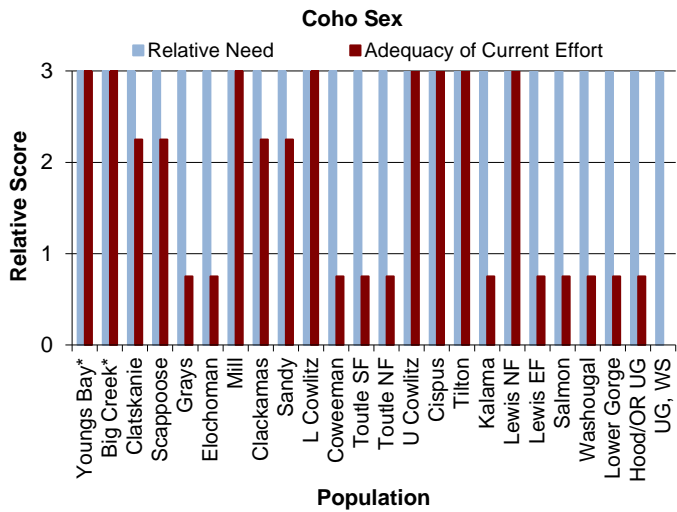
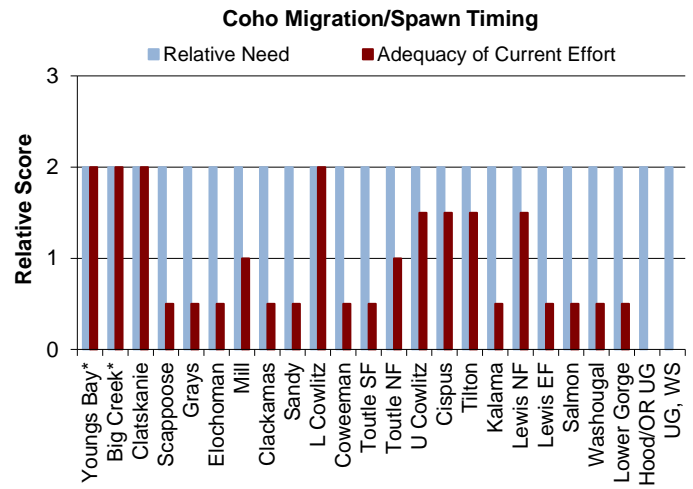
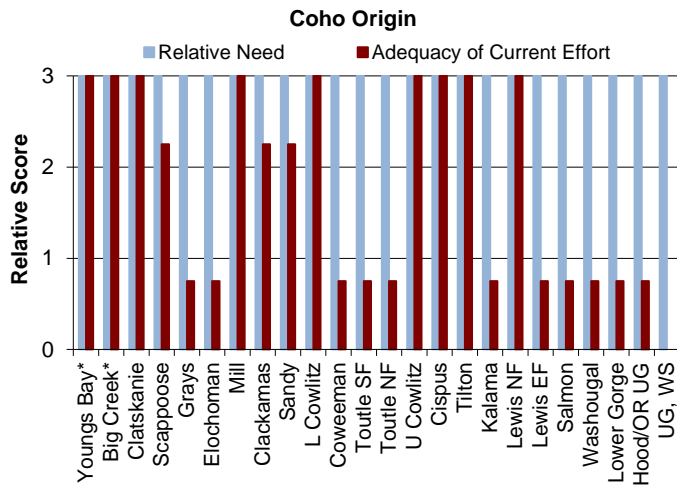


Figure 10 continued. Comparison of adult coho salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. (U = Upper; NF= North Fork; L = Lower; Hood/OR UG = Hood River and Upper Gorge tributaries, OR; SF = South Fork; EF = East Fork; UG,WS = White Salmon River and Upper Gorge tributaries, WA).

Fall Chinook Salmon

Assessment of fall Chinook monitoring priorities compared to current monitoring efforts are found in Figure 11. Most monitoring efforts on LCR fall Chinook populations are close to meeting their priority score. However the Grays, Scappoose, Clatskanie, Clackamas, and Sandy population monitoring efforts need moderate improvement while the White Salmon and Hood River populations need additional effort. The Salmon Creek population in Washington is functionally extinct and is not monitored at this time. Monitoring on the Youngs Bay and Big Creek populations have low monitoring priorities because these populations are functionally extinct with too few fish to effectively monitor. The assessment of the current juvenile fall Chinook monitoring efforts compared to monitoring priorities is found in Figure 12. Monitoring efforts on the Clackamas, Sandy, and Hood River populations are inadequate due to the lack of comprehensive juvenile outmigrant monitoring.

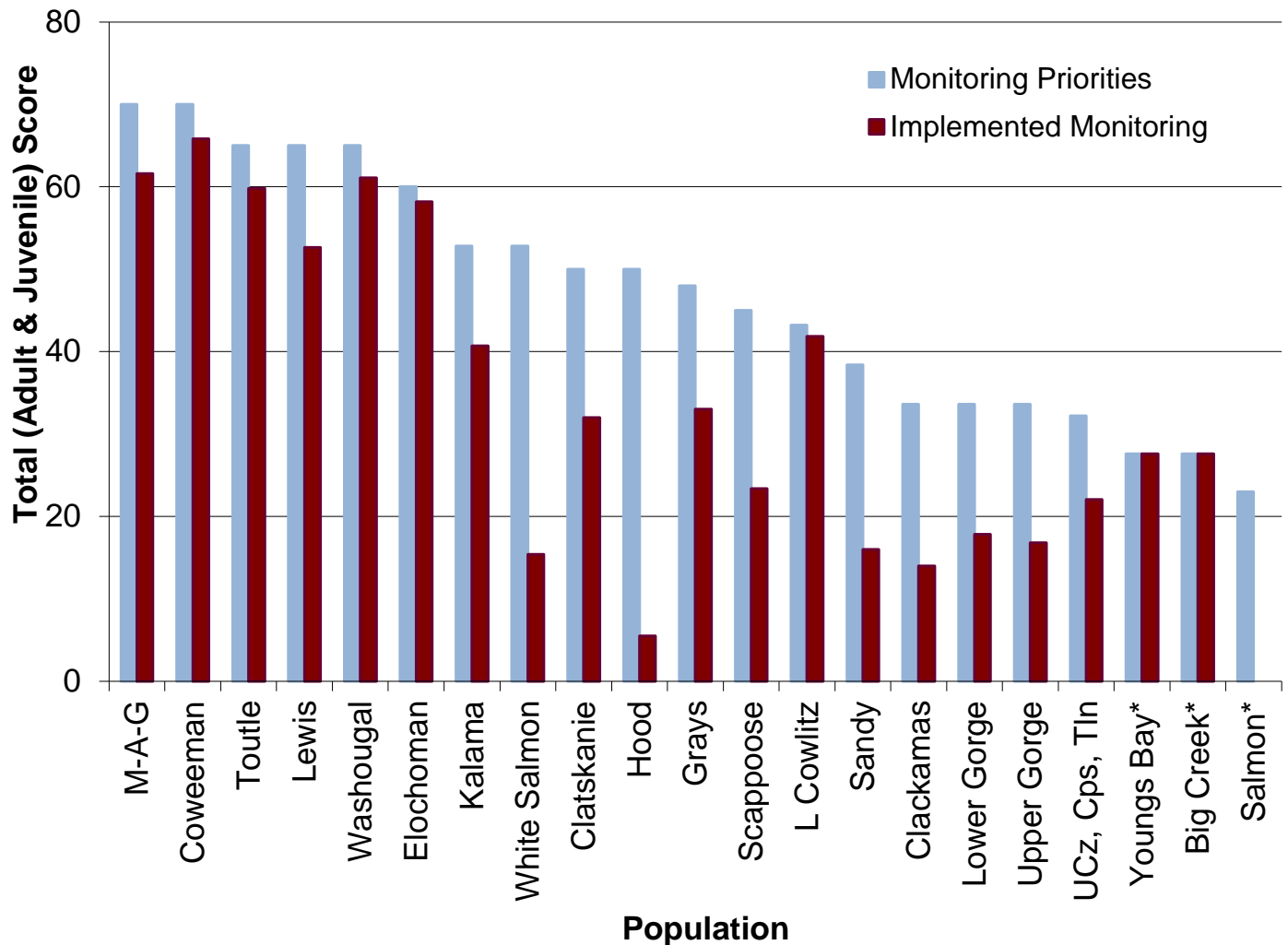


Figure 11. Comparison of fall Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. The extirpated Salmon Creek population is not monitored. (M-A-G = Mill-Abernathy-Germany; L = Lower; UCz, Cps, Tln = Upper Cowlitz, Cispus, and Tilton rivers).

Assessment of monitoring priority compared to current monitoring efforts for adult fall Chinook salmon is found in Figure 13. The Hood and White Salmon populations need the most improvement relative to their monitoring priorities. Examination of the individual adult indicators suggests that monitoring efforts for several populations do not meet spawner abundance monitoring goals either because of small population sizes or untested critical assumptions. The large CWT program for tule fall Chinook provides estimates of

harvest for hatchery stocks; however, DIT programs, which provide a more accurate assessment of selective fisheries impacts are not in place. The spawner distribution for fall Chinook is accurately captured in the LCR except where weir monitoring is not accompanied by radio tagging or spawning ground surveys. The migration/spawn timing indicator is met for most populations except where monitoring programs are not in place.

The assessment of monitoring efforts for the VSP diversity indicators of age and origin indicate that monitoring efforts meet priority goals for some populations. Populations with low spawner abundance present a challenge to monitoring efforts because it is difficult to collect enough samples from carcasses on the spawning ground to adequately calculate metrics for the diversity indicators.

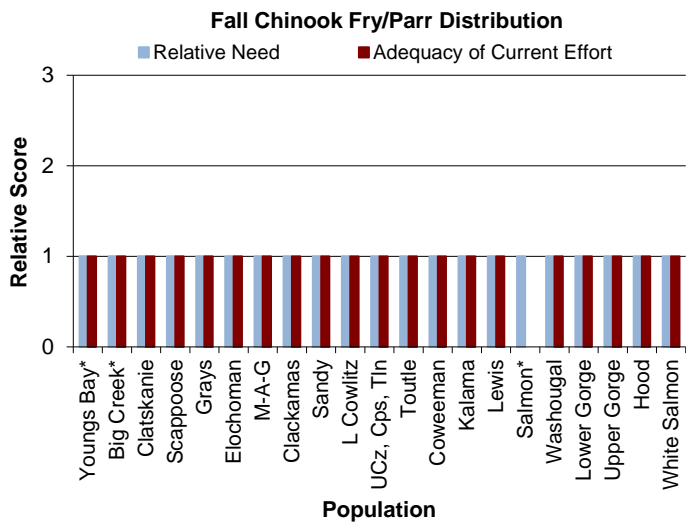
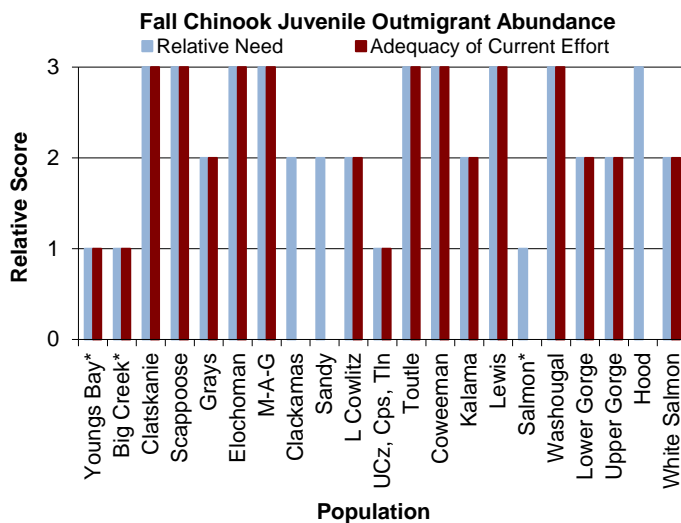
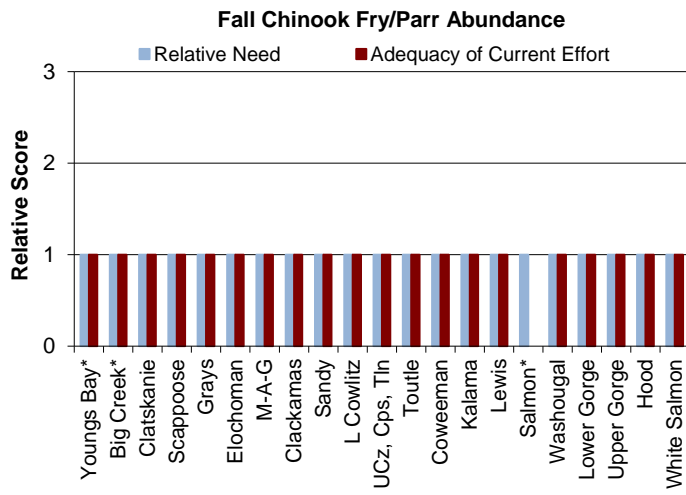
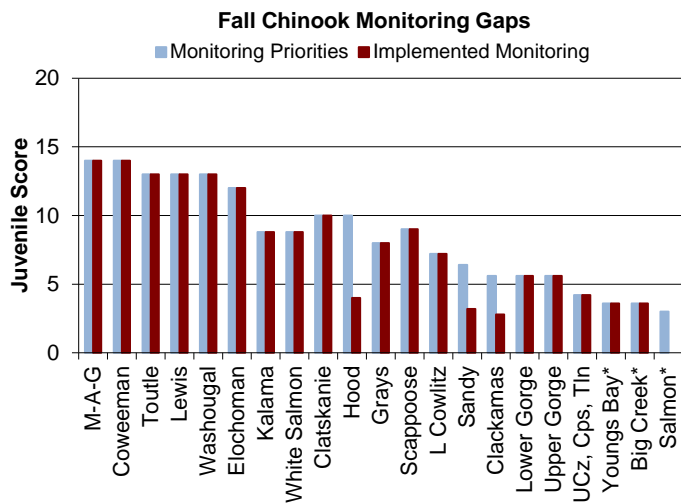


Figure 12. Comparison of juvenile fall Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. The extirpated Salmon Creek population is not monitored. (M-A-G = Mill-Abernathy-Germany; L = Lower; UCz, Cps, Tin = Upper Cowlitz, Cispus, and Tilton rivers).

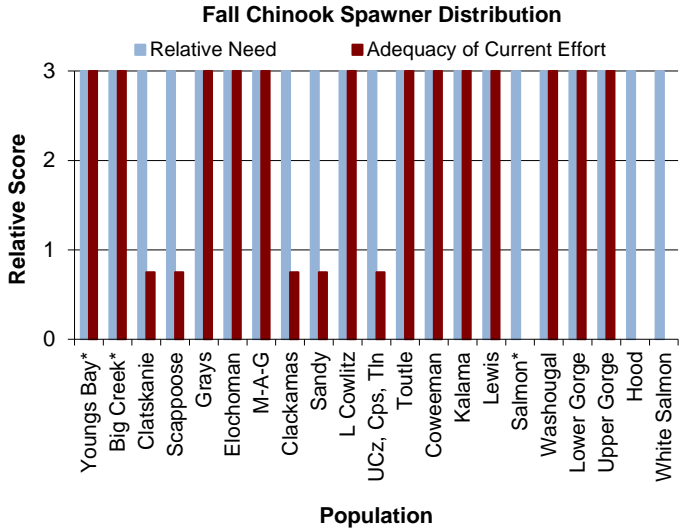
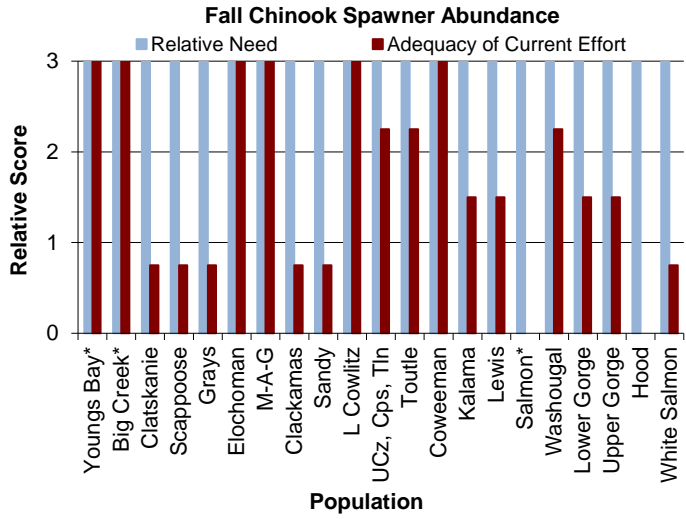
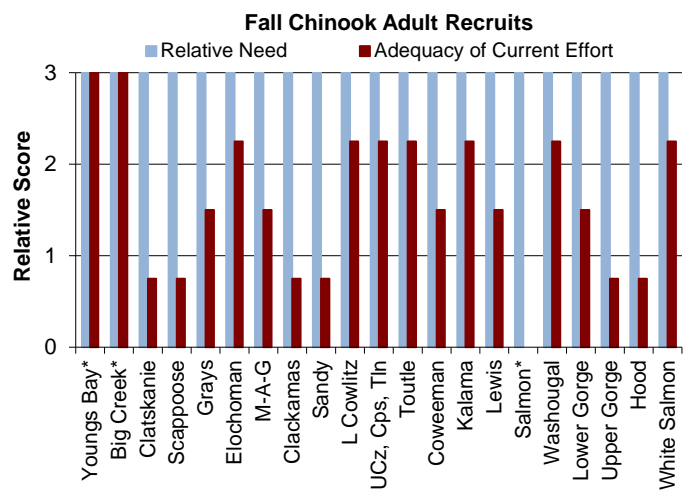
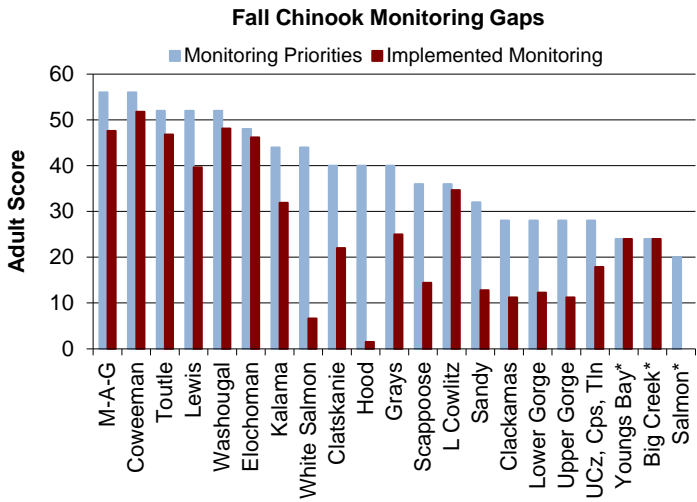


Figure 13. Comparison of adult fall Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. The extirpated Salmon Creek population is not monitored. (M-A-G = Mill-Abernathy-Germany; L = Lower; UCZ, CPS, TTN = Upper Cowlitz, Cispus, and Tilton rivers).

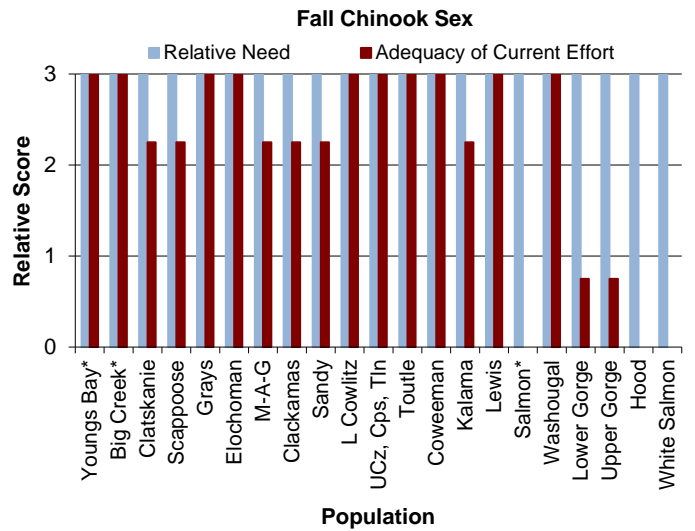
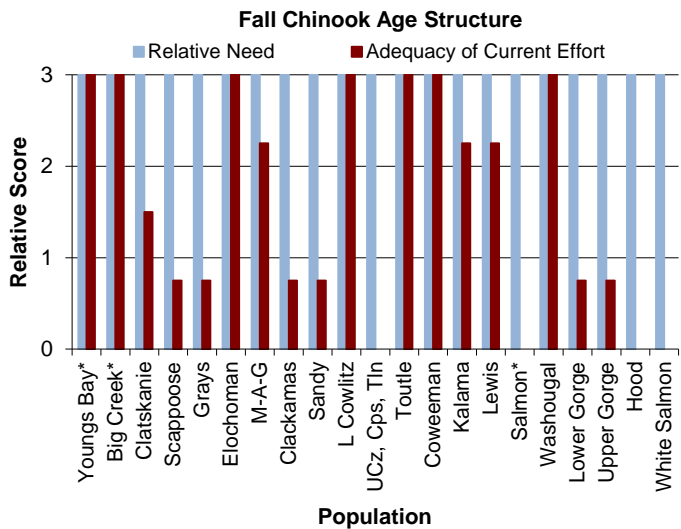
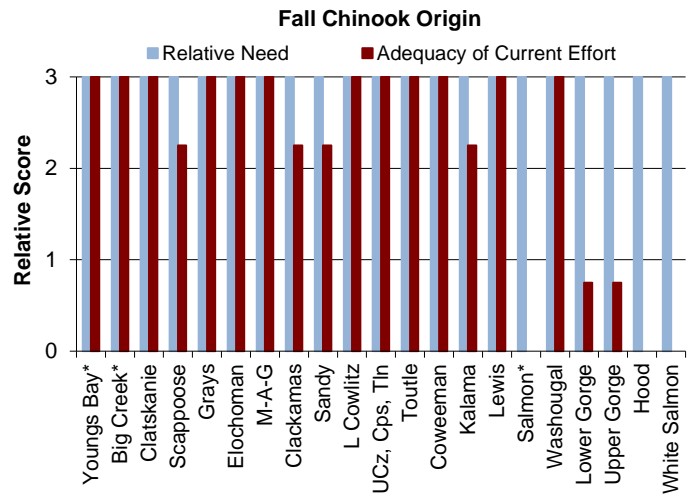
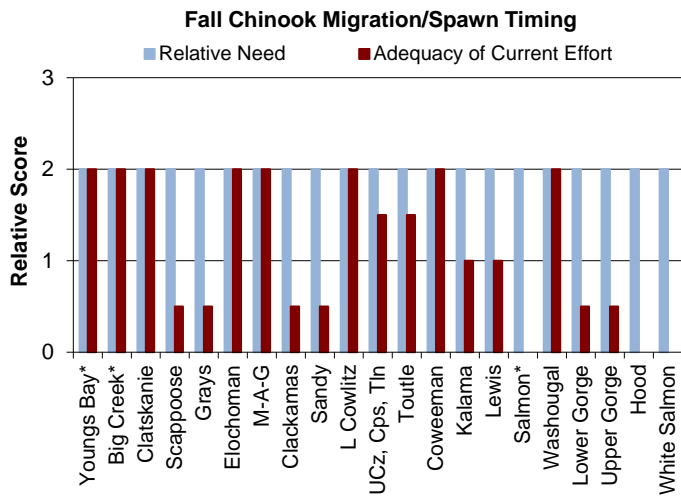


Figure 13 continued. Comparison of adult fall Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis are extirpated or functionally extinct populations; monitoring precision standards may not be met for these populations because of inadequate numbers of fish to effectively monitor. The extirpated Salmon Creek population is not monitored. (M-A-G = Mill-Abernathy-Germany; L = Lower; UCZ, CPS, TTN = Upper Cowlitz, Cispus, and Tilton rivers).

Late Fall Chinook Salmon

Late fall Chinook salmon populations are found in the Lewis and Sandy rivers. The monitoring gaps for these populations are found in Figure 14. Monitoring assessments on both populations indicate that current monitoring efforts on these populations need improvement. The spatial distribution of late fall Chinook salmon fry and parr is not currently monitored in the LCR, so monitoring effort was scored as zero for this fry/parr indicator. Additional monitoring efforts are needed in the juvenile outmigrant monitoring programs in both basins (Figure 15). Currently an index of juvenile Chinook salmon abundance is estimated through back-calculation of CWTs applied to juveniles in the NF Lewis. A proposal to install a juvenile trap below most of the spawning areas in the NF Lewis River is currently under consideration; however, it is unclear how effective this will be in a large river. Funding for a juvenile outmigrant trapping program to estimate the juvenile abundance of these fish has been recommended.

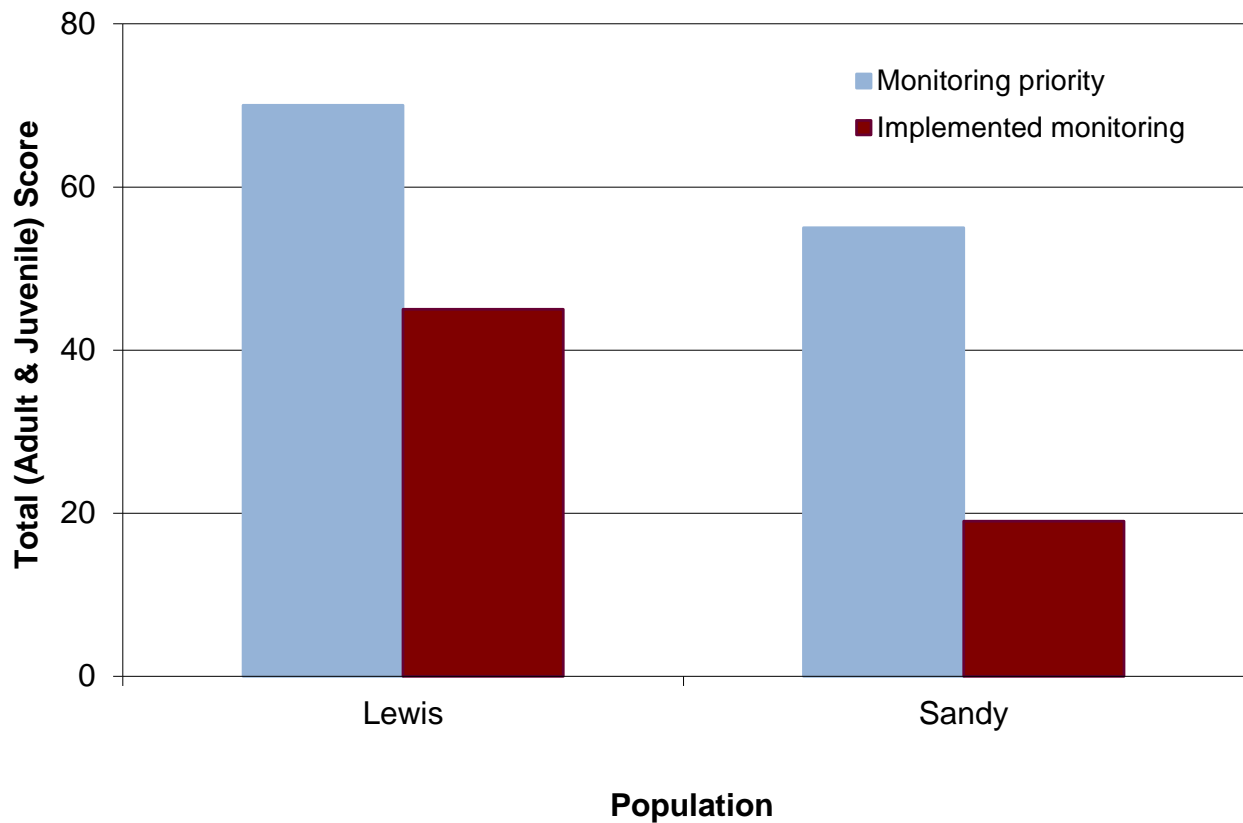


Figure 14. Comparison of late fall Chinook salmon monitoring priorities and current monitoring efforts in the LCR by population.

Adult monitoring efforts for late fall Chinook salmon also need to improve in the Lewis and Sandy rivers (Figure 16). Currently there is adequate monitoring for sex and origin in both watersheds and for adult recruitment and spawn timing in the Lewis River. Current monitoring efforts are inadequate to estimate spawner abundance, distribution, and age structure of late fall Chinook populations in the Sandy and Lewis rivers, and adult recruitment and spawning time in the Sandy River.

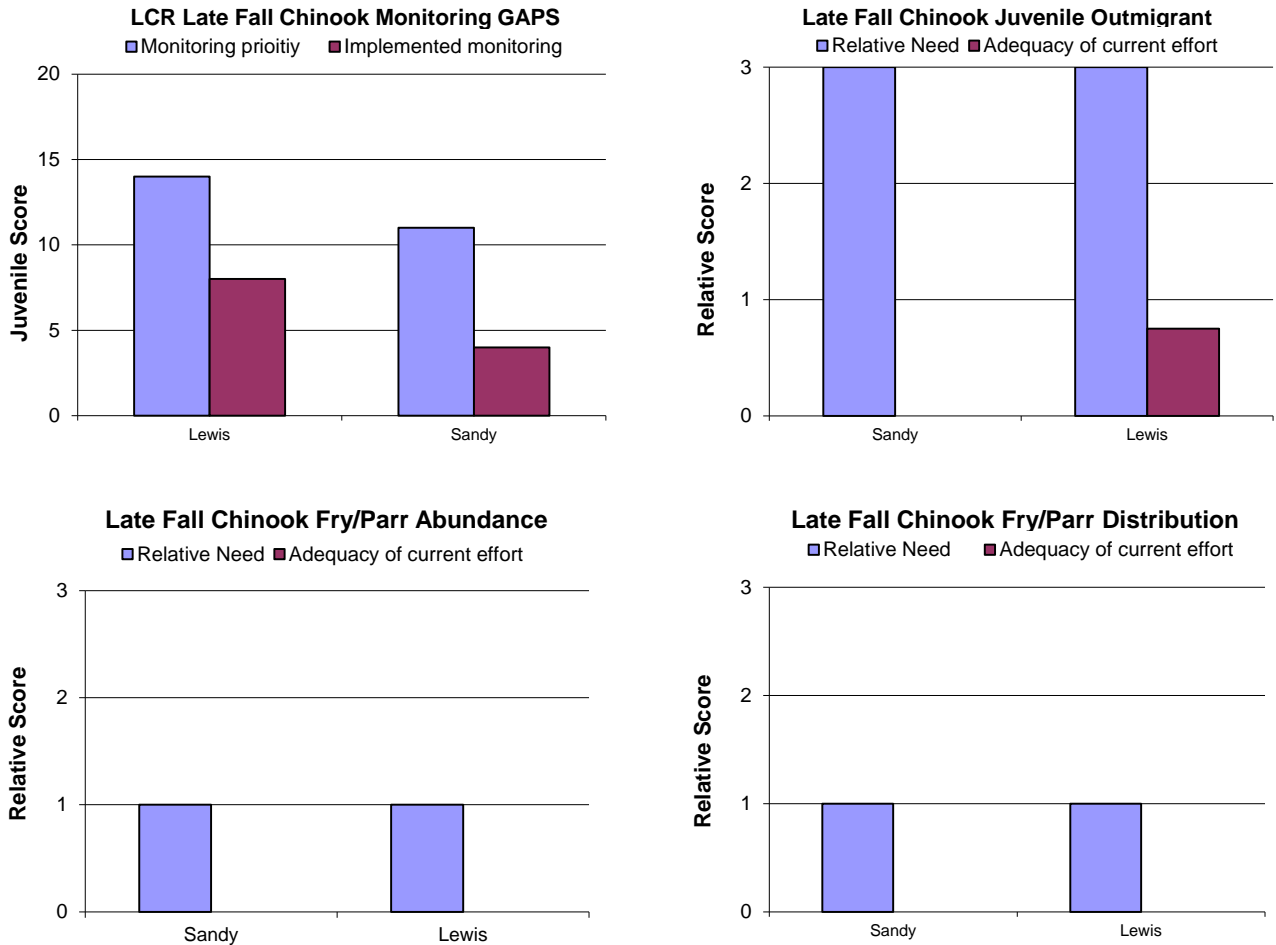


Figure 15. Comparison of juvenile late fall Chinook monitoring priorities and current monitoring efforts in the LCR by population. There are no current monitoring efforts on the fall Chinook fry/parr life stage in the LCR.

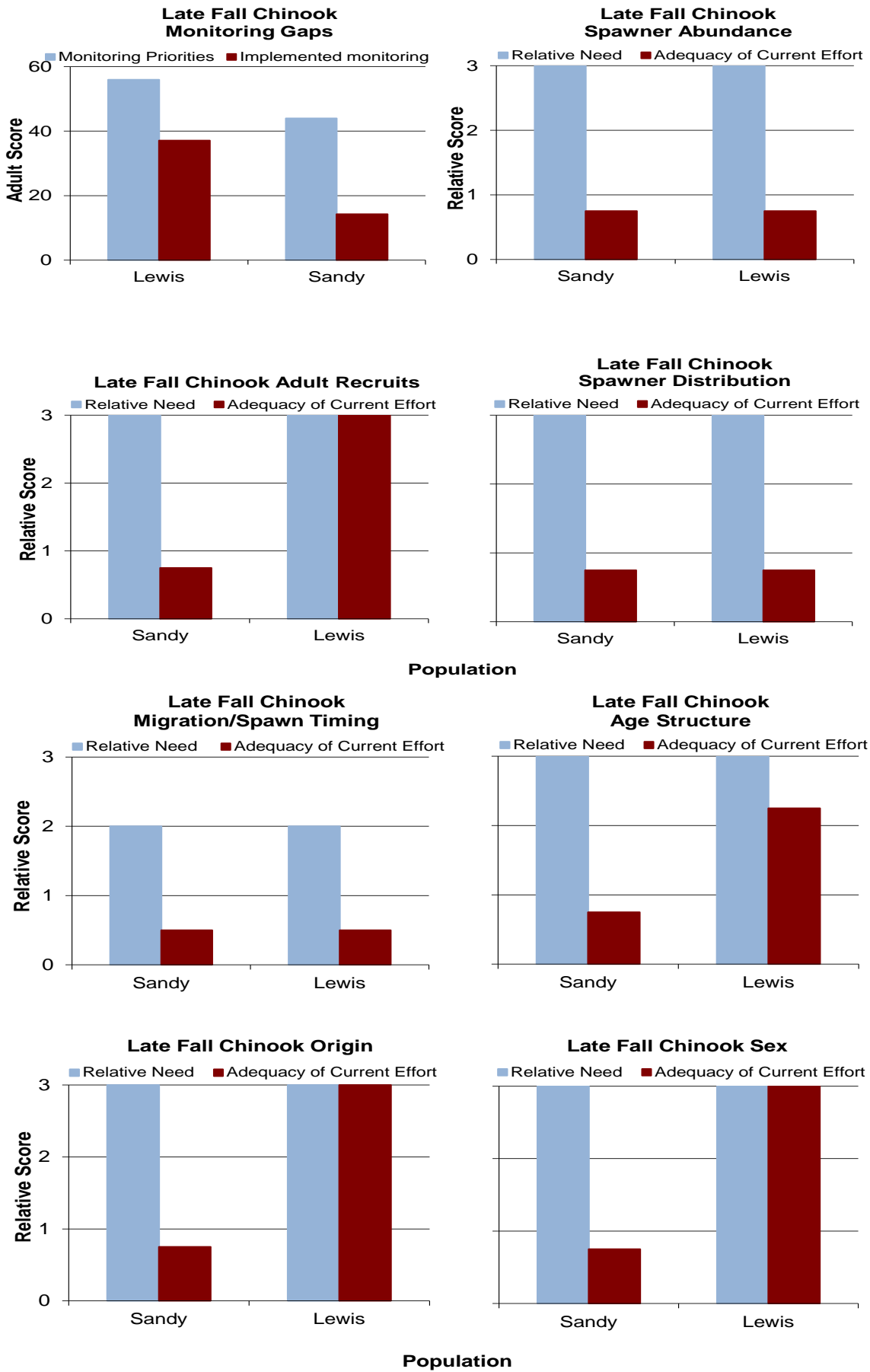


Figure 16. Comparison of adult late fall Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population.

Spring Chinook Salmon

Historically there were 10 spring Chinook salmon populations in the LCR. Populations in the Tilton, Toutle, Kalama, Lewis, Hood, and White Salmon rivers have been extirpated. The population in the Cowlitz River is maintained through hatchery releases. Currently populations in the Kalama, Lewis, Clackamas, Sandy, and Hood rivers are supplemented with hatchery stock. The Lewis River spring Chinook population has been restricted to the lower 20 miles of river. This river reach does not support a naturally spawning population of spring Chinook salmon. However, there are plans to reintroduce spring Chinook salmon into this historical habitat in the upper Lewis River. The monitoring gaps for these populations are found in Figure 17. Because the Tilton, White Salmon, Toutle, and NF Lewis river spring Chinook populations are extirpated, there are no monitoring efforts and no monitoring assessment bars on the graphs for these fish populations. Only slight improvements in monitoring efforts are needed for the Kalama River populations but additional monitoring efforts are needed on the Clackamas, Upper Cowlitz, Cispus, Sandy, and Hood spring Chinook populations.

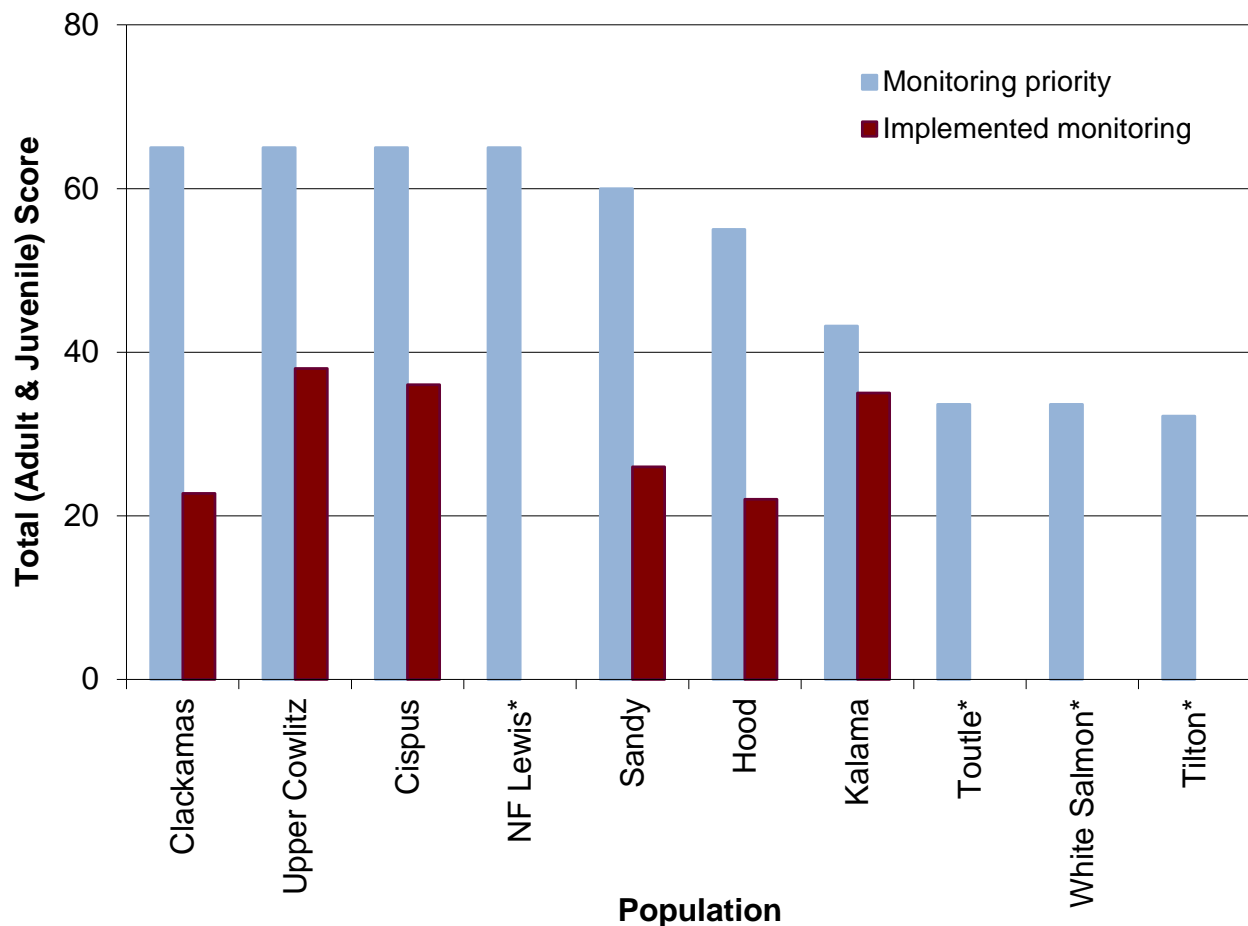


Figure 17. Comparison of spring Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show an “Implemented monitoring” bar on the graph because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (NF = North Fork).

Juvenile spring Chinook monitoring gaps are displayed in Figure 18. No monitoring effort assessment bars appear for the adequacy of current efforts because no monitoring is conducted on extinct populations. Fry/parr distribution and abundance monitoring on these extirpated populations are given low monitoring

priority. However, opportunities exist to improve juvenile outmigrant trapping methods on juvenile spring Chinook populations in the Upper Cowlitz, Cispus, Clackamas, Sandy, and Hood rivers by upgrading seasonal trap efficiencies and intermittent operations at juvenile bypass and collection facilities. Juvenile spring Chinook collections are planned for the upper Lewis River but it is unclear how effective this effort will be.

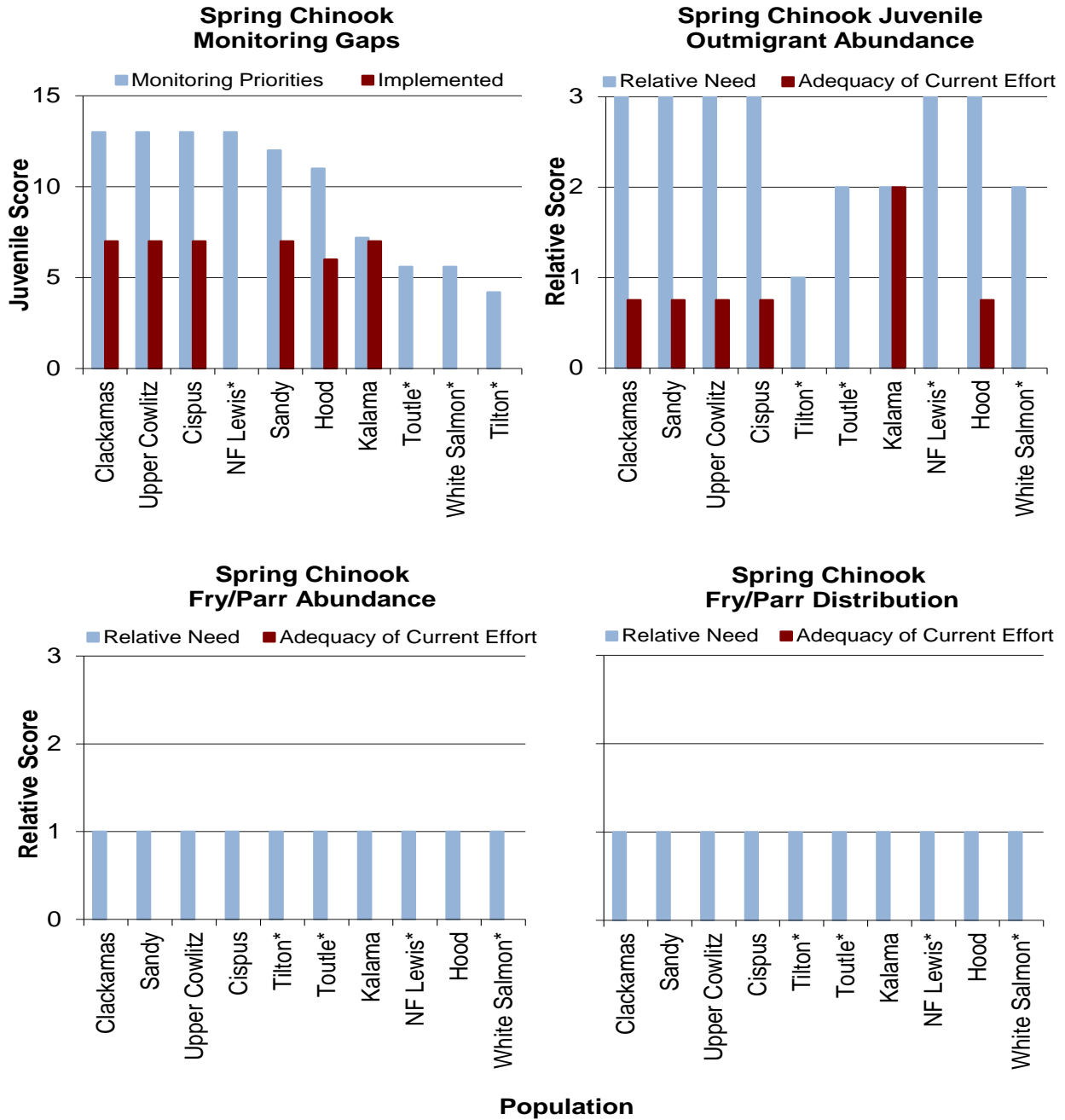


Figure 18. Comparison of juvenile spring Chinook monitoring priorities and current monitoring efforts in the Lower Columbia River by population. There are no current monitoring efforts on the spring Chinook fry/parr life stage in the LCR. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (NF = North Fork).

The difference between adult monitoring priorities and current monitoring efforts on spring Chinook are found in Figure 19. Spawner abundance monitoring methods need to be improved for Cispus, Upper Cowlitz, Kalama, Clackamas, Sandy and Hood river populations. For the populations sampled with weirs, accurate

estimates of pre-spawning mortality and fall back are needed. For spawner abundance estimates based on redd surveys, better estimates on females-per-redd and the sex ratio of adults on the spawning grounds are needed.

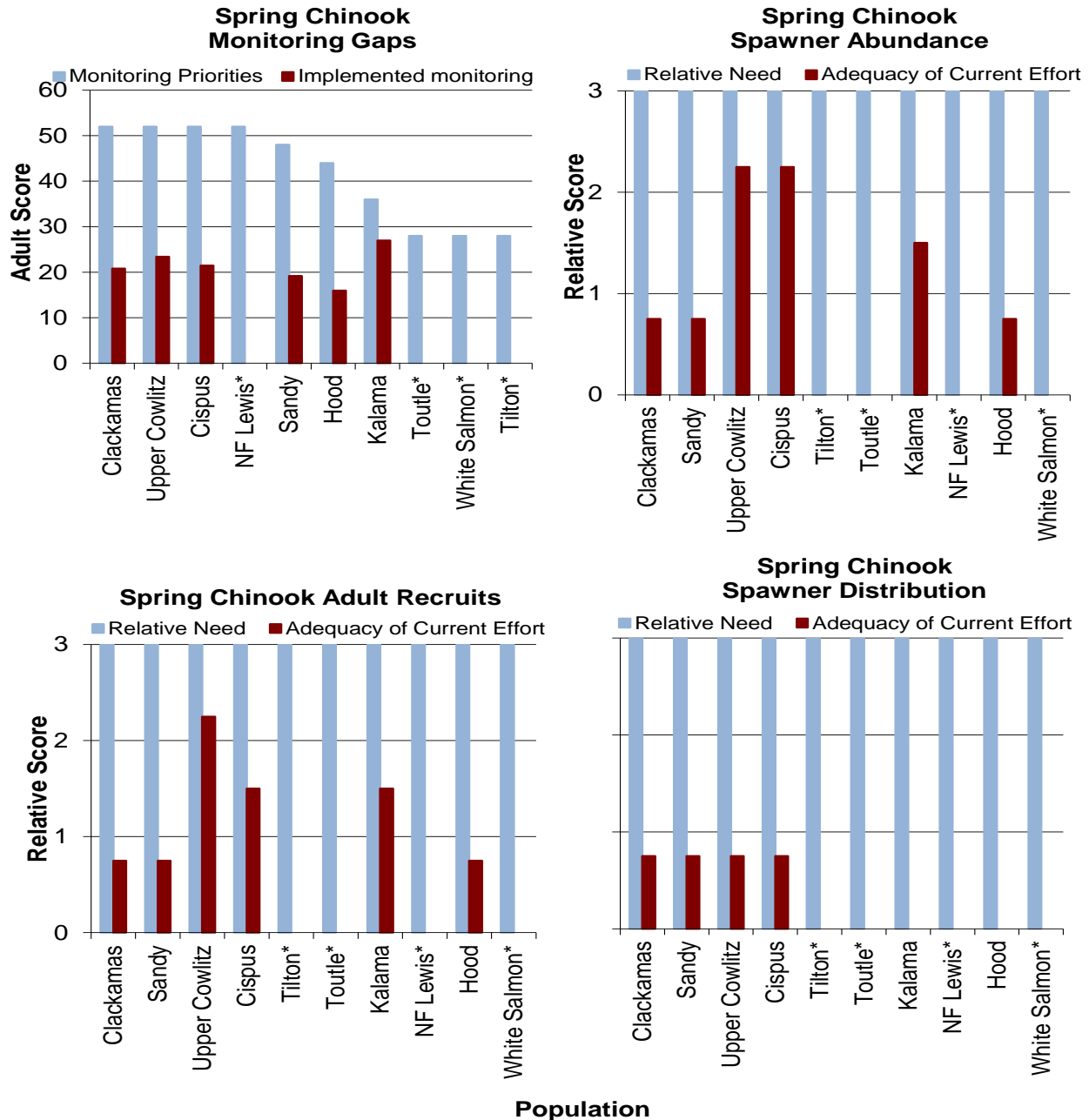


Figure 19. Comparison of adult spring Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (NF = North Fork).

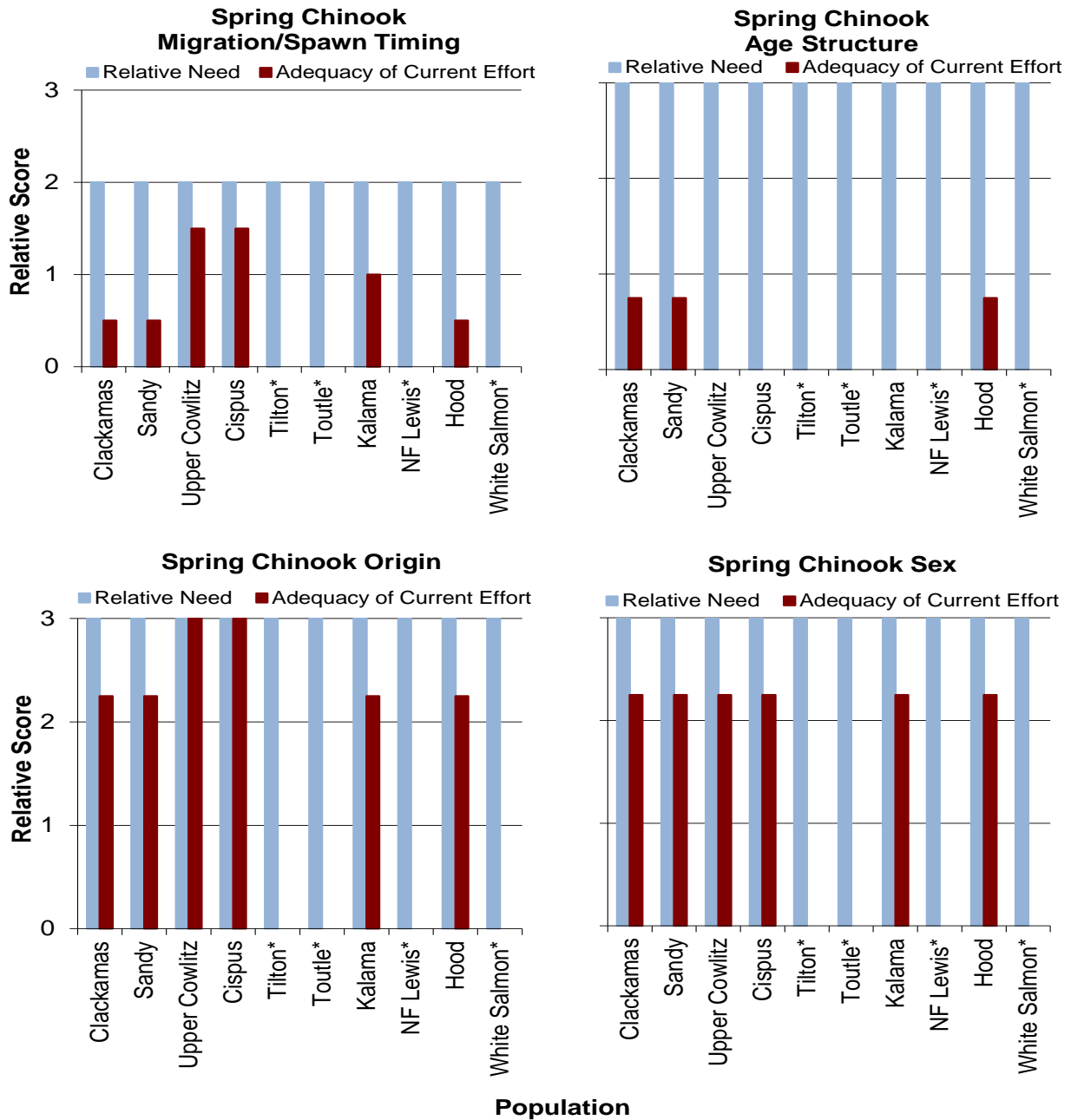


Figure 19 continued. Comparison of adult spring Chinook salmon monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (NF =North Fork).

Winter Steelhead

The gaps in current winter steelhead monitoring efforts are displayed in Figure 20. Monitoring efforts on all LCR winter steelhead populations require substantial improvement. Examination of the juvenile gaps shown in Figure 21 indicate that juvenile outmigrant monitoring needs improvement on the Clackamas, Sandy, and Hood rivers. Current monitoring efforts meet monitoring priorities for all other populations. Of the monitoring efforts used to estimate indices of parr and fry abundance and distribution, only the Oregon coastal strata comes close to meeting monitoring priority goals. Other Oregon and Washington populations have low or zero monitoring effort scores relative to monitoring priorities for parr and fry abundance and distribution because monitoring efforts have not been implemented.

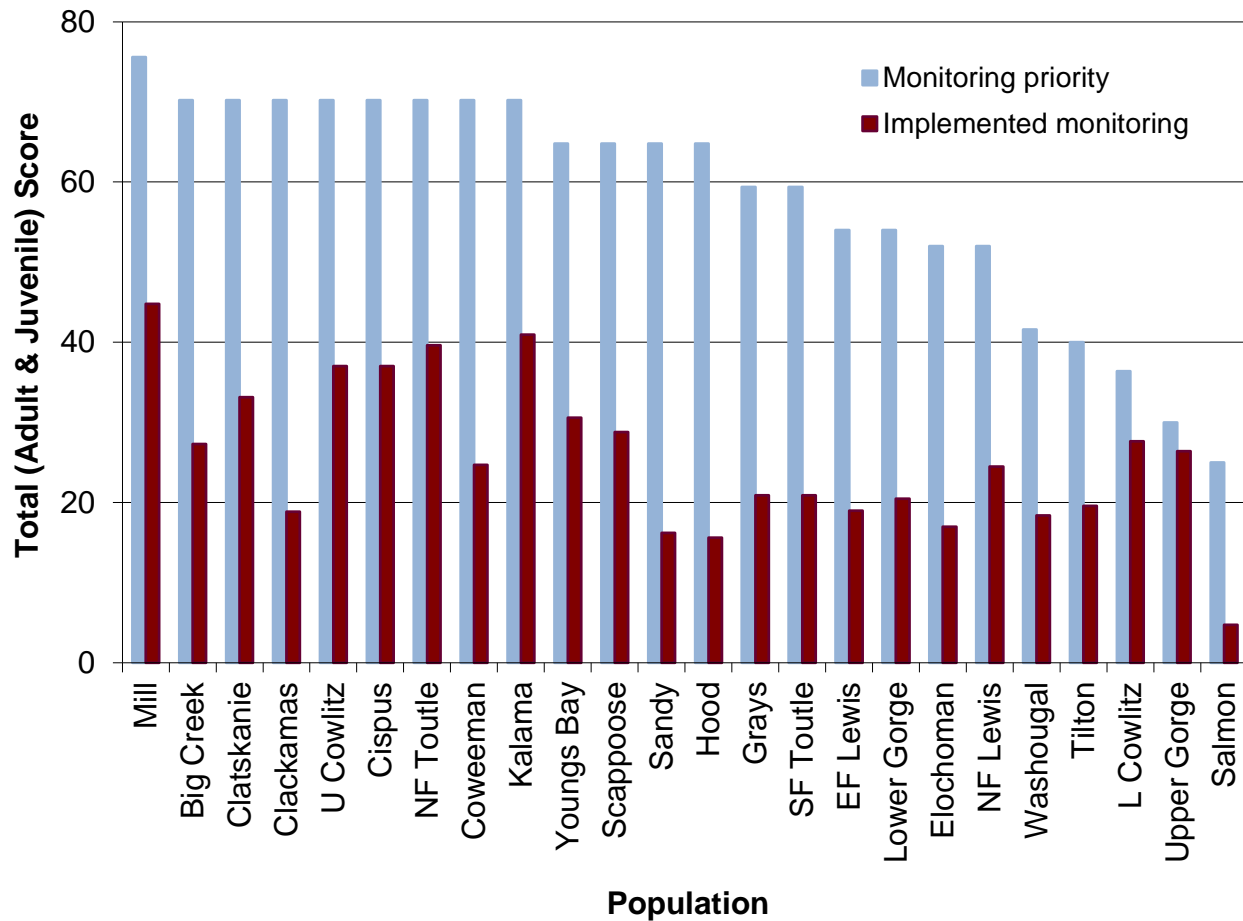


Figure 20. Comparison of winter steelhead monitoring priorities and current monitoring efforts in the Lower Columbia River by population (U = Upper; NF = North Fork; SF = South Fork; EF = East Fork; L = Lower).

The gaps between monitoring priorities and efforts for adult winter steelhead abundance are found in Figure 22. There are no gaps in migration/spawn timing priority versus effort except for the Salmon Creek population, which is not monitored. There are gaps between monitoring priorities and current monitoring efforts for all other adult VSP indicators. For spawner abundance and distribution, scores are highest for sites that are monitored with weirs. Washington state’s spawner abundance and distribution monitoring program could be improved by using probabilistic sampling designs. In addition, Washington’s females-per-redd data from Snow Creek in Puget Sound has coefficient of variation (CV) equal to 0.22, which is sufficiently large that it precludes meeting the precision standards for spawner abundance. Winter steelhead recruitment is generally scored low. While all LCR wild winter steelhead are required to be released, the number of wild fish released from

mainstem or tributary fisheries is not monitored. The Washougal River population has a high monitoring effort score relative to its monitoring priority due in part to a creel survey program. Mainstem fisheries impacts to winter steelhead populations are based on professional judgment and need to be improved.

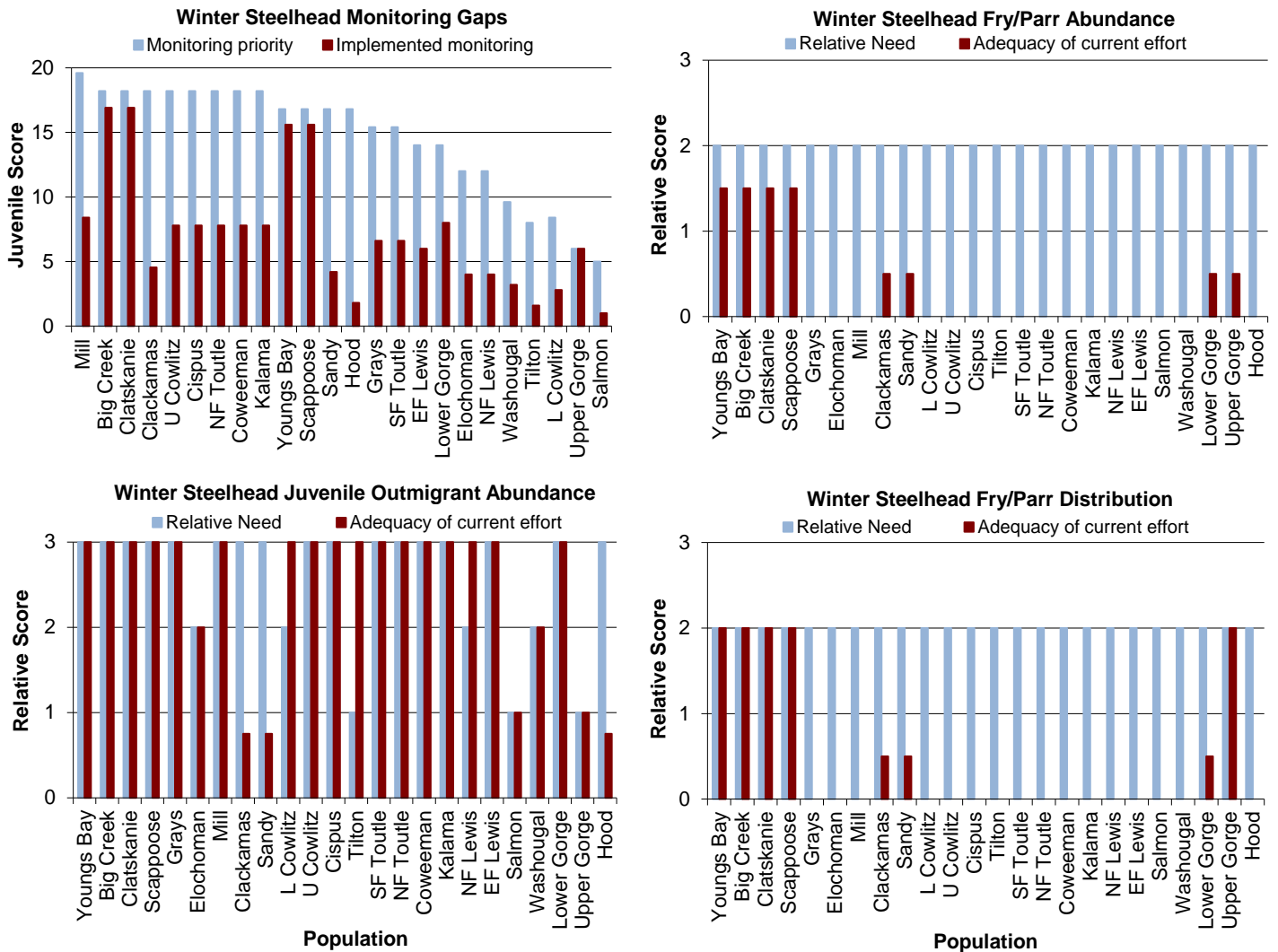


Figure 21. Comparison of juvenile winter steelhead monitoring priorities and current monitoring efforts in the Lower Columbia River by population (U = Upper; NF = North Fork; SF = South Fork; EF = East Fork; L = Lower).

There are important monitoring priority versus effort gaps in the diversity indicators of age, origin, and sex for LCR winter steelhead populations. Because steelhead spawn multiple times, carcass recoveries are not available to monitor populations. Data on the age and sex distributions of some steelhead populations are collected from traps throughout the LCR. This trap data is frequently applied to populations in watersheds without traps. Monitoring effort scores are lower for populations that use surrogate data from another population. In addition, some trap sites do not sample sufficient numbers of fish to meet precision standards for these indicators. There is room for improvement in the origin indicator scores. For populations in watersheds where trapping efforts are conducted, origin can be determined from scales or missing adipose fins because all hatchery fish are mass marked. For other populations, we rely on observations of fish from boats or walking surveys. These observational approaches are less precise than the careful fish examinations conducted at traps. Another potential problem is that most WDFW winter steelhead of hatchery origin spawn

earlier in the year than wild fish. However, WDFW does not directly monitor these populations but uses abundance and timing models to estimate the proportion of hatchery fish.

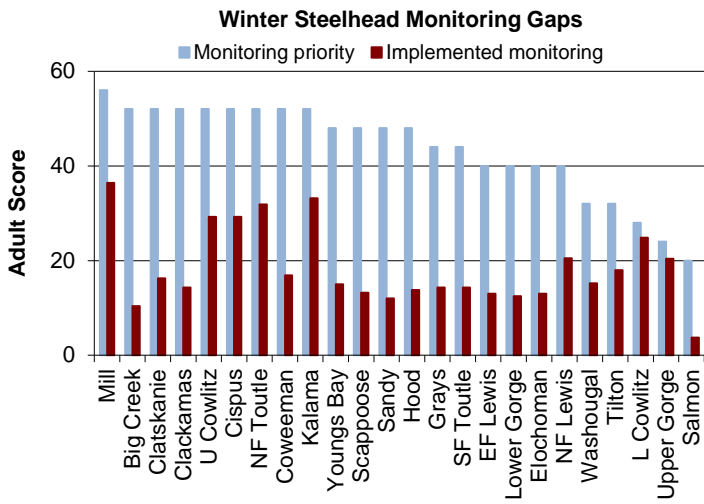
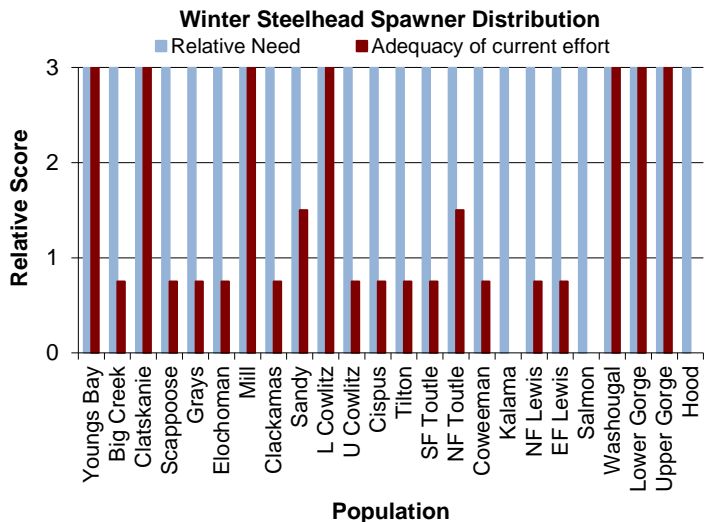
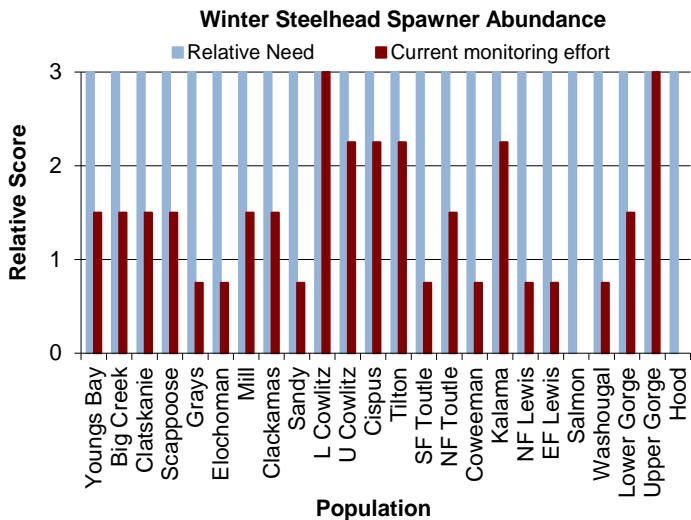
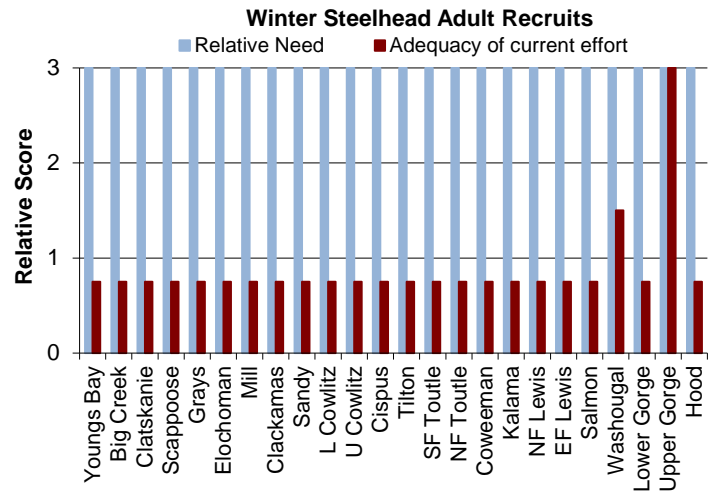


Figure 22. Comparison of adult winter steelhead



monitoring priorities and current monitoring efforts in the LCR by population (U = Upper; NF = North Fork; SF = South Fork; EF = East Fork; L = Lower).

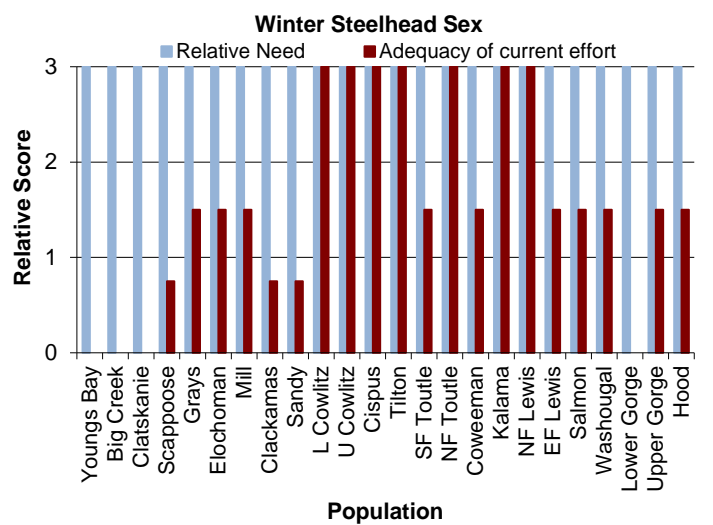
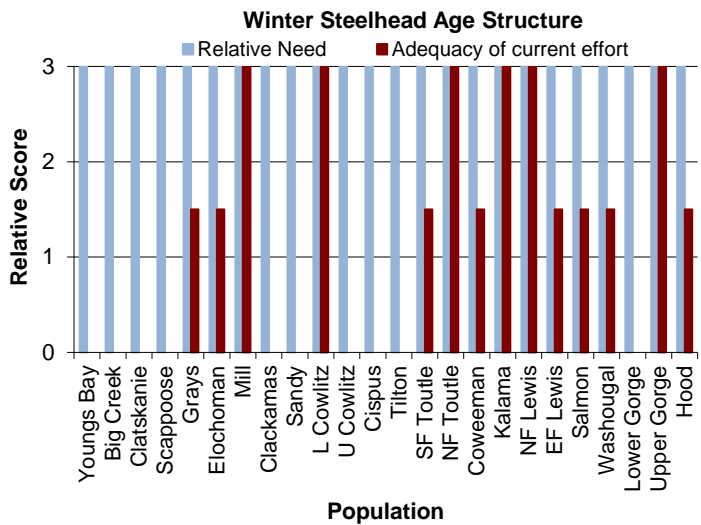
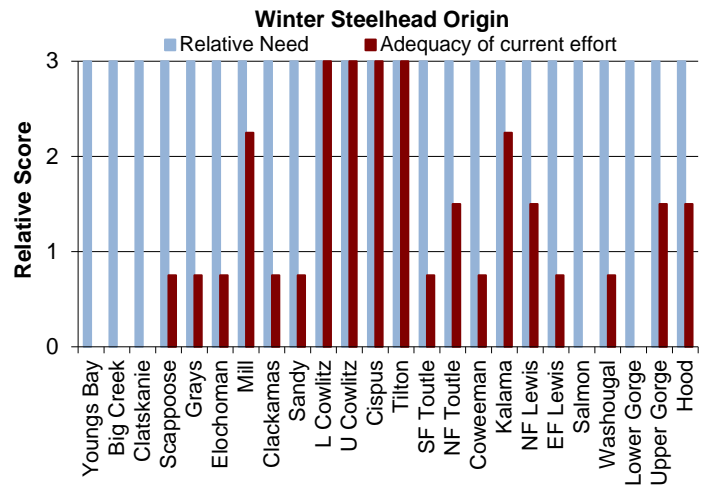
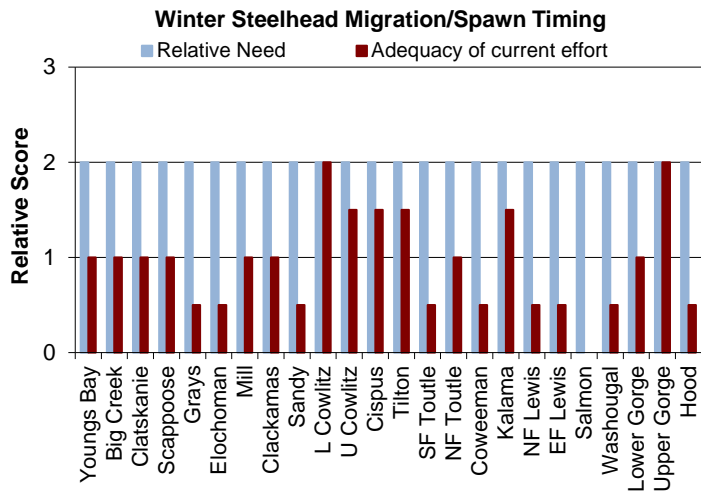


Figure 22 continued. Comparison of adult winter steelhead monitoring priorities and current monitoring efforts in the Lower Columbia River by population (U = Upper; NF = North Fork; SF = South Fork; EF = East Fork; L = Lower).

Summer Steelhead

The summer steelhead gap analysis is found in Figure 23. The NF Lewis River population has been extirpated; subsequent scoring discussions in this report exclude this population. For all other summer steelhead populations there is room for improvement. The gaps in the juvenile monitoring efforts are found in Figure 24. As with winter steelhead, juvenile outmigrant scores for summer steelhead are very high except for the Hood River population. However, scores for the index of parr abundance and distribution are zero because there is no monitoring program for this indicator.

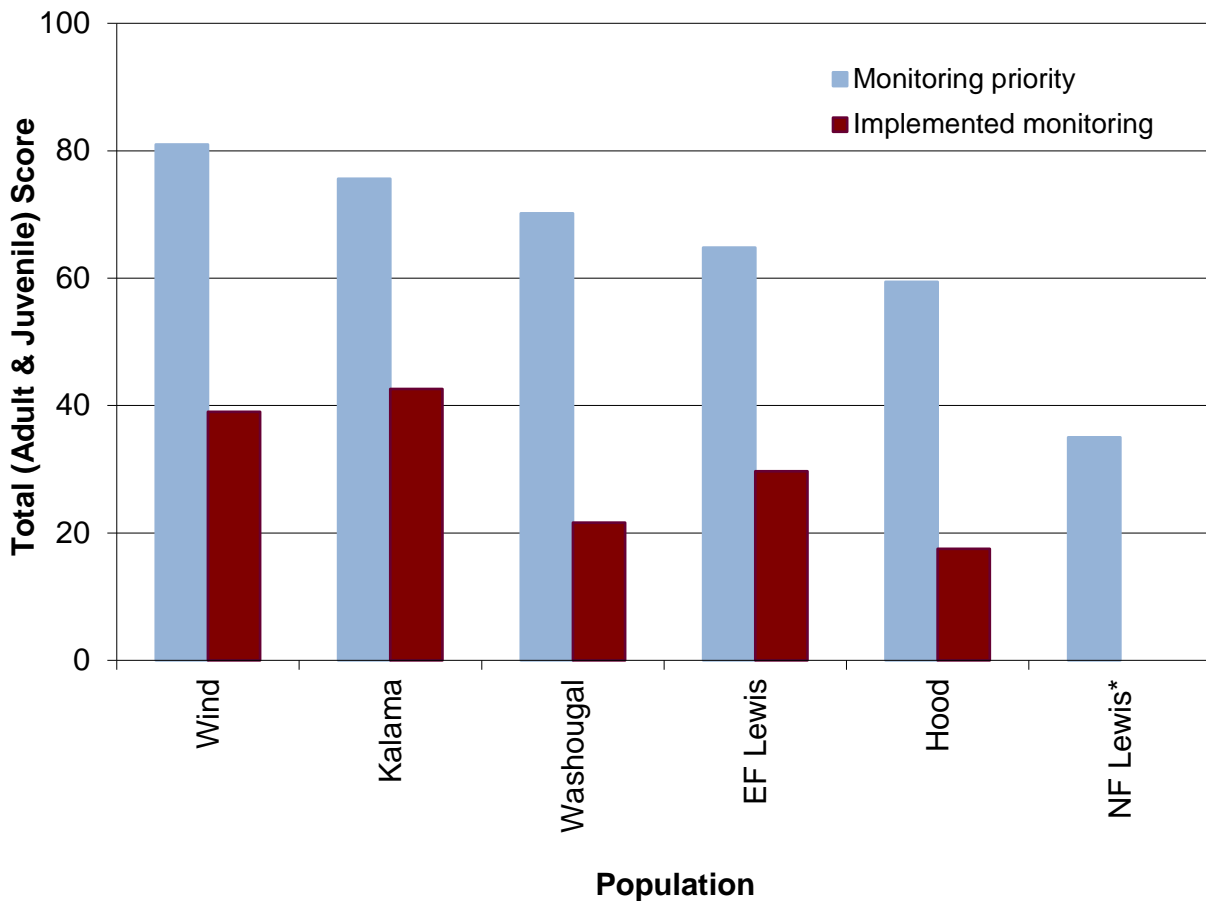


Figure 23. Comparison of summer steelhead monitoring priorities and current monitoring efforts in the LCR by population. Populations asterisked on the X axis do not show an “Implemented monitoring” bar on the graph because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor.

The gaps in the adult summer steelhead monitoring program are found in Figure 25. This assessment shows that all current monitoring efforts for adult indicators on summer steelhead need improvement. For spawner abundance, the Kalama and Wind river populations have the highest scores while the Washougal and Hood river populations score lowest among the populations. Monitoring efforts of summer steelhead recruitment generally scores low across all populations. Fisheries regulations require all LCR wild summer steelhead be released; however, the number of wild fish that are released is not monitored in mainstem or tributary fisheries. Populations with the highest scores include the Washougal River, which has a creel survey program

in effect. The impact of mainstem fisheries on summer steelhead populations is based on professional judgment and needs to be improved.

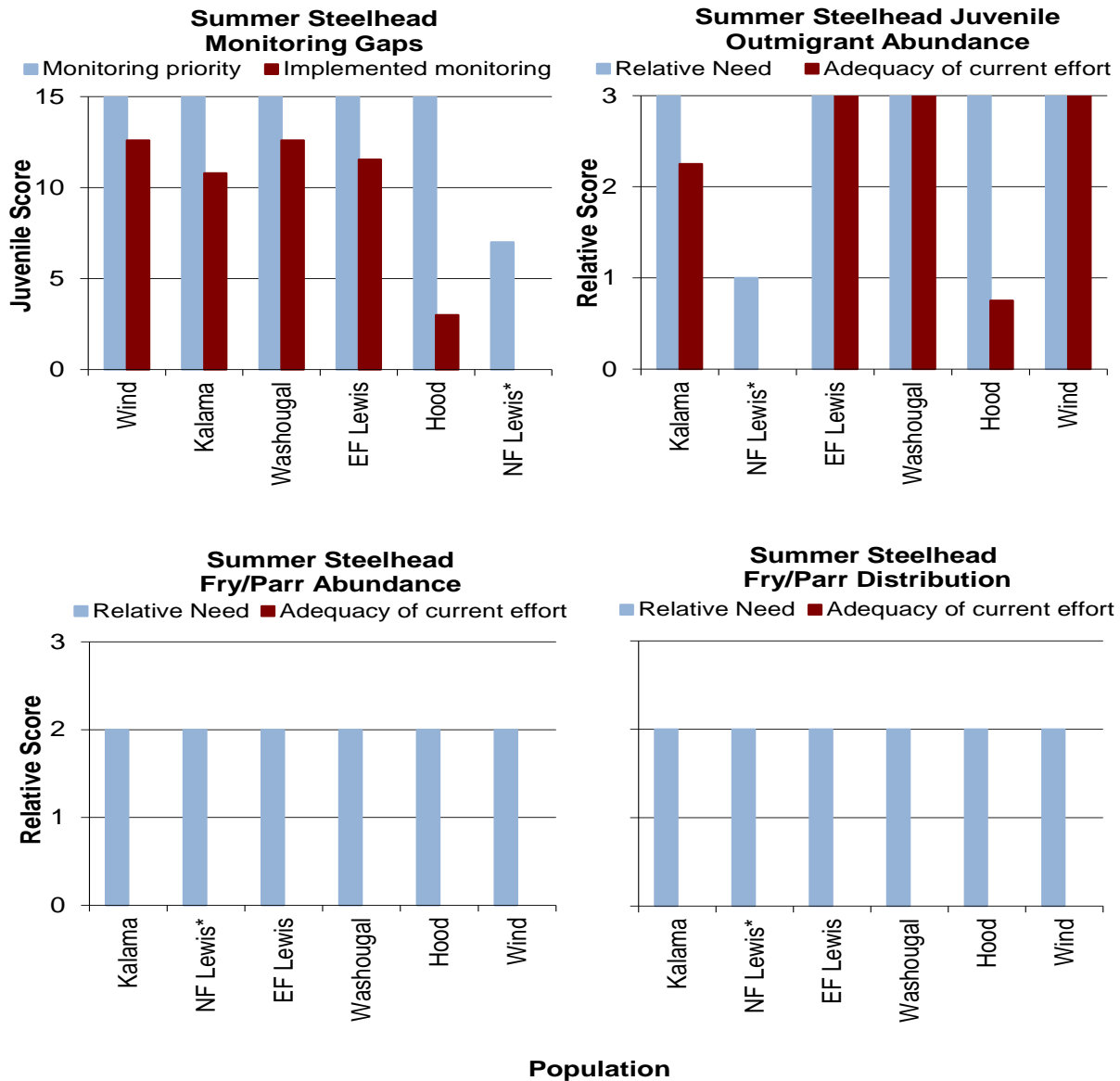


Figure 24. Comparison of juvenile summer steelhead monitoring priorities and the current monitoring effort in the LCR by population. There are no current monitoring efforts on the summer steelhead fry/parr life stage in the LCR. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (EF = East Fork; NF = North Fork).

The remaining diversity indicators of age, origin, and sex also indicate gaps between monitoring priorities and effort. Few steelhead die after spawning, so carcass recoveries are not available to provide information on spawner diversity. As an alternative, age, sex, and origin data on summer steelhead is collected from traps and seines throughout the LCR. These alternatives are problematic because summer steelhead are sexually immature when trapping and seining efforts are conducted, so differentiating males from females can be difficult. Incorporating ultrasound, sampling for genetic markers, or other standardized techniques into these kinds of monitoring efforts would improve sex differentiation of summer steelhead. Another difficulty is that

the number of fish collected during some trapping and seining efforts is insufficient to meet precision standards for the age, sex, and origin indicators. WDFW obtains additional samples for the summer steelhead origin indicator through adult snorkel surveys.

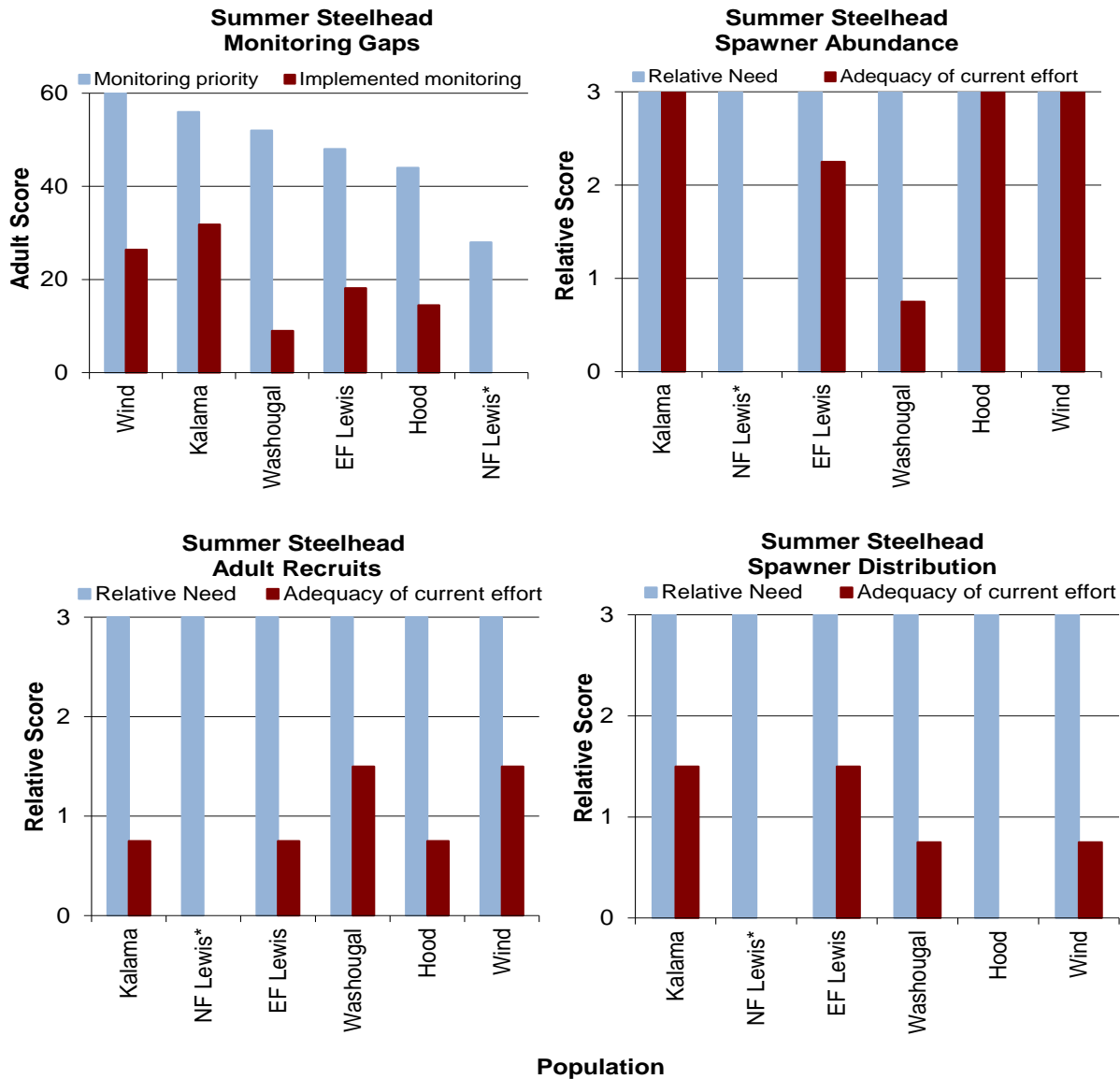
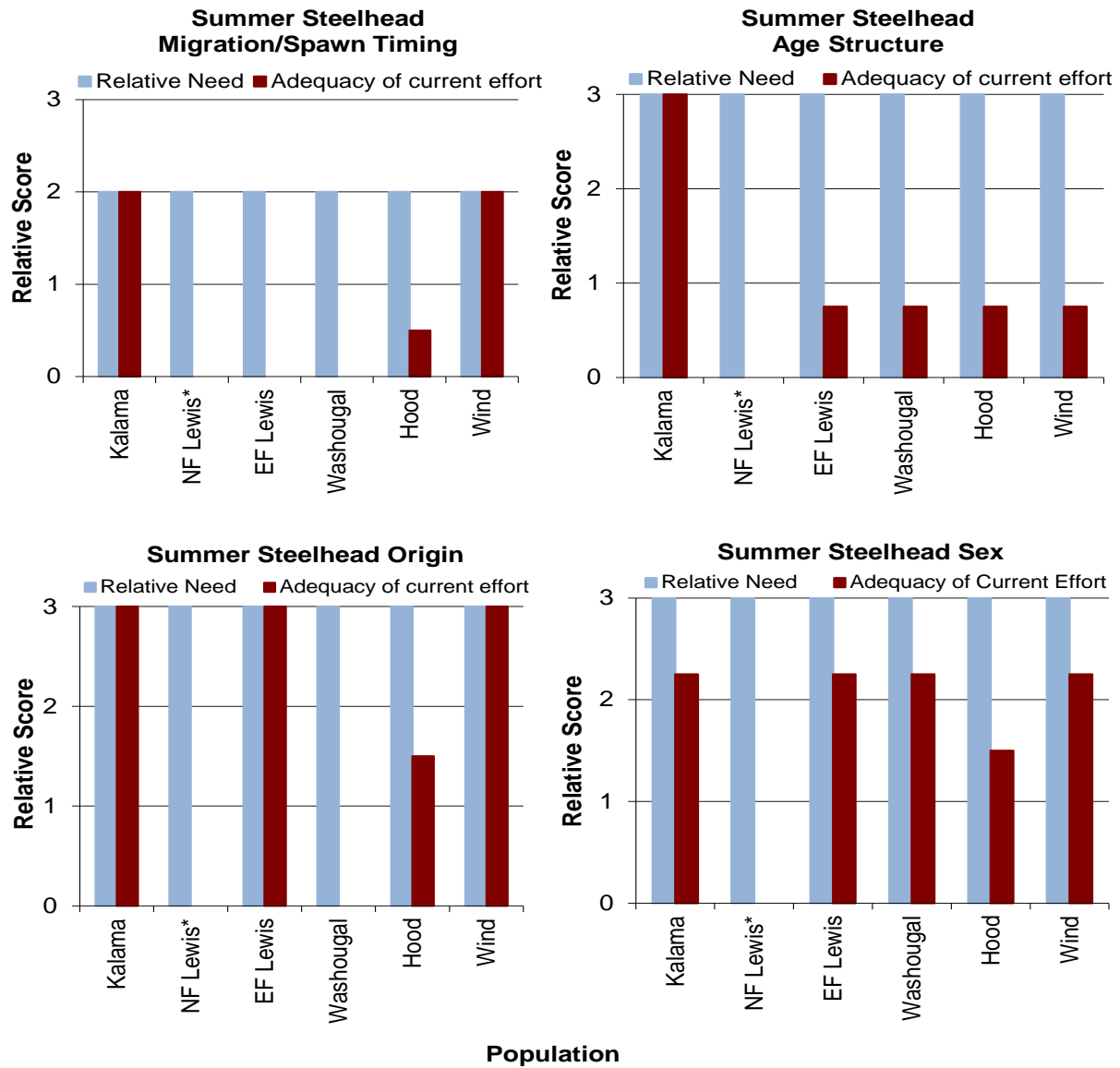


Figure 25. Comparison of adult summer steelhead monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show “Implemented monitoring” or “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (EF = East Fork; NF = North Fork).



Population

Figure 25 continued. Comparison of adult summer steelhead monitoring priorities and current monitoring efforts in the Lower Columbia River by population. Populations asterisked on the X axis do not show “Adequacy of current effort” bars on the graphs because these are extirpated or functionally extinct populations with inadequate numbers of fish to effectively monitor. (EF = East Fork; NF = North Fork).

Discussion

LCR Recommendations

Viable salmonid population monitoring on extirpated populations may not be a high priority or the most efficient use of monitoring resources. We recommend an adaptive management approach to monitoring populations that are functionally extinct and allocation of monitoring resources to populations with sufficiently large numbers of fish that precision guidelines can be met. Furthermore, as extirpated populations are reintroduced, we recommend that monitoring efforts be increased to meet monitoring priority. We also recommend increased monitoring of populations that are rebuilding and when re-colonization occurs in watersheds where the original population is extirpated or functionally extinct. We recognize the need for adaptive monitoring strategies to measure the effectiveness of targeted recovery actions, such as short-term hatchery supplementation. We believe monitoring actions need to be prioritized relative to their potential to effect change in the VSP metrics, then effectiveness monitoring implemented within that priority structure.

An overview of our findings suggests that the gaps in Oregon's monitoring efforts are largely due to untested assumptions and environmental issues (e.g., poor water visibility) that make traditional visual survey methods impractical. Washington's monitoring efforts suffer from poor spatial coverage in some areas (e.g., Salmon Creek, mainstem Toutle River, White Salmon, and Lower Gorge) and often reflect reduced monitoring efforts on low priority populations. Monitoring efforts are also hampered by environmental issues in some cases. For example, adult monitoring in the mainstem Toutle and lower White Salmon rivers is difficult at some times of the year because of high sediment loads. High sediment loads increase turbidity and make traditional visual methods of adult monitoring impractical. Index monitoring has been implemented in these locations and will continue until new methods are developed for these environmentally challenging subbasins. In many cases, monitoring gaps reflect allocation of limited monitoring resources to higher priority and/or more effectively sampled populations. Despite the precision and bias issues that arise from indexing and sampling small numbers of fish, enough information may be collected on a population to yield indicator estimates that may be useful in trend analysis.

Washington State could improve its monitoring program by adding or improving monitoring efforts in the LCR. Currently the Lower and Upper Gorge are not monitored for steelhead with the exception of the Wind River, and the Upper Gorge is not monitored for coho salmon.

Another area in need of improvement across all species is the adult recruitment or harvest monitoring. Estimates of adult recruitment for hatchery Chinook and coho salmon populations scored moderate to high based on the CWT program and the key assumption that hatchery CWT programs can serve as effective surrogates for wild populations. However, steelhead and chum salmon are believed to have negligible ocean harvest and are not CWTed. Genetic techniques are needed to estimate harvest rates on steelhead and chum in the mainstem Columbia River, but this monitoring has not been implemented. Estimates of fisheries impacts on wild salmon and steelhead that are caught and subsequently released are also needed.

Monitoring efforts on coho and winter steelhead need the most improvement in the LCR. The monitoring gaps for coho and winter steelhead populations are due to the broad geographic distribution of these fish, low spawning densities, and extended spawning times that coincide with high turbidity flows. As we mentioned previously, high turbidity flows hamper spawning ground surveys. Another issue is that coho and winter steelhead monitoring in the LCR depend on critical assumptions that were tested on populations outside the LCR. For example, WDFW uses steelhead females-per-redd data collected on the Snow Creek population in Puget Sound, and ODFW uses observer efficiency and residence times for coho salmon collected from Oregon Coast populations. The applicability of these foreign population metrics to LCR populations introduces critical uncertainties in calculated spawner abundance estimates. As a result of these uncertainties, the monitoring

effort score is reduced for populations that rely on surrogate metrics for calculating spawner abundance estimates.

The diversity indicators of age, origin, and sex are difficult to collect on LCR coho and winter steelhead populations due to low carcass recovery rates. In addition, precision standards for diversity indicators may be difficult to achieve for most primary steelhead and coho populations without implementing a broader trapping program in the LCR. Information from adjacent populations is used to generate indicator estimates for some populations.

ODFW has implemented a sampling program to index coho and steelhead parr in the LCR. WDFW has not funded this type of program. WDFW's juvenile and total monitoring effort scores for coho and steelhead would increase substantially if a parr monitoring program was implemented. Implementation of this type of program could include probabilistic rather than opportunistic parr PIT tagging efforts of M-A-G populations, snorkel surveys to obtain juvenile summer steelhead counts at a subset of sites that were probabilistically selected, and coordinated monitoring efforts with other agencies that conduct juvenile sampling.

The LCR Demonstration project is the first attempt that we are aware of to evaluate monitoring efforts on population indicators for ESA-listed salmonids. In our first report, we developed a prioritization tool that incorporated spatially explicit information on the priority of monitoring individual populations with the current feasibility/relative expense of obtaining data on factors relevant to salmon recovery and VSP monitoring. A scoring algorithm was used to prioritize monitoring by species and watershed across the LCR recovery domain (Rawding et al. 2010). Many of these watersheds are used by multiple salmonid species. In this report, we developed a generalized rule set to systematically score monitoring efforts used to generate VSP indicators based on sampling precision and the degree of methodological bias. We applied generally accepted precision and bias standards for each methodology by VSP indicator which includes indices of fry/parr abundance, juvenile outmigration monitoring, spawner abundance, adult recruitment, age structure, origin, sex ratio, migration and spawn timing, spawner distribution, and an index of juvenile distribution. When regional standards were unclear or did not exist, we clarified or proposed new standards consistent with the literature and our understanding of monitoring. In some cases, we identified indicators that needed additional specificity. We compared the prioritization scores from our first report to the monitoring assessment scores generated for each indicator. The difference or gap between the monitoring priority score and current monitoring effort score was explicitly depicted for each VSP indicator by population with bar graphs. The gap between the monitoring priority of a population and the current monitoring effort allows regional biologists and resource managers to quickly identify program deficiencies and provides rationale for upgrading monitoring efforts.

Other authors have attempted similar quantitative evaluation of salmonid monitoring efforts but many focused on a single variable such as spawner abundance and used less explicit criteria in their assessment. For example, WDFW used qualitative ratings of good, fair, or poor when abundance data was assessed for the Salmonid Stock inventory (WDFW 2011). Byrne (2007) provided some guidance on scoring the precision, accuracy, and representativeness of spawner abundance data used in the Columbia Basin State of the Resource report (CBFWA 2011). These scoring criteria, while still subjective, were more clearly defined than the qualitative approach taken by WDFW (2011). However, Byrne's (2007) guidance was limited to spawner abundance. Parsons and Skalski (2010) provided a statistical critique of spawner abundance methods and made recommendations on the use of variations of the methods presented here. While we support many of their recommendations, they only address spawner abundance, which is one of ten indicators we identified as being important for VSP monitoring. Regional VSP monitoring will play an increasingly important role in Pacific Northwest salmonid recovery efforts and will require a commitment to organizational collaboration,

monitoring standardization, and efficient use of monitoring resources. Efforts are currently underway to align VSP indicator definitions and other language used in the ISTM and Coordinated Assessments projects to further monitoring standardization.

The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) conducted over 30 assessments of salmonid monitoring programs across the Columbia basin at the population and ESU scales from 2004 to 2007. The results of this effort can be found at: <http://www.cbfwa.org/csmep/web/content.cfm?ContextID=16>. These assessments focused on the spatial scale of monitoring, methodology, precision and accuracy of collected data, strengths and weaknesses of the assessment, and the documentation of the data sources. These assessments sought to address questions similar to those included in Table 19. Some of the CSMEP questions were similar to those in this report, but CSMEP also focused on habitat status and the effectiveness of recovery actions. This ISTM Fish report focused entirely on monitoring priorities and efforts of salmonid populations in the LCR. Habitat monitoring is being addressed in another ISTM project. The prioritized framework we proposed includes fish in/out or life cycle monitoring at multiple sites. Development of specific action effectiveness monitoring using Before-After-Control-Impact (BACI) designs at life cycle sites is a preferred approach that will insure effective monitoring (Stewart-Oaten et al. 1986). The BACI approach allows implementation of action effectiveness monitoring at current (Ehinger et al. 2007) and future sites as different strategies are evaluated. In contrast to the CSMEP approach, the ISTM approach works toward a standardized assessment of monitoring efforts used to generate VSP indicators so assessments can be compared among populations and species.

Table 19. CSMEP assessment questions for ecosystem status, population and habitat status monitoring, and action effectiveness monitoring. Table number will change after results tables are included.

Tier 1 Questions: Ecosystem Status
<p>Q 1.1 What is the distribution of adult salmonid fishes across broad regions?</p> <p>Q 1.2 What is the ecosystem status for Columbia River Basin (CRB) fish populations?</p>
Tier 2 Questions: Population and Habitat Status Monitoring
<p>Q 2.1 What is the size of CRB fish populations?</p> <p>Q 2.2 What is the annualized growth rate of CRB fish populations?</p> <p>Q 2.3 What is the freshwater productivity (e.g., smolt or subadult /female) of CRB fish populations?</p> <p>Q 2.4 What is the age-structure of CRB fish populations?</p> <p>Q 2.5 What is the fraction of potential natural spawners that are of hatchery origin?</p> <p>Q 2.6 How frequently do resident fish spawn?</p> <p>Q 2.7 What life history types make up different populations? (e.g., for bull trout: adfluvial, fluvial, resident)</p> <p>Q 2.8 What is the biological condition of CRB fish spawning and rearing habitat?</p> <p>Q 2.9 What is the chemical water quality in CRB fish spawning and rearing habitat?</p> <p>Q 2.10 What is the physical habitat condition of CRB fish spawning and rearing habitat?</p>
Tier 3 Questions: Monitor Effectiveness of Specific Recovery Actions (habitat, hydro, hatchery, or harvest management)
<p>Q 3.1 Have specific projects affected habitat conditions and local fish population survival, abundance or condition?</p> <p>Q 3.2 Did groups of projects within a subpopulation or sub watershed on aggregate affect fish survival, abundance or condition in a larger demographic unit?</p> <p>Q 3.3 Are particular classes of projects effective?</p> <p>Q 3.4 What are the mechanistic connections between recovery actions and fish population responses?</p>

We considered alternate scoring approaches. The scoring system we chose emphasizes achieving the precision standard; if the precision standard is not met, the monitoring effort receives a score of zero. A more graduated approach could give partial credit to monitoring efforts that come close to the actual precision

standard. This alternate scoring approach obviously results in higher monitoring assessment scores at the expense of the precision standard. However, we want to emphasize that our scoring approach and resultant graphs that compare monitoring priority to monitoring effort should not be evaluated as absolute differences. Our approach to monitoring effort assessment can be used as a tool to identify monitoring efforts that need improvement, and provides a relative scale of the magnitude of improvement needed. Our approach provided high scores juvenile outmigrant monitoring for all populations within an MPG if one or more were monitored. This approach allowed rapid assessment of juvenile monitoring at a salmon recovery scale, the results for individual populations are misleading.

This report represents our understanding of current VSP monitoring priorities compared to monitoring efforts. The scoring system that we developed allows for flexibility as specific indicator standards for precision and bias are developed or refined, and new methodologies such as a change-in-ratio or sonar to estimate spawner abundance are adopted (Seber 1982; Alexandersdottir 2005; Maxwell 2007). We encourage other planning domains to build off the work presented here to identify monitoring priorities and systematically assess current monitoring efforts using the framework we developed. We believe this framework has application in the Columbia basin and throughout the Pacific Northwest and could be specifically extended to action effectiveness monitoring.

This report represents completion of the second of five objectives of the PNAMP ISTM Fish Monitoring Project. These five objectives are described in the Background section of this report. The next objective of the ISTM Fish project is to identify the most appropriate monitoring designs to inform priority management decisions, questions, and objectives. That effort will be followed up with a trade-off analysis and final monitoring and reporting recommendations for the LCR planning domain.

References

- Alexander, R.F., R. C. Bocking, W. J. Gazey, R.J. Bussanich and S. C. Kingshott. 2010. Estimating the Abundance of Adult Chinook Salmon Returning to the Nass River, BC, using Mark-recapture Techniques, 2009. Report for the Sentinel Stocks Program of the Pacific Salmon Commission. Vancouver, BC. 103pp. http://fund.psc.org/2009/SSP_Reports/SSP_3_Stephens.pdf
- Alexandersdottir, M., 2005. Nisqually 2003 Chinook salmon abundance estimates from change in ratio. Technical report, Northwest Indian Fisheries Commission.
- Amstrup, S.C., McDonald, T.L., and B.F.J. Manly (eds). 2005. Handbook of capture-recapture Analysis. Princeton University Press. Princeton, NJ. 313p.
- Arnason, A.N, Kirby C.W., C.J. Schwarz, and J.R. Irvine. 1996. Computer analysis of marking data from stratified populations for estimation of salmon escapements and the size of other populations. Can. Tech. Rep. Fish. Aquat. Sci. No. 2106.
- Ashbrook, C.E., J.F. Dixon, K.W. Hassel, E.A. Schwartz, and J.R. Skalski. 2008. Estimating bycatch survival in a mark-selective fishery. Pages 677-686 in J.L. Nielsen, J.J. Dodson, K. Friedland, T.R. Hamon, J. Musick, and E. Verspoor, editors. Reconciling fisheries with conservation: proceedings of the Fourth World Fisheries Congress. American Fisheries Society, Symposium 49, Bethesda, Maryland.
- Begich, R.N. 1993. Assessment of the 1992 returns of steelhead to the Karluk River, Alaska. Alaska Department of fish and Game, Fishery Data Series No 93-56, Anchorage.
- Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of Chinook salmon released in the Kenai River, Alaska. North American Journal of Fish Management 13: 540-549.
- Bernard, D. R., and J. E. Clark. 1996. Estimating salmon harvest based on return of coded-wire tags. Canadian Journal of Fisheries and Aquatic Sciences 53:2323-2332.
- Bernard, D.R., R.P. Marshall and J.E. Clark. 1998. Planning programs to estimate salmon harvest with CWTs. Can. J. Fish. Aquat. Sci. 55: 1983-1995.
- Bjorkstedt, E. 2000. DARR (Darroch analysis with rank reduction): A method for analysis of stratified mark-recapture data from small populations with application to estimating abundance of smolts from outmigrant trap data. NOAA-NMFS Southwest Fisheries Science Center. Administrative Report SC-00-02. 28 pp. <http://santacruz.nmfs.noaa.gov/files/pubs/00116.pdf>
- Bonar, S. A., G. L. Thomas, G. B. Pauly, and R. W. Martin. 1989. Use of ultrasonic images for rapid nonlethal determination of sex and maturity of Pacific herring. North American Journal of Fisheries Management 9:364-366.
- Bonner, S.J., and C.J. Schwarz. 2011. Smoothing Population Size Estimates for Time-Stratified Mark-Recapture Experiments Using Bayesian P-Splines. Biometrics 67, 1498-1507.
- Bradford, R. H., S. A. Leider, P. L. Hulett, and C. W. Wagemann. 1996. Differential leaping success by adult summer and winter steelhead at Kalama Falls: implications for estimation of steelhead spawner escapement. WDFW, Fish Management Program Report #RAD 96-02, Olympia.

Brooks, S. P., E.A. Catchpole, and B.J.T. Morgan. 2000. Bayesian animal survival estimation. *Statistical Science* 15, 357–376.

Bue, B. G., S. M. Fried, S. Sharr, D. G. Sharp, J. 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 Fisheries Commission Bulletin* 1:240–250.

Byrne, A. 2007. State of the resource data quality guide. CSMEP. 7 pp.

<http://www.cbfwa.org/csmep/web/documents/general/Documents/State%20of%20the%20Resource%20Data%20Quality%20Guide.doc>

Carlson, S. R., L. G. Coggins, and C. O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. *Alaska Fishery Research Bulletin* 5:88-102.

CBFWA. 2011. State of fish and wildlife resources in the Columbia River basin. Columbia Basin Fish and Wildlife Authority. Portland, OR. 23pp.

Cooper R., L.A. Campbell, J. P. Sneva. 2011(DRAFT). Salmonid Scale Sampling Manual. WDFW Technical Report. Working Draft. Olympia, WA.

Cormack, R.M. 1992. Interval estimation for mark-recapture studies of closed populations. *Biometric* 48:567-576.

Courbois, J-Y, and 7 co-authors. 2008. Evaluating probability sampling strategies for estimating redd counts an example with Chinook salmon (*Oncorhynchus tshawytscha*). *CJAFS* 65:1814-1830.

Cousens, N.B.F., G.A. Thomas, C.G. Swann, and M.C. Healy. 1982. A review of salmon escapement estimation techniques. *Canadian Technical Report of Fisheries and Aquatic Sciences* 1108.

Cowen, L., and C.J. Schwarz. 2006. The Jolly-Seber model with tag loss. *Biometrics* 62, 69-705

Cowen, L., N. Trouton, and R.E. Bailey. 2007. Effects of angling for Chinook salmon for the Nicola River, British Columbia, 1996-2002. *North American Journal of Fisheries Management* 27:256–267.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007. Carcass Counts. Pages 59-86 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.

Crawford, B.A. and S. Rumsey. 2009. Guidance for monitoring recovery of salmon and steelhead listed under the federal Endangered Species Act (Idaho, Oregon, and Washington). Draft June 12, 2009. NOAA Fisheries, Portland, Oregon.

Crisp, D. T., and P. A. Carling. 1989. Observations on sitting, dimensions, and structure of salmonid redds. *Journal of Fish Biology* 34:119–134.

Collaborative Systemwide Monitoring and Evaluation Project (CSMEP). 2007. Marmorek, D.R., M. Porter, D. Pickard, and K. Wieckowski (eds.). In preparation: Collaborative Systemwide Monitoring and Evaluation Project

(CSMEP) Snake River Basin Pilot Study: Volume 1 & 2. Prepared by ESSA Technologies Ltd., Vancouver, B.C. on behalf of the Columbia Basin Fish and Wildlife Authority, Portland, OR

Darroch, J. N. 1961. The two-sampled capture–recapture census when tagging and sampling are stratified. *Biometrika* 48:241–260.

Dempson, J.B., and D.E. Stansbury. 1991. Using partial counting fences and a two- sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. *North American Journal of Fisheries Management* 11:27-37.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. U.S. Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-GTR-83, Asheville, North Carolina.

Dunham, J., B. Rieman, and K. Davis. 2001. Sources and magnitude of sampling error in redd counts for Bull Trout. *North American Journal of Fisheries Management* 21:343–352.

Dupuis, J.A., and C.J. Schwarz. 2007. A Bayesian approach to the multistate Jolly-Seber capture-recapture model. *Biometrics* 63:1015-1022.

Eames, M. and M. Hino. 1981. A mark-recapture study of an enumerated coho spawning escapement. Wash. Dept. Fisheries Prog. Rept. 148. Olympia, WA. 22p.

Ehinger, W., Quinn, T., Volkhardt, G., McHenry, M., Beamer, E. Roni, P. Greene, C. and Bilby, R. 2007. Study Plan for the Intensively Monitored Watershed Program: Lower Columbia Complex. Prepared by Intensively Monitored Watersheds Scientific Oversight Committee.

English, K. K., R. C. Bocking, 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* 49:1982–1989.

Firman, J.C. and S.E. Jacobs. 2002. A survey design for integrated monitoring of salmonids. <http://oregonstate.edu/dept/odfw/spawn/pdf%20files/reports/emappaper.pdf>.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook and coho salmon and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. *North American Journal of Fisheries Management* 25:284–300.

Gallagher, S.P., P.K.J. Hahn, and D.H. Johnson. 2007. Redd Counts. Pages 197-234 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.

Gray, S. 2006. Determine the Origin, Movements, and Relative Abundance of Bull Trout in Bonneville Reservoir, 2005-2006 Annual Report, Project No. 200306500. 81 electronic pages. BPA Report DOE/BP-00022537-1

Griffith, D.C., A. Peery, C.E. Ashbrook, K.W. Yi, and J.D. Dixon. 2009. Evaluating behavior and survival of adult steelhead (*Oncorhynchus mykiss*) captured in tangle nets using radio telemetry. Pages 2-1 to 2-12 in C.

- Ashbrook, J. Dixon, D. Griffith, K. Hassel, C. Peery, and E. Schwartz. Evaluate Live Capture Selective Harvest Methods: 2003. Annual Report for BPA Contract 2001-007-00. Olympia, Washington. 100 p.
- Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Canadian Journal of Fisheries and Aquatic Sciences* 45:834–844.
- Groot, C., and L. Margolis (eds). 1991. *Pacific Salmon Life Histories*. UBC Press. Vancouver, BC. 564pp.
- Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Canadian Journal of Fisheries and Aquatic Sciences* 45:834-844.
- Hankin, D.G., J.H. Clark, R.B. Deriso, J.C. Garza, G.S. Morishima, B.E. Riddell, C. Schwarz, and J.B. Scott. 2005. Report of the Expert Panel on the Future of the Coded Wire Tag Program for Pacific Salmon. PSC Tech. Rep. No. 18, November 2005. 300 p (includes agency responses as appendices).
http://www.psc.org/publications_tech_psctechreport.htm
- Harlan, K. 1999. Washington Columbia River and tributary stream survey sampling results, 1997. Columbia River Progress Rep., 99-09. Washington Department of Fish and Wildlife. Vancouver, WA.
- Hatch, D.R., M. Schwartzberg, and P.R. Mundy. 1994. Estimation of Pacific salmon escapement with a time-lapse video recording technique. *North American Journal of Fisheries Management* 14:626-635.
- Hetrick, N.J. and M.J. Nemeth. 2003. Survey of coho salmon races on the Pacific coast of the Alaska Peninsula and Becharof National Wildlife Refuges, 1994 with estimates of escapement for two small streams in 1995 and 1996. Alaska Fisheries Technical Report No. 63.
- Hiebert, S., L.A. Helfrich, D.L. Weigmann, and C. Liston. 2000. Anadromous salmonid passage and video image quality under infrared and visible light at Prosser Dam, Yakima River, Washington. *North American Journal of Fisheries Management* 17:461-466.
- Hilborn, R, and C.J. Walters. 1992. *Quantitative fisheries stock assessment: choice, dynamics, and uncertainty*. Chapman and Hall. New York, NY. 570pp.
- Hilborn, R., B.G. Bue, and S. Sharr. 1999. Estimating spawning escapement from periodic counts: a comparison of methods. *Can. J. Fish. Aquat. Sci.* 56: 888-896.
- Hill, R. A. 1997. Optimizing aerial count frequency for the area-under-the-curve method of estimating escapement. *North American Journal of Fisheries Management* 17:461–466.
- Hillson, T. 2002. Re-Introduction of Lower Columbia River Chum Salmon into Duncan Creek, Project No. 2001-05300. 63 electronic pages. (BPA Report DOE/BP-00007373-1).
- Holt, K.R. 2006. Evaluation of visual survey programs for monitoring coho salmon escapement in relation to coho conservation guidelines. Master's thesis. Simon Frazier University. 98pp.
- Hooten, R.S. 1987. Catch and Release as a Management Strategy for Steelhead in British Columbia. Pages 143-156 in R.A. Barnhart and T.D. Roelofs, editors. *Catch-and-Release Fishing: A Decade of Experience*, Symposium Proceedings. Humboldt State University, Arcata, California.

- Irvine, J. R., R. C. Blocking, 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.
- Irvine, J.R, D. Chen, J.T. Schnute. 2003. Retrospective sampling: A planning tool for field programs. *Fisheries* 28: 25-30.
- Jacobs, S. E. and C. X. Cooney. 1997. Oregon coastal salmon spawning survey, 1994 and 1995. Information Reports Number 97-5. Oregon Dept. of Fish and Wildlife.
- Jacobs, S. 2002. Calibration of estimates of coho spawner abundance in the Smith River basin, 2004. Monitoring Program Report Number OPSW-ODFW-2002-06, Oregon Department of Fish and Wildlife, Portland, Oregon.
- Johnson, J.K. 1990. Regional overview of coded wire tagging of anadromous salmon and steelhead in northwest America. *American Fisheries Society Symposium* 7:782-816.
- Johnson, J.K. 2004. Regional overview of coded wire tagging of anadromous salmon and steelhead in northwest America. Paper updated from 1989 to 2004 for use by the Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon (June 7-10, 2004, Seattle, WA.).
http://www.psc.org/info_codedwiretagreview_bgpapers.htm
- Johnson D.H., B.M. Shrier, L.S. O'Neal, J.A. Knutzen, X. Augerot, T. A. O'Neil, and T.N. Pearsons. 2007. *Salmonid Protocols Handbook: Techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society. Bethesda MD. p. 478.
- Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration: stochastic model. *Biometrika* 52:225-247.
- Jones, E.L.III, T.J. Quinn II, and B.W. Van Allen. 1998. Observer accuracy and precision in aerial survey counts of pink salmon in a southeast Alaska stream. *North American Journal of Fish Management* 18:832-846.
- Kassler, T., D. Rawding, B.M. Baker, A. Marshall, J.B. Shaklee. 2002. Genetic Mixed Stock Analysis of Steelhead at Bonneville Dam and in the Columbia River Zone 6 Fishery. 1997- 2000. Final Report submitted to NOAA/NMFS, Northwest Fisheries Science Center, Seattle, WA. Contract No. 50ABNF700089,44 pp.
- Kinsel, C., P. Hanratty, M. Zimmerman, B. Glaser, S. Gray, T. Hillson, D. Rawding, and S. VanderPloeg. 2009. Intensively monitored watersheds: 2008 fish population studies in the Hood Canal and Lower Columbia stream complexes. Washington Department of Fish and Wildlife. Vancouver, WA. 177pp.
- Keller, K. 2005. Evaluate Spawning of Fall Chinook and Chum Salmon below the Four Lowermost Columbia River Mainstem Dams; 2004 Columbia River Chum Salmon Return, 2004-2005 Annual Report, Project No. 199900301. 75 electronic pages (BPA Report DOE/BP-00007583-2).
- Korman, J., R.N.M. Ahrens, P.S. Higgins, and C.J. Walters. 2002. Effects of observer efficiency, arrival timing, and survey life on estimates of escapement for steelhead trout (*Oncorhynchus mykiss*) derived from repeat mark-recapture experiments. *Can. J. Fish. Aquat. Sci.* 59:1116-1131.

- Kuligowski, D. R., M. J. Ford, and B. A. Berejikian. 2005. Breeding structure of steelhead inferred from patterns of genetic relatedness among nests. *Transactions of the American Fisheries Society* 134:1202–1212.
- Lady, J. M., and J. R. Skalski. 1998. Estimators of stream residence time of Pacific salmon (*Oncorhynchus* spp.) based on release-recapture data. *Canadian Journal of Fisheries and Aquatic Sciences* 57:241–246.
- Lindsay, R. B., R. K. Schroeder, K. R. Kenaston, R. N. Toman, and M. A. Buckman. 2004. Hooking mortality by anatomical location and its use in estimating mortality of spring Chinook salmon caught and released in a river recreational fishery. *North American Journal of Fisheries Management* 24:367-378.
- Link, W.A., and R.J. Barker. 2010. Bayesian Inference with ecological applications. Academic Press. New York, NY. 339 pages.
- Lower Columbia Fish Recovery Board (LCFRB). 2010a. Research, Monitoring and Evaluation Program for Lower Columbia Salmon and Steelhead. LCFRB. Longview, WA.
- Lower Columbia Fish Recovery Board (LCFRB). 2010b. Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. LCFRB. Longview, WA.
- Lower Columbia Tule Chinook Working Group (LCTCWG). 2008. Addendum to Analyses to support a review of an ESA jeopardy consultation on fisheries impacting Lower Columbia River tule Chinook salmon, October 5, 2007. NOAA-Fisheries, Seattle, WA. 38pp.
- Macdonald, P.D.M. and T.J. Pitcher. 1979. Age-groups from size-frequency data: A versatile and efficient method of analyzing distribution mixtures. *J. Fish. Res. Board Can.* 36, pp. 987-1001.
- Manske, M., and C. J. Schwarz. 2000. Estimates of stream residence time and escapement based on capture-recapture data. *Canadian Journal of Fisheries and Aquatic Sciences* 57:241–246.
- Mäntyniemi, S., and A. Romakkaniemi. 2002. Bayesian mark–recapture estimation with an application to a salmonid smolt population. *Canadian Journal of Fisheries and Aquatic Sciences* 59:1748–1758.
- Maxwell, S.L. 2007. Hydroacoustics:Rivers. Pages 133-153 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.
- Mayer, K., Schuck, M., Wilson, S., and B. Johnson. 2005. Assess Salmonids in the Asotin Creek Watershed, 2004-2005 Annual Report, Project No. 200205300, 40 electronic pages, BPA Report No. DOE/BP-00018229 and No. DOE/BP-00022720.
- McElhany P., M.H. Ruckelshaus, M.J. Ford, T.C.Wainright, and E.P Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-42. 156pp.
- McPherson, S. A., D. R. Bernard, R. J. Yanusz, P. A. Milligan, and P. Timpany, 1999. Spawning abundance of Chinook salmon in the Taku River in 1998. Technical report, Alaska Department of Fish and Game, Division of Sport Fish.

- Miller, S., B. Riggers, E. Clemons, S. Kennedy, J. Patni. 2010. Oregon's NOC escapement indicator stock Chinook enumeration and spawner survey calibration – Nehalem and Siletz River basins. Oregon Department of Fish and Wildlife. Corvallis, OR.
- Milner, G. B., D. J. Teel, F. Utter, G. A. Winans. 1985. A genetic method of stock identification in mixed populations of Pacific salmon. *Marine Fisheries Review*, 47(1):1-8.
- Monitoring Oversight Committee (MOC). 2002. The Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery. Volume 1. 26pp.
http://www.rco.wa.gov/documents/monitoring/Executive_Report_final.pdf
- Muhlfeld, C. C., M. L. Taper, and D. F. Staples. 2006. Observer error structure in bull trout redd counts in Montana streams: implications for inference on true redd numbers. *Transactions of the American Fisheries Society* 135:643–654.
- Murdoch, A.R., T.N. Pearsons, and T.W. Maitland. 2010. Estimating the spawning escapement of hatchery- and natural-origin spring Chinook salmon using redd and carcass Data. *North American Journal of Fisheries Management* 29: 1206-1213.
- Narum, S.R., M. Banks, T.D. Beacham, M.R. Bellinger, M.R. Campbell, S.J. Dekoning, A. Eliz, C.M. Guthrie III, C. Kozfkay, K.M. Miller, P. Moran, R. Phillips, L.W. Seeb, C.T. Smith, K. Warheit, S.F. Young, J.C. Garza. 2008. Differentiating salmon populations at broad and fine geographic scales with microsatellite and single nucleotide polymorphisms. *Molecular Ecology* 17:3464-3477.
- Nelsen, T.C., M.L. Rosenau, and N.T. Johnson. 2005. Behavior and survival of wild and hatchery-origin winter steelhead spawners caught and released in a recreational fishery. *North American Journal of Fisheries Management* 25:931–943, 2005
- Newman, K. B. 2009. Overview of Methods for Estimating Chinook Salmon Escapement. United States Fish and Wildlife Service. Stockton, CA. 37pp.
- Northwest Power and Conservation Council (NPCC). 2010. Draft- Columbia River Basin Monitoring, Evaluation, Research, and Reporting (MERR) Plan. NPCC. Portland, Oregon.
- Olsen, E., R. French, and A. Ritchey. 1995. 1994 Hood River and Pelton Ladder Evaluation Studies, Project No. 1988-05304. 161 electronic pages. (BPA Report DOE/BP-81758-1).
- O'Neal, J.S. 2007. Snorkel surveys. Pages 325-340 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.
- Oregon Department of Fish and Wildlife (ODFW). 2010. Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead. ODFW. Salem, OR.
- Pacific Northwest Aquatic Monitoring Partnership (PNAMP). 2005. Strategy for coordinating monitoring of aquatic environments in the Pacific Northwest.

www.pnamp.org/web/workgroups/General/documents/General/PNAMPStrategyFebruary2005.pdf. PNAMP. Cook, WA.

Pacific Northwest Aquatic Monitoring Partnership (PNAMP). 2009. Integscore Aquatic Ecosystem and Fish Status and Trend Monitoring in the Lower Columbia River: Overview. PNAMP. Cook, WA.

Pacific Salmon Commission Coded Wire Tag Workgroup. 2008. An action plan in response to Coded Wire Tag (CWT) Expert Panel Recommendations. Pacific Salmon Comm. Tech. Rep. No. 25: 170 p.
http://www.psc.org/publications_tech_psctechreport.htm

Parken, C.K., R.E. Bailey, and J.R. Irvine. 2003. Incorporate uncertainty into area under the curve and peak count salmon escapement estimation. *North American Journal of Fisheries Management* 23:78-90.

Parsons, A. L., and J. R. Skalski. 2009a. The design and analysis of tagging studies in the Columbia Basin, Volume XXIV: A statistical critic of estimating salmon escapement in the Pacific Northwest. Bonneville Power Administration. Portland, OR. 267pp.

Parsons, A. L., and J. R. Skalski. 2009b. A bibliography of literature on estimating salmon escapement with focus on the Pacific Northwest. Volume XXV in *The Design and Analysis of Salmonid Tagging Studies in the Columbia Basin*. Bonneville Power Administration, Portland, OR.

Parsons, A. L., and J. R. Skalski. 2010. Quantitative assessment of salmonid escapement. *Reviews in Fisheries Science*, 18(4): 301-314.

Peirce, J.M., E.O. Otis, M. S. Wipfli, E. H. Follmann. 2011. Radiotelemetry to estimate stream life of adult chum salmon in the McNeil River, Alaska. *North American Journal of Fisheries Management* 31: 315 – 322.

Pollock, K.H., J.E. Hines, and J.D. Nicholas. 1985. Goodness of fit test for open capture-recapture experiments. *Biometrics* 41:399-410.

Pollock, J.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. *Wild. Monogr.* 107:97p.

Pollock, K.H., C.M. Jones, and T.L. Brown. 1994. Angler surveys and their application to fisheries management. *American Fisheries Society Special Publication* 25. Bethesda, MD.

Rajwani, N.K., and C.J. Schwarz. 1997. Adjusting for missing tags in salmon escapement surveys. *Can. J. Fish. Aquat. Sci.* 54:800-808.

Rawding, D, P.C. Cochran, and T. King. 1999. Wind River steelhead smolt and parr production monitoring during the 1998 spring outmigration. Washington Department of Fish and Wildlife. Vancouver, WA. 30pp.

Rawding, D., and S. VanderPloeg. 2001. The relationship between the 2000 juvenile salmon and steelhead smolt yield and salmon habitat in the EF Lewis River. Wash. Dept. Fish and Wild. Olympia, WA. 25pp.

Rawding, D., and T. Hillson. 2003. Population Estimates for Chum Salmon Spawning in the Mainstem Columbia River, Project No. 2001-05300. 47 electronic pages, (BPA Report DOE/BP-00007373-3).

- Rawding, D., and M. Groesbeck. 2004. 2004 Cedar Creek juvenile salmonid production evaluation. WDFW, Region 5 Fish Program. Vancouver, WA. 24p.
- Rawding, D. and P.C. Cochran. 2005. Wind River winter and summer steelhead adult and smolt population estimates, 2000-2004. Washington Department of Fish and Wildlife. Vancouver, WA. 29pp.
- Rawding D, T. Hillson , B. Glaser , K. Jenkins , and S. VanderPloeg. 2006a. Abundance and spawning distribution of Chinook salmon in Mill, Abernathy, and Germany Creeks during 2005. Wash. Dept. of Fish and Wild. Vancouver, WA. 37pp.
- Rawding, D, B. Glaser, and S. VanderPloeg. 2006b. 2005 Adult Winter Steelhead Distribution and Abundance. Wash. Dept. of Fish and Wild. Vancouver, WA. 26pp.
- Rawding, D. 2009a. Key assumptions for estimating salmon escapement. Washington Department of Fish and Wildlife. Olympia, WA. 26pp.
- Rawding, D. 2009b. Application of methods for estimating Chinook salmon escapement to Washington populations. Washington Department of Fish and Wildlife. Olympia, WA. 12pp.
- Rawding, D., J. Rodgers, and B.G. Hudson. 2010a. Identification and prioritization of management decisions, questions, and objectives for Lower Columbia River Integrated Status and Trend (ISTM) Salmon and steelhead monitoring. Pacific Northwest Aquatic Monitoring Partnership PNAMP Series 2010-004. Cook, WA. 56pp.
- Rawding, D., T. Cooney, and C. Sharpe. 2010b. Life history of Tule fall Chinook salmon in Lower Columbia River tributaries with estimates of juvenile survival, intrinsic productivity, and capacity from life cycle studies. Washington Department of Fish and Wildlife. Olympia, WA. 41pp.
- Reidinger, K. 2009. Escapement estimation methods for Washington's Chinook salmon stocks: a review of selected case studies. Washington Department of Fish and Wildlife. Olympia, WA. 26pp.
- Rivot, E., and E. Prevost. 2002. Hierarchical Bayesian analysis of capture-mark-recapture data. *Can. J. Fish. Aquat. Sci.* 53:2157-2165.
- Robson, D.S., and H.A. Regier. 1964. Sample size in Petersen mark-recapture experiments. *Transactions of the American Fisheries Society* 93: 215-226.
- Rodgers, J. D., M. F. Solazzi, S. L. Johnson, and M. A. Buckman. 1992. Comparison of three techniques to estimate juvenile coho populations in small streams. *North American Journal of Fisheries Management* 12:79-86.
- Royale, J.A., and R.M. Dorazio. 2008. Hierarchical modeling and inference in ecology: the analysis of data from metapopulations and communities. Academic Press. New York, NY. 444pp.
- Rub, A. M. W., L G. Gilbreath, R. L. McComas, B. P. Sandford, D. J. Teel, and J. W. Ferguson. 2010. A Study to evaluate survival of adult spring/summer Chinook salmon migscorefrom the mouth of the Columbia River to Bonneville Dam: preliminary results of pilot work conducted by NOAA Fisheries in spring 2010. NOAA Fisheries – Northwest Science Center. Seattle, WA. 13pp.

- Schwarz, C.J., R.E. Bailey, J.R. Irvine, and F.C. Dalziel. 1993. Estimating salmon escapement using capture-recapture methods. *Can. J. Fish. Aquat. Sci.* 50:1181-1197.
- Schwarz, C. J., and B. D. Dempson. 1994. Mark-recapture estimation of a salmon smolt population. *Biometrics* 50:98-108.
- Schwarz, C.J., and A.N. Arnason. 1996. A general method for analysis of capture-recapture experiments in open populations. *Biometrics* 52:860-873.
- Schwarz, C.J., and G.G. Taylor. 1998. The use of the stratified-Petersen estimator in fisheries management: estimating pink salmon (*Oncorhynchus gorbuscha*) in the Frazier River. *Can. J. Fish. Aquat. Sci.* 55:281-297.
- Schwarz, C.J., and G.A.F. Seber. 1999. A review of estimating animal abundance III. *Statistical Science* 14, 427-456.
- Scott, J. B. Jr. and W.T. Gill. 2008. DRAFT *Oncorhynchus mykiss*: Assessment of Washington State's anadromous populations and programs. WDFW. Olympia, WA.
- Seber, G.A.F. 1965. A note on the multiple-recapture census. *Biometrika* 52:249-259.
- Seber, G. A. F., and R. Felton. 1981. Tag loss and the Petersen mark-recapture experiment. *Biometrika* 68: 211-219.
- Seber, G. A. F. 1982. *The Estimation of Animal Abundance and Related Parameters*, 2nd edition. Edward Arnold: London.
- Seber, G. A. F. 1986. A review of estimating animal abundance. *Biometrics* 42:267-292.
- Seber, G. A. F. 1992. A review of estimating animal abundance. II. *International Statistical Review* 60:129-166.
- Seeb L.W., A. Antonovich, M.A. Banks, T.D. Beacham, M.R. Bellinger, S. M. Blankenship, M. Campbell, N.A. Decovich, J.C. Garza, C.M. Guthrie III, T. A. Lundrigan, P. Moran, S.R. Narum, J.J. Stephenson, K.J. Supernault, D.J. Teel, W.D. Templin, J.K. Wenburg, S.F. Young, C.T. Smith. 2007. Development of a standardized DNA database for Chinook salmon. *Fisheries* 32 (11): 540-552.
- Seiler, D., and L. Kishimoto. 1999. 1998 Cedar River sockeye salmon fry production evaluation. Washington Department of Fish and Wildlife. Olympia, WA. 15pp.
- Seiler, D., G. Volkhardt, and L. Kishimoto. 2001. 1999 Cedar River sockeye salmon fry production evaluation. Washington Department of Fish and Wildlife. Olympia, WA. 40pp.
- Seiler, D., G. Volkhardt, L. Peterson, L. Fleischer, S. Neuhauser, P. Hanratty, and L. Kishimoto. 2003 *Juvenile Salmonid Production Evaluation and Adult Escapement: Intensively Monitored Watersheds (IMW)*, Annual Report. Washington Department of Fish and Wildlife. Olympia, WA. 58pp.
- Shaklee, J. 1986. Summary of the 1986 Columbia River spring Chinook gill net fishery GSI analysis. Washington Department of Fisheries. Olympia, WA.

- Shardlow, T, R. Hilborn, and D, Lightly. 1987. Component analysis of instream escapement methods for Pacific Salmon. *Can. J. Fish Aquat. Sci.* 44:1031-1037
- Shardlow, T.F., and K.D. Hyatt. 2004. Assessment of the Counting Accuracy of the Vaki Infrared Counter on Chum Salmon. *North American Journal of Fisheries Management* 24:249-252.
- Shardlow, T.F., K.D. Hyatt, and S.R, Pearson. 2007. A new microcontrolled tag for accurately estimating life span and survey life of spawning salmon. *Aquatic Living Resources* 20: 197-203.
- Sharpe, C.S. and B.G. Glaser. 2007. 2005 Coweeman River juvenile salmonid production evaluation. Washington Department of Fish and Wildlife. Olympia, WA. WDFW Report FPA07-07. 32 pp.
- Sharpe, C.S., B.G. Glaser, and D.J. Rawding. 2011. Spawning Escapement, Juvenile Production, and Contribution to Fisheries of Coweeman River Fall Chinook Salmon: A progress report for work in 2010. Washington Department of Fish and Wildlife. Olympia, WA. 53pp.
- Solazzi, M. 1984. Relationship between visual counts of coho, Chinook, and chum salmon from spawning fish surveys and the actual number of fish present. Information Report Number 84-7. Oregon Department of Fish and Wildlife. Portland, OR.
- Solazzi, M.F., S.L. Johnson, B. Miller, T. Dalton. 2001. Salmonid Life-Cycle Monitoring Project 2000 Monitoring Program Report Number OPSW-ODFW-2001-2, Oregon Department of Fish and Wildlife, Portland, Oregon.
- Stevens, D. L. 2002. Sampling design and statistical methods for the integrated biological and physical monitoring of Oregon streams. Oregon State University, Department of Statistics, Corvallis, Oregon, and EPA National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon.
- Stewart-Oaten, A., W. W. Murdoch and K. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? *Ecology* 67(4): 929-940.
- Suring, E.J., E.T. Brown, and K.M.S. Moore. 2006. Lower Columbia River coho status report 2002-4: Population abundance, distribution, racestimming, and hatchery influence: Report Number OPSW-ODFW-2006-6, Oregon Department of Fish and Wildlife, Salem, Oregon.
- Swenson, E.A., A.E. Rosenberger, and P.J. Howell. 2007. Validation of endoscopy for determination of maturity in small salmonids and sex of mature individuals. *Transactions of the American Fisheries Society* 136:994–998.
- Sykes, S.D, and L.W. Botsford. 1986. Chinook salmon, *Oncorhynchus tshawytscha*, spawning escapement based on multiple mark-recapture of carcasses. *Fish. Bull.* 84:261-270.
- Szerlong, R.G., and D.E. Rundio. 2007. A statistical modeling method for estimating mortality and abundance of spawning salmon from a time series of counts. *Canadian Journal of Fisheries and Aquatic Sciences* 65:17-26.
- Temple, G.M., and T.N. Pearsons. 2007. Electrofishing backpack and drift boat. Pages 95-132 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.

- Thedinga, J. F., S. W. Johnson, K V. Koski, J. M. Lorenz, and M. L. Murphy. 1994. Determination of salmonid smolt yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. *North American Journal of Fisheries Management* 14:837-851.
- Thompson, D.L., E.G. Cooch, and M.J. Conroy (eds). 2008. *Modeling demographic processes in marked populations*. Springer. New York, NY. 1131pp.
- Thompson, W.L., G.C. White, and C. Gowan. 1998: *Monitoring vertebrate populations*. Academic Press, Inc., San Diego.
- Thompson, W.L. (ed). 2004. *Sampling rare or elusive species*. Island Press. Washington, DC. 429pp.
- Thurow, R.F. 1994. *Underwater methods for the study of salmonids in the intermountain west*. U.S. Dept of Agriculture, USFS, General Technical Report INT-GTR-307. July 1994.
- Topping, P. and Zimmerman, M. 2011. *Green River Juvenile Salmonid Production Evaluation: 2009 and 2010 Annual Report, FPA 11-01*. Washington Department of Fish and Wildlife. Olympia, WA.
- Vander Haegen, G. E., C. E. Ashbrook, K. W. Yi, and J. F. Dixon. 2004. Survival of spring Chinook salmon captured and released in a selective commercial fishery using gill nets and tangle nets. *Fisheries Bulletin* 68:123–133.
- Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.
- Walters, C.J, and D. Ludwig. 1981. Effect of measurement errors on the assessment of stock-recruitment relationships. *CJFAS* 38: 704-710.
- WDFW. 2011. Salmonid Stock Inventory available at: <http://wdfw.wa.gov/mapping/salmonscape/index.html>
- White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46 Supplement, 120-138.
- Williams, B.K., J.D. Nichols, and M.J. Conroy. 2002. *Analysis and management of animal populations*. Academic Press. New York, NY. 817 pages.
- Willis, R. A. 1954. The length of time that silver salmon spent before death on spawning grounds at Spring Creek, Wilson River in 1951-52. *Fish Commission of Oregon Research Briefs* 5: 27-31.
- Winans, G. A., M. M. Paquin, D. M. Van Doornik, B. M. Baker, P. J. Thornton, D. Rawding, A. R. Marshall, P. Moran, S. T. Kalinowski. 2004. Genetic stock identification of steelhead in the Columbia River basin: an evaluation of different molecular markers. *North American Journal of Fisheries Management*, 24:672-685.
- Zhou, S. (2002) Size-Dependent Recovery of Chinook Salmon in Carcass Surveys. *Transactions of the American Fisheries Society*: Vol. 131, No. 6, pp. 1194–1202

Zimmerman, C.E., and G.H. Reeves. 2000. Population structure of sympatric anadromous and nonanadromous *Oncorhynchus mykiss*: evidence from spawning ground surveys and otolith microchemistry. *Canadian Journal of Fisheries and Aquatic Sciences* 57:2152-2162.

Zimmerman, C.E., and L.M. Zubkar. 2007. Weirs. Pages 385-398 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland.

Appendix A. Status of Monitoring Biological Recovery of Salmon and Steelhead Populations in the Oregon Portion of the Lower Columbia River

Assessment of monitoring efforts used to determine the biological recovery status of salmon and steelhead populations in the LCR relied on the collection and analyses of data used to estimate four Viable Salmonid Population (VSP) indicators. The VSP indicators are abundance, productivity, diversity, and spatial structure. Current and planned VSP indicator monitoring efforts for Oregon salmon and steelhead populations in the LCR recovery area are summarized below by species (Tables 1–7). Monitoring efforts in Washington are discussed in Appendix B. The productivity indicator is not explicitly addressed here because this indicator is derived from more basic biological metrics such as spawner abundance. With the exception of juvenile rearing abundance monitoring at the stratum scale, no additional monitoring efforts are planned for the Youngs Bay and Big Creek coho and fall Chinook populations. Spawner abundance for these populations is very low. These populations are considered at high or very high risk of extinction, and recovery efforts are not a high priority because of their low abundance. No monitoring is described for chum salmon populations in Oregon other than for the Clatskanie and Scappoose populations. Chum salmon reintroduction studies are planned for the Clatskanie and Scappoose rivers.

Chum Salmon—Current Monitoring Status

Table 1. Scores for existing chum salmon monitoring efforts in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Asterisked population names indicate extirpated or functionally extinct populations. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Chum Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Youngs Bay*	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Big Creek *	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Clatskanie	High	0.00	1.00	0.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cascade	Scappoose	High	0.00	1.00	0.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Clackamas*	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gorge	Sandy*	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lower Gorge	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Upper Gorge	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Abundance-Juvenile Rearing (Clatskanie and Scappoose Chum)

No monitoring: Not applicable to chum because their life history (i.e., migrants leave natal streams shortly after emergence). This precludes useful inference about chum status based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Screw trap is planned for operation near the head of tide. The trap will be operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates will be conducted on a daily basis by release of marked fish above the trap.

Needs: None.

Abundance-Adult Recruits (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Most/all Columbia River and associated OR/WA tributary recreational fisheries are closed to chum retention. Mainstem sport salmon fisheries are monitored through October of each year. Retention of chum is allowed in the mainstem Columbia (treaty and non-treaty) and Select Area commercial fisheries. Commercial fisheries chum landings are accounted for through fish tickets. CWT recoveries from hatchery programs are used to estimate local stock in an adjacent river at moderate/high rates. Recovered fish are sampling for biological data. Point estimates are made of harvest and release mortality rates.

Needs: Genetic samples collected for/by ODFW and WDFW when chum are retained in commercial fisheries. Recommend genetic analysis to segregate chum catch by population. Conduct angler surveys in open tributaries when chum are present.

Abundance-Spawners (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Census-based spawning ground surveys are funded. Exact protocol is being developed for these surveys. An adult weir near head of tide has been funded.

Needs: None at this time.

Diversity-Natural Origin Age Structure (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Adult weir is planned for operation near head of tide on the Clatskanie River. Captured fish will be sampled for scales. Although census-based spawning ground surveys are planned in both the Clatskanie and Scappoose rivers, these surveys may not provide unbiased data on chum age structure because there may be differential carcass recovery rates related to fish size (and age).

Needs: None at this time. Assessment of the adequacy of age structure monitoring cannot be made until monitoring is implemented and size capture bias of the weir is evaluated.

Diversity-Migration/Spawning Time (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Census-based spawning ground surveys are funded. Exact protocol is being developed. An adult weir near the head of tide on the Clatskanie River is funded.

Needs: None at this time.

Diversity-Sex (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Census-based spawning ground surveys are funded. Exact protocol is being developed. An adult weir near the head of tide in the Clatskanie River is funded.

Needs: Compare sex ratios of carcasses recovered during Clatskanie spawning surveys to those of fish passing the Clatskanie floating weir to assess bias of spawning survey sex ratios.

Diversity-Origin (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Census-based spawning ground surveys are funded. Exact protocol is being developed. An adult weir near the head of tide in the Clatskanie River is funded.

Needs: None at this time.

Spatial Structure-Fry/Parr (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: None.

Needs: None. Determining chum fry distribution and abundance in streams and rivers is a low monitoring priority since these juvenile fish migrate to the estuary soon after emergence.

Spatial Structure-Spawners (Clatskanie and Scappoose Chum)

Current or Planned Monitoring: Census-based spawning ground surveys are funded. Exact protocol is being developed.

Needs: None at this time.

Coho Salmon Current Monitoring Status

Table 2. Scores for existing coho salmon monitoring efforts in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Coho Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Youngs Bay	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Big Creek	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Clatskanie	High	0.75	1.00	0.25	0.25	0.25	0.25	0.75	1.00	1.00	1.00
	Scappoose	High	0.75	1.00	0.25	0.25	0.25	0.25	0.75	0.75	1.00	0.50
Cascade	Clackamas	High	0.25	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.25	0.25
	Sandy	High	0.25	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.25	0.25
Gorge	Lower Gorge	High	0.25	0.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Hood River & Upper Gorge, OR	High	0.00	0.00	0.25	0.00	0.00	0.00	0.25	0.25	0.00	0.00

Abundance-Juvenile Rearing (Coast Stratum Coho Populations)

Current or Planned Monitoring: Snorkel surveys based on a generalized-random-tessellation-stratified (GRTS) sampling design are planned to provide status and trend data at the stratum scale on the density of juvenile coho in pools, % of pools that are occupied by juvenile coho, and % of sites that are occupied. Goal is to snorkel at least 40 sites/year. All pools that are present in 1000m long survey reaches/reaches are snorkeled. CVs are <15%. Resurveys are conducted on 10-20% of the sites by supervisors for QA/QC with an r-square of ~0.98; this suggests that the results of these surveys are highly repeatable.

Needs: None at this time; however, implementation of a program to monitor juvenile abundance using pass-removal or mark-recapture techniques would provide less biased data. Implementing surveys at the population scale instead of at the coast stratum scale would improve spatial resolution.

Abundance-Juvenile Rearing (Cascade and Gorge Strata Coho Populations)

Current or Planned Monitoring: Snorkel surveys based on a GRTS-based sampling design are planned to provide status and trend data at the combined Cascade and Gorge strata scale on the density of juvenile coho in pools, % of pools that are occupied by juvenile coho, and % of sites that are occupied. The monitoring effort target is to snorkel at least 40 sites/year in the combined strata. However, separate rather than combined estimates need to be conducted for the Cascade and Gorge strata. Current monitoring efforts provide an unbiased sample for the Cascade stratum but the sample for the Gorge stratum is biased because only a small portion of the lower Hood River basin is sampled. All pools in the 1000m long survey reaches are snorkeled. CVs are <15%. Resurvey is conducted on 10-20% of sites by supervisors for QA/QC with an r-square of ~0.98; this suggests that surveys results are highly repeatable.

Needs: An additional two person snorkel crew is needed so that separate estimates can be made in the Cascade and Gorge strata. Implementation of a program to monitoring juvenile abundance using pass-removal or mark-recapture techniques would provide less biased data. Implementation of surveys at the population instead of the stratum scale would improve spatial resolution.

Abundance-Juvenile Outmigrants (Clatskanie Coho)

Current or Planned Monitoring: Screw trap is planned for operation near the head of tide primarily to monitor chum and Chinook juvenile outmigrants (JOM). The trap will be operated 24/7 throughout the spring juvenile

migration period (March thru mid-June). Trap efficiency estimates will be conducted on a daily basis by release of marked fish above the trap.

Needs: None at this time. Will need to evaluate effectiveness of JOM trap for estimating coho JOM.

Abundance-Juvenile Outmigrants (Scappoose Coho)

Current or Planned Monitoring: A screw trap is operated on the Scappoose River and near Bonnie Falls on the North Fork of the Scappoose River. The trap is operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates are conducted on a daily basis through the release of marked fish above the trap. CVs are <15%. A screw trap operation is planned for near the head of tide on the Scappoose River. This trap will primarily be used to monitor chum and Chinook juvenile outmigrants (JOM). The trap will operate 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates will be conducted on a daily basis through release of marked fish above the trap.

Needs: None at this time. The effectiveness of new JOM trap near head of tide will need to be evaluated for JOM coho estimates.

Abundance-Juvenile Outmigrants (Clackamas Coho)

Current or Planned Monitoring: Juvenile migrant trapping occurs at North Fork Dam on the Clackamas River. The juvenile outmigration passage at North Fork Dam occurs in one of three ways: 1) through the hydropower turbines, 2) over the spill way, and 3) through the JOM trap. During periods of no spill, PGE estimates that they capture approximately 95% of coho JOM. No estimates are available for the capture efficiency of the juvenile trap when the dam spills water. Juvenile outmigrant counts may be significantly biased during periods of spill, particularly in years when outmigration occurs during periods of high river flow and spill.

Needs: Comprehensive mark/recapture studies are needed to improve JOM trap efficiencies.

Abundance-Juvenile Outmigrants (Sandy Coho)

Current or Planned Monitoring: Seven screw traps are operated in the Sandy River basin each year. Three of the traps are at fixed sites and four traps are rotated between two different sites each on alternate years. These traps provide an estimate of the JOM from approximately 43% of the miles of habitat available to anadromous salmonids in the Sandy River basin. The traps are operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates are conducted on a daily basis through release of marked fish above the traps.

Needs: Additional funding is needed to support operations at one fixed site (Cedar Creek). Significant improvements are needed to upgrade confidence limits. For example, in 2009, confidence limits ranged from 21% to 109% or were not calculated.

Abundance-Juvenile Outmigrants (Lower Gorge Coho)

Current or Planned Monitoring: None.

Needs: Funding is needed to implement an effective JOM trap for at least one population in the Gorge stratum.

Abundance-Juvenile Outmigrants (Gorge/Hood Coho)

Current or Planned Monitoring: Juvenile outmigrant trapping is currently conducted in the EF, WF, and MF of the Hood River. Few juvenile coho are captured in these traps because natural coho production is very low in the Hood River basin.

Needs: Funding is needed to implement an effective JOM trap for at least one population in the Gorge stratum. Natural origin abundance will have to increase before the precision and bias of this effort can be assessed.

Abundance-Adult Recruits (All Coho Populations)

Current or Planned Monitoring: Landed catch from ocean, mainstem Columbia River, and Select Area commercial and recreational (Buoy 10 and lower Columbia) fisheries monitor for CWTs, mark rate, and biological data. The in-river sample rate is high, and impacts to unmarked fish are monitored and reported. Fall commercial fisheries in the Columbia River are not mark-selective, but recreational fisheries are mark-selective. Adult carcass surveys are conducted in select systems (OR). An acoustic/PIT tagging study was initiated in fall 2011 to track unmarked coho. Adult coho are captured, tagged, and released in the lower Columbia River to continue their migration to terminal streams. The intent of this study is to provide additional information on the migration timing and spawning location of unmarked coho. This study is scheduled to continue in 2012. A CWT program is used to monitor Big Creek, Bonneville, and Sandy hatchery stocks. There is a year-round creel survey in the Hood River but very few coho are observed.

Needs: A local wild broodstock CWT program needs to be developed. It will be difficult to implement this program on populations with low abundance. The coefficient of variation needs to be calculated for harvest and release mortality rates.

Abundance-Spawners (All Coho Populations)

Current or Planned Monitoring: GRTS-based spawning ground surveys are planned for all coho population areas. Only a few sites are located in the Hood River portion of the Upper Gorge/Hood population area. Walking surveys are conducted every 10 days throughout the spawning season. Live fish counts for adult coho (i.e., estimated MEPS length >430 cm) are expanded to total abundance using area-under-the-curve estimation. Although the number of live jacks (estimated MEPS length \leq 430 cm) are recorded, the low observation probability associated with jack counts precludes AUC estimate expansion. Target sample sizes are 30 sample sites (each approximately 1 mile long) or enough sites to survey approximately 30% of available spawning habitat (whichever comes first). Since the start of the monitoring program in 2004, CVs have been significantly above the target of 15%. Adult coho are counted as they pass over North Fork Dam on the Clackamas River, and at the Cedar Creek hatchery weir on the Sandy River. A trap is operated on Neal Creek in the Hood River, although no coho have been captured there to date. These coho counts represent migrating adults and do not account for pre-spawning mortality.

A floating adult weir is planned for near the head of tide in the Clatskanie River. This weir is primarily intended to monitor chum and fall Chinook, but may also provide improved estimates of adult coho entering the Clatskanie River.

Needs: CVs need to be improved by increasing the number of sites for which valid AUCs can be calculated. In addition, there are three locally untested critical assumptions associated with this monitoring effort. The first is that the average spawning life for coho is 11.3 days. This value is based on the results of studies conducted in Oregon coastal streams. The second assumption is that the correct number of spawning miles must be used to expand the average number of spawners per mile surveyed to total number of spawners in the population area. The third assumption is that on average 75% of the live adult coho present during a survey are actually observed. All of these critical assumptions have been tested on the Oregon coast but not in the Lower Columbia ESU. There is also a need to develop and fund spawner abundance monitoring in Hood River that does not rely on visual observations of fish on spawning grounds because glacial till makes it difficult to observe fish in some areas. A floating weir is planned for the Clatskanie River. This weir could significantly improve coho spawner abundance estimates if it can be operated in a manner that will provide accurate adult coho estimates. This would make current issues with the precision and bias of the GRTS program moot.

Diversity-Natural Origin Age Structure (Clatskanie Coho)

Current or Planned Monitoring: Some scale samples are taken from carcasses recoveries during GRTS-based spawning surveys. These samples are likely biased because no attempt is made to adjust for differences in

carcass observation probabilities (which are probably lower for younger/smaller fish). A floating fish weir for monitoring returning chum and fall Chinook is planned for installation just above tidewater in the Clatskanie River and but may provide information on coho as well.

Needs: An age bias selectivity study needs to be designed and implemented to compare the age structure of carcasses recovered during spawning surveys to that of fish passed over the floating weir.

Diversity-Natural Origin Age Structure (Scappoose Coho)

Current or Planned Monitoring: Scale samples can be collected from natural origin fish that migrate above Bonnie Falls on the NF Scappoose River as well as juvenile outmigrants captured in a rotary trap that operates below Bonnie Falls. Currently scales are not being collected at these sites due to lack of funding for scale analysis. It is not known whether these fish are representative of natural origin fish in the population as a whole. Some scales are collected from carcasses recovered during GRTS-based spawning surveys but these samples are likely biased because no attempt is made to adjust for differences in carcass observation probabilities (which are probably lower for younger/smaller fish).

Needs: There are two untested critical assumptions associated with coho age structure monitoring in the Scappoose population area: 1) coho \leq 430 cm MEPS are two years old and fish >430 cm MEPS are three years old, and 2) the age structure of adult fish that migrate above the Bonnie Falls represent the age structure of Scappoose coho spawners as a whole. Additional funding is needed to test these assumptions and pay for scale analysis to assess the freshwater and ocean age of fish. The accuracy of age data collected from carcasses recovered during GRTS-based spawning surveys could be assessed if funding was made available to conduct these surveys above Bonnie Falls with the results compared to those obtained from fish captured and passed above Bonnie Falls SEE BELOW how you rephrased this. Age bias selectivity testing needs to be implemented.

Diversity-Natural Origin Age Structure (Clackamas Coho)

Current or Planned Monitoring: Scale samples could be collected from natural origin fish that pass above North Fork Dam as well as juvenile outmigrants captured in the downstream migrant traps at the dam. Currently scale samples are not being collected at these locations. It is unknown how representative these fish are of natural origin fish in the population as a whole. There are plans to implement video monitoring of fish at North Fork Dam by 2013 to eliminate physical handling of adults passed above the dam. Although some scales are taken from carcasses recovered during GRTS-based spawning surveys, these samples are most likely biased because no attempt is made to adjust for differences in carcass observation probabilities (which are probably lower for younger/smaller fish).

Needs: There are two untested critical assumptions associated with coho age structure monitoring in the Clackamas population area: 1) coho \leq 430 cm MEPS are two years old and >430 cm MEPS are three years old, and 2) the age structure of fish passed above North Fork Dam represents the age structure of Clackamas River coho spawners as a whole. Additional funding is needed to test these assumptions and support scale analysis to assess the freshwater and ocean age of fish. The accuracy of age data collected from carcasses recovered during GRTS-based spawning surveys could also be assessed if funding was available to conduct these surveys above North Fork Dam. The results of these surveys would be compared to those obtained from fish captured and passed above North Fork Dam. Age bias selectivity testing needs to be implemented.

Diversity-Natural Origin Age Structure (Sandy Coho)

Current or Planned Monitoring: Scale samples can be collected from natural origin fish passed above the Cedar Creek hatchery weir and from juvenile outmigrants captured in rotary traps operated in the Sandy River, but these samples are not currently collected. It is unknown how representative these fish (in particular spawners above Cedar Creek Hatchery) are of natural origin fish in the population as a whole. Although some scales are taken from carcasses recovered during GRTS-based spawning surveys, these samples are most likely

biased because no attempt is made to adjust for differences in carcass observation probabilities (which are probably lower for younger/smaller fish).

Needs: There are two untested critical assumptions associated with coho age structure monitoring in the Sandy population area: 1) coho ≤ 430 cm MEPS are two years old and >430 cm MEPS are three years old, and 2) the age structure observed in fish passed above Cedar Creek Hatchery represents the age structure of Sandy coho spawners as a whole. Additional funding is needed to test these assumptions as well as pay for scale reading to assess both freshwater and ocean age. The accuracy of age data collected from carcasses recovered during GRTS-based spawning surveys could also be assessed if funding was available to conduct surveys above the Cedar Creek weir. The results of these surveys could be compared to those obtained from fish captured and passed above the weir. Age bias selectivity testing needs to be implemented.

Diversity-Natural Origin Age Structure (Lower Gorge Coho)

Current or Planned Monitoring: Some scale samples are taken from carcasses recovered during GRTS-based spawning surveys. These samples are likely biased because no attempt was made to adjust for differences in carcass observation probabilities (which are probably lower for younger/smaller fish).

Needs: Additional funding is needed to develop and implement a study to monitor Gorge coho age structure. Age bias selectivity testing needs to be implemented. This will be difficult while abundance of natural origin fish is so low.

Diversity-Natural Origin Age Structure (Hood/Upper Gorge, OR Coho)

Current or Planned Monitoring: Few GRTS-based sampling efforts are conducted in the Hood River basin. Although some scales are taken from carcasses recovered during GRTS-based spawning surveys, these samples are most likely biased because no attempt was made to adjust for differences in carcass observation probabilities (which are probably lower for younger/smaller fish). Adult trapping is conducted in Neal Creek, but no adult coho have been captured at this site. This is probably due to the low overall abundance of natural origin coho in the Hood River.

Needs: Additional funding is needed to develop and implement a study to monitor the age structure of coho in the Hood/Upper Gorge, OR. Age bias selectivity testing needs to be implemented. This will be difficult while abundance of natural origin fish is so low.

Diversity-Migration/Spawning Time (All Coho Populations)

Current or Planned Monitoring: Spawn timing is provided by GRTS-based spawning ground surveys for coho in all population areas surveyed. Surveys are not conducted above North Fork Dam on the Clackamas River, and few surveys are conducted in the Hood River. Migration timing rather than spawn timing is captured for fish passed above North Fork Dam on the Clackamas River.

Needs: Sample sizes need to be increased by increasing the number of sites where valid AUCs can be calculated. This may prove difficult given that the primary reason for invalid AUC estimates is high stream flows which may result in missed survey intervals and missed spawning peaks. There is a need to develop and fund a monitoring program for coho spawning in the Hood River that does not rely on visual observations of fish because glacial till makes it difficult to observe fish on the spawning grounds in some areas.

Diversity-Sex (All Coho Populations)

Current or Planned Monitoring: Sex ratios are provided by GRTS-based spawning ground surveys for coho in all population areas except above the North Fork Dam on the Clackamas River. There are only a few of these survey sites on the Hood River. Sex ratios are not currently monitored on coho passed above North Fork Dam on the Clackamas River but this information could be collected there. Sex ratios are obtained from adult coho passed above the Cedar Creek weir in the Sandy River coho population area and from fish passed over the

adult trap at Bonnie Falls in the Scappoose River population. Low population abundance in some areas results in few carcass recoveries which makes unbiased sex sampling difficult.

Needs: Sex sampling bias testing (i.e., selectivity test) needs implementation.

Diversity-Origin (All Coho Populations)

Current or Planned Monitoring: Spawner carcasses are currently recovered during GRTS-based spawning ground surveys for coho in all population areas except above North Fork Dam on the Clackamas River. Only a few spawning ground surveys are conducted in the Hood River. Origin data could be collected from coho passed above North Fork Dam on the Clackamas River but currently are not. Origin data are obtained from adult coho passed above the Cedar Creek weir in the Sandy River coho population area and from fish passed over the adult trap at Bonnie Falls in the Scappoose River population. Low population abundance in some areas results in few carcass recoveries making unbiased sampling difficult.

Needs: Origin selectivity testing (i.e., are marked fish recoveries biased towards fish of certain origins) needs to be implemented.

Spatial Structure-Fry/Parr (All Coho Populations)

Current or Planned Monitoring: See Abundance-Juvenile Rearing sections for coho.

Needs: See Abundance-Juvenile Rearing sections for coho.

Spatial Structure-Spawners (All Coho Populations)

Current or Planned Monitoring: See Abundance-Spawners section for coho.

Needs: See Abundance-Spawners section for coho.

Fall Chinook Salmon Current Monitoring Status

Table 3. Scores for the existing monitoring efforts on fall Chinook salmon in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority with darker gradients indicating higher priority.

Stratum	Fall Chinook Population	Recovery Priority	Abundance				Diversity				Distribution		
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution	
Coast	Youngs Bay	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Big Creek	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Clatskanie	High	0.00	0.00	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.25	0.25
	Scappoose	High	0.00	0.00	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.25	0.25
Cascade	Clackamas	Medium	0.00	0.00	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.25	0.25
	Sandy	Medium	0.00	0.00	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.25	0.25
Gorge	Lower Gorge	Medium	0.00	0.00	0.25	0.50	0.25	0.25	0.25	0.25	0.00	0.50	0.50
	Upper Gorge	Medium	0.00	0.00	0.25	0.50	0.25	0.25	0.25	0.25	0.00	0.50	0.50
	Hood	High	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Abundance-Fry/Parr (All fall Chinook Populations)

Not applicable to fall Chinook because their life history (i.e., many fish migrate out of natal streams shortly after emergence). This early life migratory behavior precludes useful inference about fall Chinook status based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants (Clackamas and Scappoose fall Chinook)

Current or Planned Monitoring: A screw trap monitoring effort is planned for near the head of tide as part of chum salmon reintroduction study. This trapping effort should also provide good JOM estimates for fall Chinook. The trap will be operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates will be conducted on a daily basis through release of marked fish above the trap.

Needs: None.

Abundance-Juvenile Outmigrants (Cascade and Gorge strata fall Chinook populations)

Current or Planned Monitoring: Seven screw traps are operated in the Sandy River, but none of them capture significant numbers of juvenile fall Chinook. In the Hood River, JOM trapping occurs in EF, WF, and MF of the river as well as in the lower river near the Powerdale Dam site. Low numbers of juvenile fall Chinook are captured at these trapping sites. The small fall Chinook population size in the Hood River makes it difficult to estimate the number of downstream fall Chinook migrants. In addition, fall Chinook are distributed low in the Hood River basin and many fish may be downstream of the mainstem migrant trap. Differentiating between juveniles from the fall and spring runs is a problem.

Needs: Effective JOM monitoring needs to be implemented for at least one fall Chinook population within the Cascade and Gorge strata. A method of differentiating fall and spring Chinook juveniles is needed in the Clackamas, Sandy, and Hood rivers.

Abundance-Adult Recruits (All fall Chinook populations)

Current or Planned Monitoring: Landed catch from ocean, mainstem commercial, Select Area, and recreational (Buoy 10 and lower Columbia) fisheries are monitored for CWTs, mark rate, and biological data. There is a CWT program for Big Creek and Bonneville hatchery stock tules.

Needs: Development of a CWT program using local wild broodstock. This will be difficult for some populations due to low natural origin population size. Coefficient of variation needs to be calculated for harvest and release mortality rates.

Abundance-Spawners (All fall Chinook populations)

Current or Planned Monitoring: GRTS-based spawning ground surveys for fall Chinook are conducted in all population areas, but there are only a few sites in the Hood River. Walking surveys are conducted every 10 days throughout the spawning season. Live fish counts on adult fall Chinook (i.e., estimated MEPS length >510 cm) are expanded to total abundance using area-under-the-curve estimation. Although the number of live jacks (estimated MEPS length ≤ 510 cm) are routinely recorded, the low observation probability associated with jack counts precludes AUC estimate expansion. Target sample sizes are 30 sample sites (each approximately 1 mile long) or enough sites to survey approximately 30% of available spawning habitat (whichever comes first). So far, the precision of the spawner abundance estimates provided by this monitoring program (which began in 2009) are not promising. In most cases the 95% confidence intervals exceed the point estimate, making it difficult to draw inferences from the data. Because of this issue, no data from these surveys are reported here. A floating adult weir is planned for near the head of tide in the Clatskanie River.

Needs: Based on professional experience with coho surveys, it is likely that additional survey resources will be needed to meet precision goals. In addition, the surveys are biased toward smaller wadeable streams because poor visibility in larger, non-wadeable spawning reaches results in missed survey intervals at many sites. When survey intervals are missed, AUC estimates cannot be calculated at these sites. Within stratum estimates on the longevity of spawners on spawning grounds, spawner observation probabilities, redd life, and redds/adult need to be developed. Tissue samples need to be collected from carcasses in the Clackamas, Sandy, and Hood rivers to determine if they are fall, late fall, or spring Chinook. Within stratum studies are needed to determine whether AUC or redd count expansions provide the most accurate approach. There is a

need to develop and fund a spawning monitoring program in the Hood River that does not rely on visual observations of fish on spawning grounds. This need arises because glacial till in the Hood River makes it difficult to observe spawning fish in some areas. If the floating weir planned for the Clatskanie River can be operated to successfully provide accurate adult fall Chinook estimates, a significant improvement to fall Chinook spawner abundance estimates may be possible, and make current issues with the precision and bias of the GRTS-based survey program moot.

Diversity-Natural Origin Age Structure (All fall Chinook populations)

Current or Planned Monitoring: Some scale samples are taken from carcasses recovered during GRTS-based spawning surveys conducted in population areas. Age estimates from these surveys are likely biased because no attempt is made to adjust for differences in carcass observation probabilities which are probably lower for younger/smaller fish. A floating fish weir intended primarily to monitor returning chum and fall Chinook is planned for installation just above tidewater in the Clatskanie River. Fall Chinook age structure can also be monitored on fish passed over Cedar Creek weir in the Sandy River population area.

Needs: Improved scale collection and analysis efforts are needed but collecting enough samples to satisfy precision goals for estimates may be difficult for populations with low natural origin abundance. Age bias selectivity testing needs to be implemented. In particular, an age bias selectivity study/test is needed for fall Chinook on the Clatskanie River to compare the age structure of carcasses recovered during spawning surveys to those obtained from fish passed over the floating weir. Monitoring efforts also need to collect tissue samples from carcasses in Clackamas, Sandy, and Hood rivers to determine if they are fall, late fall, or spring Chinook.

Diversity-Migration/Spawning Time: (All fall Chinook populations)

Current or Planned Monitoring: Spawn timing estimates for fall Chinook are made from GRTS-based spawning ground surveys in all population areas, but few surveys are conducted in Hood River. There is a potential for bias towards the timing of spawning in wadeable streams because high flow conditions in larger streams often result in significant temporal gaps between surveys. A floating fish weir intended primarily to monitor returning chum and fall Chinook is planned for installation just above tidewater in the Clatskanie River.

Needs: Based on professional experience with coho surveys, it is likely that additional survey resources will be needed to increase the number of sites surveyed at regular intervals in order to accurately capture spawn timing. Spawner surveys are likely biased towards smaller wadeable streams since poor visibility in larger, non-wadeable spawning reaches results in missed survey intervals at many sites so AUC estimates cannot be calculated for these sites. Within stratum estimates on the longevity of spawners on spawning grounds, spawner observation probabilities, redd life, and redds/adult need to be developed. Tissue samples need to be collected from carcasses to determine if fish are fall, late fall, or spring Chinook. A spawning monitoring program needs to be developed and funded in the Hood River that does not rely on visual observations of fish on spawning grounds because glacial till makes it difficult to observe spawning fish in some areas. Significant improvement in estimates of fall Chinook migration timing may be possible if the floating weir planned for the Clatskanie River can be operated to successfully provide accurate counts of adult fall Chinook.

Diversity-Sex (All fall Chinook populations)

Current or Planned Monitoring: Sex ratios are determined from GRTS-based spawning ground surveys for fall Chinook in all populations areas, but few surveys are conducted in the Hood River. A floating fish weir primarily intended to monitor returning chum and fall Chinook is planned for installation just above tidewater in the Clatskanie River. Sex ratios of fall Chinook can be obtained from fish passed over Cedar Creek weir in the Sandy River population area.

Needs: Monitoring of sex ratios for Hood River fall Chinook spawners needs to be developed and implemented. Sex sampling bias testing (i.e., selectivity test) needs to be implemented. Low carcass

recoveries for some populations may bias results; carcass recoveries are low in these populations because of low adult abundance. Tissue samples need to be collected from carcasses on the Clackamas, Sandy, and Hood rivers to determine if fish are fall, late fall, or spring Chinook. A significant improvement to fall Chinook sex ratio estimates may be possible if the floating weir planned for the Clatskanie River provides accurate adult fall Chinook counts.

Diversity-Origin (All fall Chinook populations)

Current or Planned Monitoring: Carcasses recovered during GRTS-based spawning ground surveys for fall Chinook are examined for fin clips in all population areas, but few sites are sampled in the Hood River. A floating fish weir intended primarily to monitor returning chum and fall Chinook is planned for installation just above tidewater in the Clatskanie River. Samples to determine origin can be obtained from fish passed over Cedar Creek weir in the Sandy River population area.

Needs: A program to monitor adult fall Chinook in the Hood River needs to be developed and implemented. Selectivity testing needs to be implemented with adequate sample sizes. The low abundance of adult fish in some populations will make this difficult. A significant improvement to fall Chinook origin estimates may be possible if the floating weir planned for the Clatskanie River provides accurate adult fall Chinook counts.

Spatial Structure-Fry/Parr (All fall Chinook populations)

Current or Planned Monitoring: See Abundance-Juvenile Rearing sections for fall Chinook.

Needs: See Abundance-Juvenile Rearing sections for fall Chinook.

Spatial Structure-Spawners (All fall Chinook populations)

Current or Planned Monitoring: See Abundance-Spawners section for fall Chinook.

Needs: See Abundance-Spawners section for fall Chinook.

Late Fall Chinook Salmon Current Monitoring Status

Table 4. Scores for existing monitoring efforts on late fall Chinook salmon in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Late Fall Chinook Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Stucture	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Cascade	Sandy	High	0.00	0.00	0.25	0.25	0.25	0.25	0.75	0.25	0.00	0.25

See Sandy River fall Chinook for text that summarizes monitoring status and needs for Sandy River late fall Chinook.

Spring Chinook Salmon Current Monitoring Status

Table 5. Scores for the existing monitoring efforts on spring Chinook salmon in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts on the life stage/population at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Spring Chinook Population	Priority	Abundance				Diversity				Distribution	
	Sandy	High	0.00	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.25
Gorge	Hood	High	0.00	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.00	0.00

Abundance-Fry/Parr (All spring Chinook populations)

This indicator does not apply to LCR spring Chinook because many fry/parr migrate out of natal streams shortly after emergence. This life history behavior precludes useful inference about spring Chinook status based on resident juvenile abundance in streams and rivers in the LCR.

Abundance-Juvenile Outmigrants (Clackamas spring Chinook)

Current or Planned Monitoring: Juvenile migrant trapping occurs at North Fork Dam. Juvenile outmigrants pass North Fork Dam in one of three ways: 1) through the hydropower turbines, 2) over the spillway, or 3) through the JOM trap. When there is no spill, PGE estimates that the trap collects approximately 95% of coho JOM. Based on this data, trap efficiency may also be high for spring Chinook JOM when there is no spill at North Fork Dam. During spill, and in particular when fish are migrating during periods of high river flows and spill, no estimates are available for the capture efficiency of the juvenile trap. As a result, JOM counts at North Fork Dam may be significantly biased when these conditions exist.

Needs: Improved estimates of JOM trap efficiencies are needed and can be achieved with comprehensive mark/recapture studies.

Abundance-Juvenile Outmigrants (Sandy spring Chinook)

Current or Planned Monitoring: Seven screw traps are operated annually in the Sandy River basin. Three of the traps are at fixed sites and four traps are rotated between two different sites on alternate years. These traps provide estimates of JOM from approximately 43% of the miles of habitat available to anadromous salmonids in the Sandy River basin. The traps are operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates are conducted on a daily basis through release of marked fish above the traps.

Needs: Significant improvements need to be achieved in the confidence limits of estimates, which ranged from 21% to 109% in 2009, or were not calculated.

Abundance-Juvenile Outmigrants (Hood Spring Chinook)

Current or Planned Monitoring: JOM trapping efforts occur in the EF, WF, and MF of the Hood River as well as in the lower Hood River near the Powerdale Dam site. Juveniles captured at the tributary traps are PIT tagged and monitored for PIT tags at the lower mainstem trap. Precision of downstream migrant estimates for spring Chinook are reduced by the capture efficiency of migrant traps because the traps do not operate when hatchery fish are released. Differentiating between juveniles from the fall and spring runs is difficult, and methods need to be implemented at the traps to improve differentiation of these Chinook runs.

Needs: Increasing JOM capture efficiency at the traps will also increase PIT tag recoveries by staggering and/or reducing hatchery releases. Increase trap efficiency with guidance structures.

Abundance-Adult Recruits (All Spring Chinook Populations)

Current or Planned Monitoring: Statistical creel surveys in all populations as well as in Columbia and Lower Willamette rivers. Landed catch from mainstem commercial, Select Area, and recreational fisheries is monitored for CWTs, mark rate, and biological data. All fisheries are mark-selective except the Select Area commercial. Unmarked spring Chinook handle and release mortalities for unmarked spring Chinook caught in the mainstem commercial fishery are estimated with an onboard monitoring program conducted during each

fishing period. Run forecast and reconnaissance is conducted for the Clackamas River and includes natural origin fish.

Needs: The creel survey design needs evaluation, and may need more crews. A CWT program needs to be developed with local wild broodstock. Coefficients of variation need to be calculated for harvest and release mortality rates.

Abundance-Spawners (Clackamas Spring Chinook)

Current or Planned Monitoring: There are two Clackamas River spring Chinook monitoring programs. One program is a census of spawning redds above North Fork Dam. This effort has been conducted annually since 1996 as part of an ODFW research project on Willamette spring Chinook. In addition, redd surveys are conducted three to six times over the course of the spawning period. The second monitoring program, implemented by PGE since 1986, counts adult spring Chinook as they pass over North Fork Dam. As with all visual surveys, the redd count monitoring precision and bias is subject to observer error. Redds are also monitored below the dam, but because water clarity is particularly poor below North Fork Dam, no emphasis is made to survey redds below the dam for this program. Although relatively few spring Chinook are thought to spawn below the dam, the redd count monitoring effort cannot be considered a complete census without this information. In addition, assumptions need to be made regarding factors such as adults/redd and the length of time redds are visible in order to estimate the number of adult fish with the redd counts. Dam counts provide very accurate estimates of adult spring Chinook passing upstream, but represent pre-spawning abundance, (pre-spawning mortality can be considerable), and do not include spring Chinook that spawn below North Fork Dam.

Needs: Analysis of previous data is needed to evaluate whether North Fork Dam counts can be used to calibrate redd counts in order to obtain actual fish abundance estimates. Methods to reduce uncertainty in redd counts due to observer error (e.g., multiple surveys by different crews on the same day) need to be implemented. Because redd surveys are conducted as part of a research project, there is no guarantee that these surveys will continue once the research project is completed (no completion date has been established). A precision method for estimating spawner abundance below North Fork Dam needs to be developed and implemented. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs.

Abundance-Spawners (Sandy Spring Chinook)

Current or Planned Monitoring: After the removal of Marmot Dam on the Sandy River in 2008, spring Chinook spawner abundance monitoring in the Sandy population area has consisted of a redd census of all available spawning habitat above the old Marmot Dam site and counts of natural origin spring Chinook passed over weirs in Stihl and Zig Zag creeks and the Salmon River. Redd surveys are conducted three to six times over the course of the spawning period. These surveys have been conducted since 1996 as part of an ODFW research project on Willamette spring Chinook. As with all visual surveys, redd count monitoring precision and bias is subject to observer error. Because water clarity is particularly poor below the old Marmot Dam site due to glacial till, no emphasis is put on redd surveys below the dam site. Because of this, the redd count monitoring cannot be considered a complete census. In addition, assumptions are made regarding factors such as adults/redd and length of time redds are visible in order to convert redd counts to adult abundance estimates.

Needs: A method for calibrating redd counts to actual spawner abundance needs to be developed. Methods of reducing the uncertainty in redd counts due to observer error, such as multiple surveys by different crews on the same day, need to be implemented. Because redd surveys are conducted as part of an ODFW research project, there is no guarantee these surveys will continue once the research project is completed (no completion date has been established). Methods need to be developed to estimate spawner abundance below the Marmot Dam site. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs.

Abundance-Spawners (Hood Spring Chinook)

Current or Planned Monitoring: Spawning surveys at index sites have been conducted by the Confederated Tribes of Warm Springs in selected areas upstream of Powerdale Dam since the early 2000s. These surveys may provide reasonable trend information but may be biased for yearly abundance estimates because the survey sites are not random. Furthermore, the precision of these estimates are not available. Spawning surveys are subject to environmental and observer bias, and glacial turbidity can significantly hinder the ability of observers to identify redds in some years. A floating weir above the confluence of the WF Hood River captures fish going into the MF of the river. A trap/fish ladder is being built at Moving Falls and will begin operation in 2013. A fixed panel weir on the WF was operated by the Warm Springs tribe in 2011 and 2012 will be replaced by the Moving Falls trap in 2013. There is also a trap at Rogers Spring Creek at the Parkdale Tribal Fish Facility. This trap exclusively captures hatchery origin fish.

Needs: Spawning ground surveys should continue in order to better define spatial spawning distribution, examine weir effect, and estimate spawning downstream of the weir. The feasibility of installing sonar (i.e., DIDSON) low in the system to monitor escapement needs to be investigated. A precision estimate needs to be calculated on trap data.

Diversity-Natural Origin Age Structure (Clackamas Spring Chinook)

Current or Planned Monitoring: Scale samples can be collected from natural origin fish passed above North Fork Dam as well as from juvenile outmigrants captured in the downstream migrant trap at the dam, these data are not currently collected. It is unknown how representative these fish would be of natural origin fish in the population as a whole. There are plans to eliminate the physical handling of adults passed above North Fork Dam by 2013 by implementing video monitoring. Although some scales are taken from carcasses recovered during GRTS-based spawning surveys, these samples are most likely biased because no attempt is made to adjust for differences in carcass observation probabilities which are probably lower for younger/smaller fish.

Needs: A representative scale sample needs to be collected from spring Chinook passed over North Fork Dam. These scale samples need to be analyzed for age at ocean entry and age at return. Tissue samples need to be collected and analyzed from spring Chinook carcasses below North Fork Dam to assess the extent of spawning below the dam. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs. Age bias selectivity testing needs to be implemented.

Diversity-Natural Origin Age Structure (Sandy Spring Chinook)

Current or Planned Monitoring: Scale samples are collected from all carcasses recovered during census-based spawning surveys above the Marmot Dam site. These scales provide information on the age of ocean entry and age at return of spring Chinook in this population area. Redd surveys are conducted three to six times over the course of the spawning period. These surveys are potentially biased because an unknown number of spring Chinook spawn below the Marmot Dam site and because observation probabilities of detecting carcasses of different sizes/ages are not known.

Needs: A monitoring program to representatively sample the age structure of Sandy River spring Chinook needs to be developed and implemented. The extent of spring Chinook spawning below Marmot Dam needs to be assessed. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs.

Age bias selectivity testing needs to be implemented.

Diversity-Natural Origin Age Structure (Hood Spring Chinook)

Current or Planned Monitoring: Spawning surveys at index sites have been conducted by the Confederated Tribes of Warm Springs in selected areas upstream of Powerdale Dam, since the early 2000s; these sites were

not randomly selected. A floating weir above the confluence of the WF Hood River captures fish going to the MF Hood River. A new trap/fish ladder will be operational at Moving Falls in 2013. A fixed panel weir on the WF Hood River was operated by the tribe in 2011 and 2012 but will not be used once Moving Falls trap is operational. There is also a trap at Rogers Spring Creek at the Parkdale Tribal Fish Facility. The Rogers Spring Creek trap exclusively captures hatchery origin fish.

Needs: Testing needs to be implemented to determine if the new Moving Falls trap catch represents the spawner population.

Diversity-Migration/Spawn Timing: (Clackamas Spring Chinook)

Current or Planned Monitoring: The migration timing estimate is determined from daily counts of spring Chinook passed over North Fork Dam. Spawn timing is obtained from census-based redd surveys above North Fork Dam. Redd surveys are conducted three to six times over the course of the spawning period.

Needs: Past data needs to be analyzed and evaluated to determine if the migration timing of fish passing over North Fork Dam correlates with spawn timing as indicated by redd counts. The uncertainty associated with redd counts due to observer error needs to be reduced. Methods of reducing this uncertainty need to be investigated but one approach is to conduct multiple redd count surveys by different crews on the same day. Note that these redd surveys are conducted as part of a research project on the Clackamas River. There is no guarantee that these red surveys will continue once the research project is completed. No completion date for this research project has been established. Methods need to be developed to monitor spawn timing below North Fork Dam. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs.

Diversity-Migration/Spawning Time: (Sandy Spring Chinook)

Current or Planned Monitoring: Spawn timing is obtained for census-based redd surveys above the Marmot Dam site. Redd surveys are conducted three to six times over the course of the spawning season.

Needs: Investigate ways to reduce uncertainty in redd counts due to observer error (e.g., multiple surveys by different crews on the same day). ALSO NOTE that because redd surveys are conducted as part of a research project, there is no guarantee that surveys will continue once the research project is completed (no completion date has been established). Develop ways to monitor spawn timing below Marmot Dam site. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs.

Diversity-Migration/Spawning Time (Hood Spring Chinook)

Current or Planned Monitoring: Spawning surveys at index sites have been conducted by the Confederated Tribes of Warm Springs in selected areas upstream of Powerdale Dam, since early 2000s. These surveys may be biased for spawn timing since the sites were not randomly picked. Spawning surveys are subject to environmental and observer bias. Glacial turbidity can significantly hinder observer's ability to identify redds in some years. The floating weir above the confluence of the WF Hood River captures fish going into the MF. Plans are in place to build a trap/fish ladder at Moving Falls (online 2013). A fixed panel weir on the WF operated by the tribe in 2011 and 2012 will not be in operation once Moving Falls traps comes online. There is also a trap at Rogers Spring Creek at the Tribal Parkdale Fish Facility. This trap exclusively captures hatchery origin fish.

Needs: Assess potential of migration delay caused by weirs and representativeness of redd surveys.

Diversity-Sex (Clackamas Spring Chinook)

Current or Planned Monitoring: Sex ratios are obtained from carcasses recovered during census-based redd surveys above North Fork Dam. Redd surveys are conducted three to six times over the course of the spawning season.

Needs: The similarity of sex ratios of spring Chinook that spawn below and above North Fork Dam needs to be determined. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs. Sex sampling bias testing needs to be implemented (i.e., selectivity test).

Diversity-Sex (Sandy Spring Chinook)

Current or Planned Monitoring: Sex ratios are obtained from carcasses recovered during census-based redd surveys above the Marmot Dam site. Redd surveys are conducted three to six times over the course of the spawning season.

Needs: The similarity of sex ratios of spring Chinook that spawn below and above the Marmot Dam site needs to be determined. Genetic samples need to be collected in order to differentiate between fish from the fall and spring Chinook runs. Sex sampling bias testing needs to be implemented (i.e., selectivity test).

Diversity-Sex (Hood Spring Chinook)

Current or Planned Monitoring: The Confederated Tribes of Warm Springs have conducted spawning surveys at index sites upstream of Powerdale Dam since the early 2000s. These survey sites were not randomly selected and may generate biased sex ratios estimates. Spawning surveys are subject to environmental and observer bias. Glacial turbidity can significantly hinder observer's ability to find carcasses in some years. A floating weir above the confluence of the WF Hood River captures fish going into the MF Hood River. A new trap/fish ladder will be operational at Moving Falls in 2013. A fixed panel weir on the WF Hood River was operated by the tribe in 2011 and 2012 but will not be used once Moving Falls trap is operational. There is also a trap at Rogers Spring Creek at the Parkdale Tribal Fish Facility. The Rogers Spring Creek trap exclusively captures hatchery origin fish.

Needs: Sex sampling bias testing needs to be implemented (i.e., selectivity test).

Diversity-Origin (Clackamas Spring Chinook)

Current or Planned Monitoring: All hatchery origin spring Chinook are fin clipped and temperature-based otolith marked. No fin clipped adult spring Chinook are intentionally passed over North Fork Dam. Carcasses recovered during census-based spawning ground surveys above North Fork Dam are examined for fin clips; the otoliths are removed from carcasses without fin clips to determine if there is a hatchery temperature marks. Redd surveys are conducted three to six times over the course of the spawning season.

Needs: The origin of spring Chinook that spawn below North Fork Dam needs to be assessed. Selectivity testing for origin needs to be implemented.

Diversity-Origin (Sandy spring Chinook)

Current or Planned Monitoring: All hatchery origin spring Chinook are marked by clipping the adipose fin clipped and using temperature-based to mark the otolith marked. Carcasses recovered during census-based spawning ground surveys above the Marmot Dam site are examined for fin clips; the otoliths are removed from carcasses without fin clips to determine if there are hatchery temperature marks. Redd surveys are conducted three to six times over the course of the spawning season.

Needs: The origin of spring Chinook that spawn below the Marmot Dam site needs to be assessed. Selectivity testing for origin needs to be implemented.

Diversity-Origin (Hood spring Chinook)

Current or Planned Monitoring: Spawning surveys at index sites have been conducted by the Confederated Tribes of Warm Springs in selected areas upstream of Powerdale Dam since the early 2000s. These surveys may be biased for origin since the survey sites were not randomly selected. Spawning surveys are subject to environmental and observer bias. Glacial turbidity can significantly hinder observer's ability to find carcasses in some years. A floating weir above the confluence of WF Hood River captures fish going into the MF Hood

River. A new trap/fish ladder will be operational at Moving Falls in 2013. A fixed panel weir on the WF Hood River was operated by the tribe in 2011 and 2012 but will not be used once Moving Falls trap is operational. There is also a trap at Rogers Spring Creek at the Parkdale Tribal Fish Facility. The Rogers Spring Creek trap exclusively captures hatchery origin fish.

Needs: Selectivity testing for origin needs to be implemented.

Spatial Structure-Fry/Parr (All Spring Chinook Populations)

Current or Planned Monitoring: See Abundance-Juvenile Rearing sections for spring Chinook.

Needs: See Abundance-Juvenile Rearing sections for spring Chinook.

Spatial Structure-Spawners (All Spring Chinook Populations)

Current or Planned Monitoring: See Abundance-Spawners section for spring Chinook.

Needs: See Abundance-Spawners section for spring Chinook.

Winter Steelhead Current Monitoring Status

Table 6. Scores for the existing monitoring efforts on winter steelhead in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority with darker gradients indicating higher monitoring priority.

Stratum	Winter Steelhead Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration/Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Youngs Bay	High	0.75	0.00	0.25	0.50	0.00	0.50	0.00	0.00	1.00	0.50
	Big Creek	High	0.75	0.00	0.25	0.50	0.00	0.50	0.00	0.00	1.00	0.50
	Clatskanie	High	0.75	1.00	0.25	0.50	0.00	0.50	0.00	0.00	1.00	0.50
	Scappoose	High	0.75	1.00	0.25	0.50	0.00	0.50	0.25	0.25	1.00	0.50
Cascade	Clackamas	High	0.25	0.25	0.25	0.50	0.00	0.50	0.25	0.25	0.25	0.50
Gorge	Lower Gorge	High	0.25	0.00	0.25	0.50	0.00	0.50	0.00	0.00	0.25	0.50
	Upper Gorge	Low	0.25	0.00	0.25	0.50	0.00	0.50	0.00	0.00	0.25	0.50
	Hood	High	0.00	0.25	0.25	0.25	0.50	0.25	0.50	0.50	0.00	0.25

Abundance-Juvenile Rearing (Coast Stratum Winter Steelhead Populations)

Current or Planned Monitoring: GRTS-based snorkel surveys are conducted to provide status and trend data at the stratum scale on the density of juvenile steelhead in pools, % of pools that are occupied by juvenile steelhead, and % of sites that are occupied. The monitoring goal is to snorkel at least 40 sites/year. All pools that are present in the 1000m long survey reaches are snorkeled. Coefficients of variation are <15%.

Supervisors resurvey 10-20% of sites for QA/QC with an r-square of ~0.84, suggesting that these survey results are highly repeatable.

Needs: None at this time. However, implementation of a juvenile abundance monitoring program that uses pass-removal or mark-recapture techniques would provide less biased data. Implementing surveys at the population rather than Coast stratus scale would improve spatial resolution.

Abundance-Juvenile Rearing (Cascade and Gorge Strata Winter Steelhead Populations)

Current or Planned Monitoring: GRTS-based snorkel surveys are conducted to provide status and trend data at the combined Cascade and Gorge stratum scale on the density of juvenile steelhead in pools, % of pools that are occupied by juvenile steelhead, and % of sites that are occupied. The monitoring goal is to snorkel at least 40 sites/year within the combined strata. All pools present in the 1000m long survey reaches are snorkeled.

Coefficients of variation are <15%. Supervisors resurvey 10-20% of site for QA/QC with an r-square of ~0.84, which suggests survey results are highly repeatable. Very few survey sites are located in the Hood River basin. *Needs:* An additional two person snorkel crew would allow separate estimates for the Cascade and Gorge strata. Implementation of a program to monitor juvenile abundance using pass-removal or mark-recapture techniques would provide less biased data. Implementation of surveys at the population rather than stratum scale would improve spatial resolution.

Abundance-Juvenile Outmigrants (Youngs Bay and Big Creek Winter Steelhead)

Current or Planned Monitoring: None.

Needs: None at this time. If JOM traps planned for Clatskanie and Scappoose river chum and Chinook populations can be operated to effectively obtain winter steelhead JOM estimates, then no additional JOM traps are needed in this stratum.

Abundance-Juvenile Outmigrants (Clatskanie and Scappoose Winter Steelhead)

Current or Planned Monitoring: A screw trap will be installed near the head of tide on the Clatskanie River primarily to monitor chum and Chinook JOM. The trap will be operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates will be conducted on a daily basis by release of marked fish above the trap. A screw trap is operated at Bonnie Falls on the North Fork Scappoose River. The trap is operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates are conducted on a daily basis through release of marked fish above the trap. The coefficient of variation is <15%.

Needs: None at this time. The effectiveness of the Clatskanie head of tide JOM trap needs to be evaluated for winter steelhead JOM estimates.

Abundance-Juvenile Outmigrants (Clackamas Winter Steelhead)

Current or Planned Monitoring: Juvenile outmigrant trapping is conducted at North Fork Dam. Juveniles migrating downstream may pass North Fork Dam in one of three ways: 1) through the hydropower turbines, 2) over the spill way, or 3) through the JOM trap. When there is no spill over North Fork Dam, PGE estimates that approximately 95% of coho JOM are collected. Based on this data, trap efficiency for steelhead JOM may also be high at the dam when there is no spill. No estimates are available for the capture efficiency of the juvenile trap when the dam spills water, particularly when fish migrate during periods of high river flows and spill. As a result, the JOM counts may be significantly biased in some years.

Needs: Improved estimates of JOM trap efficiencies are needed and can be achieved by implementing comprehensive mark/recapture studies.

Abundance-Juvenile Outmigrants (Sandy Winter Steelhead)

Current or Planned Monitoring: Seven screw traps are operated each year in the Sandy River basin. Three of the traps are at fixed sites and four are rotated between two different sites on alternate years. These traps provide estimates of JOM migration from approximately 43% of the miles of habitat available to anadromous salmonids in the Sandy River basin. The traps are operated 24/7 throughout the spring juvenile migration period (March thru mid-June). Trap efficiency estimates are conducted on a daily basis through release of marked fish above the traps.

Needs: Additional funding may be needed to continue operations at one fixed site (Cedar Creek). Significant improvements need to be made to increase precision of confidence limits estimates (which ranged from 21% to 109% in 2009, or were not calculated).

Abundance-Juvenile Outmigrants (Gorge Stratum Winter Steelhead)

Current or Planned Monitoring: JOM trapping occurs in EF, WF, and MR of the Hood River as well as in the lower Hood River near the Powerdale Dam site. Juveniles captured at the tributary traps are PIT tagged and PIT tag monitoring is conducted at the lower mainstem trap. Differentiating between juveniles from the winter and summer runs in the in the Hood River is problematic.

Needs: Capture efficiency needs to increase at the traps. This will also increase the number of PIT tag recoveries.

Abundance-Adult Recruits (All Winter Steelhead Populations)

Current or Planned Monitoring: Partial season creel survey coverage (from February on) and in Willamette (from March on). A statistical creel survey is conducted in the Hood River. The number of winter steelhead (WWS) handled during mainstem spring Chinook (CHS) fisheries are monitored during each fishing period. Total winter steelhead handled is estimated as follows:

$$\left(\frac{WWS \text{ observed}}{\text{marked CHS observed}} \right) \times \text{landed marked CHS}$$

This method provides a reasonable estimate of the number of winter steelhead handled in the LCR ESU as a result of the spring Chinook fisheries. This approach does not allow specific population estimates unless the count of handled winter steelhead were apportioned based on population-specific abundance as a percentage of the entire winter steelhead run. Genetic sampling could be implemented to provide more information on the population-specific impacts of this fishery on winter steelhead. ODFW and WDFW have collected some DNA samples from mainstem commercial fisheries.

Needs: The creel survey design needs to be evaluated. Additional field crews could enhance monitoring efforts in the Hood River. A CWT program needs to be developed for local wild broodstock. Coefficients of variation need to be calculated for harvest and release mortality rates.

Abundance-Spawners (All Winter Steelhead Populations)

Current or Planned Monitoring: GRTS-based redd surveys were implemented for steelhead in January 2012 at all winter steelhead population areas except Hood River; adult traps are operated in the EF Hood River and Neal Creek. No redd surveys are conducted in areas above dams or weirs where counts of upstream migrating adult fish are obtained (i.e., North Fork Dam on the Clackamas River, Cedar Creek weir in the Sandy River, in the NF Scappoose River at Bonnie Falls). Based on studies conducted on steelhead redd life in Oregon coastal streams, surveys are conducted every 14 days throughout the spawning season. Redds are marked with colored rocks and flagging to prevent re-counting during subsequent surveys. Redd counts are expanded to adult female and male abundance using regression curves developed from studies on the Oregon coast. Target sample sizes are 30 sample sites (each approximately 1 mile long) or enough sites to survey approximately 30% of available spawning habitat (whichever comes first). Past experience with these kinds of surveys on the Oregon coast and in Lower Columbia streams (2004) suggest that this protocol is adequate to meet survey precision and bias goals.

Needs: Assumptions about redd life, redd to female and male ratios come from studies conducted in Oregon coastal streams. Studies need to be conducted in the Lower Columbia Cascade Stratum streams to test these assumptions. The impact of stray hatchery steelhead on surveys conducted below North Fork Dam on the Clackamas River needs to be determined. Methods need to be developed in order to reduce bias associated with surveys above the Marmot Dam site (Sandy River). Winter weather conditions may bias results because of poor access to the survey sites upstream of Marmot Dam. The impact of stray hatchery steelhead on surveys conducted below the Marmot Dam site needs to be evaluated. Funding is needed for a two person spawning survey crew in the Hood River.

Diversity-Natural Origin Age Structure (Coast Stratum Winter Steelhead)

Current or Planned Monitoring: None.

Needs: Scale sampling and aging needs to be implemented on adult winter steelhead passed above the NF Clatskanie River weir to assess how representative these fish are of the Youngs Bay population as a whole. Scale sampling and aging needs to be implemented on adult winter steelhead passed above the Big Creek weir to assess how representative these fish are of the Big Creek population as a whole. Scale sampling and aging needs to be implemented on adult winter steelhead passed above the Bonnie Falls (NF Scappoose River) to assess how representative these fish are of the Scappoose River population as a whole. Develop, fund, and implement monitoring of natural origin winter steelhead age structure in the Clatskanie River winter steelhead population area.

Diversity-Natural Origin Age Structure (Clackamas Winter Steelhead)

Current or Planned Monitoring: Scale sampling could be conducted on natural origin fish passed above North Fork Dam and on juvenile outmigrants captured in the downstream migrant trap at the dam but it is unknown how representative these fish would be of natural origin fish in the population as a whole. There are plans to eliminate the physical handling of adults passed above North Fork Dam in 2013 by implementing video monitoring.

Needs: Develop, fund, and implement monitoring of natural origin winter steelhead age structure in the Clackamas River.

Diversity-Natural Origin Age Structure (Sandy Winter Steelhead)

Current or Planned Monitoring: Scale sampling could be conducted on natural origin fish passed above the Cedar Creek Hatchery weir and on juvenile outmigrants captured in a rotary traps operated in the Sandy River, it is unknown how representative these fish (in particular spawners above Cedar Creek Hatchery) are of natural origin fish in the population as a whole.

Needs: Develop, fund, and implement monitoring of natural origin winter steelhead age structure in the Sandy River.

Diversity-Natural Origin Age Structure (Lower and Upper Gorge Winter Steelhead)

Current or Planned Monitoring: None.

Needs: Develop, fund, and implement monitoring of natural origin winter steelhead age structure in the Lower and Upper Gorge population areas.

Diversity-Natural Origin Age Structure (Hood Winter Steelhead)

Current or Planned Monitoring: Adult traps operate in the EF Hood River and Neal Creek.

Needs: The assumption that these trap data are representative of the entire Hood River winter steelhead population needs to be tested.

Diversity-Migration/Spawning Time (All Winter Steelhead Populations)

Current or Planned Monitoring: See Abundance-Spawners section for winter steelhead.

Needs: See Abundance-Spawners section for winter steelhead.

Diversity-Sex (All Winter Steelhead Populations)

Current or Planned Monitoring: No sex ratio monitoring is planned for the Youngs Bay, Big Creek, Clatskanie, Lower Gorge, or Upper Gorge populations. In the Clackamas River, sex ratios are currently obtained from fish passed above North Fork Dam. There are plans to eliminate the physical handling of adults passed above North Fork Dam in 2013 which may eliminate the ability to determine the sex ratio of these fish. In the Sandy River sex ratios are obtained from fish passed over the Cedar Creek weir. In the Hood River, sex ratios are obtained from adult trapping conducted in the EF Hood River and Neal Creek.

Needs: Sex ratio monitoring efforts need to be implemented for population areas with no current sex monitoring. For population areas where sex ratio monitoring efforts are conducted, the representativeness of the sample to the whole population needs to be determined. In addition, the impact of implementing video monitoring at North Fork Dam on the Clackamas River on determination of population sex ratios needs to be investigated.

Diversity-Origin (All Winter Steelhead Populations)

Current or Planned Monitoring: No origin monitoring is planned for the Youngs Bay, Big Creek, Clatskanie, Lower Gorge, or Upper Gorge populations. In the Clackamas River, origin is currently obtained from fish passed over North Fork Dam. There are plans to eliminate the physical handling of adults passed above this dam by 2013 which may eliminate the ability to identify origin. In the Sandy River, origin is obtained from fish passed over the Cedar Creek weir. In Hood River, origin is obtained from adult trapping in EF Hood River and Neal Creek.

Needs: Monitoring efforts for origin need to be implemented for population areas with no origin monitoring. For population areas with origin monitoring programs, the representativeness of the sample to the whole population needs to be determined. In addition, the impact that implementing video monitoring at North Fork Dam on the Clackamas River will have on the ability to identify fish origin needs to be evaluated.

Spatial Structure-Fry/Parr (All Winter Steelhead Populations)

Current or Planned Monitoring: See Abundance-Juvenile Rearing sections for winter steelhead.

Needs: See Abundance-Juvenile Rearing sections for winter steelhead.

Spatial Structure-Spawners (All Winter Steelhead Populations)

Current or Planned Monitoring: See Abundance-Spawners section for winter steelhead.

Needs: See Abundance-Spawners section for winter steelhead.

Summer Steelhead Current Monitoring Status

Table 7. Scores for the existing monitoring efforts on summer steelhead in the Oregon portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority with darker gradients indicating higher priority.

Stratum	Summer Steelhead Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration/Spawning Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Gorge	Hood	High	0.00	0.25	0.25	1.00	0.25	0.25	0.50	0.50	0.00	0.00

Abundance-Juvenile Rearing

Current or Planned Monitoring: Snorkeling surveys are conducted at a small number of GRTS-base snorkel sites but this method does not allow differentiation of winter and summer steelhead.

Needs: The bias issue associated with the difficulty of differentiating winter from summer steelhead needs to be solved. Alternative monitoring approaches need to be considered because snorkel surveys are not effective in some areas of the Hood River basin due to visibility issues related to glacial till. Funding is needed for a two person snorkel crew.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: JOM trapping is conducted in the EF, WF, and MF of the Hood River and in the lower Hood River near the Powerdale Dam site. Juvenile fish captured at tributary traps are PIT tagged and monitoring for PIT tags occurs at the lower mainstem trap. Visual differentiation of winter and summer run juveniles is problematic.

Needs: The capture efficiency of traps needs to improve, and the number PIT tag recoveries need to increase.

Abundance-Adult Recruits

Current or Planned Monitoring: A creel survey is conducted in the Hood River. A statistical creel program is conducted in the mainstem Columbia River from February through October and in the Willamette River from March through June. These surveys estimate the number of salmonids caught and released in these fisheries. The impact of the mainstem commercial fisheries on summer steelhead is estimated with historic steelhead to landed Chinook ratios. These ratios were verified during observations in 2009-2011. Estimates of fish handling impacts on wild steelhead populations are generated for the Columbia River as a whole, but if genetic sampling was conducted on commercially caught steelhead, population-specific impacts could be determined.

Needs: Mainstem sport and commercial fisheries monitoring programs need to be implemented to estimate incidental impacts of these fisheries on summer steelhead populations.

Abundance-Spawners

Current or Planned Monitoring: A new fish trap at the Moving Falls ladder will be operational in 2013.

Needs: None at this time. The effectiveness of the new trap at Moving Falls fish ladder will need to be evaluated.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: A new fish trap at the Moving Falls ladder will be operational in 2013.

Needs: Determine the representativeness of natural origin estimates at the Moving Falls trap to the entire Hood River summer steelhead population.

Diversity-Migration/Spawn Timing

Current or Planned Monitoring: Migration timing will be assessed from adults passed above the Moving Falls fish trap and from PIT tag detections at Bonneville, Lower Hood and Moving Falls trap.

Needs: Determine the representativeness of fish migration timing at the Moving Falls trap to the entire Hood River summer steelhead population.

Diversity-Sex

Current or Planned Monitoring: The sex of returning summer steelhead adults will be monitored at the Moving Falls fish trap beginning in 2013.

Needs: Determine the representativeness of fish sex ratios at the Moving Falls trap to the entire Hood River summer steelhead population.

Diversity-Origin

Current or Planned Monitoring: The origin of returning summer steelhead adults will be monitored at the planned Moving Falls fish trap.

Needs: Determine the representativeness of fish origin at the Moving Falls trap to the entire Hood River summer steelhead population.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: See Abundance-Juvenile Rearing sections for summer steelhead.

Needs: See Abundance-Juvenile Rearing sections for summer steelhead.

Spatial Structure-Spawners

Current or Planned Monitoring: No systematic surveys are planned.

Needs: Design, fund, and implement a monitoring program.

Appendix B. Status of Monitoring Biological Recovery of Salmon and Steelhead Populations in the Washington Portion of the Lower Columbia River

Assessments of the biological recovery status of salmon and steelhead populations in the Lower Columbia River (LCR) relies on collecting and analysis of data related to the four Viable Salmonid Population (VSP) parameters of abundance, productivity, diversity, and spatial structure. This appendix is a summary of current or planned salmon and steelhead population monitoring for VSP indicators in Washington's portion of the LCR recovery area. Monitoring for productivity is not explicitly addressed because estimates of productivity are derived from more basic biological indicators such as spawner abundance.

Chum Salmon Current Monitoring Status

Chum salmon are functionally extinct in the Mill-Abernathy-Germany (M-A-G), Kalama, and Salmon population areas. As a result, chum salmon are monitored at a low effort or not monitored at all in these areas. Asterisked population names accompanied by scores of 0.00 for the indicators in Table 1 reflect the lack of current monitoring efforts on extirpated or functionally extinct populations. As chum salmon populations recover, monitoring efforts will need to be implemented to assess these populations.

Table 1. Scores for the existing monitoring efforts on chum salmon in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicates monitoring priority, with darker gradients indicating higher priority (M-A-G = Mill-Abernathy-Germany; L=Lower).

Stratum	Chum Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Grays	High	0.00	1.00	0.25	1.00	1.00	1.00	1.00	0.75	0.00	1.00
	Elochoman	High	0.00	0.00	0.25	0.25	0.50	0.25	0.50	0.00	0.00	0.25
	M-A-G*	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cascade	L Cowlitz, Coweeman, Toutle	Medium	0.00	0.00	0.25	0.25	0.25	0.25	0.25	0.00	0.00	0.25
	Kalama*	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lewis	High	0.00	0.00	0.25	0.25	0.25	0.25	0.25	0.00	0.00	0.25
	Salmon*	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Washougal	High	0.00	0.00	0.25	0.25	0.25	0.25	0.25	0.75	0.00	0.25
Gorge	Lower Gorge	High	0.00	0.25	0.25	1.00	1.00	1.00	1.00	0.75	0.00	1.00
	Upper Gorge, White Salmon	Medium	0.00	0.25	0.25	0.50	0.50	0.50	0.00	0.00	0.00	0.50

Abundance-Juvenile Rearing

Not applicable to chum because their life history (i.e., fish migrate from natal streams shortly after emergence). This life history precludes useful inference about chum salmon status based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Weirs and screw traps are operated to target chum salmon in the Grays and Lower Gorge tributaries. The traps are operated 24 hours a day, seven days a week throughout the juvenile outmigration period (February - May). Trap efficiency estimates are conducted three days per week through release of marked fish above the trap.

Needs: Currently there are no monitoring needs but as chum salmon populations recover juvenile outmigrant trapping should be implemented in the Cascade stratum.

Abundance-Adult Recruits

Current or Planned Monitoring: Most if not all Columbia River and associated OR/WA tributary recreational fisheries are closed to chum salmon retention. Mainstem Columbia River sport salmon fisheries are only monitored through October of each year, and retention of chum salmon is allowed in the mainstem Columbia (treaty and non-treaty) and Select Area commercial fisheries. Commercial chum landings are tracked with fish tickets. Biological data and the rate of CWT recoveries on hatchery fish provides surrogate data on local stocks in adjacent tributaries. Point estimates are used for harvest and release mortality rates.

Needs: WDFW and ODFW have collected genetic samples from chum salmon retained in commercial fisheries. These agencies recommend the use of genetic analysis to segregate chum salmon catch by population or stratum. WDFW recommends that angler surveys be conducted in tributaries fisheries when chum salmon are present to estimate the number of chum salmon caught and released.

Abundance-Spawners

Current or Planned Monitoring: The Upper Gorge chum population is estimated from counts at Bonneville Dam (BON). Mark-recapture estimates using the Jolly-Seber (JS) model are developed annually for the Grays River and Lower Gorge populations, which are the largest chum salmon populations in Washington. Spawner abundance is estimated for the remaining populations with periodic surveys of the entire spawning frame using the Area-Under-the-Curve (AUC) method. Apparent residence time metric for the AUC method is calculated from concurrent AUC surveys and JS estimates from the Grays and Lower Gorge tributaries.

Needs: Radio tagging data on chum salmon fallback at Bonneville Dam collected in the early 2000s could be used to improve spawner abundance estimates. Estimates of apparent residence time are highly variable for this species, which may affect the precision of estimates. The use of modeling approaches to predict the residence time of these fish might improve the precision of estimates.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Carcasses can be sampled during spawning ground surveys and this approach is adequate for determining origin for the largest populations. Precision targets for age are not always met for populations with low spawner abundance even when scale sampling is conducted on all carcasses encountered.

Needs: Explore age selectivity in carcass recoveries using Grays River tagging data collected in the early 2000s and the correlation between chum salmon ages, populations, and years, and the use of hierarchical models to improve age structure precision.

Diversity-Migration/Spawn Timing:

Current or Planned Monitoring: The migration timing of the Upper Gorge chum population is estimated from Bonneville Dam fish counts. Mark-recapture estimates using the JS model are developed annually for the Grays River and Lower Gorge populations. For the remaining populations, spawner abundance is estimated with periodic surveys of the entire spawning frame using the AUC method. Migration or spawn timing is derived from spawner abundance estimates made over the spawning period.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Monitoring programs sample carcasses during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for sex are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore sex selectivity in carcass recoveries based on Grays tagging data collected in the early 2000s. Explore sex ratio diversity correlations among populations and years. Explore the opportunity to use hierarchical models to improve sex ratio estimates. Implement scale collections Barrier Dam on the Cowlitz River.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery chum salmon releases are otolith marked. Monitoring programs sample carcasses encountered during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for origin are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Improve the QA/QC on hatchery thermal marking of chum salmon otoliths.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: None.

Needs: None. Determination of Chum fry distribution and abundance in streams and rivers is a low priority because these fish migrate to the estuary soon after emergence.

Spatial Structure-Spawners

Current or Planned Monitoring: The Upper Gorge population size is estimated from counts at Bonneville Dam. Mark-recapture estimates using the JS model are developed annually for the large Grays and Lower Gorge chum populations. Spawner abundance is estimated for the remaining populations by periodic surveys of the entire spawning frame using the AUC method. Spatial structure is derived from spawner abundance estimates.

Needs: See Abundance-Spawners section recommendations. Develop a spatial structure design for monitoring the Upper Gorge population because spawner abundance is currently based on adult counts at Bonneville Dam.

Coho Salmon Current Monitoring Status

Table 2. Scores for the existing monitoring efforts on coho salmon in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority with darker gradients indicating higher priority.

Stratum	Coho Population	Recovery Priority	Abundance				Diversity				Distribution		
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution	
Coast	Grays	High	0.00	0.00	0.75	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.25
	Elochoman	High	0.00	0.00	0.75	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.25
	Mill	Medium	0.25	0.00	0.50	0.50	0.00	0.50	0.00	0.00	0.25	0.25	0.50
	Toutle NF	High	0.00	0.00	0.75	0.50	0.25	0.50	0.25	0.25	0.25	0.00	0.25
	Upper Cowlitz	High	0.00	0.00	0.75	0.75	0.25	0.75	0.00	0.00	0.00	0.00	0.25
	Salmon	Low	0.00	0.00	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.25
	Washougal	Medium	0.00	0.00	0.75	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.25
Gorge	Lower Gorge	High	0.25	0.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Upper Gorge, White Salmon	High	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Abundance-Juvenile Rearing

Current or Planned Monitoring: Data for this indicator are not collected.

Needs: Implement a program similar to that used by ODFW which uses a GRTS-based snorkel survey design to provide the status and trend of coho at the stratum scale for the density of juvenile coho salmon in pools, percent of pools that are occupied by juvenile coho salmon, and percent of sites that are occupied. All pools that are present in a 1000 m long survey reach are snorkeled. The goal is to snorkel at least 40 sites per year with coefficients of variation (CVs) of <15%. Supervisors resurvey 10-20% of sites and the resulting coefficient

of determination (r^2) is approximately 0.98, which suggests that there is little variability among sample sites and that survey results are highly repeatable.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Screw traps are operated to target coho salmon in the Mill, Coweeman, and Hamilton Creek populations. Hamilton Creek coho are part of the Lower Gorge population. Additional coho trapping occurs in the Grays, Cowlitz and Lewis river populations. Traps are operated 24/7 throughout the juvenile outmigration migration period (March - June). Trap efficiency estimates are conducted weekly through the release of marked fish above the trap.

Needs: None.

Abundance-Adult Recruits

Current or Planned Monitoring: Landed catch from the ocean, mainstem Columbia River, and Select Area commercial and recreational (Buoy 10 and lower Columbia) fisheries are monitored for CWTs, mark rate, and biological data. Sample rates above 20% are common in the mainstem Columbia River but tributary sport rates are often less than 5%. Impacts to unmarked fish are monitored and reported. Fall Columbia River commercial fisheries are not mark-selective but recreational fisheries are mark-selective. Adult carcass surveys are conducted on Washington populations. A study initiated in fall 2011 tracks previously unmarked coho in the lower river using an acoustic/PIT tagging capture/tag/release approach and follows these fish as they progress to terminal streams. The intent of this study is to provide additional information on the timing and spawning location of unmarked coho. This study is scheduled to continue in 2012. There is a CWT program in effect for Grays, Elochoman, Cowlitz, Kalama, Lewis, and Washougal hatchery stocks.

Needs: Develop a CWT monitoring program based on an integrated hatchery program. Coefficient of variation estimates need to be calculated for harvest and release mortality rates.

Abundance-Spawners

Current or Planned Monitoring: WDFW has weir/dam-based coho spawner abundance estimates in the Cowlitz and North Fork (NF) Toutle rivers and mark-recapture estimates in Abernathy Creek and Cedar Creek (tributary of the NF Lewis). GRTS-based spawning ground surveys are conducted for the remaining coho salmon populations. The GRTS-based surveys began in 2010. Walking surveys are scheduled every seven days throughout the spawning period over the entire spawning frame. Redd counts of adult coho salmon are expanded to total abundance using redds per female estimates above selected traps and weirs. Although the number of live jacks is recorded during these surveys, the low observation probability associated with jack counts precludes AUC estimate expansion. WDFW is evaluating redd or AUC based estimates from the GRTS designs. The coefficient of variation of estimates based on GRTS designs will likely be above the 15% target.

Needs: Improve the coefficient of variation of estimates by increasing the number of sites sampled. There are two locally untested critical assumptions associated with the AUC monitoring effort; these are assumptions on spawning life and observer efficiency. For the redd-based surveys, the untested local assumptions that all redds are visible for at least one survey and the number of females per redd need to be tested. Study designs are being implemented above weir or mark-recapture sites to estimate observer efficiency, spawning life, females per redd, and redd duration.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Monitoring programs sample carcasses during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for natural origin age structure are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore age selectivity based on adult tagging programs in Cedar and Abernathy creeks. Explore correlations of salmon ages among populations and years. If appropriate, explore the use of hierarchical models to improve age structure estimates. Implement scale collection at Barrier Dam on the Cowlitz River.

Diversity-Migration/Spawn Timing

Current or Planned Monitoring: WDFW uses weir/dam-based coho salmon estimates in the Cowlitz and NF Toutle rivers and mark-recapture estimates in Abernathy Creek and Cedar Creek (tributary of the NF Lewis). GRTS-based spawning ground surveys are conducted on the remaining coho salmon populations. Walking surveys are scheduled every seven days throughout the spawning season over the entire spawning frame. Redd counts are expanded to total abundance based on females per redd estimated from local streams above weirs. Although the number of live jacks is recorded, the low observation probability associated with jack counts precludes AUC estimate expansion. WDFW is evaluating redd or AUC based estimates from GRTS designs. It is likely that coefficients of variation for GRTS designs will be above the 15% target. Migration or spawn timing is derived from spawning abundance estimates on each population.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Monitoring programs sample carcasses during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for fish sex are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore sex selectivity in carcass recoveries based on Abernathy and Cedar tagging data. Explore salmon sex correlations among populations and years. If appropriate, explore the use of hierarchical models to improve sex ratio estimates.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are adipose fin clipped except for double index groups (DIT). Monitoring programs sample carcasses during spawning ground surveys and use the mass mark to identify hatchery fish. This approach is adequate for populations with high spawner abundance. Precision targets for origin are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore origin selectivity in carcass recoveries based on Abernathy and Cedar tagging data. Explore correlations of salmon origin among populations, years, and hatchery mass mark rates. If appropriate explore the use of hierarchical models to improve origin estimates.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: Data for this indicator is not collected.

Needs: See Abundance-Juvenile Rearing sections recommendations.

Spatial Structure-Spawners

Current or Planned Monitoring: WDFW uses weir/dam-based coho salmon estimates in the Cowlitz and NF Toutle river, and mark-recapture estimates in Abernathy Creek and Cedar Creek (tributary of the NF Lewis). GRTS-based spawning ground surveys are conducted on the remaining coho salmon populations. Walking surveys are scheduled every seven days throughout the spawning season over the entire spawning frame. Live fish counts of adult coho salmon are expanded to total abundance using AUC estimation. Although the number of live jacks is recorded, the low observation probability associated with jack counts precludes AUC estimate expansion. WDFW is evaluating the use of redd or AUC based estimates from the GRTS designs. Coefficient of variation on estimates based on GRTS designs are expected to be above the 15% target. Spatial structure is derived from spawning abundance estimates.

Needs: See Abundance-Spawners section recommendations.

Fall Chinook Salmon Current Monitoring Status

Table 3. Scores for the existing monitoring efforts on fall Chinook salmon in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicates monitoring priority, with darker gradients indicating higher monitoring priority (M-A-G=Mill-Abernathy-Germany).

Stratum	Fall Chinook Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Grays	Medium	0.00	1.00	0.50	0.25	0.25	0.25	1.00	1.00	0.00	0.25
	Elochoman	High	0.00	0.00	0.75	1.00	1.00	1.00	1.00	1.00	0.00	1.00
	M-A-G	High	0.00	1.00	0.50	1.00	0.75	1.00	0.75	1.00	0.00	1.00
Cascade	Lower Cowlitz	Medium	0.00	1.00	0.75	1.00	1.00	1.00	1.00	1.00	0.00	1.00
	Upper Cowlitz, Cispus, Tilton	Low	0.00	1.00	0.75	0.75	0.00	0.75	1.00	1.00	0.00	0.25
	Toutle	High	0.00	0.00	0.75	0.75	1.00	0.75	1.00	1.00	0.00	0.75
	Coweeman	High	0.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	0.00	1.00
	Kalama	Medium	0.00	0.00	0.75	0.50	0.75	0.50	0.75	0.75	0.00	0.50
	Lewis	High	0.00	1.00	0.50	0.50	0.75	0.50	1.00	1.00	0.00	0.50
	Salmon*	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Washougal	High	0.00	1.00	0.75	0.75	1.00	0.75	1.00	1.00	0.00	0.75
Gorge	Lower Gorge	Medium	0.00	0.00	0.50	0.50	0.25	0.50	0.25	0.25	0.00	0.50
	Upper Gorge	Medium	0.00	0.00	0.25	0.50	0.25	0.50	0.25	0.25	0.00	0.50
	White Salmon	Medium	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Fall Chinook salmon are functionally extinct in Salmon Creek and are currently not monitored. Salmonid populations that are extinct or functionally extinct are difficult or impossible to monitor. In these cases, an asterisked score of 0.00* appears in the monitoring effort tables (e.g., Table 3). The asterisked score (0.00*) denotes there is no current monitoring effort on the population because the population is extirpated or functionally extinct. Monitoring efforts will need to be implemented on these populations as the numbers of juvenile and adult fish increase in response to natural decolonization and/or recovery efforts.

Abundance-Fry/Parr

This monitoring is not applicable to fall Chinook in the LCR because many fish migrate out of natal streams shortly after emergence. This early migratory behavior precludes useful inference about fall Chinook salmon status based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Screw traps are operated to collect juvenile outmigration abundance on fall Chinook salmon populations in the Grays, Mill, and Coweeman rivers. Fall Chinook trapping also occurs in the Cowlitz and Lewis rivers. The traps are operated 24 hours a day, seven days a week throughout the juvenile outmigration migration period (February - June or August). Trap efficiency estimates are conducted weekly through release of marked fish above the trap.

Needs: A juvenile migrant trapping program needs to be implemented in the Gorge stratum. The White Salmon River is a potential site for a fall Chinook juvenile trapping program in the Gorge stratum.

Abundance-Adult Recruits

Current or Planned Monitoring: Landed catch from the ocean, mainstem commercial, Select Area, and recreational (Buoy 10 and lower Columbia) fisheries are monitored for CWTs, mark rate, and biological data. The freshwater fisheries are non-mark selective. WDFW collected DNA from these fisheries in 2010-2011.

Spawning ground surveys are used to estimate adult abundance and trends. Carcass surveys are conducted in all watersheds and are used to collect additional biological information on straying. Hatchery releases are adipose fin clipped. There is a CWT program for Elochoman, Cowlitz, Kalama, Toutle, Washougal, and Spring Creek hatchery stock tules.

Needs: A CWT program needs to be developed for the integrated hatchery program. Coefficient of variation metrics need to be calculated for harvest and release mortality rates.

Abundance-Spawners

Current or Planned Monitoring: Chinook salmon abundance is estimated in the Grays, Elochoman, Green, Coweeman, and Washougal rivers using the Petersen mark-recapture method. A Jolly-Seber approach is used to estimate abundance of the Mill Creek population. A genetic mark-recapture approach is used to estimate the Coweeman River population and this method has been proposed for Cowlitz River fall Chinook. Weir-based estimates are made on the Tilton and Upper Cowlitz river populations. Peak count expansions, redd or AUC surveys are used for other populations, in these cases weekly spawner surveys are conducted over the spawning periods.

Needs: WDFW should move away from peak surveys due to the lack of representative spatial and temporal sampling. Redd or AUC based surveys are a likely to be a cost effective alternative. However, estimates of apparent residence time or female per redd may be variable for this species; this variability can reduce the precision of estimates. The efficacy of using modeling to explain residence time variation should be explored.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Monitoring programs sample carcasses during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for origin are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore age selectivity based on adult tagging programs in Grays, Elochoman, Coweeman, and Green rivers. Explore correlations of salmon ages among populations and years. If appropriate, explore the use of hierarchical models to improve age structure estimates. Implement scale collection at the Barrier Dam on the Cowlitz River.

Diversity-Migration/Spawning Time:

Current or Planned Monitoring: This information is collected during spawner abundance surveys. WDFW estimates Chinook salmon abundance using Petersen mark-recapture estimates for the Grays, Elochoman, Green, Coweeman, and Washougal rivers, and Jolly-Seber estimates for Mill Creek. A genetic mark-recapture method is used for Coweeman River Chinook and this approach has also been proposed for the Cowlitz population. Weir-based migration timing estimates are made on the Tilton and Upper Cowlitz populations. Peak count expansions or AUC surveys occur for other populations with weekly surveys conducted over the spawning frame. In these cases, the migration or spawning time estimate is derived from the spawner abundance estimates and ratings.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Monitoring programs sample carcasses during spawning ground surveys and this approach is adequate for populations with high abundance. Precision targets for fish sex are not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore sex selectivity in carcass recoveries based on Grays, Elochoman, Coweeman, and Green tagging data. Explore salmon sex correlations among populations and years. If appropriate, explore the use of hierarchical models to improve sex ratio estimates.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are scheduled for adipose fin clips except for double index groups (DIT). Based on the mass marking of hatchery fish, sample carcasses are checked for origin during spawning ground surveys. This approach is adequate for populations with high abundance. Precision targets for fish origin is not always met for populations with low spawner abundance despite sampling all carcasses encountered during surveys.

Needs: Explore origin selectivity in carcass recoveries based on Grays, Elochoman, Coweeman, and Green tagging data. Explore salmon origin correlations among populations and years, and hatchery mass mark rates. If appropriate, explore the use of hierarchical models to improve origin estimates.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: This indicator is not applicable to LCR fall Chinook populations because many fish migrate out of natal streams shortly after emergence. This life history strategy precludes useful inference about fall Chinook spatial structure based on resident juvenile abundance in streams and rivers.

Needs: See Abundance-Juvenile Rearing section recommendations.

Spatial Structure-Spawners (All Fall Chinook Populations)

Current or Planned Monitoring: This information is collected during spawner abundance surveys.

Needs: See Abundance-Spawners section recommendations.

Late Fall Chinook Salmon Current Monitoring Status

Table 4. Scores for the existing monitoring efforts on late fall Chinook salmon in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Late Fall Chinook Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Cascade	Lewis	High	0.00	0.25	1.00	0.25	0.75	0.25	1.00	1.00	0.00	0.25

Abundance-Fry/Parr

This indicator is not applicable to LCR late fall Chinook salmon because many fish migrate out of natal streams shortly after emergence. This aspect of late fall Chinook life history precludes useful inference about the status of these fish based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: A Petersen estimate-based index of juvenile abundance is made through CWT tagging of juveniles and recovery of tagged and untagged adults.

Needs: A juvenile migrant trapping program is recommended for Lewis River late fall Chinook because this is an index population.

Abundance-Adult Recruits

Current or Planned Monitoring: Landed catch from the ocean, mainstem commercial, Select Area, and recreational (Buoy 10 and lower Columbia) fisheries are monitored for CWTs, mark rate, and biological data. WDFW collected DNA from these fisheries in 2010-2011. Freshwater fisheries are non-mark selective. Spawning ground surveys are used to estimate the adult abundance and trends of populations. WDFW conducts carcass sampling for biological information including straying during spawning surveys in all systems. This stock has a wild CWT program.

Needs: None.

Abundance-Spawners

Current or Planned Monitoring: WDFW estimates spawner abundance on this population based on peak count expansions or carcass expansion rates developed from a mark-recapture study.

Needs: Determine a method that meets precision and bias goals.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Carcasses are sampled for biological information including origin during spawning ground surveys. Based on age selectivity tests from 2000-03, this data is adequate to estimate natural origin age structure of the Lewis late fall Chinook population.

Needs: None

Diversity-Migration/Spawning Time:

Current or Planned Monitoring: WDFW estimates abundance based on peak count expansions or carcass expansion rates developed from a mark-recapture study. Migration or spawn timing is derived from the spawning abundance estimates and ratings.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Carcasses are sampled for biological information such as sex during spawning ground surveys. Based on sex selectivity studies in 2000 – 2003, this approach is adequate for the Lewis River late fall Chinook population.

Needs: None.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are adipose fin clipped except for double index groups (DIT). Carcasses are sampled for biological information such as origin during spawning ground surveys. Based on sex selectivity studies in 2000 – 2003, this approach is adequate for the Lewis River late fall Chinook population.

Needs: None.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: This indicator is not applicable to LCR late fall Chinook salmon because many fish migrate out of natal streams shortly after emergence. This aspect of late fall Chinook life history precludes useful inference about population status based on resident juvenile abundance in streams and rivers.

Needs: See Abundance-Juvenile Rearing section recommendations.

Spatial Structure-Spawners (All Fall Chinook Populations)

Current or Planned Monitoring: WDFW estimates abundance based on peak count expansions or carcass expansion rates developed from a mark-recapture study.

Needs: See Abundance-Spawners section recommendations.

Spring Chinook Salmon Current Monitoring Status

Table 5. Scores for the existing monitoring efforts on spring Chinook salmon in the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Asterisked population names indicate extirpated or functionally extinct populations. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Spring Chinook Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Cascade	Upper Cowlitz	High	0.00	0.25	0.75	0.75	0.00	0.75	0.75	1.00	0.00	0.25
	Cispus	High	0.00	0.25	0.50	0.75	0.00	0.75	0.75	1.00	0.00	0.25
	Tilton*	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Toutle*	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Kalama	Medium	0.00	1.00	0.50	0.50	1.00	0.50	0.75	1.00	0.00	0.50
	NF Lewis*	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gorge	White Salmon*	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Abundance-Fry/Parr

This indicator is not applicable to LCR spring Chinook salmon because many fish migrate out of natal streams shortly after emergence. This aspect of LCR spring Chinook life history precludes useful inference about population status based on resident juvenile abundance in streams and rivers.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Juvenile migrant trapping occurs at Cowlitz Falls dam and the Kalama River at river mile 10. Kalama and Upper Cowlitz trapping does not cover the outmigration period of spring Chinook and trap retention of fry is poor with the current screw trap in the Kalama.

Needs: Improve trap designs and extend the duration of trapping to increase trap efficiencies for spring Chinook on the Cowlitz and Kalama rivers.

Abundance-Adult Recruits

Current or Planned Monitoring: Landed catch from the ocean, mainstem commercial, Select Area, and recreational (Buoy 10 and lower Columbia River) fisheries are monitored for CWTs, mark rate, and biological data. All fisheries are mark-selective except Select Area fisheries. Carcass surveys are conducted on WA populations for biological information including straying. Unmarked spring Chinook handling and release mortalities for mainstem commercial fisheries are estimated through an onboard monitoring program conducted during each fishing period. Hatchery released spring Chinook are adipose fin clipped. A CWT program is in place for Cowlitz, Kalama, Lewis, Wind, and Little White salmon hatchery stocks.

Needs: Develop a CWT program for an integrated hatchery program. Coefficient of variation needs to be calculated for harvest and release mortality estimates.

Abundance-Spawners

Current or Planned Monitoring: The upper Cowlitz, Cispus, Kalama, and Upper Lewis rivers may be able to support spring Chinook salmon populations. All current and planned spawner abundance estimates are based

on weir passage but fallback and natural mortality rates are not always estimated. In some cases fall and spring Chinook runs are present at the same time on the spawning grounds.

Needs: Genetic samples are needed to differentiate the fall and spring Chinook runs in some cases. Studies are needed to estimate escapement from passage counts.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Biological sampling programs that sample trapped adults or carcasses during spawning ground surveys provide information on age structure. These approaches are generally adequate in order to generate precision estimates of natural origin age structure for high abundance populations.

Precision targets are not always met for natural origin age structure estimate on low abundance populations due to small sample sizes and nonrandom sampling efforts.

Needs: Explore age selectivity testing based on adult tagging programs in the Kalama River. Explore salmon age correlations among populations and years. If appropriate, explore the use of hierarchical models in order to improve age structure estimates. Implement scale collection on spring Chinook at the Barrier Dam on the Cowlitz River.

Diversity-Migration/Spawn Timing:

Current or Planned Monitoring: All current and planned spawner abundances estimates are based on weir passage but fallback and natural mortality rates are not always estimated. Migration or spawn timing are derived from spawner abundance estimates and ratings.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Biological samples are collected on trapped live fish or from carcasses during spawning ground surveys. This approach is adequate for estimating sex in populations with high spawner abundance. Precision targets for fish sex ratios are not always met for populations with low spawner abundance despite sampling of all carcasses encountered during surveys.

Needs: Explore sex selectivity in carcass recoveries based Kalama tagging data. Explore salmon sex correlations among populations and years. If appropriate, explore the use of hierarchical models to improve sex ratio estimates. Sex identification could be improved for spring Chinook through the use of ultrasound, modeling, or other methods.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are adipose fin clipped except for double index groups (DIT). Biological sampling for origin is based on the mass marking used to identify hatchery fish. Adults are surveyed for the hatchery fin clip during trapping operations and this mass mark is identified on carcasses during spawning ground surveys. These approaches are generally adequate for populations with high spawner abundance. Precision targets for fish origin are not always met for populations with low spawner abundance despite sampling of all trapped fish and carcasses encountered during surveys.

Needs: Explore origin selectivity in carcass recoveries based on Kalama tagging data. Explore salmon origin correlations among populations, years, and hatchery mass mark rates. If appropriate, explore the use of hierarchical models to improve origin estimates.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: This indicator is not applicable to LCR spring Chinook salmon because many fish migrate out of natal streams shortly after emergence. This aspect of LCR spring Chinook life history precludes useful inference about population status based on resident juvenile abundance in streams and rivers.

Needs: See Abundance-Juvenile Rearing section recommendations.

Winter Steelhead Current Monitoring Status

Table 6. Scores for the existing monitoring efforts on winter steelhead in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Asterisked population names indicate extirpated or functionally extinct populations. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Winter Steelhead Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Coast	Grays	High	0.00	1.00	0.25	0.25	0.50	0.25	0.50	0.25	0.00	0.25
	Elochoman	Medium	0.00	1.00	0.25	0.25	0.50	0.25	0.50	0.25	0.00	0.25
	Mill	High	0.00	1.00	0.25	0.50	1.00	0.50	0.50	0.75	0.00	0.50
Cascade	Lower Cowlitz	Medium	0.00	1.00	0.25	1.00	1.00	1.00	1.00	1.00	0.00	1.00
	Upper Cowlitz	High	0.00	1.00	0.25	0.75	0.00	0.75	1.00	1.00	0.00	0.25
	Cispus	High	0.00	1.00	0.25	0.75	0.00	0.75	1.00	1.00	0.00	0.25
	Tilton	Low	0.00	1.00	0.25	0.75	0.00	0.75	1.00	1.00	0.00	0.25
	SF Toutle	High	0.00	1.00	0.25	0.25	0.50	0.25	0.50	0.25	0.00	0.25
	NF Toutle	High	0.00	1.00	0.25	0.50	1.00	0.50	1.00	0.50	0.00	0.50
	Coweeman	High	0.00	1.00	0.25	0.25	0.50	0.25	0.50	0.25	0.00	0.25
	Kalama	High	0.00	1.00	0.25	0.75	1.00	0.75	1.00	0.75	0.00	0.00
	NF Lewis	Medium	0.00	1.00	0.25	0.25	1.00	0.25	1.00	0.50	0.00	0.25
	EF Lewis	High	0.00	1.00	0.25	0.25	0.50	0.25	0.50	0.25	0.00	0.25
	Salmon	Low	0.00	1.00	0.25	0.00	0.50	0.00	0.50	0.00	0.00	0.00
Washougal	Medium	0.00	1.00	0.50	0.25	0.50	0.25	0.50	0.25	0.00	0.25	
Gorge	Lower Gorge	High	0.00	1.00	0.25	0.50	0.00	0.50	0.00	0.00	0.25	1.00
	Upper Gorge	Low	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	1.00	1.00

Abundance-Juvenile Rearing

Current or Planned Monitoring: Data for this indicator is not collected.

Needs: WDFW needs to implement a GRTS-based snorkel survey similar to that of ODFW's design to provide status and trend at the stratum scale for the density of juvenile steelhead in pools, percent of pools that are occupied by juvenile steelhead, and percent of sites that are occupied. Using ODFW's approach, all pools that are present in a 1000 m long survey reach are snorkeled, and the goal is to snorkel at least 40 sites per year. Using this approach, ODFW's coefficients of variation for winter steelhead juvenile rearing metrics are <15%. ODFW supervisors resurvey 10-20% of survey sites; this method results in a coefficient of determination (r^2) of approximately 0.98. Results of the ODFW resurveys suggest that sampling variability is low and that their survey results are highly repeatable for winter steelhead.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Screw traps are operated to target steelhead in the Mill Coweeman, and Kalama river populations, and in Hamilton Creek (Lower Gorge population). Additional JOM trapping for winter steelhead occurs in the Grays, Cowlitz, Lewis, and Wind rivers. The traps are operated 24 hours a day, seven days a week throughout the juvenile outmigration migration period (March - June). Trap efficiency estimates are conducted weekly through the release of marked fish above the trap.

Needs: None.

Abundance-Adult Recruits

Current or Planned Monitoring: There is partial mainstem creel coverage beginning in February and angler interviews in the Washougal and Toutle Rivers. The number of winter steelhead handled in mainstem commercial fisheries for spring Chinook are estimated through an onboard monitoring program. The estimate is derived from the ratio of total wild winter steelhead (WWS) handled to the number of marked spring Chinook multiplied by the number of landed marked hatchery spring Chinook salmon. This provides a reasonable estimate of fish handled across the ESU but is not population specific. Population-specific ratios could be estimated by incorporating population-specific WWS abundance as a percentage of the entire WWS run into these calculations. Population or stratum specific impacts could be estimated with genetic analysis. In the past, ODFW and WDFW have collected some DNA samples from mainstem commercial fisheries.

Needs: Genetic analysis to incorporate this information into harvest estimates by population or stratum. Evaluate tributary angler survey designs and implement surveys for additional populations if existing survey design is effective. Coefficients of variation need to be calculated for harvest and release mortality rates.

Abundance-Spawners

Current or Planned Monitoring: Weir or mark-recapture spawner abundance estimates are planned for the Cowlitz, NF Toutle, Kalama, Cedar Creek, and Wind winter steelhead populations and redd surveys will be implemented in other basins. Studies conducted on steelhead redd life in Oregon and Washington coastal streams indicate that these surveys should be conducted every 14 days throughout the spawning season. Redds should be marked with flags to prevent re-counting during subsequent surveys. Redd counts will be expanded to adult female and male abundance using female per redd from Washington's Snow Creek. In general, current monitoring efforts are prioritized by accessibility, coverage, and representativeness rather than by run. Redd surveys are not conducted for hatchery winter steelhead, which are thought to spawn earlier in the spring than wild fish.

Needs: Assumptions about females per redd comes from studies conducted in Washington coastal streams. The number of females per red may be different in coastal streams than in Lower Columbia streams. Local studies need to be conducted to test this assumption, develop methodologies to estimate early timed hatchery steelhead abundance, and implement statistically valid representative sampling designs.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Biological sampling for age is conducted on adult fish at traps in the Toutle, Kalama, and Wind rivers, and at Cedar Creek. This approach is adequate for estimating the age structure of populations with high spawner abundance. Precision targets for fish age structure are not always met for populations with low spawner abundance despite sampling of all carcasses encountered during surveys.

Needs: Explore steelhead age correlations among populations and years. If appropriate, explore the use of hierarchical models to improve age structure estimates. Implement scale collection at the Barrier Dam on the Cowlitz River.

Diversity-Migration/Spawn Timing

Current or Planned Monitoring: Weir or mark-recapture monitoring efforts for migration/spawning time estimates are planned for the Cowlitz, NF Toutle, Kalama, Cedar Creek, and Wind river populations with redd surveys implemented in the other basins. Studies conducted on steelhead redd life in Oregon and Washington coastal streams indicate red surveys need to be conducted every 14 days throughout the spawning season. Redds will be marked with flags to prevent re-counting during subsequent surveys. Redd counts will be expanded to adult female and male abundance using female per redd from Washington's Snow Creek. Redd surveys are not conducted for hatchery winter steelhead, which spawn earlier in the spring. Migration or spawn timing estimates are derived from the spawner abundance estimates and ratings.

Needs: See Abundance-Spawners section recommendations.

Diversity-Sex

Current or Planned Monitoring: Biological information on adult sex ratios are collected from live fish at traps on the Cowlitz, Toutle, Kalama, Cedar, and Wind rivers. This approach is adequate for estimating sex ratio for populations with high spawner abundance. Precision targets for fish sex ratios are not always met for populations with low spawner abundance despite sampling of all carcasses encountered during surveys.

Needs: Explore salmon sex ratio correlations among populations and years. If appropriate, explore the use of hierarchical models to improve sex ratio estimates. Sex identification methodology should be improved for immature winter steelhead through the use of ultrasound, modeling techniques, or other method.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are scheduled to be adipose fin clipped. Biological information on origin is collected from live fish at traps. This approach is adequate for estimating origin on populations with high spawner abundance. Precision targets for origin are not always met for populations with low spawner abundance despite sampling of all carcasses encountered during surveys. WDFW recently explored the use of snorkel surveys to improve origin identification.

Needs: Explore steelhead origin correlations among populations, years, and hatchery mass mark rates. If appropriate, explore the use of hierarchical models to improve origin estimates.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: Data for this indicator is not collected.

Needs: See Abundance-Juvenile Rearing sections for recommendations.

Spatial Structure-Spawners

Current or Planned Monitoring: Weir or mark-recapture methods are used to estimate the spatial structure of spawners for the Cowlitz, NF Toutle, Kalama, Cedar Creek, and Wind populations, redd surveys are used in other basins. Studies conducted on steelhead redd life in Oregon and Washington coastal streams indicate these surveys should be conducted every 14 days throughout the spawning season. Redds will be marked with flags to prevent re-counting during subsequent surveys. Redd counts will be expanded to adult female and male abundance using females per redd from Washington's Snow Creek. In general, current monitoring efforts are prioritized by accessibility, coverage, and representativeness rather than by run. Redd surveys are not conducted for hatchery winter steelhead, which are thought to spawn earlier in the spring than wild fish.

Needs: See Abundance-Spawners section for recommendations.

Summer Steelhead Current Monitoring Status

Table 7. Scores for the existing monitoring efforts on summer steelhead in the Washington portion of the Lower Columbia River. See main report (Tables 2-18) for scoring criteria. Asterisked population names indicate extirpated or functionally extinct populations. Scores with values of 0.00 indicate there are no current or planned monitoring efforts at this time. Shaded cells indicate monitoring priority, with darker gradients indicating higher priority.

Stratum	Summer Steelhead Population	Recovery Priority	Abundance				Diversity				Distribution	
			Fry/Parr	Juvenile Migrants	Adult Recruits (Harvest)	Spawners	Age Structure	Migration /Spawn Timing	Sex	Origin	Fry/Parr Distribution	Spawner Distribution
Cascade	Kalama	High	0.75	0.75	0.25	1.00	1.00	1.00	0.75	1.00	0.00	0.50
	NF Lewis*	Low	0.00	0.00	0.00	0.00	0.00	1.00	0.75	0.00	0.00	0.00
	EF Lewis	High	0.00	0.00	0.25	0.75	0.25	0.00	0.75	1.00	0.00	0.50
	Washougal	High	0.00	0.00	0.50	0.25	0.25	0.00	0.75	0.00	0.00	0.25
Gorge	Wind	High	0.00	1.00	0.50	1.00	0.25	1.00	0.75	1.00	0.00	0.25

Abundance-Juvenile Rearing

Current or Planned Monitoring: Data for this indicator is not collected.

Needs: WDFW needs to implement a GRTS-based snorkel survey similar to that of ODFW's design to provided status and trend at the stratum scale for the density of juvenile steelhead in pools, percent of pools that are occupied by juvenile steelhead, and percent of sites that are occupied. Using ODFW's approach, all pools that are present in a 1000 m long survey reach are snorkeled, and the goal is to snorkel at least 40 sites per year. Using this approach, ODFW's coefficients of variation for winter steelhead juvenile rearing metrics are <15%. ODFW supervisors resurvey 10-20% of survey sites; this method results in a coefficient of determination (r^2) of approximately 0.98. Results of the ODFW resurveys suggest that their sampling variability is low and that survey results are highly repeatable for winter steelhead.

Abundance-Juvenile Outmigrants

Current or Planned Monitoring: Screw traps are operated to target juvenile steelhead in the Kalama and Wind river populations. The traps are operated 24 hours a day, seven days a week throughout the juvenile outmigration migration period (March - June). Trap efficiency estimates are conducted weekly through the release of marked fish above the trap.

Needs: None.

Abundance-Adult Recruits

Current or Planned Monitoring: Adult recruitment is monitored through a partial mainstem creel survey that begins in February, angler interviews throughout the fishing season in the Washougal River, and a creel survey on the Wind River. The statistical creel monitoring program in the mainstem Columbia River occurs from Feb to Oct and estimates the kept and released catch of salmonids including steelhead. Hatchery fish mass marked with an adipose fin clip can be kept, unmarked fish must be released. The impact of the mainstem commercial fisheries on summer steelhead is evaluated through historic steelhead to landed Chinook ratios. The validity of these historic ratios was verified during 2009-2011 observations. Estimates of fish handling impacts are generated for wild steelhead populations in the Columbia River as a whole. Genetic data needs to be collected in order to generate ESU or population specific impacts.

Needs: Develop mainstem sport and commercial fisheries sampling programs to estimate incidental fisheries impacts on summer steelhead populations. This monitoring effort should include genetic sampling. Evaluate angler surveys designs and implement surveys on additional populations if effective.

Abundance-Spawners

Current or Planned Monitoring: Mark-recapture estimates for the Kalama, EF Lewis, Washougal and Wind. These estimates assume that the percentage of summer steelhead passing the Kalama are representative of EF Lewis and Washougal river spawner abundance. Washougal River surveys do not include the NF Washougal River.

Needs: A fish tagging and survey effort needs to be implemented on the NF Washougal River.

Diversity-Natural Origin Age Structure

Current or Planned Monitoring: Biological information is collected by sampling adult fish at traps and seines in the Kalama, EF Lewis, Washougal, and Wind rivers. This approach is adequate for estimating the age structure of populations with high spawner abundance. Precision targets for age are not always met for populations with low spawner abundance despite sampling of all fish encountered during surveys.

Needs: Explore steelhead age correlations among populations and years. If appropriate, explore the use of hierarchical models to improve age structure estimates.

Diversity-Migration/Spawn Timing

Current or Planned Monitoring: Mark-recapture estimates for the Kalama, EF Lewis, Washougal and Wind river populations. Assumes percentage of summer steelhead passing in the Kalama is representative of EF Lewis and Washougal populations. Migration time is derived from the spawning abundance estimates in the Kalama and Wind rivers and ratings.

Needs: See Abundance-Spawners section recommendations and develop methods for timing on the EF Lewis and Washougal rivers.

Diversity-Sex

Current or Planned Monitoring: Biological information is sampled from live trapped fish on the Kalama, EF Lewis, Washougal, and Wind rivers. This approach is adequate for estimating the sex ratio of populations with high spawner abundance. Precision targets for sex ratio are not always met for populations with low spawner abundance despite sampling of all fish encountered during surveys.

Needs: Explore salmon sex ratio correlations among populations and years. If appropriate, explore the use of hierarchical models to improve sex ratio estimates. Sex identification of immature summer steelhead could be improved through the use of ultrasound, modeling techniques, or other methods.

Diversity-Origin

Current or Planned Monitoring: All Washington hatchery releases are scheduled to be adipose fin clipped. Biological information is sampled from live trapped fish, and is based on the identification of hatchery fish through the clipped adipose fin mass mark. This approach is adequate for estimating the origin of populations with high spawner abundance. Precision targets for origin are not always met for populations with low spawner abundance despite sampling of all fish encountered during surveys.

WDFW uses scale readings and the clipped adipose fin mass mark to identify hatchery steelhead.

Needs: Explore summer steelhead origin correlations among populations and years by hatchery mass mark rates. If appropriate, explore the use of hierarchical models to improve origin estimates.

Spatial Structure-Fry/Parr

Current or Planned Monitoring: Data for this indicator is not collected.

Needs: See Abundance-Juvenile Rearing sections for recommendations.

Spatial Structure-Spawners

Current or Planned Monitoring: Mark-recapture methods are used to estimate spawner spatial structure for the Kalama, EF Lewis, Washougal and Wind river populations. This methodology assumes that the percentage of summer steelhead passing the Kalama is representative of spawner spatial structure in the EF Lewis and Washougal river populations. Washougal River surveys do not include the NF Washougal River.

Needs: See Abundance-Spawners section for recommendations. Alternate methods to estimate summer steelhead spatial structure need to be developed.